



RELATED INFORMATION 1 SAMPLE TEST DATA SHEET

NOTE: This related information is not an official part of SEMI F11 and is not intended to modify or supercede the official guide. It has been derived from industry specifications. Publication was authorized by full letter ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

Test Date:	Operator:	Test Facility:
Tube Manufacturer:		Fitting Manufacturer:
Tube O.D.:		Fitting Type:
Tube Wall Thickness:		Fitting Size:
Tube P/N:		Fitting P/N:
Tube Material:		Fitting Material:

Failure Temperatures = 25° , 75° , 100° , 125° , 150° , 175° , or 200° C

<i>kPa</i>	<i>Actual kPa</i>	<i>Failure #1</i>	<i>Failure #2</i>	<i>Failure #3</i>
100				
200				
400				
600				
800				
1000				
1200				

NOTE: Record the pressures and temperatures at which failures occur.

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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 F12-0998

TEST METHOD TO DETERMINE THE SEALING CAPABILITIES OF FITTINGS, MADE OF FLUOROCARBON MATERIAL, AFTER BEING SUBJECTED TO A HEAT CYCLE

1 Purpose

1.1 This method provides a uniform procedure to determine the sealing capabilities of fluorocarbon resin fittings, after they have been subjected to an elevated ambient temperature and cooled to room temperature (hereafter referred to as a “Heat Cycle”).

2 Scope

2.1 This method can be used to characterize the thermal characteristics of tube fitting connections on the basis of test data obtained under the conditions described herein, but the results are not intended to imply a performance rating.

2.2 When using this test method, a fitting body temperature range of 23° – 125°C (73° – 257°F) should be maintained.

2.3 Tube defined in this method is made of fluorocarbon materials.

2.4 Tube fittings defined in this method are made of fluorocarbon materials for all parts in contact with the internal fluid. Parts such as nuts and grippers are not limited to being made of a fluorocarbon material.

2.5 Only the seal between the tube and tube fitting being evaluated is within the scope of this document. All other seals are beyond the scope of this document.

2.6 When using this method for making comparisons between various tube fitting manufacturers, the user must be specific in the selection of the tube and tube fittings to be evaluated.

NOTE: The International System of Units (SI) is used as the standard unit of measure in this document. The U.S. Customary Units are in parentheses for reference purposes only and have been rounded to the nearest whole value.

3 Summary of Method

3.1 Measure the leakage of the tube fitting connection after being exposed to a heat cycle by subjecting the fitting to an internal pressure with nitrogen.

4 Significance and Use

4.1 In the manufacturing of semiconductor products, many types of hazardous chemicals and solvents are required. As a result, tubing and various fittings made of fluorocarbon materials (which are chemically

resistant to these fluids) are used to transport those fluids. It is important to control the testing process when evaluating various fitting designs, so that accurate comparisons of the sealing capabilities of tube fitting connections can be made.

4.2 It is the intent of this method to provide a procedure which evaluates the sealing capability of the tube fitting connection when subjected to a change in ambient temperature.

4.3 The results obtained when using this method are applicable only to conditions that specifically duplicate the procedures used within this method.

4.4 When using this test method, it is assumed that the test specimens are truly representative of the material and manufacturing process specified for that product. Departure from this assumption could introduce discrepancies that are greater than those introduced by departure from the details of the procedure outlined in this method.

5 Terminology

5.1 Acronyms

5.1.1 *O.D.* — Outside diameter

5.1.2 *P/N* — Part number

5.2 Definitions

5.2.1 *constant temperature oven* — Hot-air oven used to condition the specimens to the specified temperature.

5.2.2 *excessive leakage* — Gas leakage (measured in bubbles) from a fitting connection greater than can be humanly counted.

5.2.3 *seal cap* — An end closure or plug to block the open end of a tube or fitting to allow the specimen to be pressurized with nitrogen gas]

5.2.4 *subject* — To expose to.

5.2.5 *submersion tank* — A transparent tank filled with room temperature isopropyl alcohol used for observing leakage of nitrogen from the tube fitting connection. A cover or lid that does not create an air-tight seal is recommended while the specimen is being subjected to pressure.

6 Apparatus

6.1 Constant Temperature Oven

6.1.1 The constant temperature oven must have sufficient capacity to accommodate the specimens and control the temperature within $\pm 3^{\circ}\text{C}$ ($\pm 5^{\circ}\text{F}$).

6.1.2 See Figure 1 for test set-up.

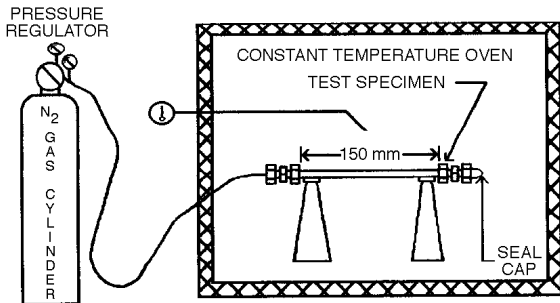


Figure 1
Test Set-Up

6.2 Nitrogen Supply

6.2.1 The supply of nitrogen must have a pressure regulator to control the pressure to the specimens accurately.

6.2.2 The nitrogen supply must include an instrument for monitoring pressure to within 2% of the test range (650 kPa, 94 psi).

6.3 *Submersion Tank* — The submersion tank is used for observing leakage of nitrogen from the fitting connection. (See Figure 2.) It consists of a container capable of holding enough isopropyl alcohol to allow the specimen to be submerged 25 ± 5 mm ($1 \pm .2$ in) below the fluid surface at a $45^{\circ} \pm 5^{\circ}$ angle.

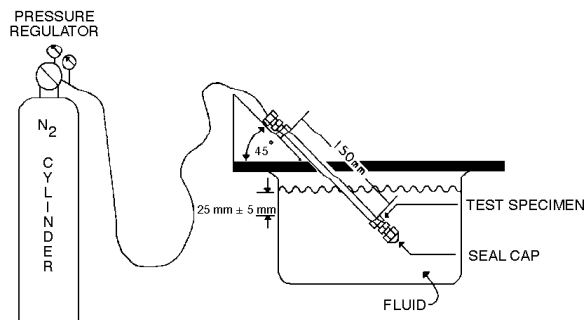


Figure 2
Submersion Tank for Observing

7 Safety Precautions

WARNING: This test method will subject test specimens to conditions that may exceed the normal performance ratings of the products

under evaluation. Adequate precautions must be taken to prevent injury to the person conducting the test.

8 Test Specimens and Conditioning

8.1 *Sample Size* — Test at least three specimens at each test condition.

8.2 *Specimen Tubing Length* — At least 150 mm (6 in).

8.3 *Specimen Surface* — All surfaces of the specimens shall be free of visible flaws, scratches, or other imperfections, unless typically found on a representative sample of the product.

8.4 All specimens must be conditioned for a minimum of one hour in an air environment of $23^{\circ} \pm 2.8^{\circ}\text{C}$ ($73^{\circ} \pm 5^{\circ}\text{F}$) prior to being subjected to test.

9 Test Procedure

9.1 A representative specimen must be assembled and should accompany the test specimens during the heat cycle but will be used for the sole purpose of monitoring temperature.

NOTE: The representative specimen must be of the same size and type as the test specimens being tested. The representative specimen shall not be pressurized during any portion of the test.

9.1.1 Insert a temperature probe into the center of the representative fitting specimen. Ensure that the temperature probe is sealed from the oven environment to prevent any of the heated air from entering the specimen. (See Figure 3.)

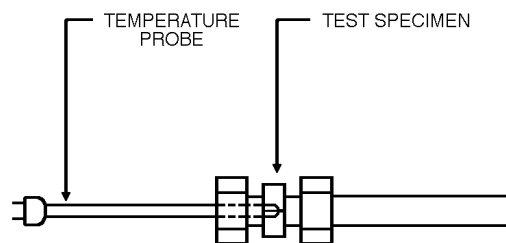


Figure 3
Placement of Probe

9.1.2 Place the representative specimen among the test specimens to monitor temperature during the heat cycle.

9.2 Assemble the test specimens in accordance with manufacturer's specifications. The test specimens shall be as described in Section 8. A seal cap shall also be attached to allow the specimen to be pressurized.

9.3 Submerge each test specimen as shown in Figure 2, and subject it to the specified pressure for the 23°C (73°F) column based on tube size as shown in Table 1. (See Appendix 1.) Observe the fitting connection for leakage for a minimum of one minute. Record the leakage results in the Proof Test area of the Test Data Sheet. (See Related Information 1.) This is a proof test to determine the integrity of the fitting connection before it is subjected to a heat cycle.

9.3.1 If excessive leakage (more than can be humanly counted) occurs, stop the test, and record as excessive leakage on the Test Data Sheet. (See Related Information 1.)

9.4 Condition the specimens to 75°C (167°F) by placing the specimens into the oven (see Figure 1) while subjecting them to the specified pressure for that temperature and tube size as shown in Table 1. (See Appendix 1.)

NOTE: More than one specimen may be conditioned simultaneously. Only fittings with the same test pressure and temperature should be conditioned simultaneously. Specimens must be leak tested individually.

9.4.1 The specimens shall remain in the oven 15 minutes after it has stabilized to the specified temperature.

9.4.2 Release nitrogen pressure from the specimens, remove from the oven, and allow to cool to room temperature $23^{\circ} \pm 2.8^{\circ}\text{C}$ ($73^{\circ} \pm 5^{\circ}\text{F}$). Do not disturb the specimens while cooling.

9.4.3 After the temperature of the specimens has reached room temperature, allow the specimens to remain undisturbed for 15 additional minutes before leak testing.

9.5 Submerge each specimen as shown in Figure 2, and pressurize to the specified pressure for the 23°C (73°F) temperature. Observe the fitting connection for leakage for a minimum of one minute.

9.6 Release the pressure in the specimen, and record the results on the Test Data Sheet. (See Related Information 1.)

NOTE: The release of pressure from the specimen when removing from the oven and from the submersion tank is for safety reasons, and compliance is strongly recommended.

9.6.1 Unit of measure for leakage is the number of nitrogen bubbles per minute.

9.6.2 Leakage from the seal cap is beyond the scope of this document and is not required to be measured or recorded.

9.7 After completion of leakage measurement, repeat Sections 9.4 through 9.6 ten times (cycles) at the same

pressure and temperature level with the same specimens.

9.7.1 If excessive leakage (more than can be humanly counted) occurs, stop the test, and record as excessive leakage on the Test Data Sheet. (See Related Information 1.)

9.8 After completion of ten cycles, repeat the test with new specimens starting at Section 9.2, but substituting for the temperature in Section 9.4, 100°C (212°F) and 125°C (257°F) as shown in Table 1. (See Appendix 1.)

10 Data Accuracy

10.1 *Pressure* — $\pm 2\%$

10.2 *Temperature* — $\pm 1^{\circ}\text{C}$ ($\pm 2^{\circ}\text{F}$)

11 Test Data Sheet

The test data sheet shall include the following information:

11.1 Date tested.

11.2 Operator and test facility.

11.3 Description of items tested, including:

Tubing — Manufacturer, O.D., wall thickness, part number, and material.

Fitting — Manufacturer, type, size, part number, and material.

11.4 All of the data described in Section 9.

NOTE: A sample test data sheet is included as Related Information 1.

APPENDIX 1

NOTE: This appendix was approved as an official part of SEMI F12 by full letter ballot procedure.

Table 1 Nitrogen Pressure for Each Test Temperature

Tube Size (Diameter × Thickness in mm (in))	Test Temperature: °C (°F)			
	23 (73)	75 (167)	100 (212)	125 (257)
	Test: Pressure kPa (psi)			
Ø3 × 0.5 (0.020 in)	570 (82)	320 (46)	230 (33)	200 (29)
Ø 3.18 (1/8 in) × 5	540 (78)	320 (46)	230 (33)	200 (29)
Ø 4 × 0.5	420 (60)	240 (35)	170 (25)	140 (20)
Ø 6 × 1	570 (82)	320 (46)	230 (33)	200 (29)
Ø 6.35 (1/4 in) × 0.5	270 (39)	150 (22)	110 (16)	90 (13)
Ø 6.35 (1/4 in) × 1.2 (0.050 in)	650 (94)	370 (54)	260 (38)	220 (32)
Ø8 × 1	430 (62)	240 (35)	170 (25)	140 (20)
Ø8 × 1.2	510 (73)	290 (42)	210 (30)	170 (25)
Ø8.53 (3/8 in) × 0.8 (0.031 in)	320 (46)	200 (29)	150 (22)	120 (17)
Ø8.53 (3/8 in) × 1.6 (0.063 in)	650 (94)	320 (46)	230 (33)	200 (29)
Ø10 × 1	340 (49)	190 (28)	140 (20)	120 (17)
Ø10 × 1.6	530 (79)	320 (46)	230 (33)	200 (29)
Ø12 × 1	280 (40)	180 (26)	120 (17)	100 (15)
Ø12 × 1.6	460 (66)	260 (38)	190 (28)	160 (23)
Ø12.7 (1/2 in) × 1.6	520 (75)	250 (36)	180 (26)	150 (22)
Ø19.06 (3/4 in) × 1.6	290 (42)	160 (23)	120 (17)	100 (15)
Ø25 × 1.5	210 (30)	120 (17)	80 (12)	70 (10)
Ø25 × 2	270 (39)	160 (23)	120 (17)	100 (15)
Ø25.4 (1 in) × 1.6	210 (30)	120 (17)	80 (12)	70 (10)

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Test Date:	Operator:	Test Facility:
Tube Manufacturer:		Fitting Manufacturer:
Tube O.D.:		Fitting Type:
Tube Wall Thickness:		Fitting Size:
Tube P/N:		Fitting P/N:
Tube Material:		Fitting Material:

Test Temperature	Amount of Leakage: Bubbles per Minute								
	75°C			100°C			125°C		
Test Sample	1	2	3	1	2	3	1	2	3
Proof Test									
<u>Heat Cycle</u>	xxxx	xxx	xxxx	xxx	xxxx	xxx	xxxx	xxx	xxxx
1st time									
2nd time									
3rd time									
4th time									
5th time									
6th time									
7th time									
8th time									
9th time									
10th time									

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SEMI F13-1101

GUIDE FOR GAS SOURCE CONTROL EQUIPMENT

This guide was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1993.

1 Purpose

1.1 The purpose of this document is to provide a guide for the design and operational requirements of gas source control equipment which is used to control pressure and flow from a gas cylinder to the point of use.

2 Scope

2.1 This document describes the components and minimum performance criteria for gas source control equipment used with hazardous production material (HPM) semiconductor gases. This guide also includes recommended component functions and operating requirements.

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 health practices and determine the applicability or regulatory limitations prior to use.

3 Related Documents

3.1 These documents should be used in the design, fabrication, installation, and operation of gas source control equipment.

3.2 SEMI Standards and Safety Guidelines

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

SEMI F2 — Specification for 316L Stainless Steel Tubing for General Purpose Semiconductor Manufacturing Applications

SEMI F3 — Guide for Welding Stainless Steel Tubing for Semiconductor Manufacturing Applications

SEMI F4 — Guide for Remotely Actuated Cylinder Valves

SEMI F6 — Guide for Secondary Containment of Hazardous Gas Piping Systems

SEMI F14 — Guide for the Design of Gas Source Equipment Enclosures

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

SEMI S4 — Safety Guideline for the Segregation/ Separation of Gas Cylinders Contained in Cabinets

SEMI S5 — Safety Guideline for Flow Limiting Devices

3.3 Compressed Gas Association Documents¹

Pamphlet P-1 — Safe Handling of Compressed Gases in Containers

Standard V-1 — Compressed Gas Cylinder Valve Outlet and Inlet Connections

3.4 National Fire Protection Association Document²

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

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Referenced Standards

4.1 Various codes and ordinances apply in different municipalities. These documents must be followed for the installation and operation of these systems. These codes may include:

Applicable Occupancy Codes — Uniform Building Code (UBC)³

Article 51 — Uniform Fire Code (companion document to above UBC)

Article 80 — Uniform Fire Code (companion document to above UBC)

Applicable Occupancy Codes — BOCA National Building Code⁴, BOCA National Fire Prevention Code⁴

Local Ordinances — As applicable.

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

1 Compressed Gas Association, Inc. (CGA), 1725 Jefferson Davis Highway, Suite 1004, Arlington, VA 22202

2 National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269

3 International Conference of Building Officials (OCBO), 5360 Workman Mill Road, Whittier, CA 90601

4 Building Officials and Code Administrators International, Inc. (BOCA), 4051 W. Flossmoor Road, Country Club Hills, IL 60478

5 Terminology

5.1 *automatic shut-off (ASO)* — A remotely actuated valve, preferably the cylinder valve, but possibly a valve located close to the cylinder valve, which can isolate the product as close to the cylinder valve as possible. It may also be a device which attaches to the cylinder valve stem or handle to close the valve.

5.2 *compressed gas association (CGA)* — Organization that sets standards for the handling and safe use of gases. Used in this document to refer to the cylinder valve outlet connection for each product as designated by the CGA.

5.3 *cylinder* — A pressure vessel designed for pressures higher than 276 kPa (40 pounds per square inch absolute) and having a circular cross section. It does not include a portable tank, multi-unit tank car tank, cargo tank, or tank car. It also refers to non-DOT low pressure containers used for liquid product having low vapor pressure.

5.4 *gas source control equipment (GSCE)* — Refers to the equipment assembly beginning at the product exit from the cylinder valve to the beginning of the distribution piping leading to the point of use (POU). These assemblies are usually mounted on panels and are sometimes referred to as process panel systems.

5.5 *hazardous production material (HPM)* — A solid, liquid, or gas that has a degree-of-hazard rating in health, flammability, or reactivity of Class 3 or 4 as ranked by NFPA 704 and which is used directly in research, laboratory, or production processes which have, as their end product, materials which are not hazardous.

5.6 *high pressure isolation (HPI) valve* — A shut-off valve located on the high-pressure side of a gas piping system that, when closed, isolates the purged volume from the pressure regulator and other downstream components.

5.7 *low pressure isolation (LPI) valve* — A shut-off valve located on the low-pressure side of a gas system that, when closed, isolates the purged volume from the distribution piping and all other downstream components.

5.8 *point of use (POU)* — Refers to the manufacturing tool which uses the product. Point of use is distinguished from the GSCE by having its own design criteria, separate function, and physical separation from the GSCE.

5.9 *product* — Refers to the gas phase in the cylinder.

6 Configuration

6.1 Manual/Auto Operation

6.1.1 *Manual* equipment without automation is adequate if it includes an ASO plus excess flow device. (Where required, per UFC articles 51 and 80.) Automated purging is generally more efficient than manual purging and is, therefore, recommended. The ASO function is achieved if the ASO valve automatically defaults to a closed position via a pneumatically actuated valve, or separate actuator that will close a manual cylinder valve. Either method should be fail-safe (default to a closed position on loss of power and/or pneumatics). This could also be initiated by any number of abnormal circumstances.

6.1.2 *Fully Automatic* — This is a broad category of designs using any number of transducers, remotely operated valves, and logic to accomplish safeguarding, monitoring, and automatic purging. Extension of this approach to central data collection, analysis, and reporting via computers and special programs offers the capability of further reducing hazards and enhancing safety.

6.2 Cylinder Connections

6.2.1 Compressed gas cylinders are connected to the panel equipment using the connection on the outlet of the cylinder valve. The appropriate regulatory agency has designated one or more connections for each product gas.

6.2.2 Other containers for liquid or low vapor pressure materials may require the connection of two fittings. One of these is used to admit gas, which either pressurizes the product, allowing liquid withdrawal, or absorbs the product, allowing withdrawal of a gas-phase mixture of the product and the gas. The other fitting is used for withdrawal. The types and labeling of the connections vary among suppliers.

6.2.3 *High Pressure Pigtail* — A semi-flexible assembly of piping, subjected to cylinder pressure, which is used to connect the cylinder to the rigidly mounted components on the panel. The intent of this flexible assembly is to accommodate the location of the cylinder outlet.

6.2.4 *No Pigtail* — An alternate acceptable method allows cylinders to be elevated or lowered to match the fixed height of the connection point on fixed panel equipment.

6.3 Cross Contamination

6.3.1 *Purge Gas Cylinder Contamination by Process Gas* — Purge gas is supplied from cylinders, with each purge gas cylinder limited to a single process gas panel or several panels using the same process gas class or

different mixture ratios of the same process gas class. A check valve should be installed in each line connecting the purge gas to the process panel equipment.

6.3.2 Process Gas Cylinder Contamination by Purge Gas — The purpose of purging is to remove air or residual process gas from the panel equipment (or part of it) back to the internal cavity of the closed cylinder valve.

WARNING: Check valves are not acceptable in this part of the process gas system because purging would be defeated. Cross contamination can only be prevented by safeguards which assure complete cylinder valve closure and process gas venting, before purging begins.

6.4 Materials — All materials furnished should be manufactured to nationally recognized standards. Metals used for the wetted surfaces should be type 316L stainless steel, or other materials that provide equal or improved compatibility with the gas in service. Nonmetallic seals that are used in valve or regulator seats must also be compatible with the product in service.

6.5 Joints — All welded joints should be butt welded (no socket welds) and should comply with SEMI F3. Connection fittings should be face seal type.

6.6 Particle Control — Particle contamination is controlled through the proper selection of components and system hardware, good design practices, clean

fabrication methods, and proper operation of the system.

6.7 Internal Volume — The internal cavities should be configured for minimum surface area and internal volume to enhance purging. Dead end legs should be eliminated or kept to a minimum volume and length.

6.8 Maintainability — Planned maintenance or forced repair is facilitated or inhibited by specific design concepts and features. From a safety point of view, it is mandatory to be able to purge the entire GSCE (all cavities) and to have a downstream shutoff (low pressure isolation valve) and disconnect fitting.

7 Performance Recommendations

7.1 Functional Recommendations

7.1.1 The ASO should be designed to close based on an alarm or fail signal from an auxiliary component. It should be designed to fail closed and should have a working pressure at least 1.1 times the product cylinder pressure. If a pressure sensor is located between the ASO and the cylinder valve, as depicted in Figure 1, it should also have a working pressure at least 1.1 times the product cylinder pressure.

7.1.2 Pressure Reduction — Gases are most commonly required at POU at less than 100 psig. Cylinder pressure is reduced to the lower pressure by a gas pressure regulator, when necessary.

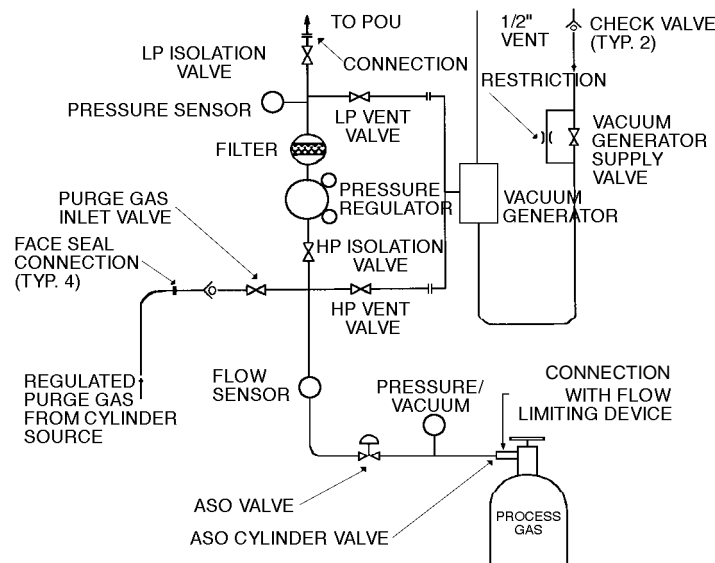


Figure 1
Typical Gas Source Control System

7.1.3 Excess Pressure Control — Provisions should be made to protect the distribution piping and process equipment from excessive pressure. This protection may include a pressure transducer, pressure switch, or indicating transmitter connected to close the ASO, a relief valve piped into the exhaust, or a redundant pressure regulator with primary regulator failure indication.

7.1.4 Cylinder Contents — The product remaining in the cylinder is determined by gas pressure measured by either a pressure transducer or gauge, or in the case of material in liquid/vapor phase, by the cylinder weight measured by a scale.

7.1.5 Delivery Pressure — The pressure delivered by the regulator is displayed by a pressure indicator. This can be either a gauge or transducer readout.

7.1.6 Filters — Particles from ambient sources, entering with the product or generated by the system elements, can be captured by including one or more filters at a variety of locations within the system. This practice tends to protect the components and the process.

7.1.7 Purge Gas Connection — A purge gas connection is provided via a branched connection to admit clean, dry, inert purge gas through an on-off valve. This is commonly located between the cylinder connection and high pressure isolation valve in the panel system. Gas purging is used for installation of a new system, before disconnecting a spent cylinder, after connecting a fresh cylinder, and for removal of equipment for maintenance purposes.

7.1.8 Vent Outlets — The normal purpose of the vent valves is to discharge process gas, air, and purge gas in conjunction with purging operations. Under special circumstances, they are used to reduce pressure in the equipment and/or transfer product. One or more vents may be used at various locations, and downstream venting may be either atmospheric pressure or vacuum from a venturi or pump. Vacuum venting is strongly recommended.

7.1.9 High Pressure Indication — A pressure indicator in common with the high pressure line connected to the cylinder valve is required to indicate the presence of residual process gas, or an open or leaking cylinder or panel valve. It also shows application of adequate purge gas pressure, and, in cases where vacuum-assisted purging is employed, an indication of the vacuum level should be included.

7.1.10 Cylinder Connection Makeup — After a fresh cylinder has been connected, the integrity of the cylinder valve connection can be tested with the use of the pressure indicator mentioned in Section 7.1.9.

7.2 Failure Modes — Any one of a number of conditions will require emergency action. Some are more serious than others. In some cases, the consequence is shutdown of the panel equipment and venting to a properly controlled discharge system. These failures should be addressed in the hardware and operational design phase of the system.

7.2.1 Excessive Delivery Pressure — Due to equipment malfunction or operator error.

7.2.2 Leaking fitting or component malfunction may require gas detection monitor.

7.2.3 Excess Flow — This can be the result of operator error or catastrophic conditions, such as a sheared delivery line.

7.2.4 Cabinet exhaust failure.

7.2.5 Mechanical failure of panel equipment parts or downstream equipment.

7.2.6 Destruction to plant through fire, explosion, earthquake, crash, etc.

7.2.7 Inadvertent mishandling of distribution equipment.

7.2.8 Process tool problems.

7.2.9 Control system failure.

7.2.10 System Abuse/Misuse — Source gas quality may affect service life and operability of the system. Poor gas product quality may cause a reduction in performance of the system that can lead to premature hardware component failures.

8 Acceptance Test

8.1 All gas source control equipment should undergo an acceptance test, agreed to and understood by the customer and supplier, before it is delivered. This test should ensure that all control and operational functions perform as required by the customer's and/or supplier's specifications.

9 Qualification Test

9.1 GSCE should be qualified at its installed location with an inert gas prior to installing the process gas cylinder. This test should include the operation of all control and hardware functions, interface with the process tool and all interconnected safety devices, systems, and alarms. This should also include a system wide leak test of all possible leak points, such as fittings and welds.

10 Labeling

10.1 The GSCE panel should be labeled for the product. Further labeling as defined in SEMI F14 should be affixed to the outside of the door of the enclosure.

11 Instructions

11.1 The purchaser's requirements will dictate the information provided with the equipment. Minimum acceptable instructions will vary with the complexity of the equipment (e.g., manual, automatic, microprocessor or pneumatically controlled, analog or digital, etc.) In all cases, the following information should be included:

11.1.1 **“WARNING:** Read Instructions Before Proceeding. (Instructions No. xxx for System No. xxx)

Do not proceed without understanding the status of the equipment as received, or damage may result.”

11.1.2 *Installation*

11.1.2.1 Certified status of equipment as shipped should include:

11.1.2.2 Leak integrity,

11.1.2.3 Particle level,

11.1.2.4 Contaminants,

11.1.2.5 Storage requirements,

11.1.2.6 Status indicators,

11.1.2.7 Removal of shipping safeguards,

11.1.2.8 Physical mounting and connection details, and

11.1.2.9 Purging during preparation and start-up.

11.1.3 *Start-Up Method*

11.1.3.1 Perform purge for initial start,

11.1.3.2 Pre-process (with substitute inert gas),

11.1.3.2.1 Confirm all component functions,

11.1.3.2.2 Confirm all operating levels and setpoints, and

11.1.3.2.3 Confirm leak integrity.

11.1.4 *Process Service* — Operational purge procedures that include the number of purge cycles and purge pressure and vent dwell times, that take into account the configuration of the system and the intended process gas, should be determined before process gas is installed.

11.1.5 *Maintenance* — Maintenance purge procedures and panel repair and replacement procedures should be defined before process gas is installed.

NOTE 3: Special warnings about the potential for dead space in components or fittings, etc. (in normal or failed mode) should be identified to avoid producing a hazardous condition for any subsequent operation or handling at any location.

APPENDIX 1

NOTE: The material in this appendix is an official part of SEMI F13 and was approved by full letter ballot procedures on August 27, 2001.

A1-1 Scope

A1-1.1 Under special circumstances, it may be necessary to cease using a product and remove it from the cabinet to a safer and/or less populated environment. This can be done in a number of ways.

A1-1.2 If the cylinder valve cannot be opened or closed, the gas supplier must be notified. Prior arrangements between the supplier and user of procedures should be in place, so that the required actions can be readily accomplished.

A1-2 Transfer Out of Cylinder

A1-2.1 Close the low pressure isolation valve, disconnect at the downstream side of either of the vent valves and connect to a suitable receiver with means of pumping if required. This depends upon knowledgeable operators, and the procedure to be followed must reflect the features of the particular GSCE and the product to be transferred. Extreme caution must be observed.

A1-3 Removal of the Cylinder

A1-3.1 A cylinder with a faulty or questionable cylinder valve may have to be removed. When a redundant valve and disconnect is installed in the pigtail, it may be closed, disconnected, and removed with the cylinder with relative ease and security. When a redundant valve is not present and a particular design allows it, the purge inlet valve, vent valve, and the HP isolation valve may be closed and removed with the pigtail still connected to the questionable cylinder. Adequate purging should precede this procedure.

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 or equipment mentioned herein. These standards are subject to change without notice.

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SEMI F14-93 (Reapproved 0699) GUIDE FOR THE DESIGN OF GAS SOURCE EQUIPMENT ENCLOSURES

This standard was technically reapproved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on December 18, 1998. Initially available on www.semi.org February 1999; to be published June 1999. Originally published in 1993.

Editorial changes were made to sections 3.1.1, 6.2.1, and 6.2.2.

1 Purpose

1.1 This document summarizes gas source equipment enclosure design considerations. It is intended for use by manufacturers and purchasers.

2 Scope

2.1 Design considerations pertaining to gas source equipment enclosures are described herein. Modifications required to accommodate specific gases, cylinders, or unusual applications (e.g., process equipment) are not addressed.

3 Referenced Documents

3.1 Various codes and ordinances apply in different municipalities. These documents must be followed for the installation and operation of these systems. These codes may include:

3.1.1 NFPA Standards¹

NFPA 13 — Installation of Sprinkler Systems

NFPA 69 — Explosion Prevention Systems

NFPA 70 — National Electrical Code

NFPA 91 — Exhaust Systems for Air Conveying Materials

3.1.2 ICBO Model Code²

Uniform Fire Code, 1991 Edition

3.1.3 SEMI Safety Guideline

SEMI S4 — Safety Guideline for the Segregation/ Separation of Gas Cylinders Contained in Cabinets

3.1.4 Other Publications

Industrial Ventilation, A Manual of Recommended Practice³

BOCA National Building Code⁴

BOCA National Fire Prevention Code⁴

Standard Building Code⁵

3.1.5 Local Ordinances

As applicable.

4 Terminology

4.1 *gas cylinder* — Usually means a high pressure compressed gas cylinder governed by Department of Transportation (DOT) regulations. It also refers to non-DOT low pressure containers used for liquid product having low vapor pressure.

4.2 *gas source equipment enclosure (enclosure)* — An enclosure for the storage of gas containers and associated equipment.

5 Functions

5.1 Five important functions are provided by an enclosure and its associated safety devices.

5.1.1 *Leaking Gas Containment* — Personnel, equipment, and the immediate working environment are protected from the hazards of leaking gases.

5.1.2 *Fire Protection* — Personnel and equipment are protected from the consequences of internal and external fires.

5.1.3 *Mechanical Protection* — The cylinder and associated equipment are protected from impact and seismic forces. (For further information, see UFC 51, *Workstations and Fabrication Areas*.)

5.1.4 *Access Control* — Unauthorized persons are inhibited from using gases and operating associated

¹ National Fire Protection Association, Batterymarch Park, Quincy, MA 02269

² International Conference of Building Officials, 5360 South Workman Mill Road, Whittier, CA 90601

³ American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Building D-7, Cincinnati, OH 45211

⁴ Building Officials & Code Administrators International, Inc., 4051 West Flossmoor Road, Country Club Hills, IL 60477

⁵ Southern Building Code Congress International, 900 Montclair Road, Birmingham, AL 35213

equipment.

5.1.5 Gas Separation — Gases that are chemically incompatible or belong to dissimilar hazard classes should be separated.

6 Design Considerations

6.1 Regulatory Requirements — The enclosure should conform to local, state, and federal regulations.

6.2 Materials

6.2.1 Enclosure top, sides, and doors should be constructed of 2.7 mm (12 gage) or thicker cold-rolled sheet steel or other suitable material so as to provide adequate mechanical stability.

6.2.2 Floors should be constructed of cold-rolled sheet steel or other suitable material, typically 3.4 mm (10 gage) or thicker, so as to adequately resist deformation by the heaviest intended cylinder.

6.2.3 Windows and skylights should be 6.5 mm (0.25 in) thick wired safety glass or other suitable material.

6.2.4 All materials should be noncombustible.

6.3 Dimensions — The enclosure should completely surround the gas cylinders and requisite accessory equipment. The design should incorporate minimum internal dimensions while still allowing safe and easy access to cylinders and equipment.

6.3.1 Heights of shelves for short cylinders should be adjustable so that cylinder valves and associated equipment are readily accessible through the limited-area access port.

6.3.2 Distances above cylinders should be adequate for installation and operation of associated equipment.

6.4 Enclosure Interior Access

6.4.1 Door — A gasketed door should enable safe and convenient installation and removal of intended cylinders, and installation, removal, and maintenance of associated equipment. The door should be self-closing and self-latching. The threshold should not interfere with cylinder installation and removal.

6.4.2 Limited-Area Access Port — The enclosure should have one or more limited-area ports that enable access to controls and associated equipment within the enclosure without compromising the air velocity across the face of the access port(s). The average air velocity across the faces of access ports should not be less than 1 m/s (200 fpm); a minimum air velocity of 0.75 m/s (150 fpm) should exist at any point.

6.4.2.1 Access ports should be self-closing.

6.4.3 Window — One or more windows should be provided to enable observation of equipment within the enclosure without compromising enclosure integrity.

6.4.4 Security — Lockable doors and access ports should be provided when unauthorized access to the enclosure interior must be precluded.

6.5 Ventilation — The enclosure should enable removal of leaking gas by local exhaust ventilation. The advantages of local exhaust ventilation over general ventilation are more fully described in NFPA 69, NFPA 91, and in Industrial Ventilation.

6.5.1 Exhaust Connection — The enclosure should enable connection to an exhaust system that will handle the required exhaust at an average duct velocity that does not exceed 8.5 m/s (1,700 fpm). The total exhaust flow includes that across open access ports as well as that through any supplementary air inlets.

6.5.2 Air Flow Path — In addition to access ports, the enclosure should include an air inlet located at the extremity of the enclosure opposite from the exhaust connection, so that ventilation of the entire enclosure is provided. The air flow path should adequately scavenge gas from all regions within the enclosure.

6.5.2.1 Structures (e.g., brackets or shelves) within the enclosure should not adversely affect exhaust capability.

6.5.2.2 Gaskets should be provided on all doors, access ports, and other penetrations.

6.6 Fire Protection

6.6.1 Sprinklers — Provisions for internal sprinklers should be made when necessary.

6.6.1.1 Sprinklers should be capable of providing adequate cooling to maintain cylinders and associated equipment at a temperature that will not actuate relief devices in the event of an internal or external fire.

6.6.1.2 Sprinkler actuation temperature should be greater than the anticipated maximum operating temperature of the enclosure interior under typical operating conditions, but less than the cylinder pressure relief device actuation temperature.

6.6.1.3 When the enclosure may be exposed to corrosive atmospheres, corrosion-resistant sprinklers should be provided. (For further information, see NFPA 13, *Corrosion-Resistant, Wax-Coated, or Similar Sprinklers*.)

6.7 *Mechanical Stabilization*

6.7.1 Provision for anchoring the enclosure to stable architectural elements should be made.

6.7.2 Fasteners should meet anticipated seismic loads in seismically active areas.

6.7.3 A means of securing each cylinder within the enclosure should be provided.

6.8 *Surface Finishes*

6.8.1 All exterior surfaces and equipment should be treated or finished to resist attack by weather elements.

6.8.2 Interior surfaces and equipment should be treated or finished to resist corrosive or solvent effects.

6.8.3 All surfaces should be free of burrs, sharp edges, and other flaws that could injure users.

6.9 *Interior Illumination* — Illumination of the enclosure interior should be adequate for safe operation of contained equipment. When ambient light is inadequate, several approaches may be taken to provide additional lighting:

6.9.1 A skylight may be provided.

6.9.2 With nonflammable gases, internal electric lights may be provided.

6.9.3 With flammable gases, power cables should not penetrate the enclosure interior except as provided for Class I, Division 2 locations (NEC, Article 501). Either internal explosion-proof lights may be provided, or external standard lights may project through an unopenable window.

6.9.4 All interior surfaces should reflect light efficiently.

6.10 *Labels*

6.10.1 *Gas Labels* — A label clearly displaying the chemical formula and common name of the gas should be attached to the enclosure exterior surface; its color should contrast with that of the enclosure.

6.10.2 *Hazard Warning Labels* — A label clearly stating requisite hazard warnings should be mechanically attached to the enclosure exterior surface in accordance with local building code requirements.

6.10.3 *Information Labels* — A label providing important specific information such as, but not limited to, emergency contacts, telephone numbers, manifold schematics, and first aid recommendations should be attached to the enclosure exterior surface.

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 F15-93 (Reapproved 1104)

TEST METHOD FOR ENCLOSURES USING SULFUR HEXAFLUORIDE TRACER GAS AND GAS CHROMATOGRAPHY

This Test Method was technically reapproved 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 July 11, 2004. Initially available on www.semi.org September 2004; to be published November 2004. Originally published in 1993; last published June 1999.

1 Purpose

1.1 The purpose of this test method is to provide a standardized method to test the ability of enclosures to contain gases and vapors and a standardized format to record and document test results.

2 Scope

2.1 This test method applies to any enclosure that possesses a local exhaust (secondary ventilation) system.

2.2 In this test method, the tracer gas of choice is sulfur hexafluoride (SF_6). It is recognized that other gases have been used as tracers, but for the purposes of this test method, tracer gas means SF_6 .

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 test method is intended to test the containment ability of a local exhaust system within an enclosure under the manufacturer's specified operating conditions. Thus, test data obtained by means of this test method apply only to the local exhaust conditions that existed within the enclosure during the testing. Extrapolation of the test data to other exhaust operating conditions is not usually possible.

3.2 Use of this test method requires knowledge of the principles of gas analysis as well as flow and pressure measurement, gas chromatographic instrumentation, and gas sampling techniques.

3.3 An acceptable enclosure, as determined in Section 7.1, does not imply a safe condition for routine equipment operation with a leak and/or a tubing/fitting failure. An acceptable enclosure is one that will contain potential worst case leaks in an emergency, non-routine situation. The fact that an enclosure is acceptable does not imply that the enclosure is safe to operate when a hazardous gas leak has been detected.

4 Referenced Standards

4.1 SEMI Standard

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

4.2 ASTM Standards¹

ASTM E 260 — Practice for Packed Column Gas Chromatography

ASTM E 697 — Practice for Use of Electron Capture Detectors in Gas Chromatography

4.3 NFPA Standard²

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

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

5 Terminology

5.1 Definitions

5.1.1 *equivalent release concentration (ERC)* — the theoretical concentration of a process gas that would be measured outside an enclosure in the event of a process line failure. The ERC can be expressed as a percentage of the TLV or PEL of the process gas.

5.1.2 *hazardous production material (HPM)* — for the purposes of this test method, a gas or vapor that has a degree-of-hazard rating in health, flammability, or reactivity of 3 or 4, as ranked by NFPA 704, that is used directly in a research, laboratory, or production process that has as its end product materials which are not hazardous.

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, Phone: (610) 832-9585, Fax: (610) 832-9555, <http://www.astm.org/>

2 National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169, Phone: 1 617 770-3000, Fax: 1 617 770-0700, <http://www.nfpa.org/>

6 Summary of Method

6.1 A test is performed by releasing tracer gas at a constant flow rate within an enclosure to simulate a worst case leak and then measuring on the periphery of the enclosure for the presence or absence of tracer. The lack of measurable tracer indicates that the release of potentially hazardous gases or vapors within the enclosure at the tracer injection point(s) will not result in their migration to the outside of the enclosure. Gas samples are taken by means of disposable syringes, sample bags, or sample vials. Gas samples are analyzed by means of electron capture gas chromatography.

7 Procedure

7.1 Test Design

7.1.1 Determine the type of enclosure to be tested, such as: non-access, access, vacuum pump, equipment cabinet, or other.

7.1.2 Determine the volume of the enclosure.

7.1.3 Measure the exhaust flow rate from the enclosure.

7.1.4 Calculate the air changes per minute of the enclosure by dividing the exhaust flow rate (Section 7.1.3) by the enclosure volume (Section 7.1.2).

7.1.5 Calculate the time at which the tracer concentration in the enclosure will achieve approximate equilibrium. Concentration equilibrium occurs when the tracer concentration in the enclosure stops changing as a function of time for a constant tracer release rate. Divide 3 by the air changes per minute to establish this time. Use this as the time to take the first sample after initiating a test. Appendix 1 provides a derivation of the equilibrium time.

NOTE 1: This test method is intended to test the containment ability of the local exhaust system within an enclosure when operated according to the manufacturer's specifications. Thus, testing should be performed with the local exhaust operating under its manufacturer's recommended conditions.

7.1.6 If an excess flow control system is used, determine the trip point for each hazardous gas used. If different gases are used in the enclosure, the largest trip point should be used to calculate the tracer release flow rate.

7.1.7 If no excess flow system or flow-restricting orifice is used, the maximum accidental release rate must be calculated from the known maximum system pressure and either valve coefficients or tubing ID. An equation for flow through straight tubing is provided in Appendix 2.

7.1.8 In the absence of guidance in the above two sections, a standard test is the release of tracer gas through 6.35 mm (0.25 inch) OD by 0.89 mm (0.035 inch) wall tubing at a rate of 28 standard liters per minute (slpm) (1 scfm). Appendix 3 derives a general equation, A3-7, that can be used when this is not the case.

7.2 *Reagents and Materials* — Use SF₆ diluted in an inert gas, such as nitrogen or argon, as the tracer source, to minimize measurement difficulties associated with small leaks of pure SF₆ from the supply cylinder and its associated piping.

7.3 Sampling

7.3.1 In selecting the location of samples collected outside the enclosure, consider 1) potential leak points, 2) the direction of the release, and 3) laminar flow characteristics in the area surrounding the enclosure. Samples should be collected from all sides of the enclosure, downstream in the prevailing room air flow, and in the operating personnel occupancy areas.

7.3.2 The time required for the enclosure to reach equilibrium should be considered when establishing the time to begin sampling. The first sample after initiating tracer flow should be taken at the enclosure equilibrium time. Collect additional samples at 1 to 2 minute intervals until the tracer source is shut off. One sample should be taken 1 minute after the tracer source is shut off. The test duration can be changed to accommodate a particular test.

7.3.3 Collect background (baseline) samples from the area surrounding the enclosure at predetermined locations. When logistics permit, analyze the background samples before releasing the tracer gas. If background levels above approximately 1 ppb are detected, evaluate the integrity of the SF₆ tracer delivery system, and postpone the test until the concentration is less than 1 ppb. Other sources of SF₆ in the immediate test area may also cause this background.

NOTE 2: If testing is performed with an SF₆ background, the background concentration must be measured and subtracted from any subsequently measured tracer concentration value.

7.3.4 Release tracer gas within the enclosure being tested by means of an injection manifold, shown schematically in Figure 1. The tracer injection manifold must be capable of measuring flow rates to an accuracy of $\pm 5\%$. The tracer gas delivery line must be routed into the enclosure and attached to a potential leak point without violating the integrity of the enclosure.

NOTE 3: To minimize tracer gas contamination of the area surrounding an enclosure during a test, the end of the tracer

injection line should be capped, except when performing an injection test.

7.3.5 Perform several tests with differing directions of release relative to any opening or penetration in the enclosure. The location and direction of the release shall effectively simulate an actual gas release or tubing/fitting failure within the enclosure. A worst case failure can be simulated by locating the tracer injection point at the potential leak location closest to a penetration or opening within the enclosure with the direction of tracer injection pointed directly at the opening or penetration.

7.3.6 After initiation of tracer injection, collect grab air samples from the area surrounding the enclosure at predetermined times and locations. These samples should be analyzed immediately after collection. If this is not possible, they should be sealed. Label the samples as to time and location. Samples may be taken with: a) Containers that are non-absorbent, inert, and that have low permeability (such as polyvinyl fluoride film or polyester film sample bags or polyethylene, polypropylene, nylon, or glass bottles) or b) disposable syringes. Disposable syringes can be used to inject samples into the gas chromatograph directly.

7.3.7 Record: a) the actual (measured) tracer gas release rate, b) the actual SF₆ concentration in the tracer gas being used, and c) the actual release time during a test.

7.3.8 Collect air samples as described in Section 7.3.6, and analyze them for the presence or absence of tracer gas using a gas chromatograph. The measurement of a non-zero tracer concentration in the area surrounding an enclosure indicates incomplete containment of contaminants within the enclosure.

7.3.9 Analyze samples according to ASTM E 260 and ASTM E 697 in conjunction with the chromatograph manufacturer's operating procedures. Samples may be analyzed immediately after a test, or they may be stored for future analysis. Experience has shown no degradation of concentration in polypropylene syringes when stored for several months as long as the needle or syringe is plugged. Polypropylene syringes should be discarded after one use to eliminate the possibility of cross contamination of samples.

8 Calculations and Interpretation of Results

8.1 The maximum concentration of SF₆ measured in a sample collected outside the enclosure is used to calculate the Equivalent Release Concentration (ERC) by the following formula:

$$\text{ERC} = \frac{\text{Conc. of process gas} \times \text{Measured SF}_6 \text{ Conc.}}{\text{Tracer Injection gas conc.}}$$

8.1.1 The above formula assumes the process gas tubing that fails is the same diameter as the tracer gas injection tubing. Appendix 3 contains a general equation that can be used when this is not the case.

8.2 Compare the Equivalent Release Concentration to the hazardous process gas TLV or PEL, whichever is lower. If the ERC is above the prescribed limits, the enclosure is not considered to be acceptable; if the ERC is less than or equal to the prescribed limit, the enclosure is considered acceptable. SEMI S2 recommends appropriate control limits for an enclosure.

9 Reporting Results

9.1 Present all results in tabular form in a manner which unambiguously notes those enclosure(s) that do not satisfy the criteria of SEMI S2. The exhaust operating conditions during each test must be provided along with each measured ERC value.

9.2 Describe tracer gas injection points within individual enclosures to detail location and proximity to openings, penetrations, exhaust grillwork, access panels, and other potential leakage sites, such that worst case leak conditions have been simulated.

9.3 Describe the unit being tested by manufacturer, model number, and serial number to provide identification of the unit being tested.

9.4 Tabulate and record the name, supply concentration, maximum flow rate, and TLV or PEL for each hazardous gas or vapor used within each enclosure being tested.

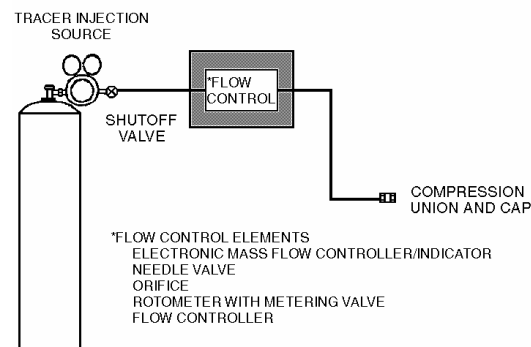


Figure 2
Schematic Drawing of Injection Manifold

10 Related Documents

29 CFR 1910.1000 — Code of Federal Regulations, Title 29, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

ACGIH — American Conference of Governmental Industrial Hygienists, 6500 Glenway, Building D-7, Cincinnati, OH 45211-4438, (513)661-7881. *Industrial Ventilation - A Manual for Recommended Practice*, 20th ed. ISBN: 0-936712-65-1.

American Industrial Hygiene Association — 345 White Pond Drive, Akron, OH 44320, (216)873-2442. *Workplace Environmental Exposure Level Guides*.

ASTM — American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103. ASTM Standard E741-83 (Determining Air Leakage Rate by Tracer Dilution).

BOCA — Building Officials and Code Administrators International Inc., 4051 West Flossmoor Road, Country Club Hills, IL 60478-5795, (708)799-2300. *National Fire Prevention Code*.

Grot, R.A. and P.L. Lagus — “Applications of Tracer Gas Analysis to Industrial Hygiene Investigations,” *Industrial Hygiene News*, May 1991.

Orcutt, J.R. — “Characterization of Hazardous Gas Releases by Tracer Gas Simulation,” *Hazardous Assessment and Control Technology in Semiconductor Manufacturing*, ACGIH, Cincinnati, OH, 1988.

SBCCI — Southern Building Code Congress International, 900 Montclair Road, Birmingham, AL 35213-1206, (205)591-1853. *Standard Fire Prevention Code*.

Tubby, R.L. — “Tracer Gas Testing of Secondary Exhaust Systems on Hazardous Gas Enclosures,” *SSA Journal*, Vol. 5, June 1991.

UFC — Uniform Fire Code. International Conference of Building Officials and Western Fire Chiefs Association, 5360 South Workman Mill Road, Whittier, CA 90601. 1988 Edition, ISSN 0896-9736.

APPENDIX 1

EQUILIBRIUM TIME FOR TRACER INJECTION

NOTICE: The material in this appendix is an official part of SEMI F15 and was approved by full letter ballot procedures.

A1-1

A1-1.1 If a tracer gas is injected at a constant rate into an enclosure that possesses a constant ventilation rate, the concentration as a function of time is given as

$$C(t) = (F/q) [1 - \exp\{-(q/V)t\}] \quad (A1-1)$$

where $C(t)$ = Concentration within the enclosure

F = Injection rate of tracer gas

q = Ventilation rate of enclosure

V = Volume of enclosure

t = Elapsed time since initiating injection

A1-1.2 Note that the term (q/V) contained in the exponential is the air change rate. In order for the concentration $C(t)$ to be constant, the exponential term must be approximately zero. This is generally taken as the time when the exponential term is equal to e^{-3} . The time at which this occurs can be found by setting $(q/V)t = 3$ and solving for t . Thus,

$$(q/V)t = 3 \quad (A1-2)$$

from which it follows that the equilibrium time is given as,

$$t = 3/(q/V) \quad (A1-3)$$

$$t = 3(V/q) \quad (A1-4)$$

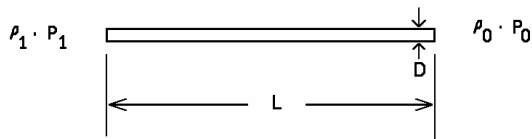
APPENDIX 2

EQUATION FOR FLOW IN A STRAIGHT TUBE

NOTICE: The material in this appendix is an official part of SEMI F15 and was approved by full letter ballot procedures.

A2-1

A2-1.1 Flow in a straight tube may be calculated if the tube characteristics, as well as the upstream and downstream pressures, are known. In the following, the upstream (drive side) conditions have a subscript of 1, while the downstream (ambient) conditions have a subscript of 0.



$$\gamma M_1^2 = \frac{1 - \left(\frac{P_1}{P_0}\right)^2}{4f\left(\frac{L}{D}\right) + \ln\left(\frac{P_1}{P_0}\right)^2} \quad (\text{A2-1})$$

$$W = A(\rho_1 P_1 \gamma M_1^2)^{0.5} \quad (\text{A2-2})$$

$$\rho_1 = \rho_0 \left(\frac{P_1}{P_0}\right) \quad (\text{A2-3})$$

where $\rho_0 = 0.00129 \text{ g/cm}^3$

$$\gamma = 1.4$$

P = Pressure (dynes/cm²)

$$4f = 0.02 \text{ (for smooth pipe)}$$

L = Length (cm)

D = Diameter (cm)

W = Mass Flowrate (g/sec)

A = Area of Flow Line (cm²)

NOTE 1: Atmospheric pressure, 10^6 dynes/cm², is approximately 14.7 psia.

APPENDIX 3

GENERAL EQUATION RELATING PROCESS GAS FLOW RATE TO TRACER INJECTION RATE

NOTICE: The material in this appendix is an official part of SEMI F15-93 and was approved by full letter ballot procedures.

A3-1

A3-1.1 In this appendix, a general equation relating process gas flow rate, tracer injection flow rate, and measured SF₆ concentration outside an enclosure to the ERC is provided. In the following, Q and L are given in volume units per unit time. Concentrations C are given in units of either vol./vol. or %. Whatever units are chosen should be used consistently in Equation A3-7.

A3-1.2 Let the tracer injection rate into a volume be Q and the ventilation rate in this volume is L. At equilibrium, the concentration of tracer within this volume is $Q/L = C_{\text{source}}$. If, in the laboratory, one measures a concentration of tracer gas C_{lab} , then the Dilution Ratio, D, can be calculated as equal to

$$C_{\text{lab}}/C_{\text{source}}]_{\text{tracer}} = D_{\text{tracer}} \quad (\text{A3-1})$$

For any conserved chemical species, D is constant. Thus, for a process gas released within the volume, one can form an analogous ratio

$$C_{\text{lab}}/C_{\text{source}}]_{\text{process}} = D_{\text{process}} \quad (\text{A3-2})$$

For all conserved chemical species, D is constant, hence

$$D_{\text{tracer}} = D_{\text{process}} \quad (\text{A3-3})$$

From this, one can form

$$C_{\text{lab}}/C_{\text{source}}]_{\text{tracer}} = C_{\text{lab}}/C_{\text{source}}]_{\text{process}} \quad (\text{A3-4})$$

so that

$$C_{\text{lab}}/C_{\text{source}}]_{\text{tracer}} \times C_{\text{source}}]_{\text{process}} = C_{\text{lab}}]_{\text{process}} \quad (\text{A3-5})$$

Here $C_{\text{lab}}]_{\text{process}}$ is the previously identified ERC.

For releases in the same test volume, this equation can be written

$$\{C_{\text{lab}}]_{\text{tracer}} \times (Q/L)_{\text{process}}\} / (Q/L)_{\text{tracer}} = \text{ERC} \quad (\text{A3-6})$$

Since the ventilation rate is the same

$$C_{\text{lab}}]_{\text{tracer}} \times Q_{\text{process}} / Q_{\text{tracer}} = \text{ERC} \quad (\text{A3-7})$$

A3-1.2.1 This equation allows the calculation of ERC when simulating a leak within an enclosure using a different diameter tubing or different flowrate. In the case where the flowrates (or tubing size and injection pressure) are the same for the tracer and the process gas, Equation A3-7 simplifies to that in Section 5.1.

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SEMI F16-94 (Withdrawn 0304) SPECIFICATION FOR 316L STAINLESS STEEL TUBING WHICH IS TO BE FINISHED AND ELECTROPOLISHED FOR HIGH PURITY SEMICONDUCTOR MANUFACTURING APPLICATIONS

NOTICE: This document was balloted and approved for withdrawal in 2004.

1 Purpose

The purpose of this specification is to identify the applicable ASTM tubing specification requirements and to define the special material composition, wall thickness, ordering, and quality assurance requirements for 316L stainless steel tubing which is to be finished into electropolished tubing, component tube stubs, and fittings made from tubing for use in high purity semiconductor manufacturing facility applications.

2 Scope

This specification defines the special criteria for procuring nominal sizes of unfinished 316L stainless steel tubing which is to be finished into tubing, component tube stubs, and fittings made from tubing for use in high purity chemical (gas or liquid) distribution systems in semiconductor manufacturing facilities.

3 Referenced Documents

The referenced documents are to be their current editions as published by their sponsors.

3.1 *ASTM Standards*¹

A 262 — Practices for Determining Susceptibility to Intergranular Attack in Austenitic Stainless Steels

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

A 270 — Seamless and Welded Austenitic Stainless Steel Sanitary Tubing

A 450/A 450M — Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

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

E 112 — Methods for Determining Average Grain Size

3.2 *Military Standards*²

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

3.4 *ANSI/ASME Standards*³

B31.1 — Power Piping

B31.3 — Chemical Plant and Petroleum Refinery Piping

Boiler and Pressure Vessel Code — Section III NCA, The Rules for Construction of Nuclear Power Plant Components

4 General Requirements

Tubing furnished under this specification shall conform to the requirements of ASTM A 450 and A 269 for nominal sizes 1/2 inch diameter and larger and to the requirements of ASTM A 450 and A 632 for nominal sizes smaller than 1/2 inch diameter, and to the additional requirements herein.

5 Ordering Information

5.1 Orders for material under this specification shall include the following, as required to describe the material adequately:

- Quantity (meters, feet, or number of lengths)
- Grade per Table 1 of ASTM A 269
- Size (nominal outside diameter and nominal wall thickness)
- This specification number
- Surface condition (if applicable)
- Special requirements and any supplementary requirements selected

6 Process

The steel shall be processed in accordance with the section on Process of ASTM A 269.

2 Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120

3 American National Standards Institute, 1430 Broadway, New York, NY 10018

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

7 Manufacture

7.1 Tubing shall be made by the seamless process for all sizes, except that welded tubing may be acceptable for nominal sizes 3 inches and above in diameter if the permissible variations in outside diameter are in accordance with Table 2 of ASTM A 270 and the other criteria specified herein are met.

7.2 Tubing must be cold finished.

8 Heat Treatment

8.1 All tubing shall be furnished in the heat treated condition in accordance with the section on Heat Treatment in ASTM A 269. If grain size is restricted by the supplementary requirement specified in Section 17.2 of this specification, the minimum annealing temperature shall not apply, provided that the tubing passes the intergranular corrosion test of Section 13 of this specification.

8.2 All tubing shall be vacuum annealed, or bright annealed in an undiluted hydrogen atmosphere, followed by rapid cooling. The adequacy of the cooling rate shall be confirmed by the intergranular corrosion test of Section 13 of this specification.

9 Surface Condition

The surface condition of tubing shall be in accordance with the requirements of the section on Finish of ASTM A 270.

10 Cleanliness

10.1 Tubing shall be supplied in accordance with the supplementary requirement for Cleanliness of ASTM A 632.

10.2 Tubing surface shall be sealed with polyethylene caps after being purged with nitrogen or a suitable inert gas. Capped tubing shall be heat sealed in a single 0.15 mm (6 mil) polyethylene bag.

11 Chemical Composition

11.1 Chemical composition of the steel shall conform to the requirements of the section on Chemical Composition in ASTM A 269 for nominal sizes 1/2 inch diameter and larger and to the section on Chemical Composition in ASTM A 632 for nominal sizes smaller than 1/2 inch diameter.

11.2 Sulfur content shall be from 0.003% to 0.010% for all nominal sizes.

12 Mechanical Properties

12.1 Tubing shall conform to the applicable requirements of ASTM A 450/A 450M unless otherwise provided herein.

12.2 Hardness of all sizes shall conform to the section on Hardness Requirements of ASTM A 269.

12.3 Tensile properties of all sizes shall conform to the section on Mechanical Properties of ASTM A 632.

13 Metallurgical Requirements

Tubing shall pass an intergranular corrosion test conducted in accordance with the supplementary requirement for Intergranular Corrosion Test of ASTM A 262. A minimum of two samples per lot shall be tested.

14 Nondestructive Testing Requirement

14.1 Eddy current testing shall be performed in accordance with the procedure and evaluation outlined in the section on Nondestructive Electric Test of ASTM A 450/A 450M except that the calibration reference notches shall not exceed 10% of the specified wall thickness of the tubing or 0.075 mm (0.003 inches), whichever is greater. If the form of product supplied makes this test technically infeasible, alternative non-destructive testing methods shall be agreed upon by the purchaser and supplier.

14.2 At the option of the purchaser, hydrostatic testing shall be conducted and evaluated in accordance with the requirements of the section on Hydrostatic Test of ASTM A 450A/450M.

15 Permissible Variations in Dimensions

15.1 Sampling for dimensional variations shall be performed in accordance with MIL-STD-105 with double normal sampling and a 2 1/2% Acceptable Quality Level (AQL).

15.2 The permissible variations in dimensions shall be as outlined in Table 2 of ASTM A 270 for all sizes.

15.3 Nominal wall thickness for tubing to be finished as shown in Table 1. The finished thicknesses must also comply with ANSI/ASME B31.1 and B31.3 specifications for the intended service temperature and pressure. A tolerance of $\pm 10\%$ shall apply to the wall thicknesses specified.

Table 1 Nominal Wall Thickness for Various Tube Nominal Sizes

<i>Nominal O.D.</i>	<i>Tube Wall Thickness</i>
1/4" , 3/8"	1.02 mm (0.040")

1/2"	1.32 mm (0.052")
3/4" , 1" , 1 1/2" , 2" , 3"	1.75 mm (0.069")
4" , 6"	2.11 mm (0.083")

16 Quality Assurance Requirements

The supplier's quality assurance program shall meet the requirements of the ASME Boiler and Pressure Vessel Code, Section III, NCA-3800 or of ISO 9000.

17 Supplementary Requirements

The following supplementary requirements shall apply only when specified by the purchaser on the inquiry, contract, or order.

17.1 Alternative Finish (Inside Surface) — The purchaser may specify alternate chemical treatment for the inside surface. Such treatment shall not promote grain boundary attack; the intergranular corrosion test requirement of Section 13 shall apply after chemical treatment.

17.2 Restricted Grain Size — At the option of the purchaser, ASTM grain size number may be restricted to 7 or finer, per ASTM E 112, provided that a maximum hardness lower than that given in the section on Hardness Requirements of ASTM A 269 is not also imposed.

18 Certification

18.1 The supplier shall provide the following reports and certifications with all shipments of tubing:

18.1.1 Type of tubing (seamless or welded)

18.1.2 Size (nominal outside diameter and nominal wall thickness)

18.1.3 Material composition report shall be provided to verify the above required grade, sulfur content, and grain size

18.1.4 Tubing provided in accordance with this specification shall be mill and heat traceable and permanently etched for correspondence to the applicable mill test reports.

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 F17-95 (Withdrawn 0704) SPECIFICATION FOR HIGH PURITY QUALITY ELECTROPOLISHED 316L STAINLESS STEEL TUBING, COMPONENT TUBE STUBS, AND FITTINGS MADE FROM TUBING

This specification was technically reapproved 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 October 25, 2002. Initially available at www.semi.org December 2002; to be published March 2003. Originally published in 1995.

NOTICE: This document was balloted and approved for withdrawal in 2004.

1 Purpose

1.1 The purpose of this specification is to define the ordering, surface condition, and quality assurance requirements for high purity quality electropolished 316L stainless steel tubing, component tube stubs, and fittings made from tubing.

2 Scope

2.1 This specification defines the special criteria for nominal sizes of electropolished 316L stainless steel tubing, component tube stubs, and fittings made from tubing for use in high purity chemical (gas or liquid) distribution systems in semiconductor manufacturing facilities.

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 Standard

SEMI F16 — Specification for 316L Stainless Steel Tubing Which Is to Be Finished and Electropolished for High Purity Semiconductor Manufacturing Applications

3.2 ANSI/ASME Standards¹

B31.1 — Power Piping

B31.3 — Chemical Plant and Petroleum Refinery Piping

B46.1 — Surface Texture: Surface Roughness, Waviness, and Lay

3.3 ASTM Standards²

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

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

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

4 General Requirements

4.1 The finished tubing, component tube stubs, and fittings made from tubing furnished under this specification shall use the tubing governed by SEMI F16 and shall meet the additional finish requirements herein.

5 Ordering Information

5.1 Orders for finished tubing, component tube stubs, or fittings made from tubing under this specification shall include the following, as a minimum, to describe the item:

- Quantity (meters, feet, number of items, or number of lengths),
- Type of tubing (seamless or welded),
- Size (nominal outside diameter and wall thickness),
- Length (specific or random), and
- Other specific dimensions (such as for fittings).

6 Surface Condition

6.1 The internal surface of all finished tubing, component tube stubs, and fittings made from tubing shall be electropolished.

1 American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017

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

6.2 The internal surface of the finished tubing, component tube stub, or fitting made from tubing shall be free from all macroscopic pitting, staining or discoloration, and surface flaws. The O.D. of the tube shall be homogeneous in texture and brightness and free of obvious flaws.

6.3 Finished tubing, component tube stubs, and fittings made from tubing shall be measured for internal surface finish. Testing shall verify conformance to a surface roughness standard of one of the following:

Table 1 Roughness Average (R_a)

<i>Multiple Measurements</i>		<i>Maximum Single Measurement</i>	
<i>micrometers</i>	<i>microinches</i>	<i>micrometers</i>	<i>microinches</i>
0.25	10	0.30	12
0.18	7	0.25	10
0.13	5	0.18	7

7 Surface Condition Measurements

7.1 *Surface Roughness* — When specified as per Section 6.3, surface roughness shall be measured in accordance with ANSI B46.1, using a stylus-type instrument and a cutoff of 760 micrometers (0.030 inches), or equivalent process (which shall be submitted for approval to the customer prior to order acceptance). The results reported shall be Roughness Average (R_a), expressed in micrometers or microinches.

7.1.1 Measurements shall be made at 0, 90, 180, and 270 degrees around the tube's inner circumference.

7.2 Scanning Electron Microscopy (SEM) photographs of the electropolished internal surfaces of tubing, component tube stubs, and fittings made from tubing shall be provided by the manufacturer in accordance with the sampling frequency criteria specified by the customer. SEM analysis shall verify that no more than 40 defects shall be distinguishable in a 3400 to 3600× field view in a 64 × 89 mm (2 1/2" × 3 1/2") picture.

7.3 Chemical analysis, using electron spectroscopy for chemical analysis (ESCA), shall be performed on the electropolished internal surfaces of tubing, component tube stubs, and fittings made from tubing and shall be provided by the manufacturer in accordance with the sampling frequency criteria specified by the customer. Elemental composition shall be expressed in atomic percent units and shall verify a minimum chromium oxide to iron oxide ratio of 2.2:1.

7.4 Auger Electron Spectroscopy (AES) analysis shall be performed on the electropolished internal surfaces of tubing, component tube stubs, and fittings made from

tubing and shall be provided by the manufacturer in accordance with the sampling frequency criteria specified by the customer.

8 Cleanliness

8.1 After electropolishing, finished tubing shall be final cleaned with a process that uses deionized (DI) water with a minimum resistivity of 17.5 megohm-cm at 25° C as the final cleaning agent, and nitrogen or a suitable filtered inert gas, as a drying agent. Both the water and the gas shall be heated to a minimum of 60° C.

8.2 Tubing, component tube stubs, and fittings made from tubing shall be sealed with polyethylene caps pressed over 0.05 mm (1.75 mil) or thicker polyamide squares after having been purged with nitrogen or a suitable inert gas. Capped tubing, stubs, or fittings shall be heat-sealed in a single 0.15 mm (6 mil) or thicker polyethylene bag.

9 Permissible Variations in Dimensions

9.1 The permissible variations in dimensions shall be as outlined in Table 3 of ASTM A 269 for nominal sizes 1/2" diameter and larger and in Table 3 of ASTM A 632 for nominal sizes smaller than 1/2" diameter.

9.2 Finished wall thicknesses for tubing, component tube stubs, and fittings made from tubing are shown in Table 2. The finished thicknesses must also comply with the requirements of ANSI/ASME B31.1 and B31.3 for the intended service temperature and pressure. The appropriate tolerances per Section 9.1 shall apply to these finished wall thicknesses.

Table 2 Finished Wall Thickness for Various Tube Sizes

<i>Nominal O.D.</i>	<i>Finished Tube Wall Thickness</i>
1/4" , 3/8"	0.89 mm (0.035")
1/2"	1.25 mm (0.049")
3/4" , 1" , 1 1/2" , 2" , 3"	1.65 mm (0.065")
4" , 6"	2.11 mm (0.083")

10 Certification

10.1 The supplier shall provide the following reports and certification with all shipments of electropolished tubing, component tube stubs, or fittings made from tubing:

10.1.1 Type of tubing (seamless or welded),

10.1.2 Size (nominal outside diameter and wall thickness),

10.1.3 Material composition report,

10.1.4 Heat code identification. Tubing, component tube stubs, and fittings made from tubing shall be mill- and heat-traceable and permanently etched for correspondence to the applicable mill test reports,

10.1.5 Surface roughness certification,

10.1.6 Microscopic surface condition certification (SEM),

10.1.7 Surface chemistry certification (ESCA), and

10.1.8 Surface depth profile certification (Auger).

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SEMI F18-95

GUIDE FOR DETERMINING THE HYDROSTATIC STRENGTH OF, AND DESIGN BASIS FOR, THERMOPLASTIC PIPE AND TUBING

1 Purpose

To identify a test method for measuring the hydrostatic strength of thermoplastic pipe and tubing, a method for estimating long-term hydrostatic strength, and recommendations for developing design bases.

2 Scope

2.1 This guide references the industry-recognized Standard Test Method for determining the time-to-failure of plastic pipe under constant internal pressure.

2.2 This guide references the industry-recognized Standard Test Method for determining the long-term hydrostatic strength of plastic pipe in order to obtain the hydrostatic design basis of the pipe material.

2.3 This guide references the Technical Report of policies and procedures for developing recommended hydrostatic design stresses for thermoplastic pipe materials from 23°C to 93.3°C (73°F to 200°F).

3 Referenced Documents

3.1 *ASTM Standards*¹

D 1598 — Standard Test Method for Time-to-Failure of Plastic Pipe under Constant Internal Pressure

D 2837 — Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials

3.2 *PPI Technical Report*²

TR-3/92 — Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermoplastic Pipe Materials

4 Terminology

Currently this document contains no terminology.

5 Summary of Referenced Documents

5.1 *ASTM Standards*

5.1.1 *D 1598* — This test method consists of exposing specimens of pipe/tube to a constant internal pressure while in a controlled environment. Such a controlled

environment may be accomplished by immersing the specimens in a controlled-temperature water or air bath. The time-to-failure is measured.

5.1.2 *D 2837* — The procedure for estimating long-term hydrostatic strength is essentially an extrapolation, with respect to time, of a stress-time regression line based on data obtained in accordance with ASTM D 1598. Stress-failure time plots are obtained for the selected temperature and environment: the extrapolation is made in such a manner that the long-term hydrostatic strength is estimated for these conditions.

5.2 *PPI Technical Report*

5.2.1 *TR-3/92* — These policies and procedures are for development of recommendations for thermoplastic pipe compounds based on test data from good quality pipes made by specific processing techniques. These recommendations may or may not be valid for pipes made by differing processing techniques.

6 Comments

6.1 The Hydrostatic Stress Committee of the Plastic Pipe Institute (PPI) has recommended a minimum safety factor of 200% based on the hydrostatic design basis. The safety factor is intended to make allowance for manufacturing and testing variables such as normal variations in the material, manufacturing process, dimensions, and in the evaluation procedures (ASTM D 2837 and D 1598).

6.2 Application conditions also need to be taken into consideration and may require an increased safety factor. For example, with liquid hydrocarbons and other chemicals, temperature can have a disproportional effect on the long-term performance of the tubing or pipe. No general safety factor has been established for these types of services, so each case should be designed on its own merit.

NOTE: It is strongly recommended that the user of pipe/tube confirm that the product has been tested per ASTM D 1598, D 2837, and TR-3/92 to ensure a proper pressure rating.

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

² Plastic Pipe Institute, 355 Lexington Avenue, New York, NY 10017



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SEMI F19-0304

SPECIFICATION FOR THE SURFACE CONDITION OF THE WETTED SURFACES OF STAINLESS STEEL COMPONENTS

This specification 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 December 4, 2003. Initially available at www.semi.org February 2004; to be published March 2004. Originally published in 1995.

NOTICE: This document was completely rewritten in 2004.

1 Purpose

1.1 The purpose of this specification is to provide a standard for the quality of the wetted surfaces of stainless steel components used in the chemical (gas and liquid) distribution systems of semiconductor manufacturing facilities.

2 Scope

2.1 This specification defines the wetted surface characterization requirements and the finish acceptance criteria for tubing and components fabricated in stainless steel per SEMI F20 and intended to control and/or contain gases and liquids used in semiconductor manufacturing.

2.2 The surface characterization tests to be performed are specified herein, and the existing standards for performing these tests are referenced.

2.3 Terms specific to this technology are either listed herein as they relate to the acceptance criteria of this specification or are defined in the referenced documents as they relate to a specific test method.

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 F20 — Specification for 316L Stainless Steel Bar, Extruded Shapes, Plate, and Investment Castings for Components Used in High Purity Semiconductor Manufacturing Applications

SEMI F37 — Method for Determination of Surface Roughness Parameters for Gas Distribution System Components

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

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

SEMI F72 — Test Method for Auger Electron Spectroscopy (AES) Evaluation of Oxide Layer of Wetted Surfaces of Passivated 316L Stainless Steel Components

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

SEMI F77 — Test Method for Electrochemical Critical Pitting Temperature Testing of Alloy Surfaces Used in Corrosive Gas Systems

3.2 ASTM¹ Standard

ASTM A 967 — Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts

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

4 Terminology

4.1 Abbreviations and Acronyms

4.1.1 Å — Angstrom (= 0.1 nm)

4.1.2 AES — Auger Electron Spectroscopy

4.1.3 Avg — Average

4.1.4 CPT — Critical Pitting Temperature

4.1.5 Cr — Chemical symbol for Chromium

4.1.6 Cr/Fe — Ratio of total Chromium to total Iron in the passive oxide layer, as defined in SEMI F60

4.1.7 CrOX — Chromium Oxide

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: <http://www.astm.org>

4.1.8 *CrOX/FeOX* — Ratio of Chromium Oxide to Iron Oxide in the passive oxide layer, as defined in SEMI F60

4.1.9 *EDS* — Energy Dispersive X-ray Spectroscopy

4.1.10 *ESCA* — Electron Spectroscopy for Chemical Analysis (sometimes referred to as XPS)

4.1.11 *Fe* — Chemical symbol for Iron

4.1.12 *FeOX* — Iron Oxide

4.1.13 *Max* — Maximum

4.1.14 *μin* — Micro inch (= 10⁻⁶ inch)

4.1.15 *μm* — Micrometer (= 10⁻⁶ meter)

4.1.16 *nm* — Nanometer (= 10⁻⁹ meter)

4.1.17 *Ra* — Roughness average of surface profile

4.1.18 *Ry* — Maximum peak-to-valley roughness height of surface profile

4.1.19 *SEM* — Scanning Electron Microscopy

4.1.20 *XPS* — X-Ray Photoelectron Spectroscopy (sometimes referred to as ESCA)

4.2 Definitions

4.2.1 *blistering* — a localized delamination within the metal that has an appearance of chipped or flaked-off areas.

4.2.2 *defect* — unintentional and undesirable irregularity in the part surface that could affect system performance. Examples of such defects include cracks, inclusions, blistering, dents, pits, stringers and scratches.

4.2.3 *dent* — an isolated irregularity on the wetted surface made by an impact.

4.2.4 *electropolishing* — a method of polishing metals and alloys in which material is removed from the surface by making the metal the anode in an electrolytic bath.

4.2.5 *etched* — a surface that has alloy structural features revealed by preferential chemical or electrochemical attack.

4.2.6 *flaw* — synonymous with defect.

4.2.7 *frostiness* — a continuous surface pattern whose appearance is like that of a sparkly, very fine, sandy-textured surface.

4.2.8 *grain boundary* — an interface separating two grains, where the orientation of the lattice changes from that of one grain to that of the other.

4.2.8.1 *stepped grain boundary* — a form of preferential etching in which the grains are attacked at different rates, resulting in one grain to appear raised with respect to an adjacent grain, forming a “step” at the grain boundary.

4.2.9 *haze* — a diminished surface brightness or specularity attributable to diffuse light scattering by concentrations of microscopic surface irregularities, or to chemical inhomogeneity.

4.2.10 *inclusion* — indigenous or foreign material within the metal, usually referring to non-metallic compound particles such as oxides, alumina, sulfides or silicates.

4.2.11 *interrupted electropolishing* — a break in the continuity of the electropolished surface appearance due to a change of electropolishing conditions at the interruption boundary; may be visible as a change in reflectivity across the boundary or a step in the surface.

4.2.12 *lay* — the direction of the predominant surface pattern, ordinarily determined by the production method used.

4.2.13 *machining Lines* — a type of process line that results from machining processes.

4.2.14 *nominal surface* — the intended surface contour, the shape and extent of which is shown and dimensioned on a drawing or descriptive definition.

4.2.15 *orange peel* — large-featured, roughened type of surface visible to the unaided eye whose surface appearance pattern is like that of an orange peel.

4.2.16 *passivation* — the chemical treatment of a stainless steel surface with an oxidizing solution for the purpose of enhancing the corrosion resistant surface film.

4.2.17 *pit* — a surface cavity or crater with a defined edge not caused by impact.

4.2.18 *process Lines* — surface features that are a result of the material removal or forming process used in manufacturing of a component.

4.2.19 *Ra Avg.* — average *Ra* of a set of surface roughness measurements.

4.2.20 *Ra Max.* — maximum *Ra* of a set of surface roughness measurements.

4.2.21 *Ry Max.* — maximum *Ry* of a set of surface roughness measurements.

4.2.22 *roughness* — the finer irregularities of the surface texture, usually including those irregularities that result from the manufacturing process. These are considered to include traverse feed marks and other

irregularities within the limits of the roughness sampling length.

4.2.23 *scratch* — an elongated mark or groove cut in the surface by mechanical means, not associated with the predominant surface texture pattern.

4.2.24 *stringer* — a microstructural configuration of alloy constituents or foreign nonmetallic material, or trace thereof, oriented in the direction of mechanical working.

4.2.25 *surface texture* — the repetitive or random deviations from the nominal surface which form the three dimensional topography of the surface. Surface texture includes roughness, waviness, lay, and flaws.

4.2.26 *waviness* — the more widely spaced component of surface texture. Unless otherwise noted, waviness is to include all irregularities whose spacing is greater than the roughness sampling length. Waviness may result from such factors as machine or work deflections, vibrations, chatter, heat treatment, or warping strains. Roughness may be considered as superimposed on a “wavy” surface.

4.2.27 *wetted surface* — surfaces of the components that are in contact with the contained gases and/or liquids used in semiconductor manufacturing processes.

5 Ordering Information

5.1 The purchase order for components to be supplied in compliance with this specification shall include the following information:

5.1.1 Purchase Order Number.

5.1.2 Supplier's (preferred) or purchaser's part number(s), including size(s).

5.1.3 Quantity of components by part number and size.

5.1.4 Grade of each part number and size per the grade classifications specified in this specification.

5.1.5 Reference to this specification number and any additional applicable specifications.

5.1.6 Documentation and certification requirements.

5.1.7 Any special and/or supplementary requirements.

6 Requirements

6.1 Requirements of this specification are divided into three grades of products:

6.1.1 *General Purpose Components (GP)* — These are components intended for use in fluid distribution systems of semiconductor manufacturing facilities that do not have stringent cleanliness requirements. Examples are clean dry air and vacuum lines.

6.1.2 *High Purity Components (HP)* — These are components intended for use in high performance capability chemical distribution systems of semiconductor manufacturing facilities.

6.1.3 *Ultra High Purity Components (UHP)* — These are components intended for use in advanced chemical distribution systems of semiconductor manufacturing facilities in which optimum performance capabilities are required.

6.2 Requirements of this specification are shown in Table 1, along with the appropriate test methods for evaluating each.

6.3 *Surface Roughness Requirements* — Surface roughness requirements for each grade of component are shown in Table 1. Measurements shall be made per the mechanical profilometry test method SEMI F37.

6.3.1 Welds, screw slots, intersections, and non-metallic parts are not measured.

6.4 *Surface Defect Requirements* — Surface defect requirements for the HP and UHP grades of components are shown in Table 1. Measurements shall be made per the SEM test method of SEMI F73.

6.5 *Surface Contamination Requirements* — Gross surface contamination on the HP and UHP grades of components observed in the SEM determination of surface defects per SEMI F73 shall be evaluated by EDS.

6.5.1 Elements expected to be found on the surfaces of components by EDS include the primary alloying elements Iron (Fe), Chromium (Cr), Nickel (Ni), and Molybdenum (Mo). The residual elements Manganese (Mn) and Silicon (Si), the Oxygen (O) of the passive layer, and adsorbed carbon are also expected to be found. Any other elements detected by EDS are to be considered contaminants and are cause for rejection.

6.6 *Surface Chemistry Requirements* — The preferred test method for evaluating the chemistry and contamination of the oxide passive layer is the ESCA test method of SEMI F60 for the HP and UHP grades of components. Alternatively, the evaluation may be performed by the AES test method of SEMI F72, per agreement between the supplier and user.

6.6.1 Elements expected to be found on the surfaces of components by ESCA or AES include the primary alloying elements Iron (Fe), Chromium (Cr), Nickel (Ni), and Molybdenum (Mo), the residual elements Manganese (Mn), Silicon (Si), Sulfur (S), Phosphorous (P), Nitrogen (N) and Silicon (Si), and the Oxygen (O) of the passive layer. Adsorbed Carbon contamination shall be < 30 atomic percent, declining to base levels within 15 Angstrom of the initial surface.

6.6.2 Sulfur (S), Phosphorous (P), Nitrogen (N) and Silicon (Si) shall be < 2 atomic percent on the initial surface by ESCA or AES.

6.6.3 All other contaminants shall be < 1 atomic percent by ESCA or AES.

Table 1 Table of Specifications and Test Methods by Product Grade

		<i>General Purpose Grade GP</i>	<i>High Purity Grade HP</i>	<i>Ultra-High Purity Grade UHP</i>
<i>Characteristic</i>	<i>Test Method</i>	<i>Value</i>	<i>Value</i>	<i>Value</i>
Surface Roughness	SEMI F37	≤ 0.50 μm (20 μin) Ra Avg. ≤ 0.62 μm (25 μin) Ra Max. ≤ 3.75 μm (150 μin) Ry Max.	≤ 0.25 μm (10 μin) Ra Avg. ≤ 0.38 μm (15 μin) Ra Max. ≤ 3.75 μm (150 μin) Ry Max.	≤ 0.13 μm (5 μin) Ra Avg. ≤ 0.25 μm (10 μin) Ra Max. ≤ 2.50 μm (100 μin) Ry Max.
Surface Defects	SEMI F73	(Not Applicable)	≤ 30 Avg, ≤ 50 Max Counts/Photo	≤ 10 Avg, ≤ 20 Max Counts/Photo
Surface Contamination	SEMI F73	(Not Applicable)	No elements detectable by EDS other than primary alloying elements Fe, Cr, Ni, Mo, residual elements Mn and Silicon (Si), the O of the passive layer, and adsorbed C.	No elements detectable by EDS other than primary alloying elements Fe, Cr, Ni, Mo, residual elements Mn and Silicon (Si), the O of the passive layer, and adsorbed C.
Surface Chemistry	SEMI F60 (or SEMI F72 by agreement)	Product must be passivated per ASTM A967	Cr/Fe and CrOX/FeOX ratios ≥ 1.0; oxide thickness $t \geq 1.5$ nm ($t \geq 15$ Å). See Note.	Cr/Fe ratio ≥ 1.5 and CrOX/FeOX ≥ 2.0; oxide thickness $t \geq 1.5$ nm ($t \geq 15$ Å). See Note.
			Adsorbed Carbon contamination shall be <30 atomic percent, declining to base levels within 1.5 nm (15 Å) of the initial surface. Sulfur (S), Phosphorous (P), Nitrogen (N) and Silicon (Si) shall be < 2 atomic percent on the initial surface. All other contaminants shall be < 1 atomic percent.	Adsorbed Carbon contamination shall be <30 atomic percent, declining to base levels within 1.5 nm (15 Å) of the initial surface. Sulfur (S), Phosphorous (P), Nitrogen (N) and Silicon (Si) shall be < 2 atomic percent on the initial surface. All other contaminants shall be < 1 atomic percent.
Corrosion Resistance	ASTM G 150; SEMI F77	As agreed upon between user and supplier.	As agreed upon between user and supplier.	As agreed upon between user and supplier.

NOTE: Oxide thickness > 5 nm (50 Å) approximately, formed by electropolishing may have an outer layer enriched in Iron, and therefore exhibit poor corrosion resistance.

6.7 Corrosion Resistance Requirements — Corrosion resistance of the surface shall be evaluated by the CPT test method of ASTM G 150 or SEMI F77.

6.8 Visual Acceptance Criteria — Visual inspection of the wetted surfaces for defects shall be performed under normal room lighting. Additional lighting may be used when appropriate to illuminate blind or darkened areas and to clarify questionable areas. Visual inspection shall be done with up to 4X magnification; if a possible problem is detected, an 8 to 10X magnifier may be used for clarification of the area in question.

6.8.1 Process and machining lines are acceptable on GP grade surfaces if the surface roughness requirements are met. Process and machining lines are not acceptable on HP and UHP surfaces. Surface finishing processes for HP and UHP surfaces are expected to “round off” the lines to the degree that they are not apparent by the SEM test method SEMI F73 and are not well defined visually.

6.8.2 Scratches and haze that meet the surface roughness requirements are acceptable on GP surfaces. These defects are not acceptable on HP and UHP surfaces.

6.8.3 Waviness is acceptable if the surface roughness requirements are met.

6.8.4 Orange peel is acceptable if the surface roughness requirements are met.

6.8.5 Dents, frostiness, blistering and interrupted electropolishing are not acceptable.

6.8.6 Contamination (water spots, rust, process residues, chemical staining, etc.) are not acceptable.

6.8.7 Pitting, stringers, and inclusions apparent to the unaided eye are not acceptable in UHP grade surfaces. Acceptance of these defects in HP and UHP grade surfaces shall be determined by the SEM test method of SEMI F73 and shall be in conformance with the specifications of Table 1.

7 Test Methods

7.1 Test methods are listed in Table 1 and described in Section 6, Requirements.

8 Sampling

8.1 Sampling shall be per agreement between component supplier and purchaser.

9 Certification

9.1 The component supplier shall provide the following reports and certifications with all shipments of processed components:

9.1.1 Name/part number/description of component(s),

9.1.2 Quantity of components by size or description,

9.1.3 Product grade of each size or category of components per the classifications in this specification, and

9.1.4 Certification that the manufacturing processes were performed per an appropriate quality control program and that the processes are qualified.

10 Product Labeling

10.1 Product labeling shall be per agreement between component supplier and purchaser.

11 Related Documents

11.1 *SEMI Standard*

SEMI F55 — Test Method for Determining the Corrosion Resistance of Mass Flow Controllers

11.2 *ASME² Standards*

ASME B46.1 — Surface Texture (Surface Roughness, Waviness and Lay)

11.3 *ASTM¹ Standards*

ASTM F 1372 — Test Method for Scanning Electron Microscope (SEM) Analysis of Metallic Surface Condition for Gas Distribution System Components

ASTM F 1374 — Test Method for Ionic/Organic Extractables of Internal Surfaces – IC/GC/FTIR for Gas Distribution System Components

ASTM F 1375 — Test Method for Energy Dispersive X-Ray Spectrometer (EDX) Analysis of Metallic Surface Condition for Gas Distribution System Components

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

ASTM F 1396 — Test Method for Determination of Oxygen Contribution by Gas Distribution System Components

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

ASTM F 1398 — Test Method for Determination of Total Hydrocarbon Contribution by Gas Distribution System Components

ASTM G 150 — Standard Test Method for Electrochemical Critical Pitting Temperature Testing of Stainless Steels

² American Society of Mechanical Engineers: United Engineering Center, Three Park Avenue, New York, NY 10016-5990, USA.

Telephone: 800.843.2763; Fax: 973.882.1717; Website: <http://www.asme.org>



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SEMI F20-0305

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

This specification 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 November 4, 2004. Initially available at www.semi.org January 2005; to be published January 2005. Originally published in 1995; previously published July 2004.

1 Purpose

1.1 The purpose of this specification is to define the metallurgical cleanliness requirements and material composition of 316L stainless steel required for use in the manufacture of components for general purpose, high purity, and ultra-high purity chemical (gas or liquid) distribution systems.

2 Scope

2.1 This specification defines the requirements for 316L stainless steel bar, forgings, and extruded shapes as specified in ASTM A 276, plate stock as specified in ASTM A 240, and tubing as specified in ASTM A 269 and ASTM A 632, for use in the manufacture of components used in general purpose and high purity chemical (gas or liquid) distribution systems in semiconductor manufacturing facilities.

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 *ASTM Standards*¹

A 182/A 182M — Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service

A 240/A 240M — Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels

A 262 — Practices for Determining Susceptibility to Intergranular Attack in Austenitic Stainless Steels

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

A 276 — Specification for Stainless and Heat-Resisting Steel Bars and Shapes

A 479/A 479M — Specification for Stainless and Heat Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

A 480/A 480M — Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet and Strip

A 484/A 484M — Specification for General Requirements for Stainless and Heat-Resisting Wrought Steel Products (Except Wire)

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

A 751 — Test Methods, Practices and Terminology for Chemical Analysis of Steel Products

¹ American Society for 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

E 45 — Recommended Practice for Determining the Inclusion Content of Steel

E 112 — Test Methods for Determining Average Grain Size

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

4 Terminology

4.1 Definitions

4.1.1 *inclusion* — Indigenous or foreign material within the metal, usually referring to non-metallic compound particles such as oxides, alumina, sulfides or silicates.

4.1.2 Grades

4.1.2.1 *General Purpose (GP) Grade* — For components intended for use in chemical distribution systems of semiconductor manufacturing facilities that do not have stringent cleanliness requirements. Examples are clean dry air and vacuum lines.

4.1.2.2 *High Purity (HP) Grade* — For components intended for use in high performance capability chemical distribution systems of semiconductor manufacturing facilities.

4.1.2.3 *Ultra High Purity (UHP) Grade* — For components intended for use in advanced chemical distribution systems of semiconductor manufacturing facilities in which optimum resistance to corrosion and contamination in critical process chemicals are required.

5 Ordering Information

5.1 Orders for bar, forgings, extruded shapes, plate, or tubular products under this specification shall include:

5.1.1 Grade – General purpose, high purity, or ultra-high purity,

5.1.2 Quantity (kilograms, pounds, meters, inches, or feet),

5.1.3 Cross section description (round, square, hex, etc. or detailed drawing),

5.1.4 Size (nominal diameter or shape dimensions for other than those identified with an extrusion drawing),

5.1.5 Wall thickness (for tubing),

5.1.6 Length (specific or random),

5.1.7 Reference to this specification number, and

5.1.8 Any special and/or supplementary requirements such as melting and refining processes.

6 Requirements

6.1 General

6.1.1 Bar stock, forgings, or extruded shapes furnished under this specification shall conform to the requirements of ASTM A 182/A 182M, ASTM A 276, ASTM A 479/A 479M, or ASTM A 484/A 484M, and the additional requirements of this specification.

6.1.2 Plate stock furnished under this specification shall conform to the requirements of ASTM A 240 or A 480/A 480M, and the additional requirements of this specification.

6.1.3 Tubing furnished under this specification shall conform to the requirements of ASTM A 269 or A 632, and the additional requirements of this specification.

6.1.4 Where the requirements of this specification conflict with referenced specifications, the requirements of this specification take precedence.

6.2 Manufacture

6.2.1 The stainless steel billet material used for processing shall be manufactured by such melting, casting and refining processes required to conform to the composition and metallurgical requirements of this specification.

6.2.2 The annealing temperature used to achieve the grain size requirements of ¶6.4.1 shall be 982°C (1800°F) minimum.

6.3 Composition

6.3.1 Material shall be type 316L stainless steel, as specified in Table I of ASTM A 182/A 182M, ASTM A 240, ASTM A 269, ASTM A 276, ASTM A 479/A 479M, or ASTM A 632, except where otherwise specified herein.

6.3.2 General purpose grade material shall have a composition per ASTM A 269 and ASTM A 632, with the exception of limited Sulfur 0.012% maximum.

6.3.3 Additional composition requirements for the high purity and ultra-high purity grades are shown in Table 1.

Table 1 Additional Composition Requirements

<i>Element</i>	<i>Range – Wt %</i>
Carbon	0.030 Max
Sulfur	0.010 Max
Manganese	1.5 Max
Copper	0.30 Max ^{#1}
Niobium	0.05 Max
Aluminum	0.01 Max
Calcium	0.02 Max
Titanium	0.02 Max
Selenium	0.02 Max

^{#1} Agreement may be reached between the supplier and the customer to accept a higher level of copper.

6.3.4 Effects of Sulfur content on welding are significant, as discussed in Appendix 1.

6.3.5 Effects of Copper content on welding are discussed in Appendix 2.

6.3.6 No deviations in material composition from the minimum or maximum values specified in the appropriate ASTM document or herein shall be allowed without approval by the purchaser.

6.4 Metallurgy

6.4.1 Grain size per ASTM E 112 shall be 5 or finer for hot or cold finished product and tubing of nominal size 3 inches in diameter and smaller, and 3 or finer for material stock greater than 3 inches. These requirements may be modified as agreed upon between supplier and user. Grain size on flats and squares shall be as agreed upon by the supplier and the user.

6.4.2 The inclusion content of the material shall be determined from representative samples of the material heat in accordance with ASTM E 45, Method A, but with ratings based on Plate III. Maximum allowable JK ratings at the billet stage are shown in Table 2.

Table 2 Maximum JK Inclusion Ratings

<i>Type</i>	<i>General Purpose Grade</i>		<i>High Purity Grade</i>		<i>Ultra-High Purity Grade</i>	
	<i>Thin</i>	<i>Heavy</i>	<i>Thin</i>	<i>Heavy</i>	<i>Thin</i>	<i>Heavy</i>
A	2.5	1.0	2.0	1.0	1.5	1.0
B	2.5	1.0	2.0	1.0	1.0	1.0
C	2.5	1.0	2.0	1.0	1.0	1.0
D	2.5	1.0	2.0	1.0	1.0	1.0

6.4.3 Material shall meet the intergranular corrosion test specified in Practice E of ASTM A 262. This requirement shall apply in the sensitized condition (1 hour at 677°C [1250°F]).



7 Certification

7.1 A certified copy of the material test report shall be provided at the time of shipment. The material test report shall include:

7.1.1 The results of the composition analysis, to include all elements required to be controlled by this specification, made in accordance with ASTM A 751.

7.1.2 Grain size.

7.1.3 JK ratings of inclusion content.

7.1.4 Mechanical properties.

8 Product Labeling

8.1 Material shall be identified with the following information:

8.1.1 Manufacturer's name,

8.1.2 Purchaser's name and order number,

8.1.3 ASTM specification number(s),

8.1.4 This specification number,

8.1.5 Heat number, and

8.1.6 Material type (i.e., 316L).

APPENDIX 1

THE EFFECTS OF SULFUR ON GTA WELDING OF 316L STAINLESS STEEL

NOTICE: The material in this appendix is an official part of SEMI F20 and was approved by full letter ballot procedures.

A1-2 Effects of Sulfur

A1-2.1 AISI Type 316L austenitic stainless steel is the preferred material for components of gas supply systems for semiconductor fabrication. The composition of 316L specified in Table I of ASTM A 182/A 182M, ASTM A 240, ASTM A 269, ASTM A 276, ASTM A 479/A 479M, or ASTM A 632, has a maximum of 0.030 percent Sulfur; however several properties affecting the manufacture and applications of 316L can vary significantly over this range of Sulfur content. Therefore a lower Sulfur maximum is specified in SEMI F20, as listed in ¶6.3.2 and Table 1 of ¶6.3.3.

A1-2.2 Sulfur has a very low solubility in austenitic stainless steels, thus in these alloys it exists as discrete inclusions of Manganese Sulfide, with some solubility for Chromium as well as other trace elements. These inclusions can initiate pits and other defects on electropolished surfaces, increasing in number with increasing Sulfur content.

A1-2.3 The Manganese Sulfide inclusions improve the machinability of stainless steel; compositions intended for machining have Sulfur compositions near the 0.030 percent maximum, whereas stainless steels with very low Sulfur levels require lower feeds and speeds and will cause reduced tool life during machining.

A1-2.4 Sulfur also strongly affects welding of stainless steel; variation of Sulfur from very low contents to the maximum permitted can increase weld bead penetration by approximately a factor of two for similar weld parameters.

A1-2.5 The effects of Sulfur are summarized in Table A1-1.

A1-2 Welding Effects of Sulfur

A1-2.1 Two effects are observed on welding with variations in Sulfur level:

A1-2.1.1 As Sulfur is reduced the heat input required for full penetration increases.

A1-2.1.2 As Sulfur is reduced below approximately 0.005 percent there is a marked change in weld pool dynamics, causing the weld pool to become wider and shallower².

Table A1-1 – Effects of Sulfur on Austenitic Stainless Steels

<i>As Sulfur increases from zero to the 0.030% maximum permitted:</i>	
<i>Effects</i>	<i>Results</i>
Machinability improves.	– Lower machining costs for machined parts.
Inclusion density increases.	– More pits, stringers, other defects on surface. – Decreased corrosion resistance, particularly on end grains.
Welding penetration increases.	– Weld settings must be reset when changing lots. – Problems welding materials with dissimilar Sulfur contents.

² K. Watanabe and K. Masuda, *Effects of Residual and Micro-Alloying Elements on Welding of Stainless Steel; Part 1: Effects on weld pool behavior by GTAW*, IIW Doc. IX-1837-96, International Institute of Welding, 1996, 17 pp. (Literature review).

As Sulfur increases from zero to the 0.030% maximum permitted:

Solidification temperature range increases.	<ul style="list-style-type: none"> – Increased segregation in weld. – Rougher weld bead surface.
---------------------------------------------	--------------------------------------------------------------------------------------------------------------------------

A1-2.1.3 The latter effect is due to a reversal of the convection currents in the weld pool at approximately 0.005 percent Sulfur. At Sulfur levels significantly above 0.005 percent the convective currents flow downward from the arc, causing deep penetration as illustrated in Figure A1-1, whereas at Sulfur levels well below about 0.005 percent the convective currents flow outward from the arc, causing a wider weld pool and shallower penetration as illustrated in Figure A1-2³.

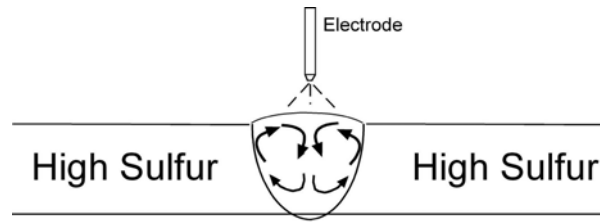


Figure A1-1

Convection Currents in the Weld Pool During Welding of Stainless Steel with $>>0.005\%$ Sulfur Levels

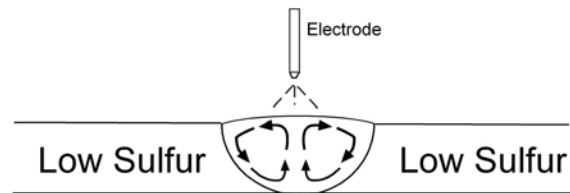


Figure A1-2

Convection Currents in the Weld Pool During Welding of Stainless Steel with $<<0.005\%$ Sulfur Levels

A1-2.1.4 Serious problems can occur when attempting to weld two pieces of stainless steel with substantially different Sulfur contents. The weld pool can become asymmetric, favoring the low Sulfur side, and cause the root of the weld to shift away from the joint, as illustrated in Figure A1-3.

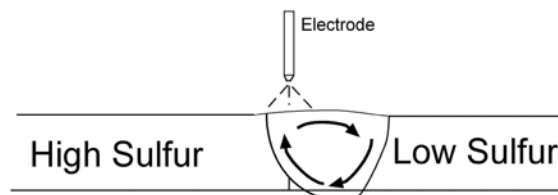


Figure A1-3

The Weld Pool is Asymmetric When Welding Stainless Steel Pieces with Significantly Different Sulfur Levels

A1-2.1.5 In order to minimize this effect it is desirable to match Sulfur contents in components to be welded to within ± 0.007 percentage points. Greater differences in Sulfur contents require very careful weld set-up to ensure full penetration to the root of the joint.

³ Pollard, B., *The Effects of Minor Elements on the Welding Characteristics of Stainless Steel*, Welding Research Supplement, 202 (Sept 1988).



A1-2.1.6 These effects lead to the following recommendations to ensure optimum weld quality when welding stainless steel:

A1-2.1.6.3 Check compositions of pieces to be welded. Match Sulfur contents to within ± 0.007 percentage points.

A1-2.1.6.3 Welding of pieces with very low Sulfur (< 0.003 % approximately) may require additional attention to the establishment of appropriate weld settings to achieve full, uniform penetration. It is recommended that product with wall thickness > 0.100 inch approximately be restricted to > 0.003 % Sulfur.

A1-2.1.6.3 Establish weld settings for piece lots to be welded; recheck whenever changing lots.

APPENDIX 2

THE EFFECTS OF COPPER AS A TRACE ELEMENT ON GTA WELDING OF 316L STAINLESS STEEL

NOTICE: The material in this appendix is an official part of SEMI F20 and was approved by full letter ballot procedures.

A2-1 Copper in Stainless Steel

A2-1.1 Copper is a residual or unspecified element in AISI 316L. It is not an intentional addition, but is present in any heat of material as a result of the composition of the furnace charge materials used, which are typically primarily scrap with elemental and master alloy additions to achieve the composition desired. Levels of unspecified elements such as Copper are permitted up to 0.50% maximum by AMS 2248E⁴. Copper content can only be reduced in the melt by dilution. Over time, as more scrap material is recycled, the residual levels of copper in heats of AISI 316L is anticipated to increase.

A2-1.2 Copper is an austenite phase stabilizer. It also has been shown to improve the resistance of austenitic stainless steels to stress corrosion cracking in chloride solutions.

A2-2 Effects of Copper on Welding

A2-2.1 In welding, copper is a surface-active element (like S, O, and Se) and has been shown to contribute significantly to weld bead meander. Like manganese, it will volatilize during welding and redeposit downstream of the weld, providing a site for the initiation of corrosion in some conditions. Some end users may restrict copper as a potential source of weld contamination or corrosion.

A2-2.2 A correlation was noted between increased copper content and weld bead meander in a wafer fab project⁵. Five heats of 0.25 in. tubing were evaluated. Copper was very prominent in the HAZ of one heat (0.47% Cu and 0.011% S) which had a bead meander problem when welded. Another heat with the same sulfur content and a lower copper content (0.03% Cu) did not exhibit bead meander. Another heat (0.31% Cu and 0.010% S) showed oxidation after welding. All welds were performed in argon.

A2-2.3 In a study of 28 heats of tubing from 0.25 to 2.0 inch in diameter, copper ranged from 0.05 to 0.41%⁶. Of the 28 heats tested, 10 had copper contents above 0.25%, and among the nine heats of 2.0 in. diameter tubing, all had copper levels above 0.22%, with four of the heats above 0.25%. Cosmetically unacceptable welds (slag, discoloration and/or bead meander) occurred on heats with: 0.26% Cu, 0.005% S; 0.28% Cu, 0.009% S; and 0.41% Cu, 0.005% S. Conversely, cosmetically acceptable welds were performed on a heat with 0.3% Cu and 0.011% S. All welds were performed using argon.

A2-2.4 Data was presented at a SEMI Workshop and repeated here concerning the effect of copper content and shield gas interactions on weldability⁷. Two examples of heats of AISI 316L tubing, 2.5 in. in diameter, with copper contents above 0.3%, demonstrated that adding hydrogen to the argon shield gas adversely affected the weldability of the tubing (see Figure A2-1). This same effect was not noted in heats of tubing with copper levels below 0.3%. In addition, the weld electrodes undergo severe degradation when welding tubing with copper contents above 0.3% and using Ar/H₂ shield gas (see Figure A2-2).

A2-2.5 Based on the above information, the following conclusions can be made:

A2-2.5.1 The copper restriction in SEMI F20 currently stands at 0.30%. This restriction is due to weldability effects.

4 Aerospace Materials Specification (AMS) 2248E, "Chemical Check Analysis Limits: Corrosion and Heat Resisting Steels and Alloys, Maraging and Other Highly Alloyed Steels, and Iron Alloys," SAE International, Warrendale, PA; issued 15 January 1960, Revised 1 October 1993, 6 pp

5 R. M. Cohen, *Identifying Trace Elements Affecting the Weldability of 316L Stainless Steel Tubing*, Future Fab International 1997, pp. 271-281

6 Sunniva Collins and Pete Williams, *Weldability and Corrosion Studies of AISI 316L Electropolished Tubing*, Proc. Interphex 2000.

7 Sunniva Collins, *The Effect of Copper on GTA Welding of 316L Stainless Steel Tubing*, Stainless Steel and Surface Analysis Workshop, SEMICON West Standards Meeting, July 14, 2003

A2-2.5.2 There appears to be a Cu/S interaction; the copper effect on welding is more pronounced at sulfur levels under 0.010%.

A2-2.5.3 Commercially available tubing of 2.0 in. diameter and above is currently being offered with residual copper levels above 0.2%.

A2-2.5.4 Cohen's data shows that oxidation after welding will occur at 0.31% Cu, 0.010% S in argon; Collins' data shows an acceptable weld at 0.30% Cu, 0.011% S in argon.

A2-2.5.5 A cosmetically unacceptable weld, with bead meander and Cu redeposited in the HAZ, was found at 0.41% and 0.47% Cu.

A2-2.5.6 Heats above 0.30% Cu may be welded successfully in argon, but may exhibit bead meander and electrode attack in Ar/H₂.



(a) 2.5 in. tubing, Cu content 0.37%. Bead meander condition became evident with addition of H₂ to shield gas.



(b) 2.5 in. tubing, Cu content 0.34%. Bead meander condition became evident with addition of H₂ to shield gas, worsened with each weld.

Figure A2-1
Weldability: Copper Content and Shield Gas Interactions

A2-2.5.7 Scanning electron micrographs of welding electrodes after welding 2.5 inch tubing with Cu content 0.34%; Shield gas Ar/H₂.

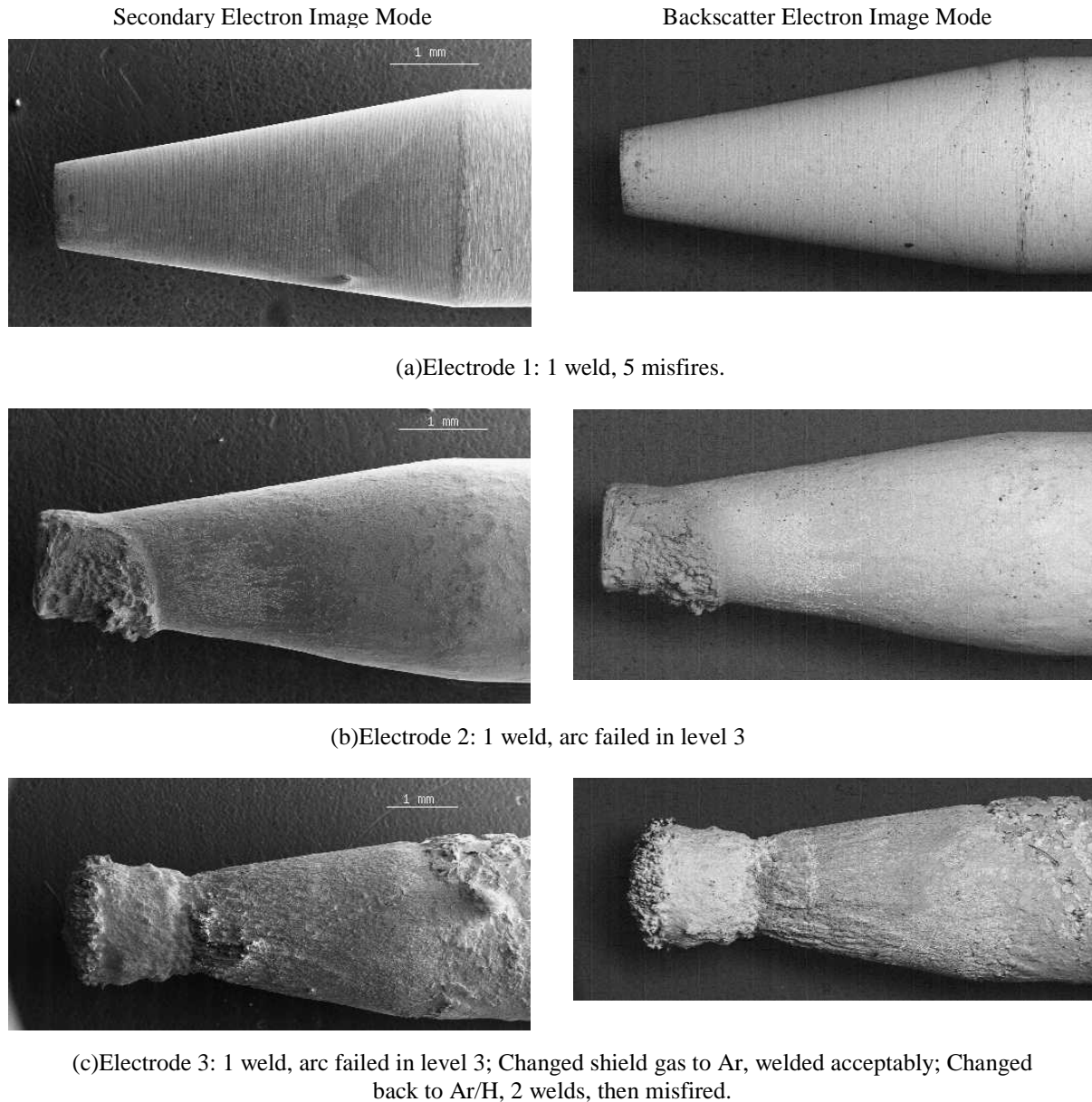


Figure A2-2
Weldability: Effect of Copper Content and Shield Gas on Weld Electrodes

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SEMI F21-1102

CLASSIFICATION OF AIRBORNE MOLECULAR CONTAMINANT LEVELS IN CLEAN ENVIRONMENTS

This classification was technically approved by the Global Facilities Committee and is the direct responsibility of the North American Facilities Committee. Current edition approved by the North American Regional Standards Committee on August 29, 2002. Initially available at www.semi.org September 2002; to be published November 2002. Originally published in 1995.

1 Purpose

1.1 The purpose of this standard is to classify microelectronics clean environments with respect to their molecular (non-particulate) contaminant levels. This standard classification provides a consistent means of communicating acceptable contaminant levels of groups of specific airborne molecular contaminants. See Related Information 1 appended to this standard.

2 Scope

2.1 This standard classification is to be used in the specification of semiconductor clean environments (including process tool environments) and of contamination control and measurement equipment performance.

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 health practices and determine the applicability or regulatory limitations prior to use.

3 Referenced Standards

None.

4 Terminology

4.1 Definitions

4.1.1 *acid* — a corrosive material whose chemical reaction characteristic is that of an electron acceptor.

4.1.2 *base* — a corrosive material whose chemical reaction characteristic is that of an electron donor.

4.1.3 *condensable* — a substance (other than water), typically having a boiling point above room temperature at atmospheric pressure, capable of condensation on a clean surface.

4.1.4 *dopant* — a chemical element which modifies the electrical properties of a semiconductive material.

5 Basis of Classification

5.1 Classification is by the maximum allowable total gas phase concentration of each category of material. This classification system is depicted in Section 6. The

combination of a quantitative class for each of the four categories yields a classification describing an environment.

5.2 The maximum cumulative gas phase concentrations of the four categories may be different.

5.3 Each category is designated by the letter “M,” followed by the first letter of the category name A, B, C, or D.

5.4 The integer following the category designator shall indicate the maximum total gas phase concentration in parts per trillion molar (pptm 1×10^{-12}). For example, a category MA-10 has a maximum allowable total concentration of 10 parts per trillion molar for the category of interest.

6 Classification

Material Category	1*	10*	100*	1000*	10,000*
Acids	MA-1	MA-10	MA-100	MA-1000	MA-10,000
Bases	MB-1	MB-10	MB-100	MB-1000	MB-10,000
Condensables	MC-1	MC-10	MC-100	MC-1000	MC-10,000
Dopants	MD-1	MD-10	MD-100	MD-1000	MD-10,000

*Concentration, in parts per trillion

7 Reference Test Methods

7.1 Analytical methods capable of measuring the classified levels at the agreed level of confidence shall be used.

8 Related Documents

8.1 SEMI Standards

SEMI E45 — Test Method for the Determination of Inorganic Contamination from Minienvironments Using Vapor Phase Decomposition-Total Reflection X-Ray Spectroscopy (VPD-TXRF), VPD-Atomic Absorption Spectroscopy (VPD-AAS), or VPD/Inductively Coupled Plasma-Mass Spectrometry (VPD/ICP-MS)

SEMI E46 — Test Method for the Determination of Organic Contamination from Minienvironments Using Ion Mobility Spectrometry (IMS)

8.2 Other

8.2.1 Berro, N., Cook, J.P.D., et al., "Airborne Contamination of Semiconductor Wafers Traced to Humidification Plant Additives," *Journal of the IES*, pp. 15–18, November 1993.

8.2.2 Buchmann, K. and Rudolph, J., "Gas Chromatography of Radioactive Inorganic Compounds," *Journal of Radiational Chemistry*, 32(2): 245–64, 1976.

8.2.3 Dixon, W.J., "Processing Data for Outliers," *Biometrics*, 9(7): 74–89.

8.2.4 Kasi, S.R., Liehr, M., Thiry, P.A., et al., "Hydrocarbon Reaction with HF-Cleaned Si (100) and Effects on Metal-Oxide-Semiconductor Device Quality," *Applied Physics Letters*, 59: 108–110, 1992.

8.2.5 Kelly, T.J. and Kinkead, D.A., "Testing of Chemically Treated Adsorbent Air Purifiers," *ASHRAE Journal*, August 1993.

8.2.6 Kinkead, D.A., "Controlling a Killer: How to Win the War Over Gaseous Contaminants," *Cleanrooms*, June 1993.

8.2.7 Kinkead, D.A. and Higley, J.K., "Targeting Gaseous Contaminants in Wafer Fabs: Fugitive Amines," *Microcontamination*, pp. 37–40, June 1993.

8.2.8 Mori, E.J., Dowdy, J.D., and Shive, L.W., "Correlating Organophosphorus Contamination of Wafer Surfaces with HEPA Filter Installation," *Microcontamination*, pp. 35–37, November 1992.

8.2.9 Muller, A.J., et al., "Volatile Cleanroom Contaminants: Sources and Detection," *Solid State Technology*, September 1994, page 61.

8.2.10 Muller, A.J., Psota-Keity, L.A., and Sinclair, J.K., "Concentrations of Organic Vapors and Their Surface Arrival Rates at Surrogate Wafers During Processing in Clean Rooms," *Proceedings of the Electrochemical Society: Semiconductor Cleaning Technology*, Hollywood, FL, Ruzyllo, J. and Novak, R.E. (eds.), vol. 90–9, pp. 204–211, 1990.

8.2.11 Seeman, D.J., "Fluid Seal Urethane Gels/Chemical Compounds: The Need to Establish Standards and Standard Test Procedures for Their Acceptance in the Cleanroom Environment," *Proceedings of 38th Annual Technical Meeting of IES*, Nashville, TN, pp. 492–497, May 1992.

8.2.12 Stevie, F.A., Harrus, A.S., Muller, A.J., et al., "Boron Contamination of Surfaces in Silicon Microelectronics Processing: Characterization and Causes," *Journal of Vacuum Science and Technology*, A9(5), 2813, 1991.

8.2.13 Tolg, G. and Tschopel, P., "Sources of Error in Trace Inorganic Analytical Chemistry," *Systemic Errors in Trace Analysis*, Verlag VCH, Weinheim, 1993 in print.

RELATED INFORMATION 1

SPECIFIC CONTAMINANTS TO MEASURE FOR VERIFICATION OF ENVIRONMENTAL COMPLIANCE

NOTE: This related information is not an official part of SEMI F21 and is not intended to modify or supercede the official standard. It has been derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

Although it is difficult to compile an inclusive list, the originating task force recommends that the user test the air for each of the contaminants listed.

R1-1 Acids

- Hydrofluoric
- Sulfuric
- Hydrochloric
- Nitric
- Phosphoric
- Hydrobromic

R1-2 Bases

- Ammonia (ammonium hydroxide)
- Tetramethylammonium hydroxide
- Trimethylamine
- Triethylamine

- NMP
- Cyclohexylamine
- Diethylaminoethanol
- Methylamine
- Dimethylamine
- Ethanolamine
- Morpholine

R1-3 Condensables

- Silicone (boiling point $\geq 150^{\circ}\text{C}$)
- Hydrocarbon (boiling point $\geq 150^{\circ}\text{C}$)

R1-4 Dopants

- Boron (usually as boric acid)
- Phosphorous (usually as organophosphates)
- Arsenic (usually as arsenates)



RELATED INFORMATION 2

EXAMPLE OF AN ANALYSIS REPORT

NOTE: This related information is not an official part of SEMI F21 and is not intended to modify or supercede the official standard. It has been derived from the work of the originating task force. Publication was authorized by full ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

Analysis for compliance with SEMI Standard Classification MA-10:

Site :	FAB 3														
Test date and duration :	18 August 1994, 0800 –1700, 9 hours														
Contaminants measured :	<table><tr><td>Hydrofluoric acid</td><td>1 pptm</td></tr><tr><td>Sulfuric acid</td><td>1 pptm</td></tr><tr><td>Hydrochloric acid</td><td>2 pptm</td></tr><tr><td>Nitric acid</td><td>1 pptm</td></tr><tr><td>Phosphoric acid</td><td>2 pptm</td></tr><tr><td>Hydrobromic acid</td><td>1 pptm</td></tr><tr><td>Total</td><td>8 pptm</td></tr></table>	Hydrofluoric acid	1 pptm	Sulfuric acid	1 pptm	Hydrochloric acid	2 pptm	Nitric acid	1 pptm	Phosphoric acid	2 pptm	Hydrobromic acid	1 pptm	Total	8 pptm
Hydrofluoric acid	1 pptm														
Sulfuric acid	1 pptm														
Hydrochloric acid	2 pptm														
Nitric acid	1 pptm														
Phosphoric acid	2 pptm														
Hydrobromic acid	1 pptm														
Total	8 pptm														
Detection Limits :	1 pptm for each analyte														
Confidence Level :	95%														
Assumptions made :	All acids determined as anions after water scrubbing; anions can be from other sources but are assumed to be in the acid form for reporting purposes.														
Conclusion :	This environment meets the MA -10 criterion in SEMI F21.														

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