6.8 *Human Handles* — All handles for use by humans must either be contained within the maximum outer dimensions of the FOUP, be detached when not in use, or be retractable into the maximum outer dimensions when not in use. Although such handles may extend past *x*53, they must still be contained within the upper limits of *x*50, *y*40, and *r*67. Handles for use by humans (if present) must follow SEMI S8, and they must require the use of both hands (each using a full wrap-around grip, given the minimum clearance requirement in SEMI E15.1). Automation handling features shall not be considered dual purpose unless they are designed to meet SEMI S8 guidelines.

6.9 *Automation Handling Features* — On the top of the FOUP is a robotic handling flange for manipulating the FOUP. Shown in Figure 12 (on the top robotic handling flange) are a center hole and 3 optional kinematic grooves (which, if present, must be implemented entirely including the radius at the peak). On the left and right sides of the FOUP are optional flanges (of unspecified thickness) for use with fork lifts. On the bottom of the FOUP are rails for use with roller conveyors. Although they are only required to extend *x*58 to the rear and *y*58 to the left and right, it is recommended that they be as long as possible. Beyond *x*58 and *y*58, only the lower bounds on *z*43 and *z*46 apply. The side fork-lift flanges and the left and right bottom conveyor rails of the FOUP also have vertical cylindrical pin holes for fork lift centering. On the bottom edges of the FOUP, 2 required conveyor rails (defined by *x*56, *x*57, *y*58, and *z*43) are located on the left and right, and an optional conveyor rail (defined by *x*58, *y*56, *y*57, and *z*43) is located on the rear. The *Optional Conveyor Placement Volume* is a volume of space reserved for the inclusion of alternate conveyor features (defined by *y*244 and *y*245, the Horizontal Datum Plane and *z*316, and $-\infty < x < \infty$). The volume defined by the dimensions above (*y*244, *y*245, *z*316) is the maximum volume into which an alternate conveying feature must fit.

6.9.1 *Optional Front Conveyor Surface* — Alternate methods of conveyor transport may require the use of the optional front conveyor surface. The *y*-dimension is defined by *y*242, *y*243. In the *x*-dimension, the optional front conveyor surface extends up to the left and right bottom conveyor rail edge closest to the BDP. In the *z*-dimension, the optional front conveyor surface must be coplanar with the bottom of the front seal zone or farther from the HDP than the bottom of the front seal zone. The optional front conveyor surface must be coplanar with the left and right bottom conveyor rails.

6.10 *Retaining Features* — Figures 8 and 9 show two features on the bottom of the FOUP that may be used for retaining the FOUP onto the kinematic couplings. This may be needed to prevent the FOUP from being knocked off the kinematic couplings by the action of pushing the FOUP against the front-opening interface. The front retaining feature contains a ramp that a wheel might roll up while the FOUP is being pushed toward the front-opening interface. The arm with the wheel (not specified here) then holds the FOUP down on the kinematic couplings. The center retaining feature consists of an oblong slot with a chamber above it. The FOUP can be clamped onto the kinematic couplings by inserting an oblong head on a shaft (not specified here) through the slot and rotating it 90° in either direction. Either retaining feature would only engage after the FOUP is fully seated on the kinematic coupling pins. Either retaining feature must be able to withstand a force in any direction of at least *f*60. It is recommended that SEMI E15.1 tool load ports be designed to accommodate the minimum hole dimensions of the retaining features to ensure carrier interchangeability. Projections on the tool load ports that mate with the retaining features should also not interfere with the misalignment correction function of the kinematic couplings. Figures 5 through 8 also show front clamp flanges and exclusion volumes (defined by *x*62, *y*60, *y*61, *z*66, *z*67, *z*68, and *z*69) behind them that can be used to clamp the FOUP to the FOUP opener when the FOUP is purged with Nitrogen. However, it is strongly recommended that the front clamp flanges not be used for pulling the FOUP from the undocked position into the FIMS interface. Also, all of the dimensions of the FOUP (such as the wafer location, etc.) are defined with reference to the kinematic coupling pins, and most FOUPs are designed so that all of the features are in the proper location only when the FOUP is held in place on the kinematic coupling pins only by gravity. Thus, if the front clamp flanges are used, the wafers and the FOUP features may be in a different position than defined in SEMI E1.9 (possibly resulting in damage to wafers, wafer handlers, and the FOUP).

6.11 *Inner and Outer Radii* — All required concave features may have a radius of up to *r*65 to allow cleaning and to prevent contaminant build-up. All required convex features may also have a radius of up to *r*66 to prevent small contact patches with large stresses that might cause wear and particles. Note that these limits on the radius of all required features are specified as a maximum (not a minimum) to ensure that the required features are not rounded off too much. The lower bound on the radius is up to the carrier supplier. Note also that this radius applies to every required feature unless another radius is called out specifically. Here a required feature is an area on the surface of the carrier specified by a dimension (or intersections of dimensions) that has a tolerance and not just a maximum or minimum (such as the edges of the robotic handling flange).

6.12 *FOUP Placement Sensing Pads* — The FOUP must have the same carrier sensing pads as is required of the cassette in SEMI E1.9, including the info pads that communicate information about the carrier such as the carrier capacity (number of wafers) and type (cassette or FOUP). See SEMI E1.9 for information about info pad configurations for different wafer carriers similar to FOUPs including front-opening shipping boxes (as defined in SEMI M31) and single-wafer interface (SWIF) systems (as defined in SEMI E103). Two additional sensing pads (that can be used continuously while the FOUP is advancing into the FIMS interface) must be located near the center of the bottom at the same distance from the horizontal datum plane as the carrier sensing pads. In addition, the surfaces on the door of the FOUP that mate with the seal zones and the reserved spaces for vacuum application may also be used for door-presence sensing.

7 Related Documents

7.1 *SEMI Standards*

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

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

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

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

APPENDIX 1
APPLICATION NOTES

NOTICE: The material in this appendix is an official part of SEMI E47.1 and was approved by full letter ballot procedures on August 27, 2001.

A1-1 The automation handling features do not need to be molded into the plastic shell of the FOUP, but can be attached as a framework around the shell.

A1-2 To increase the stability of the FOUP on the kinematic couplings, it is recommended that the points on the FOUP bottom extend as close as practical to the horizontal datum plane to minimize tipping of the FOUP.

A1-3 Skewness, warp, rock, and stiffness are implicitly defined in the geometric tolerances.

A1-4 Dimension $y52$ is given as a maximum based on the maximum distance to the port door specified in SEMI E62.

A1-5 The position tolerance of the door of the FOUP is likely to be much larger than the position tolerance of the registration pins. To make both manual and automated door opening easier, it is recommended that the holes for the registration pins on the door of the FOUP have openings with a lead-in capability.

NOTE A1-1: If the bottom of the FOUP does not extend below the bottom conveyor rail, the conveyor rail may become contaminated and may distribute particles.

A1-6 Although both of the retaining features on the bottom of the FOUP must be able to withstand a force in any direction of $f60$, continuously applied stress may result in plastic deformation.

A1-7 In order to minimize particle generation when the FOUP door is opened or closed, it is recommended that the tolerance between the FOUP door and its frame be larger than the tolerance between the FOUP door registration holes and FIMS registration pins.

A1-8 One type of carrier presence sensor uses a beam of light with an optical detector that is triggered when the beam of light is attenuated as it passes through the FOUP shell.

A1-9 The use of the registration pins for FOUP door lead-in to the loadport door is not recommended. The registration pins should be only used to limit the maximum displacement of the FOUP door while on the loadport door. Neither the FOUP nor FOUP door positions should change as a result of engaging or disengaging the registration pins. When the Loadport experiences utility loss (such as EMO, vacuum loss, electrical failure, etc.), the registration pins may be used to maintain the FOUP door's position, and to ensure that the FOUP door does not fall off. The clearance between the Registration Pins and the Registration Pin Holes should be less than the clearance between the outer edge of the FOUP Door and the inner edge of the FOUP Door Frame. Balancing these tolerances is a FOUP design issue related to the E62 Seal Zone specification. The diameter of the Registration Pin Holes should be designed to accommodate the Registration Pin tolerance defined in E62 ($x31$, $z31$, $d31$) and the Registration Pin Hole location tolerance in a FOUP.

A1-10 It is recommended that the FOUP have a capability to roughly position the FOUP door in the FOUP frame during the door close sequence (during either return of the FOUP door or during latching of the FOUP door). This positioning capability should keep the clearance between the FOUP frame and the FOUP door larger than sum of the FOUP (self) tolerance and the E62 registration pin tolerance along with the FOUP door's circumference. Possible methods for accomplishing this may include positioning by latch motion and positioning by a slope between the FOUP frame and the FOUP door.

A1-11 It is recommended that the FOUP have a lead-in mechanism on its latch key holes. This lead-in mechanism should compensate for the FOUP's latch key hole location error, as shown in Figure A1-1.

A1-12 It is recommended that the latch key hole mechanisms have some flexibility in their position for compliance with the latch key positions. The purpose of this is to adjust for any discrepancy in rotation axis between the latch key and the latch key hole mechanism. As shown in Figure A1-2, if only one side of the latch key pushes on the inside of the latch key hole, the latch key can not rotate more than half way.

A1-13 It is recommended that the torque required to rotate the FOUP latch key holes be kept small enough that it will not produce movement of the FOUP door in the x and z directions during latch key rotation.

A1-14 It is recommended that the latch key holes be maintained in the position that unlocks the FOUP door from the FOUP ($\psi = 0 \pm 1°$ as defined in SEMI E62) while the FOUP is open and in the position that locks the FOUP door to the FOUP ($\psi = 90 \pm 1°$) while the FOUP is closed. One method to accomplish this is to have the FOUP latch key hole mechanisms snap into both end points of their rotation ($\psi = 0 \pm 1°$ and $\psi = 90 \pm 1°$) using a detent mechanism. The torque required to overcome such a detent mechanism should not exceed $f30$ (as defined in SEMI E62).

A1-15 Table A1-1 can be used for communicating the compliance of FOUPs to this standard and the options chosen:

Table A1-1 Optional Features Checklist

Section	*Optional Feature*	*Choice*
4.3	carrier capacity (*c*)	☐ 13 wafers or ☐ 25 wafers
6.1	full 15-mm lead in provided by 3 features that mate with kinematic coupling pins	Primary kinematic coupling pins ☐ yes or ☐ no and secondary kinematic coupling pins ☐ yes or ☐ no
6.8	ergonomic manual handles	☐ yes or ☐ no
6.9	side fork-lift flanges	☐ yes or ☐ no
6.9	3 kinematic grooves on the top robotic handling flange	☐ yes or ☐ no
6.9	rear conveyor rail	☐ yes or ☐ no
6.9.1	front conveyor surface	☐ yes or ☐ no
6.12	info pad A height	☐ up (pad missing) or ☐ down (pad present)
6.12	info pad B height	☐ up (pad missing) or ☐ down (pad present)
6.12	info pad C height	☐ up (pad missing) or ☐ down (pad present)
6.12	info pad D height	☐ up (pad missing) or ☐ down (pad present)

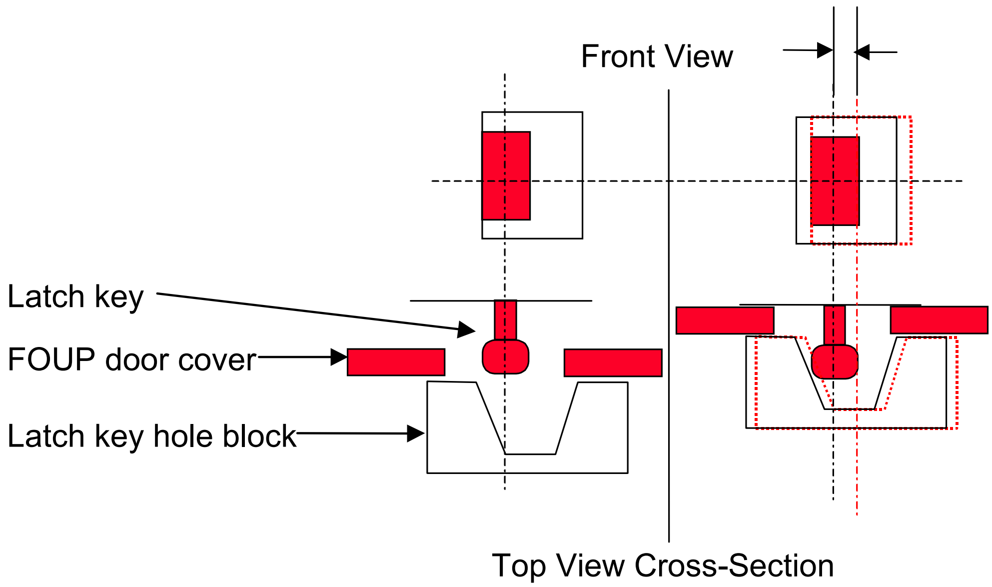

Figure A1-1
Displacement Enabled by Flexibility Around Latch Key Hole Block

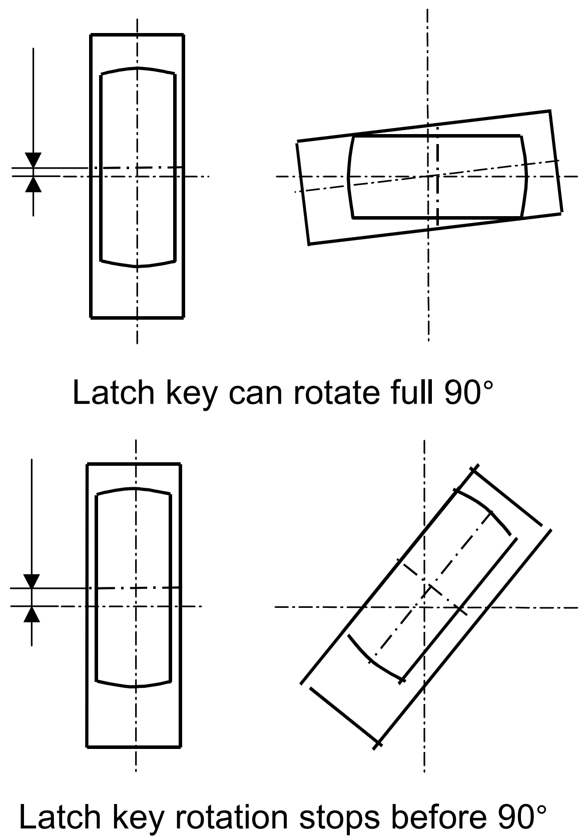

Figure A1-2
Need for Latch Key Hole Flexibility

RELATED INFORMATION 1

NOTICE: This related information is not an official part of SEMI E47.1, and it is not intended to modify or supercede the official standard. This information was inserted by the North America Physical Interfaces and Carriers Committee to alert the readers to potential changes to this provisional standard.

R1-1 A revision ballot will be submitted to require the same bottom carrier ID label area as in SEMI E1.9.

R1-2 A revision ballot will be submitted to increase the maximum thickness of the top robotic flange by 3 mm.

R1-3 A design exists for a FOUP and adapter mechanism that holds only one wafer and is supposed to comply with SEMI E47.1. A new activity to standardize a “One Wafer FOUP” is being considered.

R1-4 Alternate Conveyor Features may be incorporated into FOUPs. One example is a *rear conveyor groove.* A Rear Conveyor Groove is defined as below. This design, and/or the application of this design in AMHS systems may be protected by one or more patents.

Table R1-1

Symbol Used	*Value Specified*	*Datum Measured From*	*Feature Measured To*
ωk	17.5 ± 2.5°	conveyor groove centerline	conveyor groove lead in
ψk	3 ± 1°	conveyor groove centerline	conveyor groove lead in
R70k	0.25 mm (0.010 in.) maximum	not applicable	conveyor groove concave corners
R71k	0.5 mm ± 0.25mm (0.02 ± 0.01 in.)	not applicable	conveyor groove convex corners
X251k	132.0 ± 1mm (5.31 ± 0.04 in.)	bilateral datum plane	beginning of conveyor groove lead in
Y240k	158.0 ± 0 .5mm (6.142 ± 0.020 in.)	facial datum plane	conveyor groove side closest to facial datum plane
Y241k	8.50 ± 0.25mm (0.335 ± 0.0 in.)	conveyor groove side closest to facial datum plane	conveyor groove side furthest from facial datum plane
Z314k	5.00 ± 0.25mm (0.236 ± 0.010 in.)	horizontal datum plane	top surface of conveyor groove
Z315k	1.3 ± 0.5mm (0.052 ± 0.020 in.)	top surface of conveyor groove	beginning of conveyor groove lead in radius

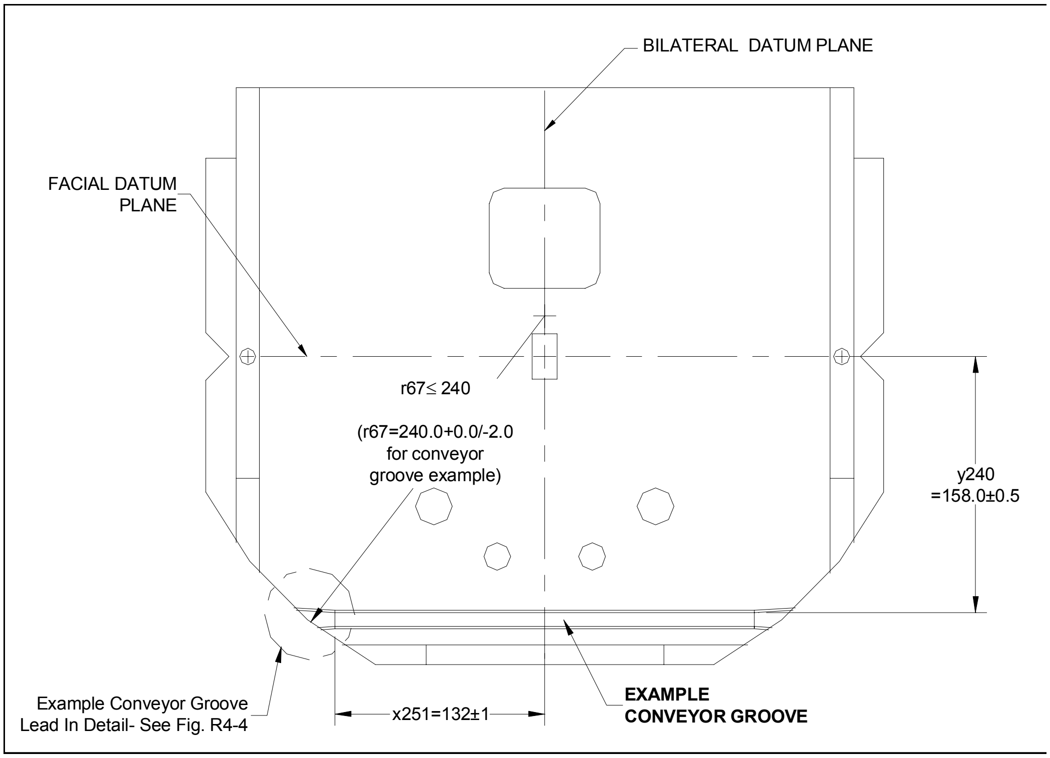

Figure R1-2
Bottom View of FOUP Showing Example Conveyor Groove

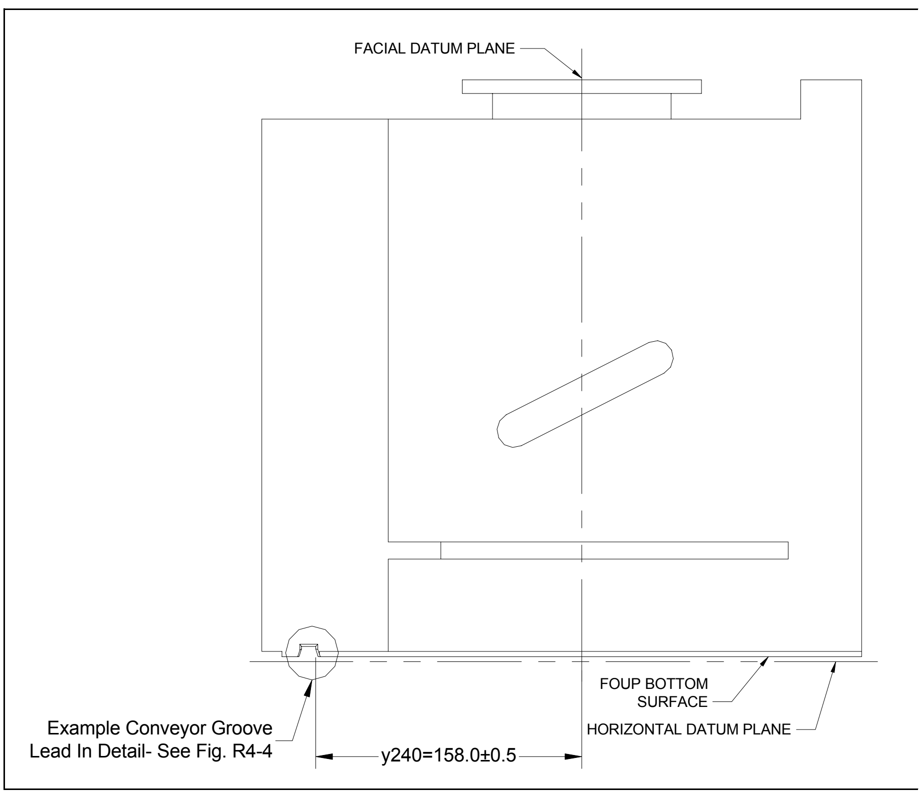

Figure R1-3
Side View of FOUP Showing Example Conveyor Groove Feature

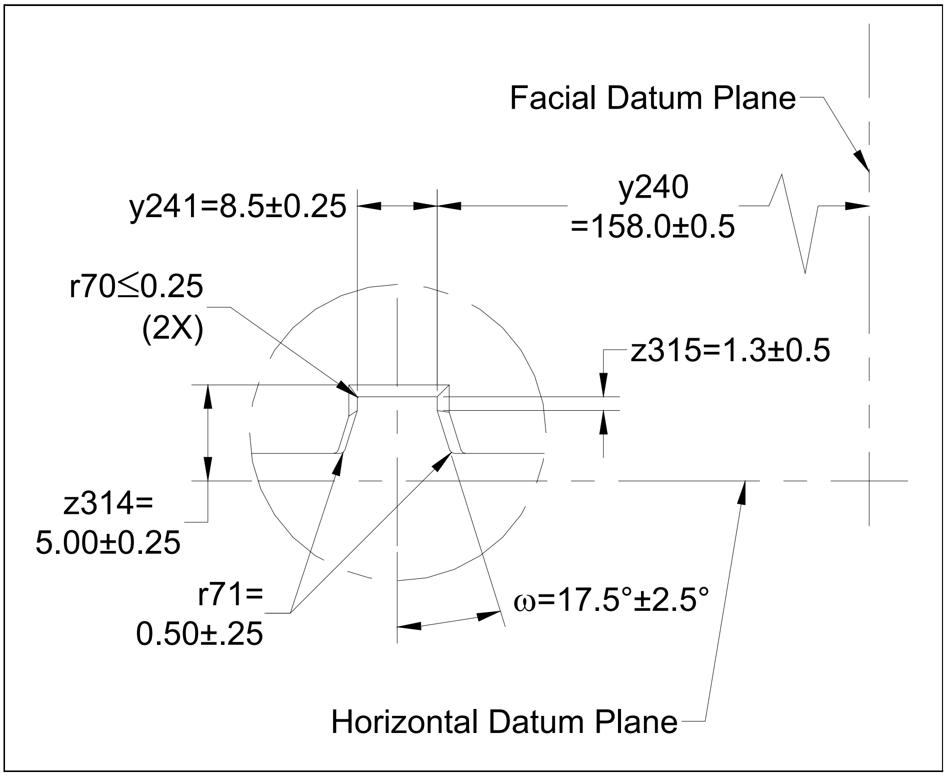

Figure R1-4
Side View Detail of Example Conveyor Groove on Bottom of FOUP

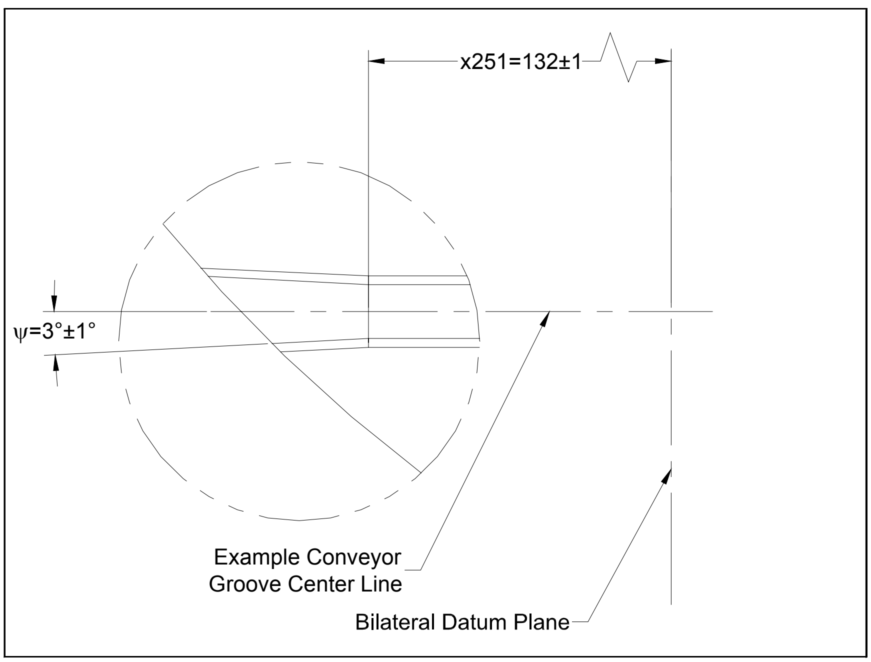

Figure R1-5
Example Conveyor Groove on Bottom of FOUP

R1-5 Alternate Conveyor Features may be incorporated into FOUPs. One example is a Rear Conveyor Recessed Rib. A Rear Conveyor Recessed Rib is defined as below. This design, and/or the application of this design in AMHS systems may be protected by one or more patents.

Table R1-2

Symbol Used	*Value Specified*	*Datum Measured From*	*Feature Measured To*
r500	240.0 +0.0/-2.0mm	*y*67 in front of nominal wafer center line (same as r67)	Extreme ends of recessed rib in X direction.
*y*501	162.25 ± 0.5mm (6.39 ± 0.02 in.)	facial datum plane	centerline of recessed rib
*y*502	4.0 +0.0/-0.5mm (0.157 +0.000/-0.020 in.)	conveyor rib wall furthest from facial datum plane	conveyor rib wall closest from facial datum plane
*z*503	1.21 ± 0.5mm (0.050 ± 0.020 in.)	bottom surface of conveyor rib	beginning of conveyor rib lead in radius
*z*504	4.0 ± 0 .5mm (0.157 ± 0.020 in.)	beginning of conveyor rib lead in radius	bottom surface of recess
ω505	10.0 ± 2.5°	conveyor rib centerline	lead in surface or rib
*r*506	0.25 +0.0/-0.25mm (0.010 +0.000/- 0.010 in.)	not applicable	conveyor rib convex corners
*r*507	0.5 ± 0.5mm (0.020 ± 0.020 in.)	not applicable	conveyor rib concave corners

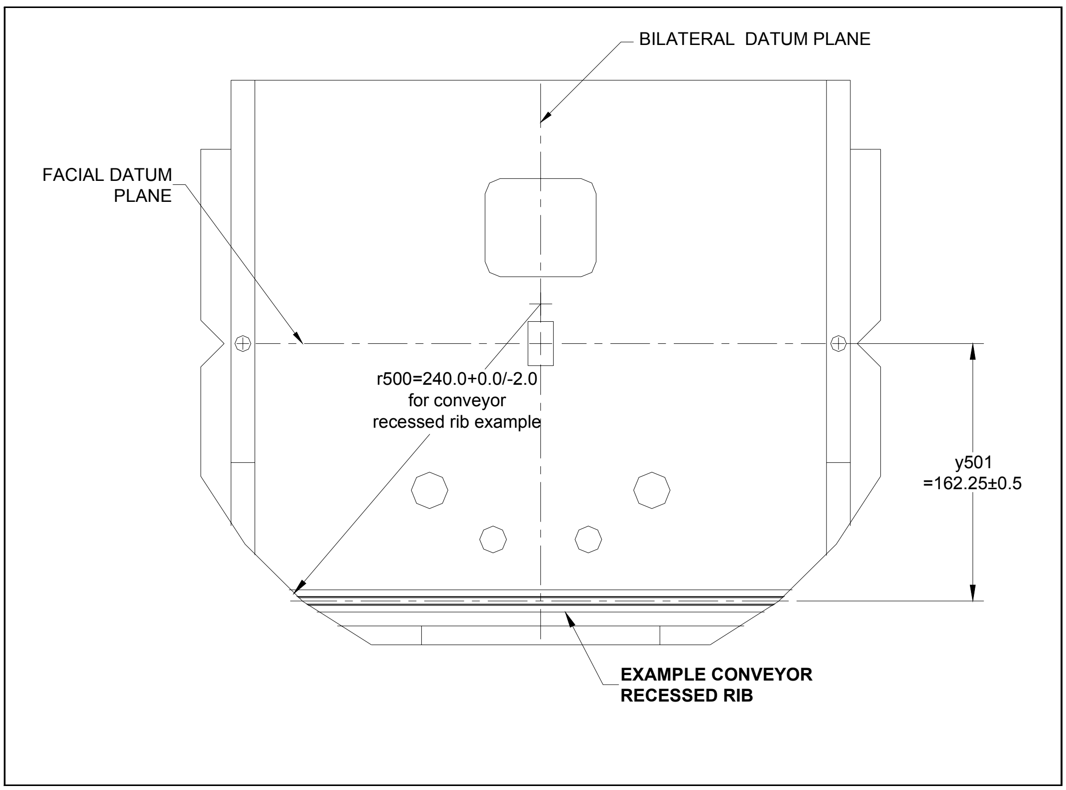

Figure R1-6
Bottom View of FOUP Showing Example Conveyor Recessed Rib

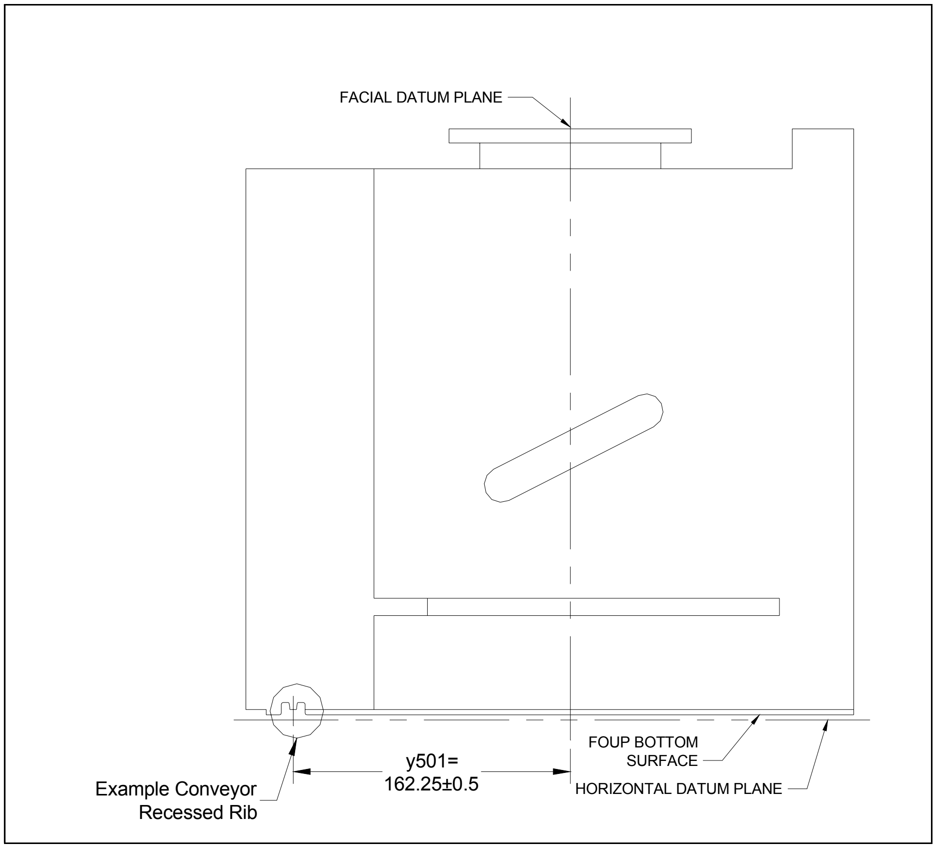

Figure R1-7
Side View of FOUP Showing Example Conveyor Recessed Rib Feature

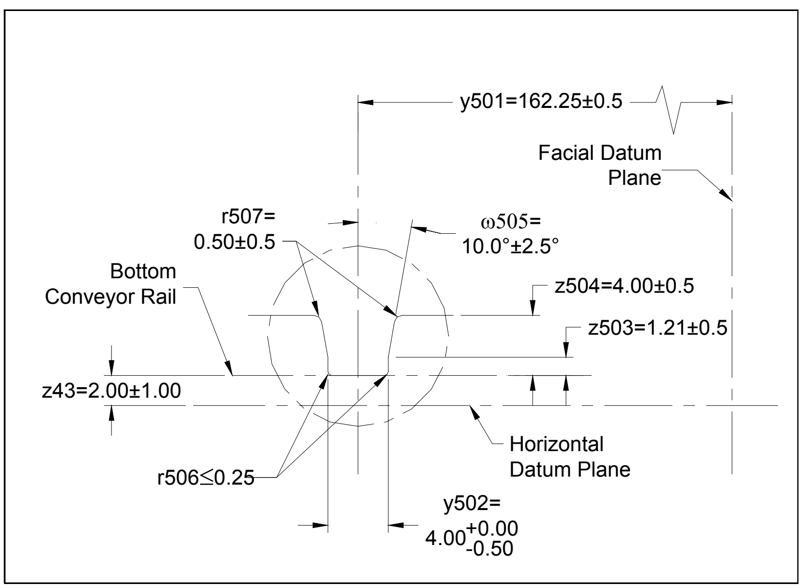

Figure R1-8
Side View Detail of Example Conveyor Recessed Rib on Bottom of FOUP

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SEMI E48-1101
SPECIFICATION FOR SMIF INDEXER VOLUME REQUIREMENT

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the European Equipment Automation Committee. Current edition approved by the European Regional Standards Committee on April 24, 2001. Initially available at www.semi.org August 2001; to be published November 2001. Originally published in 1995; previously published July 2001.

1 Purpose

1.1 The purpose of this specification is to provide the volume required within a tool that enables integration of SMIF into tools with single or multiple ports.

2 Scope

2.1 This specification defines the space necessary within a tool with respect to the interface plane. The specification refers to the Standard Mechanical InterFace (SMIF) Standard, SEMI E19.

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

3 Referenced Standards

3.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

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

4 Terminology

4.1 *cassette* — an open structure that holds one or more substrates (e.g., wafers, masks).

4.2 *integrated SMIF* — a unit including a SMIF port and a mechanism for indexing the port door. The entire unit being incorporated within the tool.

4.3 *standard mechanical interface (SMIF)* — the interface plane between a pod and another minienvironment per SEMI E19.

4.4 *wafer transfer plane* — a plane with a maximum distance from the interface plane to the level where a wafer can be transferred.

5 Requirements

5.1 Figure 1 depicts the height dimensions and terminology for integrated SMIF. Figure 2 shows the necessary footprint for the integrated SMIF on a tool. The dimensions are given with reference to SEMI E15.

5.2 The minimum distance between the interface plane and the wafer transfer plane A1 is limited by the thickness of the port plate and any wafer sensing system. This distance should be kept as small as possible for ergonomic reasons.

5.3 The dimension A2 below the interface plane takes into account the distance A1, the cassette dimensions, and the mechanical components. Process tools must provide this free space to allow integration of SMIF.

5.4 Referring to Figure 2, it can be seen that the axis of the wafer transfer, B2, does not necessarily correspond to the center line of the integrated SMIF unit. This is to allow the indexing mechanism to be placed in different locations, so that multiple ports can be furnished, still adhering to SEMI E15.

Table 1 Integrated SMIF Dimensions

		Up to 150 mm	*200 mm*
Installation Height	A1	63 mm max. (2.48" max.)	63 mm max. (2.48" max.)
	A2	400 mm min. (15.75" min.)	400 mm min. (15.75" min.)
Footprint	B1	355 mm min. (13.98" min.)	355 mm min. (13.98" min.)
	B2	177.5 mm max. (6.99" max.)	177.5 mm max. (6.99" max.)
	B3	157 mm max. (6.18" max.)	182 mm max. (7.17" max.)
	B4	390 mm min. (15.35" min.)	390 mm min. (15.35" min.)
	B5	20 mm max. (0.79" max.)	20 mm max. (0.79" max.)
SEMI E15 (Recommendation)	S	350 mm (13.8")	400 mm (15.7")

Dimension Definitions

A1 — Maximum distance from the SMIF interface plane to the wafer transfer plane.

A2 — Minimum depth, from the interface plane, required in a tool.

B1 — Minimum width required in a tool.

B2 — Maximum distance from the side of the indexer unit to the cassette or container centroid.

B3 — Maximum distance from the front of the indexer unit to the cassette or container centroid.

B4 — Minimum breadth required for the indexer unit in a tool.

B5 — Maximum distance that can be penetrated underneath the port plate.

S — Recommended minimum spacing between cassette or container controids.

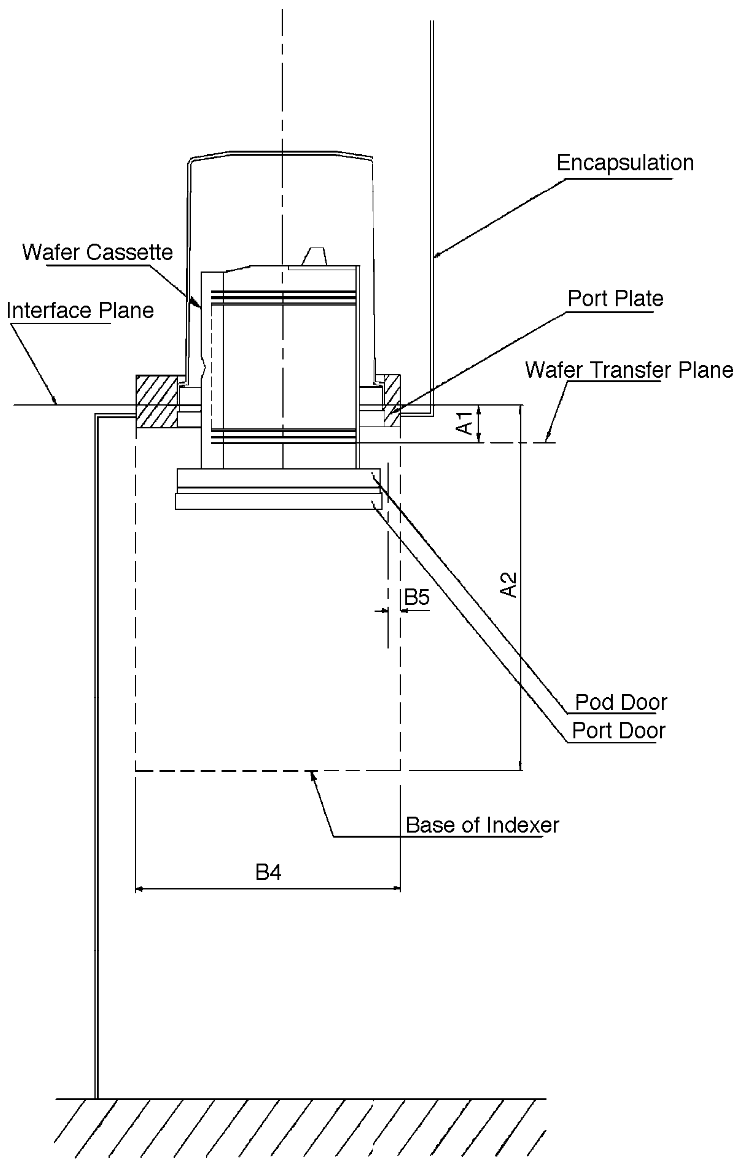

Figure 1
Integrated SMIF Side View

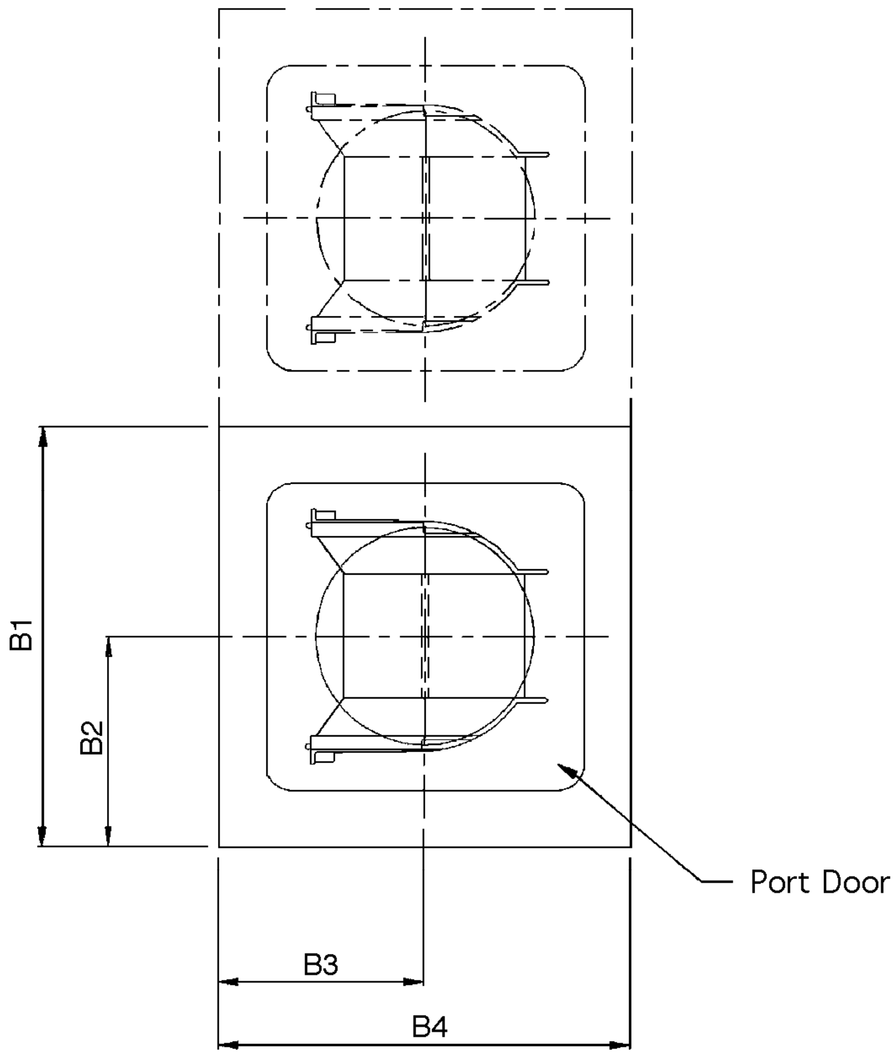

Figure 2
Integrated SMIF Top View

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

SEMI E49-1104
GUIDE FOR HIGH PURITY AND ULTRAHIGH PURITY PIPING PERFORMANCE, SUBASSEMBLIES, AND FINAL ASSEMBLIES

This standard was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on August 16, 2004. Initially available at www.semi.org September 2004; to be published November 2004. Originally published 1995; last published March 2004.

1 Purpose

1.1 The purpose of this overview document is to provide a basic set of terminology and reference documents for SEMI E49.2–E49.8 and E137.

2 Scope

2.1 This document contains terminology and reference documents used in SEMI E49.2–E49-8 and E137, which will reference performance and method standards as well as recommended practices.

2.1.1 The SEMI E49 subdocuments are organized by types of piping distribution systems — gas, DI/chemical, solvent — and by types of assembly and testing procedures — sub-assembly for stainless steel, sub-assembly for polymer and final tool assembly. Final assemblies should be tested or validated for all appropriate parameters (e.g., purity, integrity, failure rate) as specified in the applicable E49 subdocuments.

2.1.2 The piping distribution documents (SEMI E49.2 through E49.8) include guidelines for system design, performance, materials, and components. Purity and performance grades are described for each of the three types of distribution systems.

2.1.3 Users should complete an overall tool cost of ownership analysis (see SEMI E35) to determine the optimum application of HP or UHP tool features. Key parameters should include facilities cost and installation cycle time, piping system reliability and maintainability factors, tool and sub-system contribution to contamination, and resultant effects on wafer quality and wafer throughput factors.

2.2 Final assemblies should be evaluated according to the criteria of SEMI S2 for Environmental, Health and Safety (EH&S) issues associated with their use.

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

3 Referenced Standards

3.1 *SEMI Standards*

SEMI C41 — Specifications and Guidelines for 2-Propanol

SEMI E10 — Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E35 — Cost of Ownership for Semiconductor Manufacturing Equipment Metrics

SEMI E49.2 — Guideline for the Qualification of Polymer Assemblies Used in Ultrapure Water and Liquid Chemical Systems in Semiconductor Process Equipment

SEMI E49.4 — Guide for High Purity Solvent Distribution Systems In Semiconductor Manufacturing Equipment

SEMI E49.5 — Guide for High Purity Solvent Distribution Systems In Semiconductor Manufacturing Equipment

SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures - Stainless Steel Systems

SEMI E49.7 — Purity Guide for the Design and Manufacture of Ultrapure Water and Liquid Chemical Systems in Semiconductor Process Equipment

SEMI E49.8 — Guide for High Purity and Ultrahigh Purity Gas Distribution Systems In Semiconductor Manufacturing Equipment

SEMI E137 — Guide for Final Assembly, Packaging, Transportation, Unpacking, and Relocation of Semiconductor Manufacturing Equipment

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

SEM F19 — Specification for the Surface Condition of the Wetted Surfaces of Stainless Steel Components

SEMI F20 — Specification for 316L Stainless Steel Bar, Forgings, Extruded Shapes, Plate, and Tubing for Components Used in General Purpose, High Purity and Ultra-High Purity Semiconductor Manufacturing Applications

SEMI F27 — Test Method for Moisture Interaction and Content of Gas Distribution Systems and Components by Atmospheric Pressure Ionization Mass Spectrometry (APIMS)

SEMI F58 — Test Method for Determination of Moisture Dry-Down Characteristics of Surface-Mounted and Conventional Gas Distribution Systems by Atmospheric Pressure Ionization Mass Spectrometry (APIMS)

SEMI F60 — Test Method for ESCA Evaluation of Surface Composition of Wetted Surfaces of Passivated 316L Stainless Steel Components

SEMI F63 — Guidelines for Ultrapure Water Used in Semiconductor Processing

SEMI F70 — Test Method for Determination of Particle Contribution of Gas Delivery System

SEMI F73 — Test Method for Scanning Electron Microscopy (SEM) Evaluation of Wetted Surface Condition of Stainless Steel Components

SEMI F74 — Test Method for the Performance and Evaluation of Metal Seal Designs for Use in Gas Delivery Systems

SEMI F78 — Practice for Gas Tungsten Arc (GTA) Welding of Fluid Distribution Systems in Semiconductor Manufacturing Applications

SEMI F81 — Specification for Visual Inspection and Acceptance of Gas Tungsten Arc (GTA) Welds in Fluid Distribution Systems in Semiconductor Manufacturing Applications

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

3.2 *American Society of Mechanical Engineers*[1]

ASME SA479 — Specification for Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels (ASTM A 479/A 479-90) (Boiler and Pressure Vessel Codes, 1989)

3.3 *ASTM Standards*[2]

ASTM A 269 — Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

ASTM A 479 — Standard Specification for Stainless and Heat-Resisting Steel Bar and Shapes for Use in Boilers and Other Pressure Vessels

ASTM A 632 — Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service

ASTM D 4327 — Standard Test Method for Anions in Water by Chemically Suppressed Ion Chromatography

ASTM F 1373 — Test Method for Determination of Cycle Life of Automatic Valves for Gas Distribution System Components

ASTM F 1394 — Standard for Determination of Particle Contribution from Gas Distribution System Valves

ASTM F 1397 — Test Method for Determination of Moisture Contribution for Gas Distribution System Components

ASTM F 1400 — Test Method for Determination of Helium Leak Rate for Gas Distribution System Components

ASTM F 1438 — Test Method for Determination of Surface Roughness by Scanning Tunneling Microscopy for Ultra Pure Water Distribution Components

3.4 *ISO Standards*[3]

ISO 14644-1 — Cleanrooms and associated controlled environments Part 1: Classification of air cleanliness

ISO 14644-2 — Cleanrooms and associated controlled environments Part 2: Specifications for testing and monitoring to prove continued compliance with ISO 14644-1

ISO 14644-4 — Cleanrooms and associated controlled environments Part 4: Design, construction, and startup

1 American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA, Telephone: 800.843.2763 (U.S./Canada), 95.800.843.2763 (Mexico), 973.882.1167 (outside North America), Website: www.asme.org

2 American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

3 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland, Telephone: 41.22.749.01.11, Fax: 41.22.733.34.30, Website: http://www.iso.ch

3.5 *National Fire Protection Association*[4]

NFPA Fire Protection Guide to Hazardous Materials

NFPA 704 — Standard System for the Identification of the Hazards of Materials for Emergency Response

3.6 *Military Standard*[5]

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 *Abbreviations and Acronyms*

4.1.1 Ar — argon

4.1.2 C_v — valve flow coefficient

4.1.3 CVD — chemical vapor deposition

4.1.4 DSF — dead space free

4.1.5 DIW — deionized; for this document, used as deionized water

4.1.6 ESCA — electron spectroscopy for chemical analysis (also known as XPS)

4.1.7 FTIR — Fourier transform infrared

4.1.8 HD — high density, i.e., polymer

4.1.9 HP — high purity

4.1.10 HPM — hazardous production material

4.1.11 IEEE — Institute of Electrical and Electronics Engineers, Inc.

4.1.12 ID/OD — inside/outside (i.e., diameter)

4.1.13 IPA — isopropyl alcohol

4.1.14 MFC — mass flow controller

4.1.15 MTBA — mean time between assists

4.1.16 MTBF — mean time between failure

4.1.17 MTTR — mean time to repair

4.1.18 PFA — perfluoroalkoxy

4.1.19 PPB — parts per billion

4.1.20 PTFE — polytetrafluoroethylene

4.1.21 PVDF — polyvinylidene fluoride

4.1.22 QA — quality assurance

4.1.23 QC — quality control

4.1.24 R_a — roughness average (e.g., surface)

4.1.25 SMTR — Smelter's test report

4.1.26 SPC — statistical process control

4.1.27 TEOS — tetraethylorthosilicate

4.1.28 TOC — total organic carbons

4.1.29 UHP — ultrahigh purity

4.1.30 WC — water column, inches (cm) of water

4.1.31 XPS – X-ray photoelectron spectroscopy

4.2 *Definitions*

4.2.1 *high purity (HP)* — for industry standard systems consisting of high grade materials, components, and standard design/configuration, assembly method, and performance capability.

4.2.2 *ultrahigh purity (UHP)* — for advanced or special systems consisting of higher grade materials and components, with advanced or integrated design and configuration, the latest assembly methods, and enhanced performance capabilities, especially related to purge or rinse time and contamination levels.

4.2.3 *subassembly* — an assembled unit designed to be incorporated with other units in a finished product.

5 Impact

5.1 The impact of improved tool quality and standardization is:

5.1.1 Reduced tool purchase price for customized piping distribution systems, by employing standard designs and practices for HP and UHP systems.

5.1.2 Reduced tool installation cost and cycle time.

5.1.3 *Reliability, Maintainability* — Improved tool up-time, repair time, and availability will positively affect cost of ownership. Primary improvement is in system MTBF and MTTR.

5.1.4 *Sub-Assembly Contamination Control* — Cost of ownership will also be improved by lower long-term contamination levels in the process chamber or bath, resulting in wafer defect reductions and/or yield improvement. Long-term flow accuracy for mass flow controllers (MFC's) will also be improved for better wafer level uniformity.

4 National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, Telephone: 617-770-3000, Fax: 617-770-0700, Website: www.nfpa.org

5 Military Specifications, Commanding Officer, Naval Publications, and Forms Center, Attention: MPFC 105, 5801 Tabor Avenue, Philadelphia, PA 19120

5.1.5 *Final Assembly Contamination Control* — Will result in reduced possibility of cleanroom contamination upon tool delivery, and avoid time delay of tool cleaning at wafer fab site.

SEMI E49.2-1104
GUIDELINE FOR THE QUALIFICATION OF POLYMER ASSEMBLIES USED IN ULTRAPURE WATER AND LIQUID CHEMICAL SYSTEMS IN SEMICONDUCTOR PROCESS EQUIPMENT

This guideline was technically approved by the Global Liquid Chemicals Committee and is the direct responsibility of the North American Liquid Chemicals Committee. Current edition approved by the North American Regional Standards Committee on August 16, 2004. Initially available at www.semi.org September 2004; to be published November 2004. Originally published in 1995; last published February 1998.

NOTICE: This document was rewritten in its entirety in 2004, and is a replacement for the previous versions of both E49.2 & E49.3.

NOTICE: Paragraphs entitled NOTE are not an official part of this document and are not intended to modify or supercede it.

1 Purpose

1.1 The objective of this document is to provide a guideline by which the purity and mechanical integrity of all ultrapure water and liquid chemical Assemblies shipped to end users may be qualified. It is also the purpose of this guideline to complement the following:

- SEMI F57: Provisional Specification For Polymer Components Used in Ultrapure Water and Liquid Chemical Distribution Systems and;
- SEMI E49.7: Purity Guide For the Design and Manufacture of Ultrapure Water and Liquid Chemical Systems in Semiconductor Process Equipment

NOTE 1: As with any SEMI guide, the practices outlined herein are recommendations, not specifications. Users of this document should recognize that alternate practices are not excluded as long as they produce results that are equivalent to those produced using the recommendations outlined here and meet the requirements of the end user.

2 Scope

2.1 To ensure the purity and mechanical integrity of ultrapure water and liquid chemical Assemblies the following tests and quality guidelines are recommended:

- Hydrostatic Pressure Tests – See Table 1, Section 9.1, and Section 9.2.
- Ultrapure Water Flush Test – See Table 1 Section 9.1, and Section 9.3.
- Particle Test – See Table 1, Section 9.1 and Section 9.4
- Ionic and Metallic Contamination Tests – See Table 1, Section 9.1, and Section 9.5
- Certification – See Section 10 for defining, establishing, executing, and maintaining a certification program.
- Traceability – See Section 11 for the responsibilities for suppliers to verify compliance with SEMI F57, SEMI E49.7, and this document.

2.2 Typical semiconductor process equipment with ultrapure water and liquid chemical delivery Assemblies includes, but is not limited to the following:

- Wafer Handling Equipment
- Wafer Cleaning Systems
- Chemical Filtration/Mixing Skids provided by OEM
- Wet Clean Stations
- Wafer Scrubbers
- CMP
- Photolithography coaters and developers
- Ion Implanters
- Metrology equipment
- Ancillary equipment provided with the process equipment.

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

3 Limitations

3.1 For the purposes of this document, qualification recommendations are limited to the purity and mechanical integrity of Assemblies as outlined in the purpose and scope. Qualification recommendations are not intended to address any other operational parameters (for example, flow capacity, flow rates, reliability, chemical compatibility etc.).

3.2 This guideline does not define the purity performance requirements of individual components, which may be addressed by SEMI F57. Nor does this document provide guidelines for the design and manufacture of Assemblies, which may be addressed by SEMI E49.7.

3.3 Facility distribution systems are also outside the scope of this guideline.

3.4 Stainless steel or other non-polymeric Assemblies are outside the scope of this document. Refer to SEMI E49.4, SEMI E49.5, and SEMI E49.6 for information on stainless steel components and Assemblies.

3.5 This guideline is not intended to apply to Assemblies used in the delivery of liquids that do not contact the wafer's surface, for example drainage and cooling Assemblies.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C59 — Specifications and Guidelines for Nitrogen

SEMI E49.4 — Guide for High Purity Solvent Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.5 — Guide for Ultrahigh Purity Solvent Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.6 — Guide For Subsystem Assembly and Testing Procedures – Stainless Steel Systems

SEMI E49.7 — Purity Guide For the Design and Manufacture of Ultrapure Water and Liquid Chemical Systems in Semiconductor Process Equipment

SEMI F57 — Provisional Specification For Polymer Components Used in Ultrapure Water and Liquid Chemical Distribution Systems

SEMI F61 — Guide for Ultrapure Water System Used in Semiconductor Processing

4.2 *ASTM Standards*[1]

ASTM D4327 — Standard Test Method for Anions in Water by Chemically Suppressed Ion Chromatography

ASTM D5997-96 — Standard Test Method for On-Line Monitoring of Total Carbon, Inorganic Carbon in Water by Ultraviolet, Persulfate Oxidation, and Membrane Conductivity Detection

4.3 *Other Standards*

Hydrostatic Pressure and Leak Testing of Polymer Piping Systems Used in High-purity Water Applications[2]

5 Terminology

5.1 See Section 4 of SEMI E49.

5.2 For the purposes of this document, an "Assembly" or "Assemblies" is defined as a combination of two or more ultrapure water or liquid chemical delivery components and is always capitalized when used in this manner.

5.3 For the purposes of this document Assemblies shipped to end users are those Assemblies sent to semiconductor manufacturers which will not undergo any additional testing, cleaning, or other qualification processes. The semiconductor manufacturer may perform additional testing outside the tests outlined by this document.

5.4 For the purposes of this document "supply chain" is defined as those manufacturers involved in producing components, integrating or assembling components, and testing Assemblies.

5.5 For the purposes of this document components include but are not limited to all product covered by SEMI 57 as well as product not covered by SEMI F57 such as pumps, storage tanks, drums, pressure vessels, filter housing, sensors, monitors, or ultra-filtration, and pumps.

5.6 NIST is the National Institute of Standards and Technology.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555, Website: www.astm.org

2 Mayer, Burkhart, Rydzewski, UltraPure Water Journal, May/June 2002, pp. 27-40

6 Performance Guidelines

Table 1 Overview of Recommended Tests

Test	*Frequency*	*Performance Guideline*	*Test Method/Reporting of Results*
Hydrostatic Pressure	Every Assembly shipped to the end user	No visible leakage & ≤ 5% pressure decay	Section 9.1 Section 9.2
Ultrapure Water Flush	Every Assembly shipped to the end user	Resistivity: ≥ 18 meg ohm-cm @ 25°C (77°F) Allowable TOC adders (ppb): ≤ 7.5	Section 9.1 Section 9.3
Particle	Periodic testing – see Section 10.7 and 10.8	Allowable Particle adders (particles/L ≥ 0.1 µm) : ≤ 120	Section 9.1 Section 9.4
Ionic Contamination	Periodic testing – see Sections 10.7 and 10.8	Allowable ionic adders (ppb): F-: ≤ 7.5 Cl-: ≤ 0.40 NO_2-, Br-, NO_3-, HPO_4=, SO_4= ≤ 0.05	Section 9.1 Section 9.5
Metallic Contamination	Periodic testing – see Sections 10.7 and 10.8	Allowable metallic adders (ppb): Al, Ba, B, Ca, Cr, Cu, Fe, Pb, Li, Mg, Mn, Ni, K, Na, Sr, and Zn: ≤ 0.02	Section 9.1 Section 9.5

NOTE 2: Table 1 provides an overview of the tests recommended within this document and associated performance criteria. For detailed explanations of testing frequency, test methods, and some examples of tests, refer to the sections identified within the table.

7 Utility Recommendations

NOTE 3: These are minimum utility recommendations for the media used during qualification of an Assembly.

7.1 *Nitrogen*

- Nitrogen quality should meet requirements of SEMI C59.
- Particle filtration should be 99.99999% removal of .003 micron particles.

7.2 *Ultrapure Water*

- Resistivity ≥ 18 Mohm-cm @ 25°C (77°F)
- TOC — < 10 ppb
- Silica — < 5 ppb
- Particles — (≥ 0.1 µm) < 500 particles/L
- Anions (F-, Cl-, NO2-, Br-, NO3-, HPO4-, SO4-) < 0.10 ppb
- Metals (Al, Ba, B, Ca, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb, Sr, Zn) < 0.05 ppb
- Bacteria — < 10 colonies/100 milliliter

NOTE 4: If testing requirements dictate, access to higher quality Ultrapure Water may be appropriate. Additional information related to Ultrapure Water facility design and terminology may be obtained in SEMI F61, Guide for Ultrapure Water System Used in Semiconductor Processing.

7.3 *Clean Dry Air (CDA) or Oil Free Air* — Uses include pneumatic control and air actuation. CDA is not recommended for use on cleaned wetted surfaces. Nitrogen is recommended for drying cleaned wetted surfaces because the purity level is clearly defined and controlled.

8 Related Documents

8.1 *International SEMATECH Documents*[3]

SEMASPEC 92010936B — Provisional Test Method for Determining Leachable Trace Inorganics in Ultra Pure Water Distribution System Components

SEMASPEC 92010937B — Provisional Test Method for the Evaluation of Bulk Polymer Samples of Ultra Pure Water Distribution System Components

SEMASPEC 92010949B — Provisional Test Method for Determining Particle Contribution and Retention by Ultra Pure Water Distribution System Components

SEMASPEC 92010955B — Provisional Test Method for Analyzing Plastic Surface Condition of Ultra Pure Water Distribution System Components (SEM Method)

8.2 *ASTM Documents*

ASTM D5173-97 — Standard Test Method for On-Line Monitoring of Carbon Compounds in Water by Chemical Oxidation, by UV Light Oxidation, by Both, or by High Temperature Combustion Followed by NDIR or by Electrolytic Conductivity

9 Sampling and Analysis Methodology

9.1 *General Recommendations for all Tests*

9.1.1 All test reports should include:

- Confidence intervals and detection or reporting limits,
- All units of measure,
- As detailed a description as possible of the Assembly tested including part number and manufacturing date,
- Date of test and initials of person performing test,
- Additional information as specified in the specific test recommendations within this document,
- Any and all relevant data collected during testing should be summarized and included,
- Recording of Ultrapure Water and Nitrogen quality used to perform test, and
- For Sections 9.3 through 9.5 inlet and outlet water quality.

9.1.2 Trained and qualified personnel should perform all sampling and testing.

9.1.3 All instrumentation shall be calibrated with standards traceable to NIST or the equivalent national standard where those standards exist**.** The type of instrument(s) manufacturer, model #, serial # or I.D #**,** and most recent calibration date should be available.

9.1.4 If using two separate online instruments for inlet and outlet testing, determine any difference in the two readings and include that in the final calculations.

9.1.5 Incoming and outgoing water should be sampled as close as possible to the Assembly's liquid supply point and the Assembly's delivery point respectively. Where there are multiple inlets and/or outlets for an Assembly, a single representative inlet and outlet should be selected for this testing. However, all inlets and outlets should be flushed in a consistent manner

3 International SEMATECH, 2706 Montopolis Drive, Austin, TX 78741, USA, Website: www.sematech.org

such that the tests are representative of the Assembly performance.

9.1.6 For optimum results, the distance between a sample port and an instrument should be minimized. It is recommended that components comply with SEMI F57 and the assembly and design should be in accordance with SEMI E49.7.

9.1.7 Operate valves to ensure there is no entrapment and to displace any air prior to beginning a test.

9.1.8 Filter elements contained within the Assembly under test should not be included during a test as they may mask results and will need to be replaced following the test.

9.1.9 Assemblies should be dried with Nitrogen and capped following any testing with ultrapure water and prior to shipment.

9.2 *Hydrostatic Pressure Test* – This test is required for every Assembly shipped directly to an end user. This test may also be required periodically at other points in the supply chain.

9.2.1 The intent of this test is to eliminate Assembly leaks when an assembly is initially exposed to pressure and temperature (up to and including the manufacturer's maximum recommended operating pressure and temperature) at the end user's facility. The user of this test is encouraged to review "Hydrostatic Pressure and Leak Testing of Polymer Piping Systems Used in High-purity Water Applications" (Mayer, Burkhart, Rydzewski) for a thorough discussion of standards, and how the physical properties of polymers impact testing practices.

9.2.2 The Hydrostatic Pressure Test conditions are the manufacturer's maximum recommended pressure at ambient temperature. However, it is incumbent upon the manufacturer to ensure that the assembly will be leak free when exposed to maximum pressure and maximum temperature at the end user's facility. If the test conditions recommended here do not result in initial leak free operation for the end user, it is incumbent upon the end user and manufacturer to agree on appropriate corrective action(s) to comply with the intent of this Hydrostatic Pressure Test. This may include testing at elevated media temperatures.

9.2.3 *Test Method*

9.2.3.1 *Test Media* — Ultrapure Water at ambient temperature.

9.2.3.2 *Test Pressure* — Manufacturer's maximum recommended operating pressure.

9.2.3.3 *Test Procedure*

- Flush system at maximum rated flow to remove entrapped air.
- Keep assembly at constant temperature during test.
- Pressurize to the Manufacturer's maximum recommended operating pressure and wait 15 minutes.
- Repressurize to Manufacturer's maximum recommended operating pressure and wait 15 minutes.
- Repressurize to Manufacturer's maximum recommended operating pressure and wait 30 minutes.
- Repressurize to Manufacturer's maximum recommended operating pressure.
- Monitor the pressure for 15 minutes to ensure compliance with Table 1 requirement of ≤ 5% decay in pressure.
- Record pressure readings at the beginning and end of each waiting period.

9.2.4 *Hydrostatic Pressure Test Example*

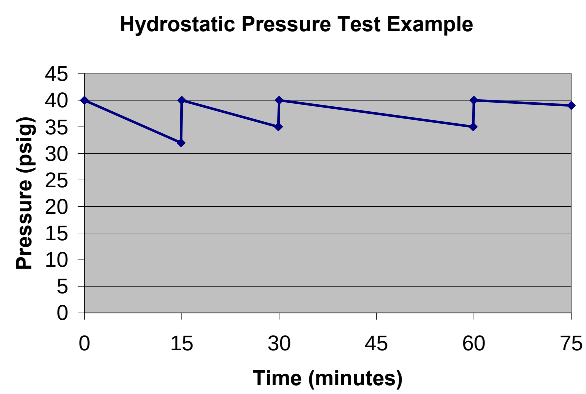

Figure 1
Hydrostatic Pressure Test Example

- Test Media: Ultrapure Water
- Test Media Temperature: 20C
- Manufacturer's maximum recommended operating pressure: 40 psig.
- Assembly is pressurized to 40 psig for 15 minutes.
- Assembly is repressurized to 40 psig for 15 minutes.
- Assembly is repressurized to 40 psig for 30 minutes.

- Assembly is repressurized to 40 psig.
- During the next 15 minutes the Assembly pressure is monitored to ensure that no visible leakage or pressure loss in excess of 2 psi (5%) is observed.

9.2.5 As noted in Table 1, the requirement to pass this test is no visible leakage and pressure decay of less than 5% of maximum recommended operating pressure. The actual pressure decay and results of a visible inspection should be noted on the test report.

9.3 *Ultrapure Water Flush Test* — This test consists of resitivity and TOC tests and is required for every Assembly shipped directly to an end user. These tests may also be required periodically at other points in the supply chain.

9.3.1 *Resistivity Testing Recommendations*

9.3.1.1 The test flow rate should be no less than the manufacturer's recommended minimum flow rate for the instrument(s) being used. The test flow rate should be no more than the maximum recommended flow for the Assembly under test or the instrument(s) being used.

9.3.1.2 Following recommended manufacturer procedures, measure resistivity just prior to the Assembly and at the Assembly outflow.

9.3.1.3 Allow the reading just prior to the Assembly to stabilize until no change outside the precision of the device is observed for at least 5 minutes and the resistivity meets or exceeds the specification in section 7.2. Repeat the procedure at the Assembly outflow.

9.3.1.4 Temperature just prior to the Assembly must not differ more than +/- 0.5 C when compared to the temperature at the Assembly outflow. Otherwise, a correction may need to be performed

9.3.1.5 Ensure that instrument connections are leak tight to avoid positive bias from atmospheric CO_2.

9.3.1.6 The inflow and outflow may be measured simultaneously using a 2-channel/2-cell resistivity meter.

9.3.1.7 As noted in Table 1, the requirement to pass this test is a resistivity $\geq$ 18 Mohm-cm @ 25°C (77°F) and both inlet and outlet. The test report should include inlet at outlet resistivity measurements.

9.3.2 *TOC Testing Recommendations*

9.3.2.1 The test flow rate should be no less than the manufacturers recommended minimum flow rate for the instrument(s) being used. The test flow rate should be no more than the maximum recommended flow for the Assembly under test or the instrument(s) being used.

9.3.2.2 Refer to ASTM Method D5997-96 (Reapproved 2000) when including UV persulfate oxidation or ASTM 5173-97 when using UV without persulfate. It should be noted which method is incorporated.

9.3.2.3 Ensure that the instrument connections are leak tight to avoid interference from atmospheric CO_2. Because TOC is determined by the difference of Total Carbon (TC) and Total Inorganic Carbon (TIC), the TOC detection limit can be no lower than 10% of the TIC reading.

9.3.2.4 Allow the readings to stabilize until at least two successive readings agree within +/- 5% and the TOC adders are $\leq$ the value specified in Table 1.

9.3.2.5 The procedure should be performed just prior to the Assembly and at the Assembly outflow.

9.3.2.6 As noted in Table 1, the requirement to pass this test is TOC adders (ppb) of $\leq$ 7.5. Both the inlet and outlet TOC measurements should be included in the test report.

9.4 *Particle Testing Recommendations* — These tests are required periodically to establish that the Assembly design is typically capable of meeting the performance criteria in Table 1.

9.4.1 The test flow rate should be no less than the manufacturers recommended minimum flow rate for the instrument(s) being used. The test flow rate should be no more than the maximum recommended flow for the Assembly under test or the instrument(s) being used.

9.4.2 Particle contribution will be determined without valves being actuated. Active components such as valves should be evaluated for particle performance at the component level to supplement this test.

9.4.3 The water supplied to the Assembly under test should be filtered with a maximum 0.05 micron filter with a retention value such that filtered particle concentration is $\leq$ 10 particle/liter $\geq$ 0.1 µm.

9.4.4 Particle contribution testing will measure the Assembly outlet particle concentration and assumes all particles are generated within the Assembly under test. Periodic verification of the inlet particle concentration specified in Section 9.4.3 should be performed and reported in accordance with Section 9.1.1. Allowable particle adders are outlined in Table 1.

9.4.5 Follow the manufacturer's recommended procedures for the optical particle counter.

9.4.6 Allow the reading to stabilize from rinse down until there is no change within the expected noise for 2 or more intervals (i.e. no change in slope). An appropriate sample interval should be chosen such that intervals with very small counts are not taken. In addition, the user should remain cognizant of the requirement in Table 1 for allowable particle adders.

9.4.7 As noted in Table 1, the requirement to pass this test is $\leq$ 120 allowable Particle adders (particles/L $\geq$ 0.1 µm). The outlet particle concentration and date and concentration of most recent inlet particle concentration verification should be noted on the test report.

9.5 *Anions and Metals Testing Recommendations* — These tests are required periodically to establish that the Assembly design is typically capable of meeting the performance criteria in Table 1.

9.5.1 The test flow rate should be no more than the maximum recommended flow for the Assembly under test or the instrument(s) being used.

9.5.2 Grab Sample Methodology for Assembly supply:

Step 1: Open and close sampling valve 5 times.

Step 2: Open valve full throttle and allow UPW to flow for at least 2 minutes.

Step 3: Adjust to approximately 1liter/minute and allow to flow at least 5 minutes.

Step 4: Use precleaned and qualified bottles one each for anions and metals.

Step 5: Fill to overflowing and empty the contents. Repeat 4 times. Avoid contact with the neck or inside of the cap with hands or sample port.

Step 6: Minimizing the distance between the port and bottle, fill the container to the bottom of the neck.

Step 7: Carefully rinse the cap and immediately secure it tightly to the bottle.

9.5.3 Grab Sample Methodology for Assembly Outflow:

Step 1: Under standard assembly operation, allow outflow to run at least 5 minutes.

Step 2: Use precleaned and qualified bottles one each for anions and metals. Note that for convenience, outflow bottles may be prerinsed using inflow UPW.

Step 3: Minimizing the distance between the outflow and bottle, fill the container to the bottom of the neck.

Step 4: Carefully rinse the cap and immediately secure it to the bottle.

9.5.4 Use ASTM D4327 with preconcentration to analyze anions. Use an industry standard method with ICP-MS to analyze metals.

9.5.5 Required precision for each analyte is such that the difference of the incoming and outgoing reading has an error of no more than +/- 20%.

9.5.6 As noted in Table 1, the requirements to pass this test are dependent on the ionic or metallic adder. The inlet and outlet concentrations for each analyte (or copies of laboratory reports) should be maintained and available upon request.

10 Certification

10.1 The supplier of an Assembly shipped to an end user is responsible for defining, establishing, executing, and maintaining a certification program based on the tests in Section 6.

10.2 By default all of the requirements within this document apply unless another agreement is made between supplier of an Assembly shipped to an end user and an end user.

10.3 Qualification tests and certification documents shall reflect current production practices.

10.4 The certification program will specify any necessary corrective action plan in the event that an Assembly fails to meet these requirements during testing.

10.5 Upon request, the supplier of an Assembly shipped to an end user is responsible for supplying documentation that proves the Assembly consistently meets the requirements of this document.

10.6 As stated in the purpose, this document is a "guideline by which the purity and mechanical integrity of all ultrapure water and liquid chemical Assemblies shipped to end users may be qualified". To ensure the purity and mechanical integrity of Assemblies shipped to end users is maintained, these guidelines must also be implemented throughout the supply chain. Section 10.7 provides recommendations for Assemblies shipped directly to an end user and Section 10.8 provides recommendations for the remainder of the supply chain.

10.7 The certification program for an Assembly delivered directly to an end user will specify the frequency of testing and the test Assembly(s).

10.7.1 Each individual Assembly delivered directly to an end user shall have the following tests performed:

- Hydrostatic test (See Table 1 and Sections 9.1 and 9.2)
- Ultrapure Water Flush test (see Table 1 and Sections 9.1, 9.3.1, and 9.3.2)

10.7.2 To avoid the cost involved in performing the Particle test (Section 9.4) and Ionic and Metallic Contamination tests (Section 9.5) on every Assembly delivered directly to an end user, Assemblies **s**hall be selected which represent all unique components and production techniques. The Assemblies will be certified as meeting the requirements within Table 1 based on the outcome of the representative tests and a periodic testing program.

10.7.3 Particular attention and increased testing frequency are recommended for Assemblies that include components not covered by SEMI F57.

10.7.4 The supplier of an Assembly shipped directly to an end user should specify which components do, and which components do not, comply with SEMI F57 where SEMI F57 is applicable.

10.8 The certification program for Assemblies not delivered directly to an end user will specify the frequency of testing and the test Assembly(s).

10.8.1 To avoid the cost involved in performing Hydrostatic testing (Section 9.2), the Ultrapure Water Flush test (section 9.3), the Particle test (Section 9.4) and the Ionic and Metallic Contamination tests (Section 9.5) on every Assembly, test Assemblies shall be selected which represent all unique components and production techniques. The Assemblies will be certified as meeting the requirements of Table 1 based on the outcome of the representative tests and periodic testing program. Particular attention and increased testing frequency are recommended for Assemblies that include components not covered by SEMI F57.

10.8.2 The supplier chain should specify which components do, and which components do not, comply with SEMI F57 where SEMI F57 is applicable.

11 Supply Chain Traceability

11.1 It will be the responsibility of all Assembly suppliers to verify that all components covered by SEMI F57 comply with the specifications set forth in SEMI F57.

11.2 It will be the responsibility of all Assembly suppliers to ensure that all components have been handled and assembled in accordance with the recommendations set forth in SEMI E49.7.

11.3 It will be the responsibility of all Assembly suppliers to maintain records that show all assemblies comply with Section 10 of this document.

11.4 It will be the responsibility of all Assembly suppliers to ensure that their sources of Assemblies are controlled to the extent that they support the requirements within Section 10.

SEMI E49.4-0298
GUIDE FOR HIGH PURITY SOLVENT DISTRIBUTION SYSTEMS IN SEMICONDUCTOR MANUFACTURING EQUIPMENT

1 Purpose

1.1 This document specifies guidelines for high purity (HP) solvent distribution systems in semiconductor production equipment.

2 Scope

2.1 The distribution systems consist of stainless steel (SS) piping designed to supply flammable solvents only.

2.2 Typical processes are photolithography track equipment, solvent wet stations, and isopropyl alcohol vapor dryers.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures - Stainless Steel Systems

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

3.2 *ASTM Standards*[1]

See Section 3.3 of SEMI E49.

3.3 *ASM Document*[2]

ASM UNS S31603 — Composition of Standard Stainless Steels

3.4 *ASME Document*[3]

ASME SA479 — Specification for Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels (ASTM A 479/A 479-90) (Boiler and Pressure Vessel Codes, 1989)

4 Terminology

See Section 4 of SEMI E49.

5 Performance Guidelines

5.1 *Leak Test and Purity Indices*

5.1.1 *Pressure Decay Test*

- Test Media — Nitrogen (N_2)
- Pressure — 2 times system operating pressure
- Time — 24 hours
- Temperature — Constant
- Fail-Pressure Loss — > 1% of test pressure

5.1.2 N_2 Particle Count (ptc), at ≥ 0.2 µm Size

- < 0.18 ptc/L (< 5 ptc/ft^3) average single count
- < 1.8 ptc/L (< 50 ptc/ft^3) maximum single count

5.2 All performance measures are absolute values, relative to respective test instrument background level.

5.3 See SEMI E49.6 for recommended gas system testing procedures.

5.4 *Reliability and Maintainability Indices* — Equipment supplier should provide actual gas system performance data and/or component reliability data, accompanied by the associated failure analysis method.

Indices	*Hours*
Mean time between failure (MTBF)	
Mean time between assists (MTBA)	
Mean time to repair (MTTR)	
Start-up time (Initial)	

6 Design Guidelines

6.1 All weld joints should be automatically orbital butt welded.

6.2 Mechanical fittings should be used where required for component removal/replacement.

6.3 Dead volumes should be less than five pipe diameters in length/height. Pressure gauges with gauge protectors should be used. Pressure transducers are optional.

6.4 A means of process liquid sampling should be installed as close as possible to point of dispense.

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2 American Society of Metals, Metals Park, OH 44073

3 American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017

6.5 Incoming process liquids require filters and should be located downstream of any regulator and as close as possible to point of dispense.

6.6 Design should include a means of flow through flushing and draining for removable components or assemblies.

6.7 Pumping systems should include surge/pulse suppression devices and provisions for vibration isolation.

6.8 Supply and drain lines on a recirculation system should be separated by an isolation valve. The system should not use one line to perform both functions.

6.9 All filters should be able to be isolated from process stream for maintenance.

6.10 Backflow/back pressure protection should be included in the system.

6.11 For processes requiring pressure control, regulators should be included in the system.

6.12 The system should have a means of manifolding supply and drain lines onboard, so that there is a single point connection for each individual liquid.

7 Materials Guidelines

7.1 *Material Mechanical Characteristics - Stainless Steel*

7.1.1 All tubing greater than or equal to 1.27 cm (1/2 in.) diameter should conform to ASTM A 269.

7.1.2 Tubing less than 1.27 cm (1/2 in.) diameter should conform to ASTM A 632.

7.1.3 All bar stock should conform to ASTM A 479 or ASME SA479.

7.1.4 All steel should conform to ASM UNS S31603 for chemical composition with the following exceptions:

- Sulfur as reported by the SMTR ≤ 0.030%
- Carbon as reported by the SMTR ≤ 0.030%

7.2 Stainless steel should be 316L electropolished for solvent system wetted flow streams or as specified by the customer.

7.3 Materials for valve seats, diaphragms, gaskets, and O-rings should be chemically compatible to the process liquid.

7.4 *Material Performance Guidelines*

7.4.1 The performance guidelines below are SS qualification values to be demonstrated by the original component manufacturer. Semiconductor equipment suppliers should provide proof that their components conform to these requirements.

7.4.2 The performance tests should be considered production qualification tests. It is the responsibility of the component manufacturer to provide statistically significant data which correlates their production tests to these qualification tests (e.g., Statistical Process Control, MIL-STD-105D).

7.4.3 The equipment supplier should be responsible for maintaining and supplying, upon request, documentation that proves their components meet the user's materials performance requirements.

Table 1 Summary of Recommended Specifications

Description	*Value*	*Units*
Internal Surface Chemistry (AUGER) Surface chromium oxide enhanced layer thickness at 1/2 peak height of measured oxygen signal level For an example of a test method, see SEMASPEC 90120573B (ESCA)	≥ 15	Å
Internal Surface Chemistry (ESCA) Total chromium to iron ratio including both reduced and oxidized stated For an example of a test method, see SEMASPEC 90120403B (ESCA)	≥ 1.25:1	value
Internal Surface Chemistry (EDX) Surface foreign elements, those elements not in the Smelter's Test Report (SMTR) Test procedures per ASTM F 1375 (EDX)	0	value
Internal Surface Defects Photos per test method Counts per photo Test procedures per ASTM F 1375 (SEM)	5 ≤ 50	value value
Internal Surface Roughness Average surface roughness Roughness average (R_a) Maximum surface R_a (individual reading) For example of a test method, see SEMASPEC 90120400B (Contact Profilometry)	≤ 0.25 (≤ 10) ≤ 0.38 (≤ 15)	µm (µin.) µm (µin.)
Particulate Contribution at ≥ 0.1 µm size at ≥ 0.02 µm size Test procedures per ASTM F 1394 (Particles)	≤ 0.71 (20) ≤ 2.6 (75)	ptc/L (ptc/ft^3) ptc/L (ptc/ft^3)
Internal Absorbed Moisture Time to recover to base line from a 2 ppm spike for low surface area component (valve, regulator) Time to recover to baseline from a 2 ppm spike for high surface area component (filters, tubing) Test procedures per ASTM F 1397	≤ 4 ≤ 6	hour hour
Total Anionic Contamination Total anionic contamination added to test water Individual anionic contaminant Test procedures per ASTM D 4327 (Total Anions)	≤ 1 ≤ 0.2	ppm ppm
Leak Rate Inboard leak rates for He Outboard leak rate for He Cross-seat leak rates for He Test procedures per SEMI F1 (Leak Rate)	$\leq 1 \times 10^{-9}$ $\leq 1 \times 10^{-5}$ $\leq 1 \times 10^{-8}$	scc/s scc/s scc/s
Cycle Life Manual values pressure automatic valves High Pressure automatic valves Low Pressure automatic valves Test procedures per ASTM F 1375 (Cycle Life)	≥ 25 K ≥ 25 K ≥ 500 K	cycles cycles cycles

8 Component Guidelines

8.1 For component leak rate and cycle life requirements, see Section 7, Materials Guidelines.

8.2 Valves should be ball (dry assembly, lubricant-free) or bellows type. Metal diaphragm valves are optional.

8.3 Regulators should be packless in design with all metal bonnet seals.

8.4 Regulators and valve flow coefficient (C_v) should be selected based on liquid flow requirements and liquid characteristics.

8.5 Mechanical fittings should be compression type or metal face seal type with solid nickel gaskets.

8.6 Pressure gauges should be liquid-filled type with compression or metal face seal fittings. Gauge isolators are recommended.

8.7 Filters should be PTFE media rated at 0.1 µm pore size.

8.8 Check valves should be disk poppet type.

9 Subsystem Assembly Guidelines

See SEMI E49.6 for recommended SS system assembly procedures.

10 Related Documents

10.1 *SEMATECH Documents*[4]

SEMASPEC 90120400B — Test Method for Determination of Surface Roughness by Contact Profilometry for Gas Distribution System Components

SEMASPEC 90120403B — Test Method for XPS Analysis of Surface Composition and Chemistry of Electropolished Stainless Steel Tubing for Gas Distribution System Components

SEMASPEC 90120573B — Test Method for AES Analysis of Surface and Oxide Composition of Electropolished Stainless Steel Tubing for Gas Distribution System Components

4 SEMATECH, Technology Transfer Department, 2706 Montopolis Drive, Austin, TX 78741

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

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

SEMI E49.5-0298
GUIDE FOR ULTRAHIGH PURITY SOLVENT DISTRIBUTION SYSTEMS IN SEMICONDUCTOR MANUFACTURING EQUIPMENT

1 Purpose

1.1 This document specifies guidelines for ultrahigh purity (UHP) solvent distribution systems in semiconductor production equipment.

2 Scope

2.1 The distribution systems consist of stainless steel (SS) piping designed to supply flammable solvents only.

2.2 Typical tools include photolithography track equipment, solvent wet stations, and isopropyl alcohol vapor dryers.

3 Referenced Documents

3.1 *SEMI Standards*

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures - Stainless Steel Systems

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

3.2 *ASM Document*[1]

ASM UNS S31603 — Composition of Standard Stainless Steels

3.3 *ASTM Standards*[2]

See Section 3.3 of SEMI E49.

4 Terminology

See Section 4 of SEMI E49.

5 Performance Guidelines

5.1 *Leak Test and Purity Indices*

5.1.1 *Pressure Decay Test*

- Test Media — Nitrogen (N_2)

Pressure — 2 times system operating pressure

- Time — 24 hours
- Temperature — Constant
- Fail-Pressure Loss — > 1% of test pressure

5.1.2 *N_2 Particle Count (ptc), at ≥ 0.1 µm Size*

- < 0.18 ptc/L (< 5 ptc/ft^3) average single count
- < 1.8 ptc/L (< 50 ptc/ft^3) maximum single count

5.1.3 *Moisture Level* — ≤ 200 ppb

5.2 All performance measures are absolute values, relative to respective test instrument background level.

5.3 See SEMI E49.6 for recommended solvent system testing procedures.

5.4 *Reliability and Maintainability Indices* — Equipment supplier should provide actual gas system performance data and/or component reliability data, accompanied by the associated failure analysis method.

Indices	*Hours*
Mean time between failure (MTBF)	
Mean time between assists (MTBA)	
Mean time to repair (MTTR)	
Start-up time (Initial)	

6 Design Guidelines

6.1 All weld joints should be automatically orbital butt welded.

6.2 Mechanical fittings should be used where required for component removal/replacement.

6.3 Dead volumes should be less than three pipe diameters in length/height. Blind runs such as pressure gauges should not be used.

6.4 A means of process liquid sampling should be installed as close as possible to point of dispense.

6.5 Incoming process liquids require filters and should be located downstream of any regulator and as close as possible to point of dispense.

6.6 The system internal volume should be minimized by use of Dead Space Free (DSF) branch valves and/or multi-component integrated assemblies.

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

6.7 Design should include a means of flow through flushing and draining for removable components or assemblies.

6.8 Pumping systems should include surge/pulse suppression devices and provisions for vibration isolation.

6.9 Supply and drain lines on a recirculation system should be separated by an isolation valve. The system should not use one line to perform both functions.

6.10 All filters should be able to be isolated from process stream for maintenance.

6.11 Ball and needle type valves should not be used.

6.12 Backflow/back pressure protection should be included in the system.

6.13 For processes requiring pressure control, regulators should be included in the system. Pressure transducers and a means of pressure display should be included on the equipment.

6.14 The systems should have a means of manifolding supply and drain lines onboard, so that there is a single point connection for each individual liquid.

7 Materials Guidelines

7.1 *Material Mechanical Characteristics - Stainless Steel*

7.1.1 All tubing greater than or equal to 1.27 cm (1/2 in.) diameter should conform to ASTM A 269.

7.1.2 Tubing less than 1.27 cm (1/2 in.) diameter should conform to ASTM A 632.

7.1.3 All bar stock should conform to ASTM A 479.

7.1.4 All steel should conform to ASM UNS S31603 for chemical composition with the following exceptions:

- Sulfur as reported by the SMTR $\leq$ 0.030%
- Carbon as reported by the SMTR $\leq$ 0.030%

7.2 Stainless steel should be 316L electropolished for solvent system wetted flow streams.

7.3 Materials for valve seats, diaphragms, gaskets, and O-rings should be chemically compatible to the process gas.

7.4 *Material Performance Guidelines*

7.4.1 The performance guidelines below are SS qualification values to be demonstrated by the original component manufacturer. Semiconductor equipment suppliers should provide proof that their components conform to these requirements.

7.4.2 The performance tests should be considered production qualification tests. It is the responsibility of the component manufacturer to provide statistically valid data which correlates their production tests to these qualification tests (e.g., Statistical Process Control, MIL-STD-105D).

7.4.3 The equipment supplier should be responsible for maintaining and supplying, upon request, documentation that proves their components meet the user's materials performance requirements.

Table 1 Summary of Recommended Specifications

Description	*Value*	*Units*
Internal Surface Chemistry (AUGER)		
Surface chromium oxide enhanced layer thickness at 1/2 peak height of measured oxygen signal level	≥ 15	Å
For an example of a test method, see SEMASPEC 90120573B (AUGER)		
Internal Surface Chemistry (ESCA)		
Total chromium to iron ratio including both reduced and oxidized states	≥ 1.25:1	value
For an example of a test method, see SEMASPEC 90120403B (ESCA)		
Internal Surface Chemistry (EDX)		
Surface foreign elements, those elements not in the Smelter's Test Report (SMTR)	0	value
Test procedures per ASTM F 1375 (EDX)		
Internal Surface Defects		
Photos per test method	5	value
Counts per photo	≤ 50	value
Test procedures per ASTM F 1372 (SEM)		
Internal Surface Roughness		
Average surface roughness	≤ 0.25	µm
Roughness average (R_a)	(≤ 10)	(µin.)
Maximum surface R_a	≤ 0.38	µm
(individual reading)	(≤ 15)	(µin.)
For an example of a test method, see SEMASPEC 90120400B (Contact Profilometry)		
Particulate Contribution		
at ≥ 0.1 µm size	≤ 0.71 (20)	ptc/L (ptc/ft^3)
at ≥ 0.02 µm size	≤ 2.6 (75)	ptc/L (ptc/ft^3)
Test procedures per ASTM F 1394 (Particles)		
Internal Absorbed Moisture		
Time to recover to base line from a 2 ppm spike	≤ 4	hour
for low surface area component (valve, regulator)	≤ 6	hour
Time to recover to baseline from a 2 ppm spike		
for high surface area component (filters, tubing)		
Test procedures per ASTM F 1397		
Total Anionic Contamination		
Total anionic contamination added to test water	≤ 1	ppm
Individual anionic contaminant	≤ 0.2	ppm
Test procedures per ASTM D 4327 (Total Anions)		
Leak Rate		
Inboard leak rates for He	$\leq 1 \times 10^{-9}$	scc/s
Outboard leak rates for He	$\leq 1 \times 10^{-5}$	scc/s
Cross-seat leak rates for He	$\leq 4 \times 10^{-8}$	scc/s
Test procedures per SEMI F1 (Leak Rate)		
Cycle Life		
Manual valves	≥ 25 K	cycles
High pressure automatic valves	≥ 25 K	cycles
Low pressure automatic valves	≥ 500 K	cycles
Test procedures per ASTM F 1373 (Cycle Life)		

8 Component Guidelines

8.1 For component leak rate and cycle life requirements, see Section 7.

8.2 Valves should be springless, packless, metal diaphragm type with all metal bonnet seals.

8.3 Regulators should be threadless, packless type with all metal bonnet seals.

8.4 Regulators and valve flow coefficient (C_v) should be selected based on liquid flow requirements and liquid characteristics.

8.5 Mechanical fittings should be all metal face seal type with solid nickel gaskets.

8.6 Pressure transducers should be used in place of bourdon tube pressure gauges.

8.7 Filters should be PTFE media rated at 0.05 µm pore size.

8.8 Check valves should be disk poppet type.

9 Subsystem Assembly Guidelines

See SEMI E49.6 for recommended SS system assembly procedures.

10 Related Documents

10.1 *SEMATECH Documents*[3]

SEMASPEC 90120400B — Test Method for Determination of Surface Roughness by Contact Profilometry for Gas Distribution System Components

SEMASPEC 90120403B — Test Method for XPS Analysis of Surface Composition and Chemistry of Electropolished Stainless Steel Tubing for Gas Distribution System Components

SEMASPEC 90120573B — Test Method for AES Analysis of Surface and Oxide Composition of Electropolished Stainless Steel Tubing for Gas Distribution System Components

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

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SEMI E49.6-1103
GUIDE FOR SUBSYSTEM ASSEMBLY AND TESTING PROCEDURES - STAINLESS STEEL SYSTEMS

This guide was technically approved by the Global Gases Committee and is the direct responsibility of the North American Gases Committee. Current edition approved by the North American Regional Standards Committee on September 3, 2003. Initially available at www.semi.org October 2003; to be published November 2003. Originally published in 1995.

NOTICE: This document was completely rewritten in 2003.

1 Purpose

1.1 The objective of this document is to establish standard guidelines for cleanroom activities specific to the manufacturing, assembly, testing, and integration of materials and components used in stainless steel semiconductor manufacturing equipment.

2 Scope

2.1 This standard has been developed as a guide for the assembly and testing of high purity and ultrahigh purity gas and solvent subsystems.

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

3 Referenced Standards

3.1 *SEMI Standards*

SEMI C3.42 — Standard for Argon (Ar), VLSI Grade, Bulk (Provisional)

SEMI C59 — Specifications and Guidelines for Nitrogen

SEMI F1 — Specification for Leak Integrity of High-Purity Gas Piping Systems and Components

SEMI F27 — Test Method for Moisture Interaction and Content of Gas Distribution Systems and Components by Atmospheric Pressure Ionization Mass Spectrometry (APIMS)

SEMI F58 — Test Method for Determination of Moisture Dry-Down Characteristics of Surface-Mounted and Conventional Gas Distribution Systems by Atmospheric Pressure Ionization Mass Spectrometry (APIMS)

SEMI F70 — Test Method for Determination of Particle Contribution of Gas Delivery System

SEMI F78 — Practice for Gas Tungsten Arc (GTA) Welding of Fluid Distribution Systems in Semiconductor Manufacturing Applications

SEMI F81 — Specification for Visual Inspection and Acceptance of Gas Tungsten Arc (GTA) Welds in Fluid Distribution Systems in Semiconductor Manufacturing Systems

3.2 *ASTM Documents*[1]

ASTM F 1397 — Standard Test Method for Determination of Moisture Contribution by Gas Distribution Systems Components

3.3 *ISO Documents*[2]

NOTE 1: Refer to the latest version of the following documents for general cleanroom protocol.

ISO 14644-1 — Cleanrooms and Aassociated controlled environments Part 1: Classification of air cleanliness.

ISO 14644-2 — Cleanrooms and associated controlled environments Part 2: Specifications for testing and monitoring to prove continued compliance with ISO 14644-1.

ISO 14644-4 — Cleanrooms and associated controlled environments Part 4: Design, construction, and startup.

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 See Section 4 of SEMI E49.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555, Website: www.astm.org

2 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30, Website: www.iso.ch

5 Facility Guidelines

5.1 *Gowning Area Class 10,000/1,000 (ISO Class 7/6) for HP/UHP* — All personnel working in cleanrooms should wear paper booties prior to entering the gowning area. Personnel should wear polyester gowns, hood, and boots, pure latex or nitrile gloves (no talc), and safety glasses before entering clean areas.

5.2 *Materials Staging Area Class 10,000/1,000 (ISO Class 7/6) for HP/UHP* — Materials used in the cleanroom should have the outer bag removed and the inner bag wiped down with cleanroom wipes saturated with a 50/50, 30/70, or 10/90 IPA/DI mix in the materials staging area prior to entry into the cleanroom.

5.3 *Assembly/Test Area Class 100 (ISO Class 5) for HP and UHP* — Welding cleanroom requirements must be met per SEMI F78

5.4 *Packaging Area Class 100 (ISO Class 5) for HP and UHP*

6 Utility System Guidelines

6.1 *Purge Gases* — Argon or nitrogen must be used for purging gas systems during assembly and for testing, using cryogenic source. Particle filtration should be 99.99999% removal of 0.003 µ m particles.

- Argon quality should meet the requirements of SEMI C3.42.
- Nitrogen quality should meet the requirements of SEMI C59.

7 Materials Procedures

7.1 *Procedures for Incoming Materials and Components (Component Suppliers)*

7.1.1 *Identification Guidelines*

7.1.1.1 Every deliverable item should have some scheme of positive and permanent identification, so that traceability is provided from the steel melt source to the final metal finishing and packaging through site installation.

7.1.1.2 This identification should provide nondestructive post installation traceability.

7.1.1.3 Clearly visible labeling (without the need to open the package) should be provided at each level of packaging.

7.1.2 *Packaging and Shipping Guidelines*

7.1.2.1 Double bagging should be required. Multiple inner bags are acceptable.

7.1.2.2 The inner bag should be cleanroom compatible and should prevent damage from normal handling.

7.1.2.3 Vacuum sealing or dry inert gas purging should be used on the inner bag.

7.1.2.4 The ends of the component should be protected using some noncontaminating method.

7.1.2.5 The outer bag may be any suitable material.

7.1.3 *Documentation*

7.1.3.1 Components should be identified by lot number or serial number.

7.1.3.2 Initial testing shall be conducted to qualify new designs and processes including changes, as applicable. The component manufacturer shall establish a procedure for periodic monitoring of the manufacturing process to ensure continual compliance to requirements as noted in this guide. Documentation records must be kept available for inspection for at least one year.

7.1.3.3 The equipment supplier should be responsible for maintaining and supplying, upon request, documentation that proves their components meet the user's materials performance requirements.

7.2 *Receiving*

7.2.1 All incoming material should be segregated from "acceptable material" until it has been formally accepted through documented procedure.

7.2.2 All cartons should be opened (100%); all goods should be checked visually for damage (e.g., torn bags, inadequate padding causing damage).

7.2.3 Material should be stored in original packaging. Do not open until ready to use or inspect. Inspection involving opening sealed plastic bags should be conducted within the materials staging cleanroom. After inspection, purge and heat-seal the material into a clean polyethylene bag.

7.2.4 Any material failing initial inspection should be immediately "red tagged" and set aside in a "quarantine" area until the supplier of the material is notified and disposition is determined.

7.3 *Acceptance and Rejection of Incoming Material*

7.3.1 All material should be identified by lot number or serial number, allowing traceability back to source documentation. All material should be identified with a heat code, allowing traceability back to the raw material heat. Only material so marked should be accepted.

7.3.2 All material should meet a purchasing specification and be provided with documentation demonstrating compliance. Only material so documented should be accepted.

7.3.3 A mutually agreeable quality program, including sampling, should be used to inspect and test components and assemblies for parameters such as: surface contamination (e.g., hydrocarbon, particulate), tubing quality, wall thickness, nicks, scratches; surface roughness, pits, stringers, particle count, weldability, helium leak rate (inboard/outboard/across seat), and dimensions.

7.3.4 The material should be accepted only after these incoming QA checks are completed.

8 Construction Procedures

8.1 Systems shall be constructed in accordance with SEMI F78 and inspected per SEMI F81.

8.2 *Subsystem Assembly Protocol*

8.2.1 Gas panel and solvent system assembly should be performed only by trained competent personnel.

8.2.2 Proper procedures for tightening face seal and other connections, valve bonnets, regulator bonnets, and other components should be followed at all times. Manufacturers recommended assembly instructions should be followed at all times.

8.2.3 To minimize entrained contaminants, components and subassemblies should be capped or under purge before and after assembly. Partially assembled gas panels should be under purge or capped at all times.

8.2.4 Assemblers should at all times be wearing clean gloves; soiled, discolored or torn gloves should be replaced immediately.

8.2.5 Components, assemblies or subassemblies which are dropped or damaged during the assembly process should be red-tagged and inspected before use. Face seal gaskets which are dropped should be discarded.

9 Assembly Qualification and Quality Assurance

9.1 Tests should be successfully completed and results documented for all performance parameters (purity indices) specified.

9.2 Leak rate tests should be conducted on 100% of all subsystems per SEMI F1.

9.3 *Design Qualification* — Gas delivery system design performance should be qualified in terms of two parameters: particulate generation and contaminant spike recovery. This testing should be performed on the initial gas delivery system prototype and on any design revision which significantly impacts the component selection or system configuration. Test results should be kept on file and made available to the end user upon request.

9.3.1 *Particulate Generation* — Static and dynamic particle testing should be performed in accordance with SEMI F70 with a flow rate of at least 3 times the maximum process flow rate at the recommended supply pressure, except during mass flow controller testing when test flow rates should be between 0% and 100% of the MFC value. Testing should be performed on all flow paths that differ significantly in components or configuration. Dynamic test protocols should be as follows:

- Each valve in the test flow path should be cycled individually.
- Starting with the valve furthest upstream, cycle each valve once every 20 seconds.
- MFC valves should be cycled from 0% to 100%.

9.3.2 *Contaminant Spike Recovery* — Contaminant spike recovery testing should be performed on all flow paths which differ significantly in configuration or components. This test should be performed at a flow rate equivalent to typical flow rates achieved in purge and vent cycles for the specific flow path. Contaminant spike recovery test protocols are:

- With all components placed in the full open position, mass flow gas moisture level should be at baseline for 30 minutes prior to testing to establish stable background (< 20 ppbv per ASTM F 1397 or < 500 pptv per SEMI F58).
- When a stable background is achieved, initiate a 2 ppm (v) moisture spike until the outlet moisture concentration reaches 2 ppm. (Remove the moisture source from the test gas, and monitor elapsed time until moisture level reaches specified level.)

9.4 *Manufacturing Qualification* — Manufacturing qualification tests should be performed to verify the manufacturing and quality control procedures followed in the manufacturing of the gas delivery system. As the configuration of gas systems varies greatly from process to process, no specification should be given here other than to state that static and dynamic particle testing, moisture level, oxygen level, and hydrocarbon testing should be performed to show that the gas delivery system will meet the purity levels required.

9.5 *Certification* — Certification for gas delivery system designs should include: leak rate certification, particle counts with specified flow rates at specified pressures and flow schematic indicating which flow paths were tested and which components were cycled; moisture level plotted against time with specified flow rates at specified pressures and flow schematic indicating which flow paths were tested; and oxygen or hydrocarbon levels plotted against time with specified flow rates at specified pressures and flow schematic indicating which flow paths were tested.

10 Labeling Protocol

10.1 All lines should be labeled by gas type and flow direction.

11 Pre-Packaging Protocol

11.1 After testing is completed, the subassembly should be pressurized with UHP grade Argon or N_2. Each process line should be sealed with a closed valve and metal fitting cap or plug; all nonprocess lines should be sealed with a plastic cap or plug before being shipped.

11.2 Lines separate from gas system should be shipped double bagged from the cleanroom. Bags should be cleanroom compatible, and purged with inert gas, then sealed from atmosphere.

12 Documentation Protocol

12.1 Documentation logs should be kept for all shop activities. Example log sheets are shown as Tables 1–5 below.

Table 1 Stainless Steel Component Inspection Log

<table>
<tr><td colspan="8">Stainless Steel Component Inspection Log</td></tr>
<tr><td colspan="7">Customer:</td><td>Date:</td></tr>
<tr><td colspan="7">Location:</td><td>Page __ of __</td></tr>
<tr><td colspan="7">Project:</td><td>Cert: Yes/No</td></tr>
<tr><td colspan="3">Date Received:</td><td colspan="2">Lot No.:</td><td colspan="3">Heat No.:</td></tr>
<tr><td colspan="8"></td></tr>
<tr><td>Description</td><td colspan="2">Wall Thickness</td><td colspan="2">Diameter</td><td>Visual</td><td>Surface Finish RA</td><td>QA</td></tr>
<tr><td></td><td>Min.</td><td>Max.</td><td>Min.</td><td>Max.</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 2 Pressure Hold Test Report

Pressure Hold Test Report	
Customer:	Date:
Location:	Report:
Project:	
System:	
Time Started:	Time Finished:
Start Temperature:	Finish Temperature:
Start Pressure:	Finish Pressure:
Elapsed Time:	Finish Pressure Corrected:
Pressure Difference Corrected:	
Elapsed Time:	
Gas (or Mixture) Used for Test:	
Pressure Gauge Range:	
Comments:	
Tested by:	Date:
QA Representative:	Date:

Table 3 Particle Count Test Report

Particle Count Test Report				
Customer:			Date:	
Location:			Report:	
Counter		Instrument/Model	Serial Number	
LPC				
CNC				
Date	Time	System	Particle Counts > 0 μ m	Flow Rate/Pressure
Comments:				
Tested by:				
QA Representative:				

Table 4 Trace Moisture and Oxygen Test Report

Trace Moisture and Oxygen Test Report				
Customer:			Date:	
Location:			Report:	
Type		Instrument/Model	Serial Number	
Trace O_2				
Trace H_2O				
Date	Time	System	Inboard Leak Rate	Comments
Comments:				
Tested by:				
QA Representative:				

Table 5 Helium Leak Test Report

Helium Leak Test Report					
Customer:			Date:		
Location:			Report:		
Project:					
Type		Instrument/Model	Serial Number		
He MSLD					
Date	Time	System	Inboard Leak Rate	Outboard Leak Rate	Comments
Comments:					
Tested by:					
QA Representative:					

NOTICE: SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacturer's instructions, product labels, product data sheets, and other relevant literature respecting any materials mentioned herein. These standards are subject to change without notice.

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

SEMI E49.7-0304
PURITY GUIDE FOR THE DESIGN AND MANUFACTURE OF ULTRAPURE WATER AND LIQUID CHEMICAL SYSTEMS IN SEMICONDUCTOR PROCESS EQUIPMENT

This guide was technically approved by the Global Liquid Chemicals Committee and is the direct responsibility of the North American Liquid Chemicals Committee. Current edition approved by the North American Regional Standards Committee on December 4, 2003. Initially available at www.semi.org February 2004 to be published March 2004. Originally published 1995, last published July 2002.

This standard was editorially modified in January 2004 to correct a typographical error. A change was made to Section 10.5.4.

1 Purpose

1.1 The objective of this document is to provide recommendations that will help maintain the quality of the liquid being delivered. Recommendations are given for activities specific to polymer ultrapure water and liquid chemical systems used in Semiconductor process equipment.

NOTE 1: As with any SEMI guide, the practices outlined herein are recommendations, not specifications. Users of this document should recognize that alternate practices are not excluded as long as they produce results that are equivalent to those produced using the recommendations outlined here and meet the requirements of the end user.

2 Scope

2.1 It is within the scope of this standard to recommend procedures that complement the requirements in SEMI F57 with the goal of ensuring the quality of the liquid being delivered. Recommendations are provided in the following areas:

- Manufacturing Facility
- Utilities
- System Design
- Pre-Production and Inspection
- Assembly
- System Testing
- Packaging
- Traceability

2.2 For the purposes of this document, systems include all liquid delivery components inside semiconductor process equipment and ancillary support equipment, as well as additional plumbing provided by the OEM with the processing equipment. This includes any assembly of two or more liquid delivery components provided with or within semiconductor process equipment.

2.3 Typical semiconductor process equipment with ultrapure water and liquid chemical delivery systems includes, but is not limited to the following:

- Wafer Handling Equip.
- Wafer Cleaning Systems
- Chemical Filtration/Mixing Skids provided by OEM
- Wet Clean Stations
- Wafer Scrubbers
- CMP
- Photolithography coaters and developers
- Ion Implanters
- Metrology equipment

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

3 Limitations

3.1 This standard does not define the performance requirements of components, which may be addressed by SEMI F57. Nor does this standard define the performance requirements of equipment systems. Facility distribution systems are also outside the scope of this standard.

3.2 Organic liquids, such as isopropyl alcohol and methyl alcohol, are typically in contact with stainless steel or other non-polymeric components. The polymer systems described within this document are NOT intended for use with such organic liquids. Refer to SEMI E49.4, SEMI E49.5, and SEMI E49.6 for information on stainless steel components.

3.3 System design issues outside those that directly impact liquid purity or quality are not within the scope of this document's recommendations and are left to the individual system designers.

3.4 Polymer systems described within this document are intended for use in ultrapure water and liquid chemical delivery only. Their performance requirements may exceed the needs of systems used in drainage and other lesser quality liquids.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI C3.28 — Standard for Nitrogen (N2), VLSI Grade in Cylinders, 99.9996% Quality

SEMI C41 — Specifications and Guidelines for 2-Propanol

SEMI E49 — Guide for Standard Performance, Practices, and Sub-Assembly for High Purity Piping Systems and Final Assembly for Semiconductor Manufacturing Equipment

SEMI E49.4 — Guide for High Purity Solvent Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.5 — Guide for Ultrahigh Purity Solvent Distribution Systems in Semiconductor Manufacturing Equipment

SEMI E49.6 — Guide for Subsystem Assembly and Testing Procedures – Stainless Steel Systems

SEMI F34 — Guide for Liquid Chemical Pipe Labeling

SEMI F57 — Provisional Specification for Polymer Components Used in Ultrapure Water and Liquid Chemical Distribution Systems

SEMI F61 — Guide for Ultrapure Water System Used in Semiconductor Processing

4.2 *Federal Standard (FED-STD)*[1]

Fed Stand 209E — Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones

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

4.3 *ISO Document*[2]

ISO 14644 — Cleanrooms and Associated Controlled Environments – Part 1 Classification of Air Cleanliness

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 See Section 4 of SEMI E49.

6 Manufacturing Facility Recommendations

6.1 Cleanroom Class designations as used within this document are defined within Federal Standard 209E Airborne Particulate Cleanliness Classes in Clean rooms and Clean Zones. (ISO standard 14644-1 classifications are listed parenthetically.)

6.2 *Materials Storage Area* — The storage area for components and assemblies should be a dedicated enclosed area, protected from the elements and separated from other materials. Only components and assemblies that have passed inspection, and are clean and packaged should be placed in the storage area.

6.3 *Gowning Area* — Gowning area should be Class 10,000 (ISO Class 7) or better. All personnel working in cleanrooms should follow appropriate gowning protocol such as: wear booties prior to entering the gowning area; and wear gowns, hood, boots, gloves, and safety glasses before entering clean areas.

6.4 *Staging Area* — Staging Area should be Class 10,000 (ISO Class 7) or better. The staging area (if used) should be located immediately outside the assembly cleanroom, with appropriate access to the assembly cleanroom.

6.5 *Assembly Areas* — All production operations such as cutting, welding, cleaning, assembly, final integration, final test, and packaging (if applicable) should be performed in a class 10,000 (ISO Class 7) cleanroom or better.

7 Utility Recommendations

7.1 *Nitrogen* (Uses include leak testing of non-brittle materials, drying, and purging.)

- Nitrogen quality should meet requirements of SEMI C3.28.
- Particle filtration should be 99.99999% removal of 0.003 micron particles.

2 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

NOTE 2: Use 316L electropolished tubing or PFA tubing for purge piping. (Use tubing that does not degrade N_2.)

7.2 *Ultrapure Water* (Uses include cleaning and rinsing.)

- Resistivity ≥ 18 mega ohm-cm @ 25° C (77° F)
- TOC — < 20 ppb
- Silica — < 5 ppb
- Particles — < 1 particle/milliliter @ 0.1 μ m size
- Bacteria — < 10 colonies/100 milliliter
- Hot Ultrapure Water Temperature — 80° C (176° F), minimum

NOTE 3: If testing requirements dictate, access to higher quality ultrapure water may be appropriate in portions of the facility. Additional information related to ultrapure water facility design and terminology may be obtained in SEMI F61.

7.3 *2-Propanol/IPA* (Uses include cleaning.)

- 2-Propanol/IPA quality should meet requirements of SEMI C41, Grade 1

7.4 *Clean Dry Air (CDA) or Oil Free Air* (Uses include pneumatic control and air actuation.)

7.4.1 CDA is not recommended for use on cleaned wetted surfaces. Nitrogen is recommended for drying cleaned wetted surfaces because the purity level is clearly defined and controlled.

8 System Design Recommendations

8.1 *General Recommendations* — The intent of this section is to recommend design practices that ensure the quality of the liquid being delivered. These recommendations should be considered along with design constraints such as minimizing liquid consumption, cost, ensuring maintainability, and limiting complexity. In addition, the appropriateness and simplicity of the facility interface should be considered.

8.2 *Component Recommendations* — Components should limit system exposure to ionic, metallic, total organic carbon, and particle contamination.

8.2.1 All applicable components should comply with SEMI F57.

8.2.2 For components not addressed in SEMI F57, a discussion of recommended materials (similar to that found in SEMI F57) may benefit the reader and is therefore provided.

8.2.2.1 Care should be taken to ensure that the materials are compatible with the liquid streams for long term applications. Additionally, it is important that the materials used be compatible with the application temperature and/or sanitization methods such as ozone, UV light and/or hydrogen peroxide.

8.2.2.2 These recommendations often imply the use of existing materials of choice, such as high purity grades of perfluoroalkoxy (PFA), polytetrafluoroethylene (PTFE), and polyvinylidene fluoride (PVDF). However, unique design specifications or new materials may result in instances where significant efficiencies may be achieved while maintaining substantially equivalent performance. These scenarios could result in the use of new or existing materials such as ethylenechlorotrifluoroethylene (ECTFE), polyether-etherketone (PEEK), polypropylene (PP), acetal resin (such as Delrin®™[3], Celcon®™[1] and others), polyvinyl chloride (PVC), perfluoromethylether-based perfluoroalkoxy (MFA), etc.

8.2.2.3 Due to purity and traceability issues, reprocessed or regrind material is not recommended.

8.3 *Joining Recommendations* — Joining technology that is free of dead space and entrapment areas is recommended to reduce negative effects such as microbial proliferation and impacts to slurry particle size distribution. For this reason pipe thread connections are not recommended.

8.3.1 Tubing should be joined with flare fittings, or similar dead space free technology. Preparation and joining of fittings should be performed in accordance with component manufacturer recommendations.

8.3.1.1 Care should be taken to ensure that dissimilar flare fittings are not joined together. When possible, one style of fitting should be used throughout the system. Manufacturers should be consulted prior to using similar style fittings from different manufacturers interchangeably.

8.3.2 Pipe should be joined with welds that minimize dead space and entrapment areas. Preparation and welding should be performed in accordance with component manufacturer's recommendations.

NOTE 4: Users of this guideline are cautioned that suitable welding methods, such as thermal butt welding, may be covered by patents or other intellectual property.

8.3.2.1 Glue, solvent, or thermal socket welding of pipe is not recommended.

8.4 *System Volume Recommendations* — When possible, dead volumes should be eliminated and overall system volume should be minimized to reduce negative effects on purity as well as flush times.

3 Delrin is a trademark of DuPont; Celcon is a trademark of Hoechst Celanese.

8.4.1 In instances where dead volumes are unavoidable, the dead leg should be ≤ 3 nominal flow path diameters.

8.4.2 Examples of components and practices which help minimize system volume include:

- Dead-space-free branch valves
- Multi-component integrated assemblies
- Use of direct flow paths
- Trickle bypass valves
- Sampling valves

8.5 *Flow Recommendations* — Due to issues related to equipment complexity and the cost of excessive liquid consumption, general flow recommendations for ultrapure water and liquid chemical delivery systems are not provided. However, Related Information 1 provides a list of practices that tend to reduce microbial proliferation in ultrapure water Systems. Because not all liquid chemicals are subject to these effects, the user is advised to obtain additional flow information related to ensuring the quality of liquid chemicals from the liquid chemical manufacturer.

8.6 *Slurry System Recommendations* — In addition to the other design recommendations within this section, the following recommendations are provided specifically for slurry liquid delivery systems used within CMP process equipment.

8.6.1 Areas of high shear can damage the quality of many slurries resulting in large particle count (LPC) growth. Sharp edges projecting into flow path, large pressure drops, tight bends, and sudden large reductions in tubing size can cause high shear.

8.6.2 Dead legs are of particular importance with respect to slurries because the abrasives may settle and agglomerate, creating LPC growth. To help minimize this issue branch lines should be oriented such that they project vertically above the main line to prevent the abrasive from settling and agglomerating.

8.6.3 If point of use filtration is incorporated, provisions to sample the slurry before and after the filter should be provided for LPC monitoring.

8.7 *Protection and Sampling Recommendations* — These recommendations are intended to protect liquids from back flow or cross contamination and to ensure that sampling is adequate for evaluating liquid quality throughout system.

8.7.1 Backflow/back pressure and cross contamination protection should be included in the system.

8.7.2 The system should have provisions to accomplish sampling. Sampling ports should be located as close as possible to the liquid supply point, to bath/tank or process chamber, and to the return header immediately before exit.

8.7.3 Provisions to completely flush, drain, and sanitize the liquid system completely (with ultrapure water or 2-propanol/IPA for example) should be included in the system.

8.8 *Filtration Recommendations* — These recommendations are intended to reduce negative effects such as particle contamination, metallic contamination, and micro bubbles.

8.8.1 Filters should be considered for all liquid delivery systems. Location, selection, installation, start up, and rinse of filters should be based on input from customer, chemical manufacturer and equipment manufacturer.

8.8.2 Process stream isolation should be provided for all filters to allow for maintenance and replacement.

8.9 *Labeling Recommendations* — In addition to the recommendations in Section 10.7, functional labels/schematics should be included with assembly for vents, drains, and other components as necessary to ensure the proper operation of the system(s).

8.10 *Maintainability Recommendations*

8.10.1 Components that require operation, inspection, or maintenance (i.e., valves, filters, pumps, gauges, etc.) should be located where readily accessible.

8.10.2 Provide support on each side of components, such as valves, where operation or assembly transmits torque to the piping/tubing.

8.10.3 Design should allow for thermal expansion if system operates at an elevated temperature.

9 Pre-Production Acceptance and Inspection Recommendations

9.1 *Identification Recommendations*

9.1.1 Applicable components should meet the traceability requirements found in SEMI F57. Where practical, the traceability requirements of SEMI F57 should also be followed for components not covered within SEMI F57 and assemblies, to ensure traceability is provided from the resin source. Component and assembly identification should provide nondestructive post installation traceability. In addition, packaging should have labels allowing for traceability as described above that are clearly visible (without the need to open the package).

NOTE 5: Practical limitations such as component size may not allow for permanent post installation marking of every component.

9.2 *Packaging Recommendations*

9.2.1 Applicable components should meet the packaging requirements found in SEMI F57. Where practical, the packaging requirements of SEMI F57 should also be followed for other components and assemblies to avoid contamination of wetted surfaces.

9.3 *Documentation*

9.3.1 The equipment supplier should be responsible for maintaining and supplying, upon request, documentation that proves their assemblies meet the user' s performance requirements. Similar requirements for maintaining component documentation are covered in SEMI F57 and are the responsibility of the component manufacturer.

9.4 *Receiving, Inspection, and Storage*

9.4.1 All incoming components and assemblies should be segregated until they have been formally accepted through a documented procedure.

9.4.1.1 Cartons should be checked visually for damage (e.g., torn bags, inadequate padding causing damage).

9.4.1.2 A statistically significant sample size should undergo minimum QA checks such as visual inspection and critical dimension inspection. In some instances further inspection of components to ensure compliance with SEMI F57 may be required.

9.4.1.3 Components and assemblies should be stored in original packaging until ready for inspection. Inspection involving opening sealed plastic bags should be conducted within the staging prefab cleanroom. After inspection, heat-seal the component (and if appropriate the assembly) into a clean and dry polyethylene bag.

9.4.2 Any component or assembly failing initial inspection should be immediately “red tagged” and set aside in a “quarantine” area until the supplier of the component is notified and disposition is determined.

9.4.3 Components and assemblies should be accepted only after these incoming QA checks are completed.

9.4.4 Accepted component and assemblies should have traceability to the appropriate incoming QA check.

9.4.5 Components and assemblies should be stored in the original shipping containers when possible. Pipe may be stored on racks with appropriate supports.

9.5 *Staging*

9.5.1 Prior to entry into the cleanroom components and assemblies should have the outer bag removed and the inner bag wiped down with cleanroom wipes using 2-propanol/IPA or 2-propanol/IPA and ultrapure water mix in the staging area.

10 Assembly Recommendations

10.1 *General*

10.1.1 Assembly should take place in assembly/cleanroom (see Section 6.5).

10.1.2 Inner bags should be removed within the assembly/cleanroom.

NOTE 6: In the event components must be handled outside cleanroom areas, personnel should wear protective gloves at all times and components returning to the cleanroom should be clean. All ends should be capped to avoid exposure of wetted surfaces.

10.1.3 If work must stop for an extended period, assemblies should be purged with nitrogen and capped immediately to isolate wetted materials from contamination.

10.2 *Pipe/Tube Cutting*

10.2.1 Use dedicated clean tools for piping/tubing system fabrication and installation. Clean tools at the start of each shift with 2-propanol/IPA, rinse with ultrapure water, and blow dry with nitrogen. Maintain tools in accordance with manufacturers’ recommendations.

10.2.2 Cut piping/tubing in accordance with manufacturers recommendations. Saws are prohibited.

10.2.3 The cut end of the pipe/tube should be finished before use to comply with the manufacturers’ recommendations for squareness and finish. Cut surfaces should be clean and free of loose particles and debris.

10.3 *Component and Assembly Cleaning*

10.3.1 What follows are limited and general recommendations for cleaning components or assemblies. It is the equipment manufacturer’s responsibility to ensure that cleaning procedures and solutions are adequate and do not impact equipment performance.

10.3.1.1 Every effort should be made to keep the interior of the pipe clean during cutting and prepping. If, however, the pipe has become contaminated and nitrogen (Section 7.1) will not dislodge the particles it can be cleaned by blowing an ultrapure water soaked swab (often called a “pig”) through it using nitrogen (see Section 7.1). The pig should be constructed of a clean, unused, cleanroom approved, cloth soaked in ultrapure water and wrapped around a plug of a diameter less than the ID of the pipe to be cleaned. The length of the pig should be about 2× its diameter.

10.3.1.2 Components or assemblies that have become contaminated should be cleaned. The procedure for cleaning cannot be defined but frequently includes:

- Rinse in ultrapure water.
- Soak in cleaning solution if necessary and compatible with process
- Rinse in flowing ultrapure water (see Section 7.2).
- After rinse, check cleanliness.
- If necessary, repeat the procedure until clean.

10.3.1.3 Any assemblies that have been wetted in a cleaning process shall be dried with Nitrogen.

10.3.2 Use 2-Propanol/IPA to remove any ink markings from the exterior of the pipe.

10.4 *Welded Connections*

NOTE 7: Refer to Sections 8.3 and 8.3.2 for general joining and weld recommendations.

10.4.1 *Welder Qualification*

10.4.1.1 Welders should have prior experience in the specific welding method of specific types of polymer components. To be qualified, the welder should be able to safely cut, prep, clean, purge, fit, and weld the sizes for which he or she is seeking qualification and produce consistently acceptable weld joints. It is recommended that welders undergo weld training and certification by a pipe manufacturer.

10.4.2 *Weld Qualification*

10.4.2.1 During fabrication, each welder should submit weld samples daily to the QA manager at the beginning of the shift. The welds should be representative of the types of welds the welder will perform during the shift.

10.4.2.2 These welds should meet a defined criteria of acceptability, which may include inspection for visible discoloration, uniformity of weld area, maximum weld misalignment, and weld bead height. These criteria may be derived from sources such as the component manufacturer, the process equipment manufacturer, and the end user. General recommendations for weld inspection are included in Section 10.4.4.

10.4.3 *Welding Procedures*

10.4.3.1 In general the use of weld methods that minimize dead space and entrapment areas are the preferred means of welding plastic pipe/tubing (i.e., PVDF, PFA, and Polypropylene). The weld method should be as shown on the fabrication drawings.

NOTE 8: Users of this guideline are cautioned that suitable welding methods, such as thermal butt welding, may be covered by patents or other intellectual property. When possible, use reduced bead welding method and fixturing to reduce areas on inside diameter where bacteria may accumulate.

10.4.3.2 Welding equipment should be maintained in accordance with manufacturer recommendations. For example, tools and heating elements should be kept clean and thermostat should be calibrated regularly.

10.4.3.3 Components should be firmly and accurately clamped in the welding equipment. Check alignment and clamp adjustment regularly.

10.4.3.4 Logs should be kept for each weld to ensure traceability back to the welding equipment, welder, date of weld, and inspector.

10.4.4 *Weld Inspection Criteria*

NOTE 9: Refer to manufacturer recommendations for socket weld inspection criteria.

10.4.4.1 All welds should exhibit little or no visible discoloration.

10.4.4.2 The maximum weld misalignment should be 10% of the wall thickness of the material.

10.4.4.3 Visual inspection for voids should be performed in accordance with manufacturers recommendations.

10.4.4.4 The physical characteristics of the weld bead should be in accordance with criteria which may be derived from component manufacturer, process equipment manufacturer, and end user recommendations.

10.5 *Mechanical Connections*

NOTE 10: Joining technology that is free of dead space and entrapment areas is recommended. See Sections 8.3 and 8.3.1 for general joining recommendations and specific mechanical connection recommendations. In the event that these recommendations cannot be followed, assembly recommendations for other commonly used mechanical connections are provided.

10.5.1 Flaring should be performed at the temperature and with the equipment recommended by the fitting manufacturer.

10.5.2 O-rings used in mechanical connections should be positioned per manufacturer recommendations before closing the fitting. Manufacturer recommendations for torque should be applied.

10.5.3 Gaskets used in flanged connections should be positioned per manufacturer recommendations before closing the fitting. Manufacturer recommendations for torque should be applied.

10.5.4 For tapered threaded connections, such as National Pipe Thread (NPT) and Japanese Industrial Standard (JIS), wrap tapered threads with a suitable tape, (such as PTFE tape) prior to assembly. Use of ¼" wide tape is recommended on nominal sizes of ½" or smaller. Wrap the threads three times in the direction that does not unravel during installation of the fitting. To reduce the possibility of tape entering the liquid stream, do not cover the last two threads at the narrow end of the fitting.

10.6 *Tubing and Pipe Support*

10.6.1 Route flexible tubing neatly and secure with tie-wraps or similar mechanical fastener.

10.6.2 Support distances and support clamps for pipe should employ the manufacturer's recommendations, where possible. These clamps typically cradle the pipe within a plastic fixture. Metal and/or constrictive types of clamps may induce stress into piping components and should be avoided. However, if they must be used then elastomer inserts between the pipe and clamp are recommended.

10.7 *Labeling Recommendations*

10.7.1 All ultrapure water and Liquid Chemical systems should be labeled in accordance with SEMI F34 when possible.

10.7.2 Additional labeling to support proper operation of the system(s) should be included when indicated on assembly drawing(s).

10.8 *Final Assembly Inspection Recommendations*

10.8.1 Inspect the system within the appropriate assembly environment.

10.8.2 Verify the following:

- System is complete per drawings
- Critical dimensions, squareness, offsets, and straightness are per drawings and assembly specifications
- Overall configuration is correct
- Support is adequate
- No pipe, tube, or fitting is nicked, cracked, or abused
- Each weld is visually acceptable
- Gaskets are in place and bolts are torqued to proper values
- Proper installation of valves per manufacturer's recommendations
- Unions and mechanical connections are tight
- Tubing, pipe, inlets, and outlets are labeled appropriately

10.8.3 Shop drawings that have been marked up should be returned to the engineering department for updates. The QA manager should be notified that the assembly has passed inspection, been tagged as such, and is ready for final testing.

11 System Testing Recommendations

11.1 The equipment manufacturer should successfully complete functional testing (for example leak and pressure decay testing). In addition, testing may be required to demonstrate that the system is not adversely affecting the quality of the liquid.

11.2 Any assemblies that have been wetted during testing shall be dried with Nitrogen.

NOTE 11: As outlined in limitations Section 3.1, it is beyond the scope of this document to define the performance requirements of the equipment systems.

12 Packaging Recommendations

12.1 Packaging is recommended to ensure the cleanliness and dryness of wetted surfaces during transport or storage. All open connections should be capped to isolate wetted materials from contamination. Additional guidelines for packaging can be found in other SEMI documents. For smaller assemblies refer to the requirements found in SEMI F57. For larger assemblies refer to the requirements found in SEMI E49.1.

13 Traceability Recommendations

13.1 A completed assembly should have permanent identification such that it is traceable to the documentation recommended within this guide. The manufacturer is responsible for maintaining records that include but are not limited to the following:

- Test methods and results
- Final assembly inspection
- Assembly drawing modifications
- Weld logs

RELATED INFORMATION 1
FLOW CONSIDERATIONS FOR ULTRAPURE WATER SYSTEMS

NOTICE: This related information is not an official part of SEMI E49.7 and was derived from North American Liquid Chemicals. This related information was approved for publication by full letter ballot on April 30, 2002.

R1-1 Ultrapure Water Considerations

R1-1.1 An ultrapure water system may benefit from maintaining continuous flow with a velocity greater than or equal to those listed in the following table:

Table R1-1

Nom. Size	*Tube ID (inches)*	*V (ft/s)*	*Tube ID (cm)*	*V (cm/s)*
¼”	0.125	5.2	0.3175	158.1
3/8”	0.250	2.6	0.6350	79.0
½”	0.375	1.7	0.9525	52.7
¾”	0.625	1.0	1.5875	31.6
1”	0.875	0.7	2.2225	22.6

R1-1.2 For reference this information is based on the following equations, using a Reynolds number of 5000 and water at a temperature of 20°C.

$$\mathrm{Re} = \frac{\rho \cdot V \cdot D}{\mu}$$

$$V = \frac{\mathrm{Re} \cdot \mu}{D \cdot \rho}$$

example:

$$V = \frac{(5000) \cdot (0.01002)}{(0.3175) \cdot (0.9982)} = 158.1$$

Where:

Re is Reynolds number (dimensionless)
ρ is density (g/cm^3)
V is fluid velocity (cm/sec)
D is tube diameter (cm)
μ is viscosity (g/cm-s)