

SEMI E49.2-0617

GUIDE FOR THE QUALIFICATION OF POLYMER ASSEMBLIES USED FOR LIQUID CHEMICAL SYSTEMS IN SEMICONDUCTOR EQUIPMENT

This Standard was technically approved by the Liquid Chemicals Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on May 16, 2017. Available at www.semiviews.org and www.semi.org in June 2017; originally published in 1995; previously published November 2004.

NOTICE: The section symbol (§) is used to reference a numbered section, paragraph, or header and all subordinate paragraphs, headers, and embedded material (i.e., EXCEPTIONs, lists) therein. The paragraph symbol (¶) is used to reference a particular numbered paragraph and embedded material therein. When duplicated (i.e., §§ and ¶¶) the symbols are used to reference more than one section or paragraph, respectively.

NOTICE: Paragraphs entitled ‘NOTE:’ are not an official part of this Standard or Safety Guideline and are not intended to modify or supersede the official Standard or Safety Guideline. These have been supplied by the global technical committee to enhance the usage of the Standard or Safety Guideline.

NOTICE: This Standard was completely rewritten in 2017.

1 Purpose

1.1 The objective of this Guide is to provide a guideline by which the purity and mechanical integrity of all ultrapure water (UPW) and liquid chemical Assemblies as shipped to end users may be qualified. This Guide also complements SEMI F57 and SEMI E49.7.

2 Scope

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

- *Hydrostatic Pressure Tests* — Refer to Table 1, §§ 9.1, 9.2, and 9.3.
- *Ultrapure Water Flush Test* — Refer to Table 1, § 9.1, and § 9.4.
- *Particle Test* — Refer to Table 1, § 9.1, and § 9.5.
- *Ionic and Metallic Contamination Tests* — Refer to Table 1, § 9.1, and § 9.6.
- *Certification* — Refer to § 11 for defining, establishing, executing, and maintaining a certification program.
- *Traceability* — Refer to § 12 for the responsibilities for suppliers to verify compliance with SEMI F57, SEMI E49.7, and this Guide.

2.2 Typical UPW and liquid chemical delivery components and systems are addressed in SEMI F57 and SEMI F61. All cleanroom equipment requiring high purity UPW and liquid chemical Assemblies are covered by this Guide. Liquid chemical Assemblies used in non-clean room systems that still require high quality and purity include, but are not limited to the following:

- BCD/PCD equipment
- Chemical and/or slurry Filtration/Mixing Skids provided by OEM
- Post CMP cleaning equipment
- Metrology equipment
- Ancillary equipment provided with the process equipment

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Assumptions

3.1 This Guide represents current industry best practice(s). If a user of this Guide has a process or criteria that is more stringent than the practices in this Guide, then some of the criteria in this Guide may not be applicable.

3.2 *Users* — Assembly supplier to OEM, Fab owner (end user), facilitizing group.

3.3 This Guide implies testing of the most critical assembly. The definition of the most critical assembly is to be defined by the end user. Non-critical Assemblies may be tested using less stringent techniques.

3.4 This Guide applies to the entire supply chain, starting from the subcomponent supplier, to the tool vendor supplier of Assemblies, to the semiconductor end-user tool install works. (The entire supply chain needs to do whatever necessary to ensure the assembly will meet the qualification criteria of this Guide.)

3.5 Under particle measurement methods, both static and dynamic condition(s) of the Assembly should be tested. In the case of complex Assemblies (complete chemical blend/dispense tools) the dynamic conditions should correspond to the normal operating states of the assembly.

3.6 If the Assembly is for components being qualified for an application or end use, this Guide can be used. If the assembly is being tested for material quality and handling, then SEMI F57 would be appropriate to use.

3.7 This Guide content is applicable for both initial Assembly qualification as well as post start up troubleshooting and analysis.

4 Limitations

4.1 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 (e.g., flow capacity, flow rates, reliability, chemical compatibility etc.).

4.2 This Guide does not define the purity performance requirements of individual components, which are expected to be addressed by SEMI F57. Nor does this Guide provide guidelines for the design and manufacture of Assemblies, which may be addressed by SEMI E49.7.

4.3 Facility distribution systems are also outside the scope of this Guide. Tool hook up piping and controls are outside the scope of this Guide. Reference SEMI F61 for UPW systems.

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

4.5 This Guide is not intended to apply to assemblies used in the delivery of liquids that do not contact the wafers or other critical surfaces, for example drainage and remediation Assemblies.

5 Referenced Standards and Documents

5.1 *SEMI Standards and Safety Guidelines*

SEMI C59 — Specification for Nitrogen

SEMI E49.4 — Guide for Ultrahigh Purity Solvent Distribution Systems with Metallic Fluid Paths in Semiconductor Manufacturing Equipment

SEMI E49.5 — Guide for the Design of Ultrahigh Purity Solvent Distribution Systems with Non-Metallic Fluid Paths in Semiconductor Manufacturing Equipment

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

SEMI E49.7 — Guide for the Design and Manufacture of Polymer Assemblies Used for Liquid Chemical Systems in Semiconductor Equipment

SEMI F57 — Guide for Quality Monitoring of Ultrapure Water Used in Semiconductor Manufacturing

SEMI F61 — Guide for Design and Operation of a Semiconductor Ultrapure Water System

5.2 ASTM® Standards¹

ASTM D5542 — Standard Test Method for Trace Anions in High Purity Water by Ion Chromatography

ASTM D5673 — Standard Test Method for Elements in Water by Inductively Coupled Plasma - Mass Spectrometry

ASTM D6317 — Standard Test Method for Low Level Determination of Total Carbon, Inorganic Carbon and Organic Carbon in Water by Ultraviolet, Persulfate Oxidation, and Membrane Conductivity Detection

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

ASTM F1094 — Standard Test Methods for Microbiological Monitoring of Water Used for Processing Electron and Microelectronic Devices by Direct Pressure Tap Sampling Valve and by Presterilized Plastic Bag Method

5.3 Other Documents

Hydrostatic Pressure and Leak Testing of Polymer Piping Systems Used in High-Purity Water Applications²

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

6 Terminology

6.1 Abbreviations and Acronyms

6.1.1 *MAWP* — maximum allowable working pressure (previously defined as Manufacturer's allowable working pressure and Manufacturer's Absolute Pressure)

6.2 Definitions

6.2.1 *assembly (or assemblies)* — a combination of two or more ultrapure water or liquid chemical delivery components and is always capitalized when used in this manner.

6.2.1.1 *Discussion* — 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 Guide.

6.2.2 *components* — include but are not limited to all product covered by SEMI F57 as well as product not covered by SEMI F57 such as pumps, storage tanks, drums, pressure vessels, sensors, monitors, and purification equipment.

6.2.3 *maximum allowable operating pressure (MAOP)* — maximum pressure that the system may be operated at. This is usually the lowest value of the considered rated pressure and MAWP of all system components.

6.2.4 *maximum allowable working pressure (MAWP)* — maximum pressure (based on the applicable design codes) that the weakest component of a system can withstand.

6.2.5 *mechanically-connected assembly* — with respect to hydrostatic pressure testing, any assembly which may be separated without the use of destructive processes into smaller non-separable components and then reassembled. Such Assemblies usually incorporate welded or machined assemblies having pipe or tube union fittings at various connection points. An example of a mechanically-connected assembly may be a fluid system which utilizes several smaller welded pipe assemblies, with each pipe assembly connected to the next via a pipe union.

6.2.6 *rated pressure* — maximum desirable pressure at which a device/component will function properly over the lifetime of the assembly. (Note that this may be less than or equal to MAWP. One example may be an air-op diaphragm valve. The body of the valve may have a MAWP of ~200 psig prior to burst, but the actuator may not be able to keep the valve closed above 150 psig.)

6.2.7 *supply chain* — manufacturers involved in producing components, integrating or assembling components, and testing assemblies.

6.2.8 *welded or machined assembly* — with respect to hydrostatic pressure testing, any assembly or sub-assembly comprised of primarily of commercially-available pipe, tube, and fittings which are joined by thermal welding

¹ ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA; Telephone: +1.610.832.9585, Fax: +1.610.832.9555, <http://www.astm.org>

² Mayer, Burkhardt, Rydzewski, UltraPure Water Journal, May/June 2002, pp. 27–40.

processes. Such assemblies may also contain fittings or elements that are machined from polymer rod, bar, or sheet stock. These assemblies, once welded together, may not be disassembled except by destructive processes (such as cutting or sawing). Examples of these assemblies include pipe spools, tube assemblies, valve manifolds, filter housings, and the like.

7 Performance Guidelines

Table 1 Overview of Recommended Tests

<i>Test</i>	<i>Frequency</i>	<i>Performance Guideline</i>	<i>Test Method</i>
Hydrostatic Pressure: Welded or machined Assemblies	Every Assembly shipped to the end user	No visible leakage and $\leq 2.5\%$ pressure decay in 15 minutes. Test pressure to be 1.5 times the normal operating pressure, but should not exceed the MAWP rating of each component in the assembly.	§ 9.1 § 9.2
Hydrostatic Pressure: Mechanically connected Assemblies	Every Assembly shipped to the end user or entire system	No visible leakage and $\leq 2.5\%$ pressure decay in 4 hours. Test pressure to be 1.3 times the normal operating pressure, but should not exceed the MAWP rating of each component in the assembly.	§ 9.1 § 9.3
UPW Flush	Every Assembly shipped to the end user.	Resistivity: $\geq 18 \text{ M}\Omega \cdot \text{cm}$ @ 25°C (77°F) Allowable TOC adders (ppb): ≤ 7.5	§ 9.1 § 9.4
Particle	Periodic testing – see Section 12.7 (at end user site)	Allowable Particle adders (Particules/L $\geq 0.1 \mu\text{m}$): ≤ 120	§ 9.1 § 9.5
Ionic Contamination	Periodic testing – see Section 12.7	Allowable ionic adders (ppb): F ⁻ : ≤ 7.5 Cl ⁻ : ≤ 0.40 NO ₂ ⁻ , Br ⁻ , NO ₃ ⁻ , HPO ₄ ⁼ , SO ₄ ⁼ ≤ 0.05	§ 9.1 § 9.6
Metallic Contamination	Periodic testing – see Section 12.7	Allowable metallic adders (ppb): Al, Ba, B, Ca, Cr, Cu, Fe, Pb, Li, Mg, Mn, Ni, K, Na, Sr, and Zn: ≤ 0.02	§ 9.1 § 9.6

NOTE 1: 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.

NOTE 2: *TOC* — For practical purposes, the grab sample technique may be preferred in some cases. In this case ASTM D6317 method should be used and the lab analytical sensitivity capability should be confirmed (minimum detection limit of 5 ppb).

NOTE 3: *Resistivity* — Resistivity sensors have known accuracy limitations. Therefore, local site quality manager should take into account the results of the ionic and metallic contamination test data when evaluating the final outcome of a specific instrument used to qualify/measure resistivity.

NOTE 4: *Resistivity* — The selection of the resistivity sensor should take into account vendor installation and operation requirements; this can affect the sensitivity of the readings.

NOTE 5: *Particles* — Dead legs (areas of no flow) in the test set up will affect the duration to achieve the desired cleanliness level. They should be eliminated in the test set up, especially if these would not be present in normal operation of the assembly.

NOTE 6: *Particles* — It is expected that reaching the target level of particles will take some time, possible as much as several days. For very complex assemblies this time line can be weeks in duration. The duration is function of the assembly components and cleanliness level desired. Higher velocity will assist in reducing the duration of the qualification (refer to Related Information 1, § R1-1).

NOTE 7: *Particles* — While this Guide recommends particle analysis on all Assemblies, this may not be practical in all situations. The local site quality manager may have to select the most critical or representative assemblies for testing in order to meet site requirements.

8 Utility Recommendations

NOTE 8: These are minimum utility recommendations for the media used during qualification of an Assembly.

8.1 Nitrogen

- Nitrogen quality should meet requirements of SEMI C59.
- Particle filtration should be 99.99999% removal of 0.003 micron particles.

8.2 UPW

- *Resistivity* — $\geq 18 \text{ M}\Omega \cdot \text{cm}$ at 25°C (77°F).
- *TOC* — $< 5 \text{ ppb}$.
- *Silica* — $< 5 \text{ ppb}$.
- *Particles* — ($\geq 0.1 \mu\text{m}$) $< 500 \text{ particles/L}$.
- *Anions* (F^- , Cl^- , NO_2^- , Br^- , NO_3^- , HPO_4^- , SO_4^-) — $< 0.10 \text{ ppb}$.
- *Metals* (Al , Ba , B , Ca , Cr , Cu , Fe , K , Li , Mg , Mn , Na , Ni , Pb , Sr , Zn) — $< 0.05 \text{ ppb}$.
- *Bacteria* — $< 10 \text{ colonies/100 milliliter}$.

NOTE 9: If testing requirements dictate, access to higher quality UPW may be appropriate. Additional information related to UPW facility design and terminology may be obtained in SEMI F61, Guide for Ultrapure Water System Used in Semiconductor Processing.

NOTE 10: For initial qualifications the preferred method for bacteria analysis is ASTM F1094.

8.3 *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.

9 Sampling and Analysis Methodology

9.1 General Recommendations for all Tests

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

9.1.2 Assemblies tested can be by either grab sample or online measurement. Refer to § 7, Table 1, for recommended tests and performance guideline.

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 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 UPW and prior to shipment.

9.2 *Hydrostatic Pressure Test (Welded or Machined Assembly)* — 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*³ 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.

NOTE 11: In situations where testing with deionized (DI)/UPW is undesirable due to possible contamination or incompatibility issues, an alternate inert gas testing method may be considered.

9.2.3 *Test Method*

9.2.3.1 *Test Media* — UPW at ambient temperature.

9.2.3.2 *Test Pressure* — Actual or pre-Manufacturer's maximum recommended operating pressure.

9.2.3.3 *Test Procedure*

9.2.3.3.1 Flush system at maximum rated flow to remove entrapped air.

9.2.3.3.2 Keep assembly at constant temperature during test.

9.2.3.3.3 Pressurize to the manufacturer's maximum recommended operating pressure and wait 15 minutes.

9.2.3.3.4 Re-pressurize to manufacturer's maximum recommended operating pressure and wait 15 minutes.

9.2.3.3.5 Re-pressurize to manufacturer's maximum recommended operating pressure and wait 30 minutes.

9.2.3.3.6 Re-pressurize to manufacturer's maximum recommended operating pressure.

9.2.3.3.7 Monitor the pressure for 15 minutes to ensure compliance with Table 1 requirement of $\leq 2.5\%$ decay in pressure.

9.2.3.3.8 Record pressure readings at the beginning and end of each waiting period.

³ Mayer, Burkhart, Rydzewski

9.2.4 Hydrostatic Pressure Test Example

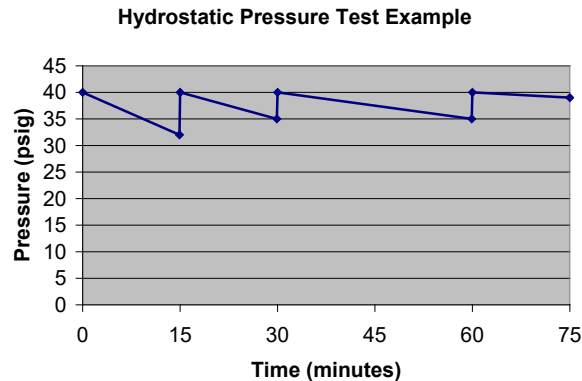


Figure 1
Hydrostatic Pressure Test Example

9.2.4.1 *Test Media* — UPW.

9.2.4.2 *Test Media Temperature* — 20°C.

9.2.4.3 *Manufacturer's Maximum Recommended Operating Pressure* — 40 psig.

9.2.4.4 Assembly is pressurized to 40 psig for 15 minutes.

9.2.4.5 Assembly is repressurized to 40 psig for 15 minutes.

9.2.4.6 Assembly is repressurized to 40 psig for 30 minutes.

9.2.4.7 Assembly is repressurized to 40 psig.

9.2.4.8 During the next 15 minutes the Assembly pressure is monitored to ensure that no visible leakage or pressure loss in excess of 1 psi (2.5%) 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 or equal to 2.5% of maximum recommended operating pressure. The actual pressure decay and results of a visible inspection should be noted on the test report.

9.3 *Hydrostatic Pressure Test (Mechanical Assembly)* — This test is required for every assembly at the end user site or at the integrator's site.

9.3.1 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 or integrator'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* or a thorough discussion of standards, and how the physical properties of polymers impact testing practices.

9.3.2 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.

9.3.3 *Test Method*

9.3.3.1 *Test Media* — UPW at ambient temperature.

9.3.3.2 *Test Pressure* — Actual or pre-manufacturer's maximum recommended operating pressure.