5.1.54 *tungsten* — non-standard term for tungsten electrode.

5.1.55 *tungsten electrode* (2) — a component of the electrical circuit that terminates at the arc, molten conductive slag, or base metal. A non-filler electrode made principally of tungsten and used in arc welding.

5.1.56 *undercut* (2) — a groove adjacent to the base metal at the edge of the weld left unfilled by weld metal.

5.1.57 *underfill* (2) — a groove weld condition in which the weld face or root surface is below the adjacent surface of the base metal.

5.1.58 *weld bead* (2) — a weld resulting from a weld pass.

5.1.59 *weld level* — a segment or portion of a weld schedule in which one or more weld parameters can be changed independently; part of a weld sequence.

5.1.60 *weld sequence* — a series of steps executed by the welding power supply to make a particular orbital weld.

5.1.61 *welder* — a person who does welding (sometimes used to refer to a welding machine or power supply).

5.1.62 *welding equipment* — power supply, weld heads, torches, and associated cables and accessories used for welding.

5.1.63 *welding operator* — a person who welds with an orbital or machine welding system.

6 Summary of Practice

6.1 The welding procedure is shown in the flow chart in Figure 1.

7 General Requirements

7.1 All welding performed under this practice shall conform to the applicable requirements of the ASME Boiler and Pressure Vessel Code, Section IX, ANSI B16.25, B31.3 Chapter V, and AWS B2.1, to the extent that they are included herein.

7.2 All welds shall be based upon Welding Procedure Specifications (WPS) and be documented with associated Procedure Qualification Records (PQR) in accordance with ASME Boiler and Pressure Vessel Code, Section IX, or with AWS B2.1.

7.3 Qualification of the welding procedures to be used, and of the performance of welders and welding operators, shall conform to the requirements of the ASME Boiler and Pressure Vessel Code, Section IX, Articles II and III, or AWS B2.1.

7.4 All welding shall be performed only by certified welders and welding operators. Certification procedures shall include, at the minimum, producing three acceptable welds in a row of typical GTA weld joints of the smallest and largest diameters of each alloy to be welded. Welding parameters shall be set by the welder or welding operator. Certification shall expire after six months of inactivity.

7.5 The weld assembly shall be kept under a continuous purge until all welding is complete.

7.6 Welders shall use clean room-compatible gloves any time that the tubing or component to be welded is removed from protective covering.

8 Apparatus

8.1 Welding equipment shall be of the GTAW, constant current, DCEN (direct current electrode negative) and electronically controlled type with rapid dynamic response capable of 5 Hz (CPS) or greater pulsed welding.

8.2 All welding fixtures and weld heads shall be clean and free of any particulate and excessive discoloration. Weld heads shall rotate freely and smoothly at all speeds. All clamping and holding fixtures shall fit tightly around applicable fittings/tubing, allowing no movement after clamping in excess of 0.003 inch (0.008 cm). The welding fixturing shall allow viewing of the weld joint to insure proper fit-up.

8.3 Electrodes shall be precision ground to the factory specification for head and weld type. Electrode gap shall be set using tooling or procedures that provide accurate and repeatable gaps to be set to within 0.002 in. (0.005 cm). The use of 2% Ce-doped or 2% La-doped tungsten electrodes is recommended.

8.4 Purge gas apparatus shall be stainless steel tubing and components with face seal fittings, when possible. PFA plastic tubing is acceptable as the final run to allow flexibility for hook-up. Lengths shall be restricted to less than ten feet. All components that come into contact with the weldment shall be stainless steel. Only heavy wall PFA or stainless tubing shall be used on the ID purge. Only stainless tubing shall be used on HP systems.

8.5 Purge gas flow shall be measured and controlled.

8.6 Facing equipment shall be of the dry end machining style. The equipment shall be capable of tolerances of 0.003 inches from a plane perpendicular to the centerline of the tube, the OD and /or ID burr of less than 0.005 inches. The equipment shall be capable of controlling the cut curl so as that it does not enter the tubing or cause scratching of the ID surface. The equipment shall not use oils or lubricants in a way that may contaminate the tubing being faced. The cutting or facing shall not be of a abrasive type.

8.7 Severing or parting equipment shall be of the machining type that will separate the tubing without contaminating the ID of the tubing. Wheel type cutters designed to cut stainless steel and CRAs are allowed with purge. Dry saws of orbital type or cutoff are allowed only when followed by cleaning to 12.5. All cut ends shall meet the tolerances for facing equipment or be followed by end preparation with a facing tool.

9 Materials

9.1 All materials to be welded shall be manufactured to ASTM specifications and so certified by the manufacturer. Certification shall conform to ASTM A450, Section 25.

9.2 All seamless austenitic stainless steel tubing shall be in conformance with SEMI F20 or customer specification.

9.3 A backing (ID) gas is required during welding, and while tacking (if tacking is used).

9.4 Weld parameters are affected by the choice of shield gas. Argon, due to its effectiveness and material compatibility, is the most commonly selected shielding and purging gas. Argon and helium are inert and therefore have no effect on the weld metal. These gases do have very different ionization potentials, thermal conductivity, and reactivity.

9.5 Argon/hydrogen mix is a reducing gas that avoids the formation of oxides. It also reduces the amperage required for a given ID weld bead width while reducing the OD bead width. Argon/hydrogen mixes adversely affect high ferrite materials (above 80% ferrite). Use of argon/hydrogen mixes will shorten tungsten electrode life. The weld parameters will be affected by hydrogen to argon percentages. Hydrogen mixes above 5 vol% are not recommended for safety reasons.

9.6 Nitrogen will cause instability of the arc in mixes above 3 vol% in the shield (OD) purge gas. It is a acceptable backing (ID) gas for austenitic stainless and many CRAs. Nitrogen when exposed to welding temperatures will cause nitride formation in some high ferrite materials (above 80% ferrite). Use of nitrogen mixes in the shielding (OD) gas will shorten the tungsten electrode life.

9.7 The ID purge gas will be certified to 99.9997%, or less than 3 ppm total contaminants (moisture, oxygen, and other contaminants).

10 Safety Precautions

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

10.2 Welding equipment used to make welds shall be operated in accordance with the manufacturer's operating and safety instructions.

10.3 All welding performed under this practice shall conform to the applicable requirements of ANSI/ASC Z49.1.

10.4 Welding gas mixtures containing more than 5 vol% H_2 are not recommended due to the potential for fire hazard.

10.5 Do not reweld stainless steel that has been used for corrosive gas delivery.

10.6 See Appendix 1 for information on stainless steel and welding fume.

11 Test Specimens: Couponing

11.1 Prior to the welding of a particular size, wall thickness, and alloy, a primary standard sample weld shall be made, sectioned, and analyzed at the job site. The primary standard sample weld shall become the on-site work sample against which other welds of the same size, wall thickness, and alloy are judged. This on-site work sample may be used indefinitely or reproduced each day at the discretion of the examiner.

11.2 The primary standard sample weld shall be checked for compliance with SEMI F81, "Specification for Visual Inspection and Acceptance of Gas Tungsten Arc (GTA) Welds in Fluid Distribution Systems in Semiconductor Manufacturing Applications." Coupons shall be cross-sectioned and inspected visually. Weld coupon criteria are the same criteria for all system welds.

11.3 Once a sample weld is found to be acceptable, all essential and supplementary essential variables shall be documented in the procedure qualification record.

11.4 Any significant deviation(s) from the on-site work sample will cause the weld(s) to be rejected. Rejected welds shall be removed and replaced.

11.5 Sample test welds shall be made periodically. These sample test welds shall be compared to the on-site work sample and checked for compliance with SEMI F81. Deviation from the on-site work sample or SEMI F81 shall be cause for rejection. If the weld inside diameter is inspectable using a sight tube or other device, sample test welds may be production welds.

Sample test welds shall be made when any of the following conditions exist:

11.5.1 Start of shift (in) or end of shift (out).

11.5.2 Change of weld parameters.

11.5.3 Change of material (heat number).

11.5.4 Change of tube size or wall thickness.

11.5.5 Change of ambient temperature ± 20°F (± 11°C).

11.5.6 Change of source of power to power supply to include addition or subtraction of extension cords.

11.5.7 Change or removal of the weld electrode.

11.5.8 Any change of equipment such as weld head, weld head extensions, or power supply.

11.5.9 Any time that a weld discrepancy is noted by the welding operator.

11.5.10 Any significant change of ID or OD purge gas (source or flow rate).

11.6 All couponing shall use the same ID purge gas and OD shielding gas as the production weld (Figure 2).

12 Procedure

12.1 Documented procedures shall exist for each weld configuration including all parameters (including purge times, orifice sizes, purge rates, and internal pressure).

12.2 Check parameters and verify that they are in accordance with the qualified welding procedure.

12.3 Perform only one weld joint at a time.

12.4 *Joint Preparation Procedure*

12.4.1 All cutting of component or tubing weld ends shall be done with a sharp-edged tool. No lubricants of any kind shall be allowed.

12.4.2 All component and tubing weld ends shall be de-burred after cutting.

12.4.3 Surfaces for welding shall be clean and shall be free from oxidation, discoloration, oil, scale, chips, or other material that is detrimental to welding.

12.4.4 Unless tubing is to be cleaned afterward, tubing shall be opened, cut, faced, and deburred in a required cleanroom environment, leaving no visible particulates inside the cut end.

12.4.5 The tube shall be faced to remove all necking/wedging caused by the tube cutters (Figure 3). For tube cutting, use a wheel cutter with lathe-type facing tool or a special designed power saw with alignment guide. Do not use lubricant. If any "nicks" are found, reface or discard the tube.

12.4.6 Unless tubing is to be cleaned afterward, all weld end preparation shall be done in such a manner as to minimize the introduction of contaminants into the system. When bending, cutting, or facing tubing a positive purge must be used to remove any particles.

12.4.7 The prepared end shall conform to ASTM A 632 (or ASTM A 269 ≥ ½ in. OD) tubing specification with regard to ovality and wall thickness.

12.4.8 The weld fit-up gap shall not exceed 0.003 in. (0.08 mm) when the entire circumference is affected (Figure 4). The maximum gap in any one area shall not exceed 0.006 in. (0.15 mm) (Figure 5). The prepared end shall be square to tube run within ¼° (angle).

12.4.9 After preparing, debur the inside diameter carefully and lightly. Do not scratch the inside diameter. Any scratched tubes shall be reprepped or scrapped.

12.4.10 Chamfering is undesirable. The maximum OD or ID chamfering shall be less than 10% of the wall thickness or 0.005 in. (0.13 mm) whichever is less (Figure 6).

12.4.11 All components shall be maintained in a clean condition until welded into the system.

12.4.12 All benders, cutters, facing tool collets, or brushes that are to be used on stainless tubing or alloy tubing shall not be used on carbon steel tubing and care shall be used on mixing alloys. All tools shall be maintained in clean condition and shall be free of grease, oil, dirt, and other foreign matter. Avoid cross-contamination from dissimilar materials.

12.4.13 Bends on the tubing shall not be made in the weld area.

12.4.14 Use only tools and handling techniques that will not mar, disturb the shape of, or in any way reduce the conformance to specifications of the materials used in this system.

12.4.15 Tube ends shall be covered while the purge is removed using a technique that will minimize the amount of infiltration or contamination. Covers shall be of non-particulating material.

12.4.16 Remove protective cover immediately prior to performing the weld.

12.5 *Tube Cleaning*

12.5.1 It is recommended that all cut tubing be cleaned. At a minimum, tubing contaminated during preparation shall be cleaned using a high purity cleaning procedure.

12.5.2 In the case of contaminated tubing, or if a cut-out or saw cut is necessary, the following cleaning procedure shall be used:

12.5.2.1 Primary rinse in cold running DI water.

12.5.2.2 Secondary rinse in hot [80°C (176°F)] DI water.

12.5.2.3 Final rinse in DI water with pressure flush.

12.5.2.4 Blow dry with pressurized hot [150°C (318°F)] N_2. Ensure that drying occurs immediately after final rinse.

12.5.2.5 Use immediately or cap and seal in plastic sleeves.

12.6 *Purging*

12.6.1 All welds must use a positive and repeatable form of ID purge pressure control. See Table 1 for suggested settings and refer to Figures 7 and 8.

12.6.2 Production welds must use the same flow rates and ID purge pressures as the qualified coupon weld.

12.6.3 During welding, all tubes, fittings, valves, sub-assemblies, and all other components shall be continuously purged.

12.6.4 Automatic orbital welding equipment shall supply a constant gas shield to the weld head during welding.

12.6.5 During all welding, a sufficient amount of purge/shield gas shall be maintained until the weld has cooled to a temperature where it can be handled, and until the weld head is removed from the newly welded parts.

12.6.6 Both purge/shield gas supply lines shall contain flow indicators to ensure proper purging.

12.6.7 For welding of installed systems that will not be subsequently cleaned, once construction begins, an ID purge shall be maintained, either a flowing purge of 3 to 5 scfh (1 to 2 L/min.) or a block purge of 30 psi (206 kPa), until the system is complete. A flowing purge is recommended on UHP systems.

12.6.8 The purge supply shall have a means to manifold it so that there is a single point of connection for each line under construction.

12.6.9 Extreme care shall be taken to ensure that all contiguous flowpaths are fully purged.

12.6.10 All dead legs must be purged out completely prior to welding.

12.6.11 All welds shall be performed with the purge flow established by the weld procedure specification sweeping the weld area during and after welding.

12.6.12 Vacuum devices may be required to overcome back pressure in components such as regulators, filters, purifiers, check valves, or others. Dead-end components such as gauges may be purged using a small-diameter tube placed inside the tubing to be welded and back-flowing purge through the weld zone.

12.6.13 Pre-purging and post-purging shall occur for as long as necessary to avoid unacceptable weld discoloration.

12.6.14 Light external oxidation may be removed with a stainless steel wire brush immediately after welding. Purge shall be maintained during the brushing process, and care shall be taken to perform the brushing process in an appropriate area so as not to contaminate the work area.

12.7 *Welding Electrode*

12.7.1 Welding electrodes shall be changed as frequently as necessary to prevent weld deterioration. Typical number of welds per electrode is as follows:

Tube diameter	Welds per electrode
¼-in. and under	25 to 50
3/8 to 1.0-in.	20 to 25
1.0 to 2.0-in.	10 to 20
2.0-in. and above	10 to 15

12.7.2 Electrode shall be cut, not broken to length.

12.8 *Additional Requirements*

12.8.1 Maintain sufficient distance between weld joints and valve seats to avoid damage to valve seats or valve stem tips when purging through the valve. Purge through the valve to the weld when possible.

12.8.2 Valves shall be located so as to allow space to operate the valve after installation at the job site.

12.8.3 Valves must be cool to the touch after welding and prior to cycling to avoid damage to the seat.

12.8.4 *Clean Room Welding*

12.8.4.1 Welders shall follow all clean room protocol and use non-powdered latex gloves any time that the tubing or component to be welded is removed from protective covering.

12.8.4.2 All tools and fixtures used for the assembly and welding shall be maintained clean and shall not be removed for use outside of the clean room preparation area.

12.8.4.3 As much welding as is feasible will be performed in the clean room preparation area in the form of sub-assemblies.

12.8.5 *Field Installation*

12.8.5.1 If a system cut-out or cut-in is required, purge shall be applied to both ends or the down stream end must be discarded or cleaned, per Section 12.5. The following cutout procedure shall be followed:

12.8.5.1.1 Set purge pressures to 5 psi max (35 kPa) for safety.

12.8.5.1.2 Make initial cut. WARNING: When the tube is cut purge gas will escape the cut area at high velocity. This gas may contain particles from the cut or the tubing. Protect yourself, others, and nearby equipment from injury or damage (Figure 8).

12.8.5.1.3 Make any additional cuts.

12.8.5.1.4 Face the ends.

12.8.5.1.5 Set single purge direction for welding.

12.8.5.1.6 All cuts shall be done in the horizontal when possible.

13 Interpretation of Results: Weld Inspection

13.1 All welds shall be 100% inspected on the outside surface and whenever possible on the ID surface to insure conformance to the weld bead specifications listed in SEMI F81.

13.2 *Dimensional and Configuration Inspection* — Dimensional and configuration inspection shall be performed as follows:

13.2.1 One hundred percent subassemblies shall be inspected. If a subassembly is opened for inspection, the inspection must be performed in a clean room of same class as the assembly area.

13.2.2 Confirm fabrication drawing is attached to the assembly; if not, reject.

13.2.3 Use check sheet to verify conformance of assembly to drawing. Check dimensions, squareness, offsets, straight edges, and levels to verify all dimensions.

13.2.4 Inspect each weld externally in reference to the coupon.

13.2.5 When subassemblies have passed inspection, they shall be tagged as such, rebagged, and released for final testing.

13.3 Any items found defective during inspection and repairable may be repaired, if the repair will not degrade the system conformance to installation specifications.

13.4 Where a weld is found defective, the preceding two welds shall be tested as indicated in Section 11. If either of these welds is rejectable per SEMI F81, then all welds made since the last welding procedure was established shall be removed and replaced.

14 Report

14.1 Coupons shall be logged with the date and time and operator identification. Coupons and coupon logs shall be retained for one year. Sample test welds shall be kept on file and may be reviewed at any time during the construction.

14.2 A daily log shall be maintained on all system welds and coupons (see Weld and Coupon Log, Table 2), and as-built drawings recording all data shall be maintained in the welding area.

14.3 All welds shall be identified with a code number and cross-referenced with the drawings for future evaluation.

15 Related Documents

AWS C5.10 — Recommended Practices for Shielding Gases for Welding and Plasma Arc Cutting

ANSI/AWS C5.5 — Recommended Practices for GTAW

Table 1 Suggested ID Purge Setting for Argon and Argon Gas Mixes

Tube Size	*Wall Thickness*	*Minimum ID Purge Rate*	*ID Purge Pressure*	*Restrictor Size*
1/16 in. n/a	0.015 in. n/a	3 scfh 1.5 l/m	13 to 16.8 torr 7 to 9 iwc 175 to 230 mmwc	n/a
1/8 in 3 mm.	0.028 in. 0.8 mm	5 scfh 2.3 l/m	9.3 to 16.8 torr 5 to 9 iwc 130 to 230 mmwc	1/16 in.
¼ in. 6 mm	0.035 in. 1 mm	7 scfh 2.5 l/m	5.2 to 6.3 torr 2.8 to 3.4 iwc 71 to 86 mmwc	1/8 in.
3/8 in. 10 mm	0.035 in. 1 mm	7 scfh 2.5 l/m	2.8 to 4.7 torr 1.5 to 2.5 iwc	1/8 in.

Tube Size	*Wall Thickness*	*Minimum ID Purge Rate*	*ID Purge Pressure*	*Restrictor Size*
			38 to 64 mmwc	
½ in. 12 mm	0.049 in. 1 mm	15 scfh 7 l/m	1.9 to 2.8 torr 1.0 to 1.5 iwc 25 to 38 mmwc	¼ in. 6mm
¾ in. 20 mm	0.065 in. 1.5 mm	20 scfh 10 l/m	1 to 2 torr 0.5 to 1.1 iwc 13 to 28 mmwc	¼ in. 6 mm
1 in. 25 mm	0.065 in. 1.5 mm	40 scfh 20 l/m	1 to 1.9 torr 0.5 to 1.0 iwc 13 to 25 mmwc	¼ in. 6 mm
1 ½ in. 38 mm	0.065 in. 1.5 mm	80 scfh 40 l/m	1 to 1.3 torr 0.5 to 0.7 iwc 13 to 18 mmwc	¼ in. 6 mm
2 in. 50 mm	0.065 in. 1.5 mm	150 scfh 70 l/m	0.7 to 1.3 torr 0.4 to 0.7 iwc 13 to 18 mmwc	3/8 in. 10 mm
3 in. 75 mm	0.065 in. 1.5 mm	320 scfh 150 l/m	0.4 to 0.9 torr 0.2 to 0.5 iwc 5 to 13 mmwc	½ in. 12 mm
4 in. 100 mm	0.083 in. 2 mm	600 scfh 275 l/m	0.4 to 0.7 torr 0.2 to 0.4 iwc 5 to 13 mmwc	¾ in. 20 mm
6 in. 150 mm	0.083 in. 2 mm	1000 scfh 475 l/m	0.2 to 0.9 torr 0.2 to 0.5 iwc 5 to 13 mmwc	¾ in. 20 mm

NOTE 1: scfh—standard cubic feet per hour. L/m—liters per minute. iwc—inches of water column. mmwc—millimeters of water column.

NOTE 2: This table is for use on butt welds only.

NOTE 3: Internal pressure shall be adjusted for ID convexity of 0 to +10% of the wall thickness at the 6 o'clock position (bottom of the weld).

NOTE 4: ID purge rates shall be adjusted to the desired ID color line.

NOTE 5: Restrictor sizes are approximate. Purge rate and pressure are critical parameters.

Table 2 Weld Log or Weld Coupon Log

Customer:									Date Begun:		
Location:									Page __ of __		
Project:									Welder:		
Number	Size	Description	ID Purge Flow/pressure		Visual	Color	Uniformity	Heat/Lot	Coupon Date	Comments	QA

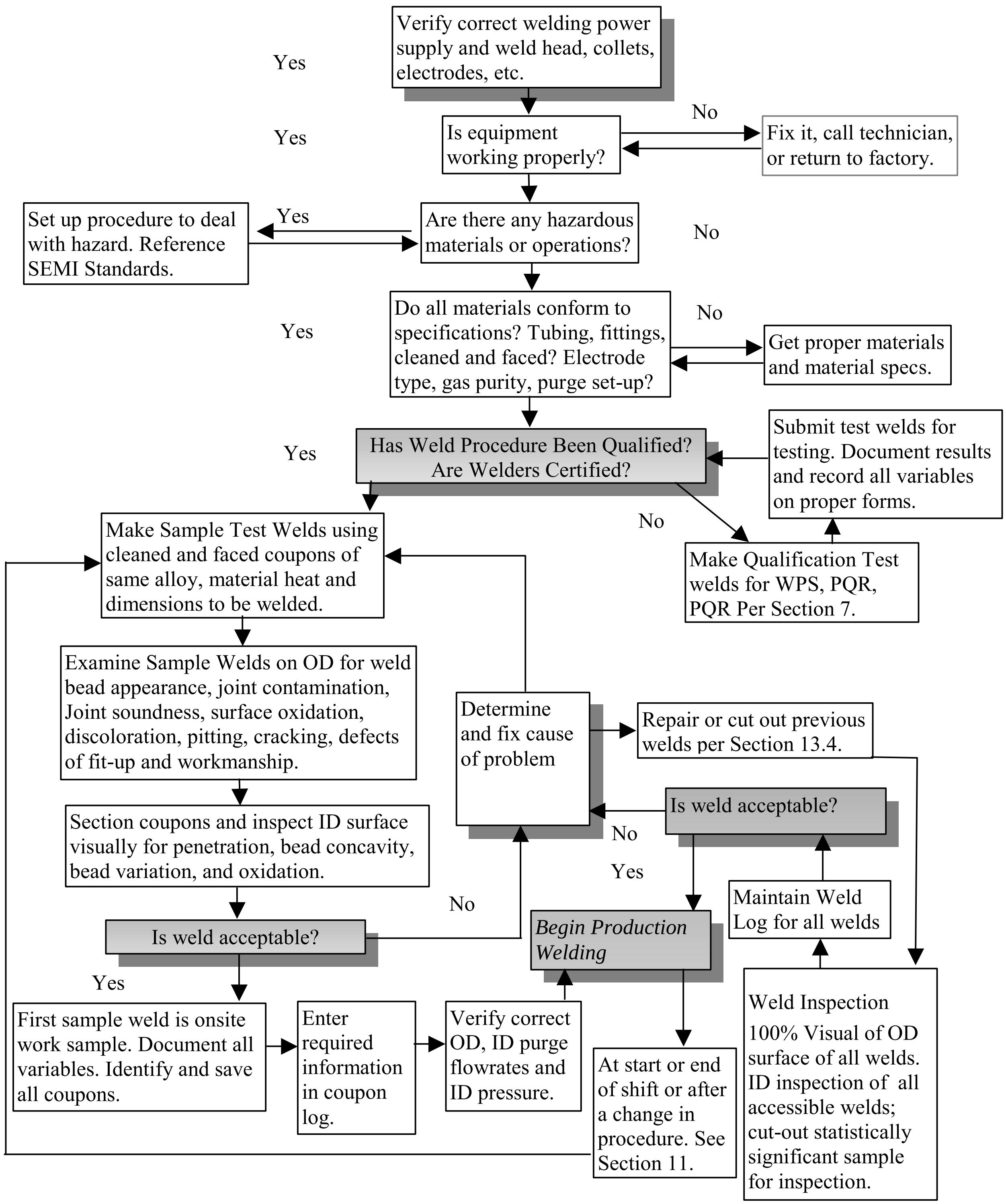
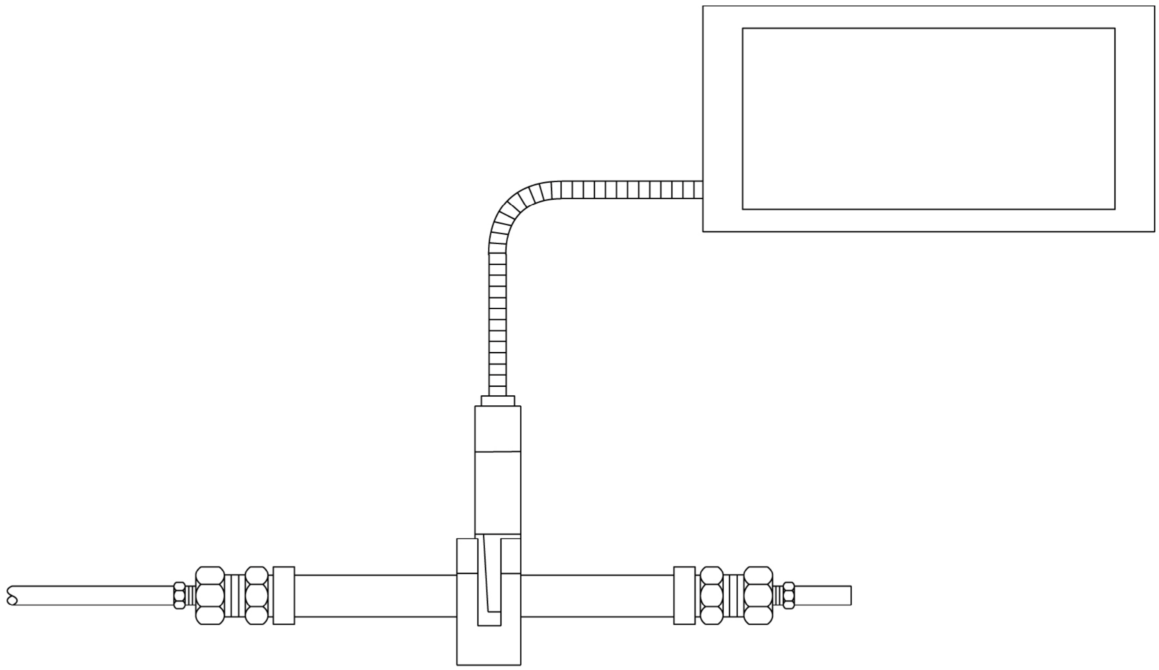
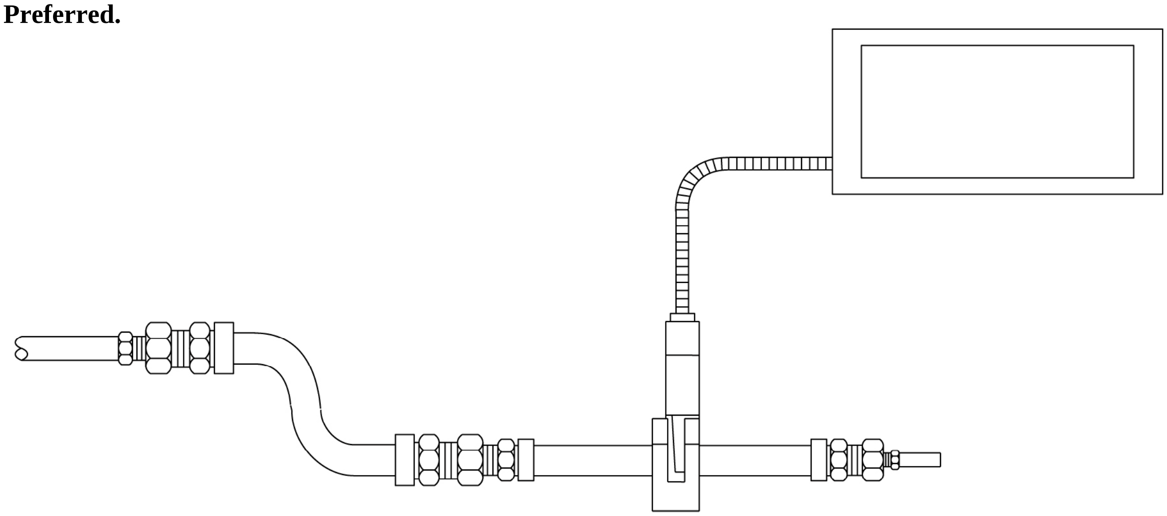


Figure 2
Welding Procedure Flow Chart



(a) Preferred.



(b) Alternate.

Figure 3
All Couponing Shall Use the System ID Purge Gas

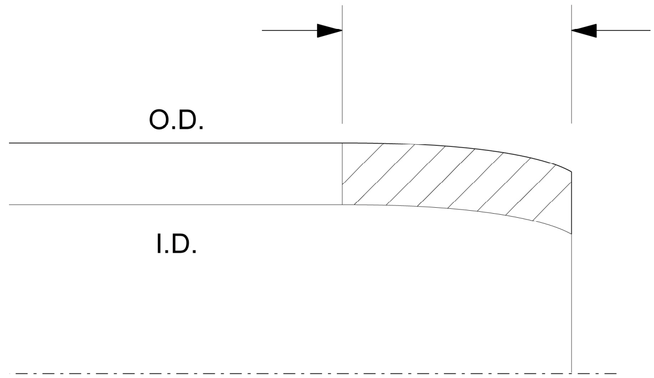


Figure 4
Tube Facing to Remove Distorted Material

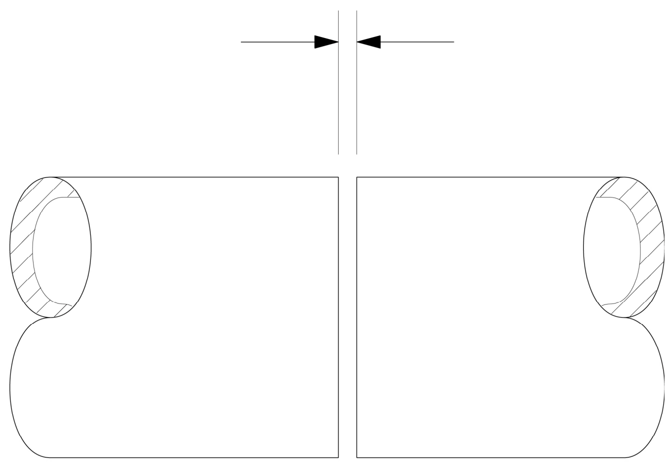


Figure 5
Weld Fit-Up Gap Not to Exceed 0.003 in. (0.08 mm)

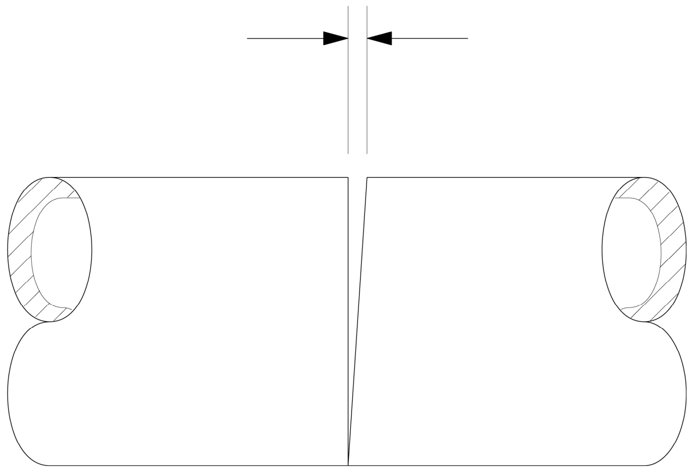


Figure 6
Maximum Open Gap Not to Exced 0.006 in. (0.15 mm)

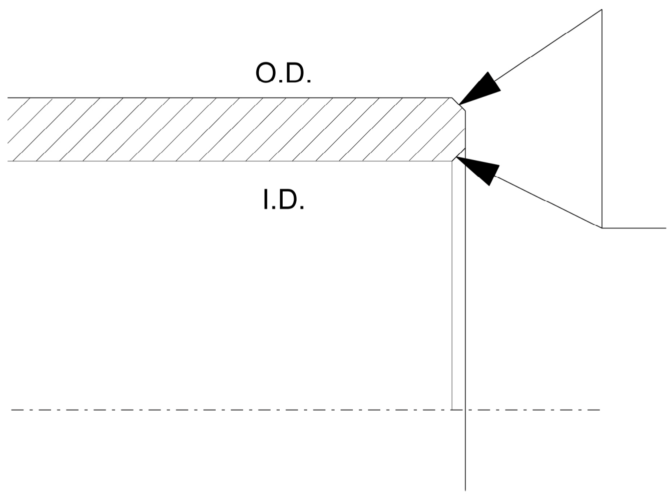


Figure 7
OD or ID Chamfering

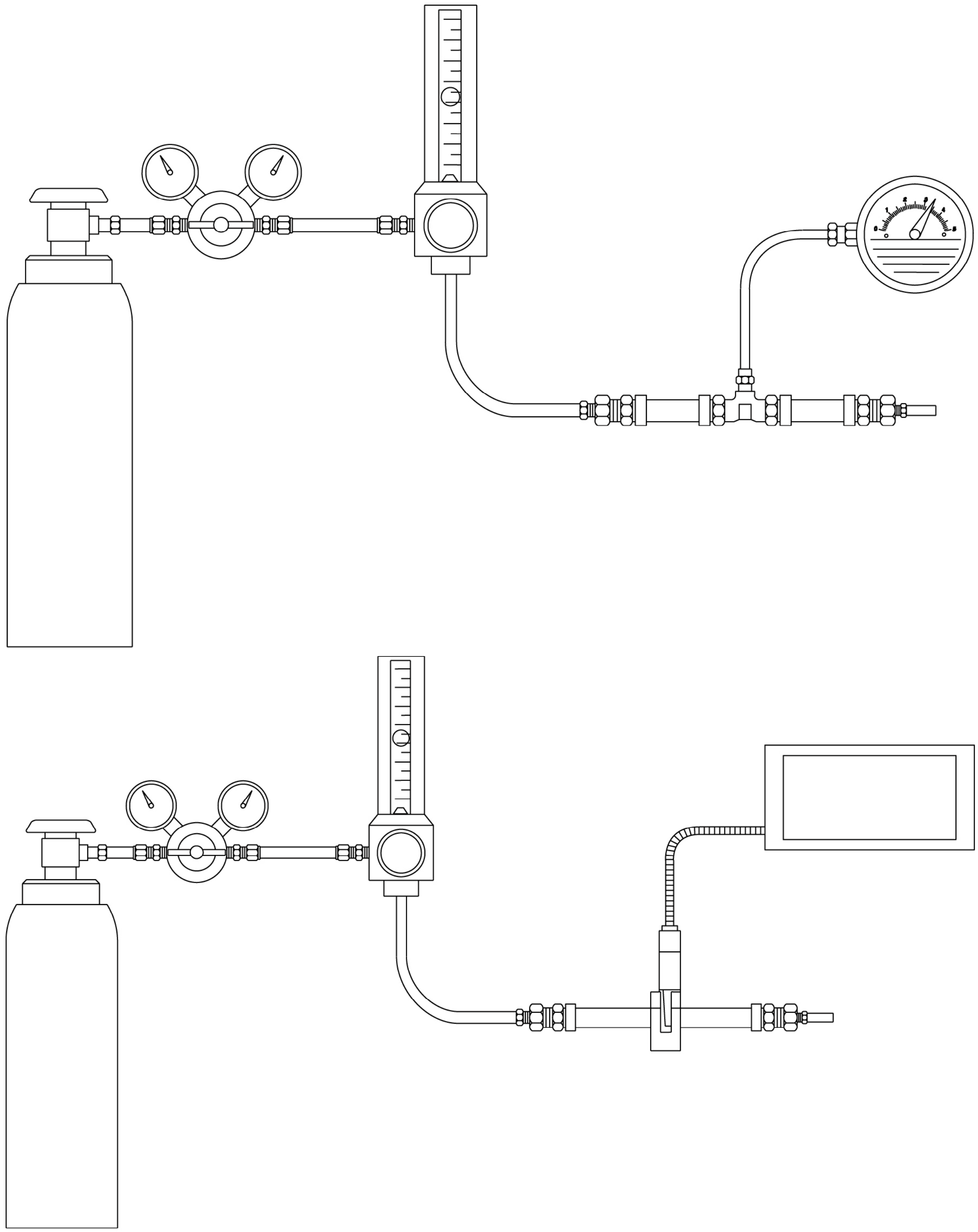


Figure 8
All Welds Must Use Positive and Repeatable Form of ID Purge

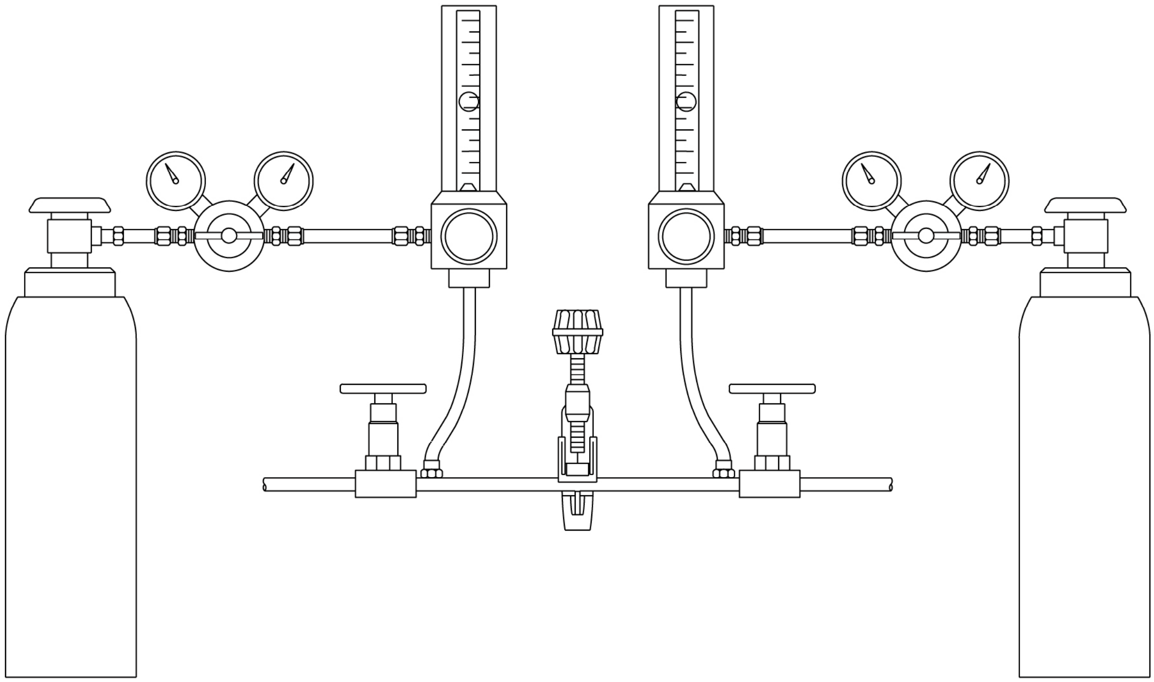


Figure 9
If a Cut-Out or Cut-In is Required, Purge Shall be Applied to Both Ends or the Downstream End Must be Discarded or Cleaned

APPENDIX 1
STAINLESS STEEL AND WELDING FUME

NOTICE: The material in this appendix is an official part of SEMI F78. It has been derived from the cited documents. Determination of the suitability of the material is solely the responsibility of the user.

A1-1 General

A1-1.1 The fume generated when welding stainless steels includes respirable particles, the composition of which—particularly with the flux-shielded welding processes—suggests a risk to cause cancers. However, epidemiological analyses have not identified any actual risk specific to stainless steels but have shown a slight excess of lung cancers among welders as a whole, i.e. both welders of non-alloyed steels and welders of stainless steels, compared with the general population. The cause of this excess has not been identified but may be connected with factors incidental to welding. Nevertheless, appropriate precautions to avoid exposure to welding fume of all kinds are advisable and indeed necessary if regulatory limits are to be observed.

A1-1.2 There is an important difference between the chemical forms of chromium in fume from the flux processes and from the gas-shielded processes. In the former group most of the chromium is present in hexavalent form (chromates), while almost all chromium in fume produced by the gas-shielded processes is in the trivalent form and hexavalent compounds are only present in very small proportions. The relevance of this difference is that, without reference to welding, hexavalent chromium compounds are classified as carcinogenic to humans (Group 1) by the IARC[5] particularly lung cancer. This fear is based on the chemical composition of the fume, especially that produced by the flux processes, and the very small size of the particles, which puts them in the respirable range, i.e., capable of penetration down to the level of the lung alveoli. Trivalent chromium compounds are unclassifiable to carcinogenicity to humans (Group 3). Nickel compounds are also classified in Group 1 by the IARC.

A1-1.3 Further information on the above topic can be found in Status Report: Stainless Steel and Welding Fume, SR-0008, March 2001, Nickel Development Institute, 214 King Street West, Suite 510, Toronto, Ontario, Canada M5H 3S6.

A1-1.4 For information about hexavalent chromium, refer to HESIS Hazard Alert, June 1992, Hazard Evaluation System & Information Service, California Occupational Health Program, 2151 Berkeley Way, Annex 11, Third Floor, Berkeley, CA 94704.

5 International Agency for Research on Cancer

SEMI F79-0703
GUIDELINE FOR GAS COMPATIBILITY WITH SILICON USED IN GAS DISTRIBUTION COMPONENTS

This guideline 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 April 11, 2003. Initially available at www.semi.org June 2003; to be published July 2003.

1 Purpose

1.1 The purpose of this guideline is to identify resource information on compatibility of gases in contact with silicon in the wetted path of a gas delivery system operating at typical gas stick conditions.

2 Scope

2.1 The information and conclusions provided are taken from published literature. References are cited. No opinion is made as to the validity of the published conclusions. The suggestions are specific to high purity silicon, single or poly crystal, covered by native oxide.

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 (Prescribed Conditions)

3.1 The guideline applies to the gas distribution system for a typical semiconductor process tool. It is assumed that silicon is in the wetted path as a coating or a silicon-based component (eg. a valve, orifice, sensor, mass flow controller) in the gas distribution system. The ambient temperature and operating temperature limits are typical for the industry. No additional energy source, thermal, radiative or ionizing, is present. The moisture content of the gas is not specified for the purpose of this guideline; the recommendations apply whether or not the conditions are anhydrous.

4 Referenced Standards

4.1 *SEMI Standard*

SEMI E52 — Practice for Referencing Gases Used in Digital Mass Flow Controllers

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

5 Classification of Gases

5.1 The gases included are taken from SEMI E52; the number assigned to a gas is the same as in that document.

5.1.1 Inerts

5.1.2 Hydrogen

5.1.3 Hydrocarbons

5.1.4 Halogenated Hydrocarbons

5.1.5 Hydrides

5.1.6 Halogens, other than Fluorine

5.1.7 Halides, other than Fluorides

5.1.8 Fluorine and Fluorides

5.1.9 Organo-metallic and Siloxanes

5.1.10 Oxygen and Oxides and Sulfides

5.1.11 Nitrogen and Nitrogen Compounds

5.1.12 Acids

5.1.13 Other

6 Review of the literature

6.1 *Inerts*

6.1.1 References (1, 2, 3, 4, 5) are cited which indicate these gases do not react with silicon under the prescribed conditions.

6.2 *Hydrogen*

6.2.1 References (1, 2, 3, 4, 5) are cited which indicate these gases do not react with silicon under the prescribed conditions. Hydrogen has been reported to react with silicon (75) and silicon carbide (76) at temperatures above 1100° C.

6.3 *Hydrocarbons*

6.3.1 References (1, 2, 3, 4, 5, 55, 56) are cited which indicate these gases do not react with silicon under the prescribed conditions.

6.4 *Halogenated Hydrocarbons*

6.4.1 References (1, 2, 3, 4, 5, 35, 51, 54, 55, 56, 57, 58, 59) are cited which indicate these gases do not react with silicon under the prescribed conditions. Extensive review papers by Flamm (55) and Coburn (56) cite numerous references on the etching of silicon and other materials using halogenated hydrocarbons. The critical requirement for etching of silicon, or any material using a halogenated hydrocarbon, is a radical specie of fluorine, chlorine or other halogen. A low pressure plasma is the typical method of creating this radical. In addition, Winters (78) points out that for an "unassisted' etching reaction to take place adsorption onto the silicon surface must be followed by four well defined steps. Should any of the steps not occur, or be interrupted, etching will not proceed.

6.4.2 Two of the most widely used halogenated hydrocarbons are CF_4 and C_4F_8 . The Matheson Gas Book (79) says this about the chemical properties of CF_4, *"...Carbon tetrafluoride is extremely stable, reacting only slightly even at the temperature of a carbon arc..."*. About C_4F_8, *"...Octafluorocyclobutane is extremely stable. It is unreactive with other materials under ordinary conditions. At high temperatures (600°C), it dissociates to form carbon and carbon tetrafluoride and some toxic compounds..."*

6.5 *Hydrides*

6.5.1 References (1, 2, 3, 4, 5, 64, 65, 66) are cited which indicate these gases do not react with silicon under the prescribed conditions.

6.6 *Halogens, other than fluorine*

6.6.1 The halogens represent a special class of materials. Molecular or atomic chlorine, iodine or bromine have been reported not to etch silicon at temperatures below 200° C orwithout the assistance of a plasma (19, 26, 50, 55, 56, 63). Schwartz (74) makes the comment. *"Although Cl_2 chemisorbs spontaneously on silicon,* (in a plasma) *at low temperatures the reaction between Si and Cl does not proceed to the formation of $SiCl_4$. That is, silicon does not etch in Cl_2 except at elevated temperature."* He goes on to note: *"...except in the case of highly doped silicon, etching occurs at low temperatures in the reactive ion etching system not because of the ease of Cl attachment but because partially reacted silicon can be sputtered readily."* Schwartz then reports the observation that there was no perceptible etching after thirty minutes in a Cl_2 plasma when there was no cathode bias on the wafer; in contrast to 4.5 microns of removal when the bias was applied.

6.6.2 Flamm (55) published in 1981 and titled "The Design of Plasma Etchants", states, *"...Chlorine containing halocarbon feed gases are frequently used instead of Cl_2 because they are not hazardous (before reaction), are noncorrosive, and they decompose in the plasma to generate radicals (in addition to chlorine atoms) which induce some desired effects."* This statement applies to a plasma based system; Flamm is pointing out the difficulty of etching silicon with just Cl_2 or Br_2 in a plasma. He points out that Wang and Maydan (from a private communication in 1979) have etched silicon in a pure Cl_2 plasma at pressures below 0.05 torr.

6.6.3 Flamm goes on to say that, *"...It seems that chlorine and bromine atoms do not spontaneously etch SiO_2 or undoped single crystal silicon but do etch some forms of polycrystalline silicon and heavily n-doped single crystal and polycrystalline silicon..."*

6.6.4 A conclusion here is that even with a plasma Cl_2 and Br_2 require very specialized conditions to etch silicon.

6.7 *Halides, Other Than Fluorides*

6.7.1 Gaseous mixtures of HCl, HBr or HI will not etch silicon at the prescribed conditions (1, 2, 3, 4, 5, 62). However, mild pitting of the silicon may be observed in HBr or HI under aqueous conditions (5). In laboratory testing (10) no reaction of the silicon was noted with 50% aqueous HBr after 45 days immersion.

6.7.2 One reason for the lack of reactivity of silicon with chlorine, bromine or iodine halides is the low vapor pressure of the reaction product. $SiCl_4$ has the lowest boiling point at 57° C; $SiBr_4$ boils at 154° C and SiI_4 at 286° C. On the other hand, the boiling point of SiF_4 is –86° C. Practical advantages of this low vapor pressure and non-reactivity were demonstrated by Texas Instruments in their patents (24, 25) on RIE etching; controlled additions of HBr, HI, BCl_3, among other gases, led to passivating films of $SiBr_4$, etc. on the silicon side walls and allowed vertical wall etching to be achieved.

6.7.3 The moisture content of the gas stream can be a critical factor in the corrosion resistance of most materials. Typical stainless steel passivity is strongly dependent upon the amount of H_2O present, declining sharply as water content increases above 1 ppm in the presence of halogens or halides (6, 9, 10, 72). Paciej (72) reported that 0.1 ppm moisture in HCl does not attack 316L stainless, while 200 ppm moisture in HCl can significantly corrode the surface of this material. Fine (9) points out similar behavior for 316L in HBr at 0.5 ppm and 100 ppm moisture over the course of 10 days.

6.7.4 However, silicon corrosion resistance is virtually unaffected by moisture content up to and including aqueous solutions. The "RCA clean" (67) and conventional wet etches (60, 68, 69) are obvious examples of this.

6.7.5 Silicon based halides, such as $SiCl_4$, SiH_2Cl_2, etc. have not been reported to react with silicon under the prescribed conditions. (55)

6.8 *Fluorine and Fluorides*

6.8.1 It is documented that fluorine (F_2) and atomic fluorine, F, will attack silicon at room temperature (19, 22, 26, 42, 49).

6.8.2 Chen (49) used fluorine gas (F_2) at room temperature on freshly cleaned silicon; he measured an etch rate of about 100A° /min at 2.3 torr and 5 sccm of F_2 flowing. He also noted a two to three hour incubation period before the etching started; the authors speculate about the causes for this incubation period.

6.8.3 Flamm (42) and Vasile (22) authored several papers detailing the mechanisms involved in atomic fluorine reacting with silicon. Flamm's data produced the following relation for the etch rate of silicon by atomic fluorine.

6.8.4 $R(Si) = 2.91*10^{-12}*n_F T^{1/2} e^{-E_{etch}/kT}$ where E_{etch} is given as 0.108 eV. At $n_F = 2.9*10^{15}$ atoms/cc , the etch rate is reported to be about 3,000 A° /min at 25° C.

6.8.5 Flamm used an RF discharge of at least 3.8 watts to produce F from F_2. Vasile used thermal dissociation of F_2 to produce F; at 800° C he measured 47% dissociation; below 650° C , negligible.

6.8.6 Flamm (55) also reports a similar relation for the etch rate of SiO_2 by atomic fluorine: $R(SiO_2) = 6.14*10^{-13}*n_F T^{1/2} e^{-E_{etch}/kT}$ where E_{etch} is given as 0.163 eV.

6.8.7 Flamm (55) states "...*Fluorine atoms react spontaneously with all forms of silicon, SiO_2 and silicon nitride to form volatile products*."

6.8.8 Ibbotson (19) examined potential etching processes which required no external energy sources. *"Silicon is rapidly etched by the gas-phase halogen fluorides ClF_3, BrF_3, BrF_5, and IF_5 , in analogy to XeF_2 etching silicon..... By contrast, ClF and Groups III and V fluorides such as NF_3, BF_3, PF_3 and PF_5 do not spontaneously etch either Si or SiO_2 under the same experimental conditions."*

6.8.9 Winters (21) and Ibbotson (20) report that XeF_2 does not etch SiO_2. Regardless, silicon, with or without additional oxide, is not recommended for use with F_2, XeF_2, ClF_3 and the other fluorine containing inter-halogens which may spontaneously decompose to atomic fluorine at temperatures below 200° C.

6.8.10 As quoted from Ibbotson's article above, excluded from this list of reactive gases are compounds such as NF_3, BF_3, PF_3 and PF_5 which have been reported not to etch Si or SiO_2 without the assistance of a plasma or RF source (19) or require temperatures above 200° C (1, 35, 37, 38).

6.8.11 The ionized fluorine atom, F^-, is reported to not react with silicon under the prescribed conditions (1, 2, 3, 4, 5, 19, 64, 65, 66). Further evidence of this is the fact that adding H_2 to fluorine containing plasmas reduces the etch rate (55). The assumed mechanism is the removal of F atoms as active species.

6.8.12 Other fluoride compounds, such as SF_6, which do not spontaneously decompose to atomic fluorine below 200° C are not a sourceof reaction (33, 34, 52, 53, 55).

6.8.13 WF_6 is a special case. Numerous articles (41 ,43, 44, 45, 46, 47) have been published on the CVD of tungsten films from WF_6. Two primary mechanisms are cited; the reduction of WF_6 by silicon and the thermal decomposition in the presence of H_2. As stated in Yarmoff's paper (43):

"The dissociative chemisorption of WF_6 on Si (111) was found to be complete, even at room temperature. The reaction is self-poisoning at room temperature, however as the fluorine liberated from WF_6 ties up the active Si sites responsible for the dissociation."

6.8.14 Tsao (41) reports that at 410° C only 200A° of W will deposit from WF_6 onto single crystal silicon which has an oxide thickness between 5 and 15 A° . C.A. van der Jeugel (46) describes the effect of doping levels on the self-limiting growth of tungsten films. It is documented (44, 45, 47) that WF_6 will not deposit on SiO_2 without the addition of hydrogen or some other initiation mechanism.

6.8.15 Using the selective deposition characteristic of WF_6 in a device, Fleming, et.al. have patented (48) a technique for producing wear resistant coatings of tungsten. Their invention requires a "clean" surface and a temperature higher than 200° C, preferably around 450° C; exposure to WF_6 then results in a self-terminating film of 5–50 nm.

6.8.15.1 Zdunek (80) reported on electrochemical based work which indicated that unprotected silicon surfaces exhibited "no degradation" after exposure to WF_6 for 5 days at 80° C. A similar result was observed for Cl_2 gas.

6.8.16 As a point of interest, metals such as stainless steel, aluminum and nickel develop corrosion resistant coatings of the respective fluoride when exposed to atomic fluorine during the proper passivation procedure (14, 23, 27, 28, 29, 30, 31, 32, 35, 39, 40).

6.8.17 Titanium, molybdenum, tungsten, brass and columbium have been reported to be unacceptable when exposed to gases such as ClF_3, which decompose to atomic fluorine (27, 32).

In summary, it is recommended that neither silicon, silicon dioxide nor silicon nitride be in the wetted path when fluorine, F_2, or the halogen fluorides, ClF_3, BrF_3, BrF_5, and IF_5, plus XeF_2 are in use.

6.9 *Organo-metallic and Siloxanes*

6.9.1 References (1, 2, 3, 4, 5, 64, 65, 66) are cited which indicate these compounds do not react with silicon under the prescribed conditions.

6.10 *Oxygen and Oxides and Sulfides*

6.10.1 References (1, 2, 3, 4, 5, 64, 65, 66) are cited which indicate these gases do not react with silicon under the prescribed conditions.

6.11 *Nitrogen and Nitrogen Compounds*

6.11.1 References (1, 2, 3, 4, 5, 64, 65, 66) are cited which indicate these gases do not react with silicon under the prescribed conditions.

6.12 *Acids*

6.12.1 Aqueous HF is the only single acid reported to etch silicon (70). Combinations of fluoride ions in solution with an oxidizing acid such as HNO_3 in an aqueous solution will etch silicon at practical rates (5, 54, 60, 64, 65, 66, 67, 68, 69).

6.12.2 Madou (70) has an excellent review of the mechanisms required for aqueous based etching; he cites Hu and Kerr (72) to report an etch rate of 0.3° A/min. for n-type, 2 ohm-cm (111) silicon in a 48% HF solution at 25° C. Madou points out the strong dependence of etch rate in aqueous solutions on doping level, light conditions and relative potential.

NOTE 1: Most bases will etch silicon and silicon dioxide; the oxide is etched very slowly.

6.13 *Other*

6.13.1 As currently designated these are materials in SEMI E52-0302 not encountered in mass flow controllers under typical conditions. The manufacturer should be consulted.

7 Cautions and Warnings

7.1 The reader is specifically requested to consult the MSDS and the manufacturer's recommended practices of any gas or liquid prior to use and to follow the suggestions prescribed.

7.1.1 All other appropriate safety procedures should be followed as well.

8 Related Documents

8.1 K. Williams and R. Muller. "Etch Rates for Micromachining Processing." IEEE J. Microelectromech. Syst., Vol. 5, No. 4, pp. 256-269, Dec. 1996.

8.2 H. Jansen, et al. "A Survey on the Reactive Ion Etching of Silicon in Microtechnology." J. Micromech. Microeng. Vol. 6, pp. 14–28, 1996.

8.3 G. Eriksen and K. Dyrbye. "Protective Coatings in Harsh Environments." J. Micromech. Microeng. Vol.6, pp. 55–57, 1996.

8.4 H. B. Pogge, ed. "Electronic Materials Chemistry." Marcel Dekker, NY, 1996.

8.5 P. Walker and W. Tarn, ed. "CRC Handbook of Metal Etchants." CRC Press, Boca Raton, FL, 1991.

8.6 E. Flaherty, et al. "Reducing the Effects of Moisture in Semiconductor Gas Systems." Solid State Technology, pg. 69, July 1987.

8.7 S. M. Fine, et al. "Optimizing the UHP Gas Distribution System for a Plasma Etch Tool." Solid State Technology, pg. 69, March 1996.

8.8 M. George, et al. "Minimizing System Contamination Potential from Gas Handling." Semiconductor International.

8.9 S. M. Fine, et al. "The Role of Moisture in the Corrosion of HBr Gas Distribution Systems." Jl.E.C.S., 142; No. 4; 1269, April 1995.

8.10 P. M. Bhadha, et al. "Joule-Thomson Expansion and Corrosion in HCl Systems." Solid State Technology, pg. S3, July 1992.

8.11 T. Ohmi. "Corrosion-free Cr_2O_3 Passivated Gas Tubing System for Specialty Gases." Solid State Technology, pg. S18, October 1995.

8.12 G. Bitko, et al. "Analytical Techniques for Examining Reliability and Failure Mechanisms of Barrier Coating Encapsulated Silicon Pressure Sensors Exposed to Harsh Media." Proc. SPIE, 2882; 248–258, 1996.

8.13 O. Hallberg, et al. "Recent Humidity Accelerations, A Base for Testing Standards." Proc. Quality and Reliability International Conf., 7, 169–180, 1991.

8.14 M. A. George, et al. "Compatibility of 316L Stainless Steels and Tungsten Hexafluoride." presented at: Tungsten and Other Refractory Metals for ULSI Applications, Dallas, TX, October 1990.

8.15 S. Lau, et al. "Performance of Diaphragm Valves in Chlorine." Solid State Technology, pg. S21, June 1997.

8.16 P. B. Henderson, et al. “Cylinder Package Effects on the Purity of Electronic Specialty Gases.” Solid State Technology, pg. S5, June 1997.

8.17 H. Kobayashi. “How Gas Panels Affect Contamination.” Semiconductor International, 81, Sept. 1994.

8.18 A. K. Henning, et al. “Contamination Reduction Using MEMS-Based, High-Precision Mass Flow Controllers.” Presented at SEMICON West, SEMI, 1998.

8.19 D. E. Ibbotson, et al. “Plasmaless Dry Etching of Silicon with Fluorine-Containing Compounds,” J. Appl. Phys. Vol. 56 (10), pp. 2939–42, 1984.

8.20 D. E. Ibbotson, et al. “Appl. Phys. Lett.” Vol. 44 (12), pp. 1129, 15 June 1984.

8.21 H. F. Winters, et al. “The Etching of Silicon with XeF_2 Vapor.” J. Appl. Phys. Lett., Vol. 34 (1), pp. 70, 1 January 1979.

8.22 M. J. Vasile, et al. “Reaction of Atomic Fluorine with Silicon: The Gas Phase Products.” J. Appl. Phys., 53 (5), 3799, 1982.

8.23 *ES and H Manual: Volume 2, Part 14: Chemical, 14.6, The Safe Handling of Fluorine*. Environment, Safety, and Health. UCRL-MA-133867, April 1, 2001 <http://www.llnl.gov/es_and_h/hsm/doc_14.06/doc14-06.html>.

8.24 M. A. Douglas. “Trench Etch Process for a single-wafer RIE Dry Etch Reactor.” U.S. Patent 4784720; Nov. 15, 1988.

8.25 M. A. Douglas. “Trench Etch Process for a single-wafer RIE Dry Etch Reactor.” U.S. Patent 4855017, Aug. 8, 1989.

8.26 W. C. Tian, et al. “Comparison of Cl_2 and F-Based Dry Etching for High Aspect Ratio Si Microstructures Etched With an Inductively Coupled Plasma Source.” J. Vac. Sci. Technol. B 18(4), Jul/Aug 2000; 1890.

8.27 J. C. Grigger, et al.. “Effect of Chlorine Trifluoride and Perchloryl Fluoride on Construction Materials.” Materials Protection, pp. 53, September 1964.

8.28 Air Products and Chemicals, Inc. “Recommended Passivation Procedure for Reactive Fluorides.” Pub. # 320-9460, August 1994.

8.29 T. Mebrahtu, et.al. “SEM and XPS Characterization of the Carbon Steel Surface Passivation Film in Anhydrous HF Media.” Corrosion 95, The NACE Int’l Annual Conference.

8.30 R. L. Farrar, Jr. “Safe Handling of Chlorine Trifluoride and the Chemistry of the Chlorine Oxides and Oxyfluorides.” Union Carbide Nuclear Company, Oak Ridge, TN, Nov. 11, 1960; K1416.

8.31 A. Zdunek, et.al. “Chlorine Trifluoride(ClF_3) Passivation of Stainless Steel Tubing.” Air Liquide, internal memo.

8.32 A. P. Taylor, et al. “Interaction of ClF_3 with Metal Alloys and Polymer Gaskets.” Semiconductor International, 201, July 1999.

8.33 R. Duguid, et.al. “Compatibility Study of a Waferpure Reactive Micro Matrix Material with SF_6.” Application Note, Millipore Corp. 3/25/99; <http://millispider.millipore.com/micro/miegas/MA019.htm>.

8.34 Compressed Gas Association, Inc. “Handbook of Compressed Gases.” Van Nostrand Reinhold, New York, 1990.

8.35 C. J. Gugliemini, et al. “Properties and Reactivity of Chlorine Trifluoride.” Semiconductor International, June 1999.

8.36 Air Products and Chemicals, Inc. “Chlorine Trifluoride Technical Data, Safety and Handling.” Pub.# 320-9711.

8.37 Air Products and Chemicals, Inc. “Nitrogen Trifluoride Reactivity, Environmental and Toxicological Data.” 1993.

8.38 Air Products and Chemicals, Inc. “Nitrogen Trifluoride Material Safety Data Sheet.” Pub.# 320-801 Rev 1/96.

8.39 M. Maeno, et al. “Fluorine-Passivated Electroless Ni-P Films.” Jl.E.C.S., 141, No. 10, Oct. 1994, 2649.

8.40 A. L. Cabrera, et al. “Surface Analysis of Copper, Brass and Steel Foils Exposed to Fluorine Containing Atmospheres.” Jl.Vac. Sci.Tech., A 8 (6); Nov./Dec.. 1990, 3988.

8.41 K.Y. Tsao, et al. “Low Pressure Chemical Vapor Deposition of Tungsten on Polycrystalline and Single-Crystal Silicon Via the Silicon Reduction.” Jl.E.C.S, 131 (11), Nov. 1984, 2702.

8.42 D. L. Flamm, et al. “The Reaction of Fluorine Atoms With Silicon.” Jl.Appl.Phys., 52(5), May 1981, 3633.

8.43 J. A. Yarmoff, et al. “Mechanism for Chemical-Vapor Deposition of Tungsten on Silicon From Tungsten Hexafluoride.” Jl.Appl.Phys., 63(11), June 1988, 5213.

8.44 J. R. Creighton. “A Mechanism for Selectivity Loss During Tungsten CVD.” Jl.E.C.S., 136 (1), Jan. 1989; 271.

8.45 A. Kepten, et al. “Studies of the Possible Reaction of WF_6 with SiO_2 and Si_3N_4 at Several Temperatures.” Jl.E.C.S., 139 (8), Aug. 1992, 2331.

8.46 C. A. van der Jeugd, et al. “The Effect of Doping Atoms on the Kinetics of Self-Limiting Tungsten Film Growth on Silicon by Reduction of Tungsten Hexafluoride.” Jl.E.C.S., 142 (4), April 1995, 1326.

8.47 Ph. Lami, et.al. “Evaluation of the Selective Tungsten Deposition Process for VLSI Circuit Applications.” Jl.E.C.S., 135 (4), April 1988, 980.

8.48 J. G. Fleming, et.al. “Tungsten Coating for Improved Wear Resistance and Reliability of Microelectromechanical Devices.” U.S. Patent 6290859, Sept. 18, 2001.

8.49 M. Chen, et al. “Etching Silicon with Fluorine Gas.” Jl.E.C.S., 126 (11), Nov. 1979, 1946.

8.50 Z. H. Walker, et al. “Kinetics of the Reaction of Molecular Bromine with Doped Polycrystalline Silicon.” Jl.E.C.S., 138 (10), Oct. 1991, 3050.

8.51 L. M. Ephrath, et al. “Parameter and Reactor Dependence of Selective Oxide RIE in CF_4 + H_2.” Jl.E.C.S., 129 (10), Oct. 1982, 2282.

8.52 K. M. Eisele. “SF_6, a Preferable Etchant for Plasma Etching Silicon.” Jl.E.C.S., 128 (1), Jan. 1981, 123.

8.53 T. Syau, et al. “Reactive Ion Etching of Silicon Trenches Using SF6/O2 Gas Mixtures.” Jl.E.C.S., 138 (10), Oct. 1991, 3076.

8.54 S. Wolf, et al. Silicon Processing for The VLSI Era. Lattice Press, 1986; ISBN 0-961672-3-7.

8.55 D. L. Flamm, et al. “The Design of Plasma Etchants.” Plasma Chemistry and Plasma Processing, 1 (4), 1981, 317.

8.56 J. W. Coburn. “Plasma-Assisted Etching.” Plasma Chemistry and Plasma Processing, 2 (1), 1982; 1.

8.57 R. d' Agostino, et al. “Diagnostics and Decomposition Mechanism in RF Discharges of Fluorocarbons Utilized for Plasma Etching or Polymerization.” Plasma Chemistry and Plasma Processing, 2 (3), 1981, 213.

8.58 E. I. du Pont de Nemours and Company, Zyron Electronic Gases, Application Guide, Dry Etching of Silicon Dioxide <www.dupont.com/zyron/appguide/app2.html>.

8.59 U. Schilling, et al. “Evaluation of c-C4F8 as Cleaning Gas in an Applied Materials Lamp Heated Universal Chamber for 200 mm Wafers.” International SEMATECH, technology Transfer #01084152A-TR, Sept. 14, 2001.

8.60 H. Robbins, et. al. “Chemical Etching of Silicon II, the System HF, HNO_3, H_2O, and $HC_2H_3O_2$.” Jl.E.C.S., 107, 1960, 108.

8.61 R. Pinto, et al. “Reactive Ion Etching in SF_6 Gas Mixtures.” Jl.E.C.S., 134 (1), Jan. 1987, 165.

8.62 C. Dominguez,et. al. “Low Pressure Chemical Etching of Silicon by HCl/H_2 Gas Mixtures.” Jl.E.C.S., 134 (1), Jan. 1987, 199.

8.63 J. Y. Choe, et al. “Analysis of the Etching of Silicon in an Inductively Coupled Chlorine Plasma Using Laser Thermal Desorption.” J.Vac.Sci.Tech., A15(6), Nov/Dec 1997, 3024.

8.64 F. A. Cotton, et al., Advanced Inorganic Chemistry. Fifth Edition. NY: John Wiley and Sons, 1988.

8.65 B. Douglas, et al. Concepts and Models of Inorganic Chemistry. 2nd Edition. NY: John Wiley and Sons, 1983.

8.66 J. E. Huheey, et al. Inorganic Chemistry: Principles of Structure and Reactivity. 4th Edition. NY: HarperCollins, 1993.

8.67 W. Kern, et al. “Cleaning Solutions Based on Hydrogen Peroxide for Use in Semiconductor Processing,” RCA Review, June 1970, 187.

8.68 W. Kern, et al. “Chemical Etching.” Thin Film Processes, Ed. J.L.Vossen. NY: Academic Press, 1978. 401–481.

8.69 S. K. Ghandhi. “VLSI Fabrication Principles.” NY, NY: John Wiley and Sons, 1994. ISBN 0-471-58005-5.

8.70 Marc Madou. “Fundamentals of Microfabrication.” Florida: CRC Press, 1997. ISBN 0-8493-9451-1.

8.71 S. M. Hu, et. al. “Observation of Etching of n-type Silicon in Aqueous HF Solutions.” Jl.E.C.S., 114, 1967, 414.

8.72 R. Paciej. “How to Foil the Curse of Corrosive Gases.” Chemical Engineering, May 1991, 158.

8.73 G. T. A. Kovacs, et.al. “Bulk Micromachining of Silicon.” Proc. IEEE, Vol.86 (8), Aug. 1998, 1536.

8.74 G. C. Schwartz, et al. “Reactive Ion Eetching of Silicon.” J.Vac.Sci.Tech., 16(2), Mar./Apr. 1979, 410.

8.75 G. A. Lange, et al. RCA Review. 24, 1963, 488.

8.76 J.M. Harris, et. al. “Etching Characteristics of Silicon Carbide in Hydrogen.” Jl.E.C.S., 116 (3), Mar. 1969, 380.

8.77 X. Wang, et al. “Gas-Phase Silicon Etching with Bromine Trifluoride.” Proc.Transducers ’97, 1997 Int.Conf. Solid-State Sensors and Actuators, Vol.2, Chicago, June 1997, 1505.

8.78 H. F. Winters, et al. “The Role of Chemisorption in Plasma Etching.” J. Appl. Phys., Vol. 49 (10), 5165, (1978).

8.79 W. Braker, et al. Matheson Gas Data Book, Sixth Edition, L of C 80-83159, (1980).

8.80 A. Zdunek, et al. “Corrosive Gas Exposure and Evaluation of Silicon for MEMS Applications.” Stainless Steel and Surface Analysis Workshop, SEMI, July 2002.

APPENDIX 1
GASES BY CATEGORY

NOTICE: The material in this appendix is an official part of SEMI F79 and was approved by full letter ballot procedures on April 11, 2003.

SEMI Gas #	*Chemical Name*	*Category*	*Symbol*	*Formula*	*Synonym*
	6.1 Inert				
4	Argon	1	Ar	Ar	
1	Helium	1	He	He	
5	Krypton	1	Kr	Kr	
2	Neon	1	Ne	Ne	
3	Radon	1	Rn	Rn	
6	Xenon	1	Xe	Xe	
	6.2 Hydrogen	2			
14	Deuterium	2	D2	H_2^2	D2
7	Hydrogen	2	H2	H_2	
159	Tritium	2	T2	H_2^3	T2
	6.3 Hydrocarbons	3			
345	1,3,5,7-Octatetraene	3	C8H10	$CH_2=CHCH=CHCH=CHCH=CH_2$	
343	1,7-Octadiyne	3	C8H10	$HC\equiv C(CH_2)_4C\equiv CH$	
344	2,6-Octadiyne	3	C8H10	$CH_3C\equiv CCH_2CH_2C\equiv CCH_3$	
342	3-one-2,5-dimethyl hexadiene	3	C8H10	$CH_2=C(CH_3)C\equiv CC(CH_3)CH_2$	
178	4-Methyl, 1-Pentene	3	C6H12	$(CH_3)_2CHCH_2CH=CH_2$	
331	Acetaldehyde Methoxy	3	C3H6O2	CH_3OCH_2CHO	
184	Acetone	3	C3H6O	CH_3COCH_3	
332	Acetone, Hydroxy	3	C3H6O2	$CH_3COCH2OH$	Acetol
42	Acetylene	3	C2H2	$HC\equiv CH$	Ethyne
66	Allene	3	C3H4	$CH_2=C=CH_2$	Propadiene
197	Benzene	3	C6H6	C_6H_6	
100	Butadiene	3	C4H6	$CH_2=C=CHCH_3$	Methylallene
117	Butane	3	C4H10	$CH_3(CH_2)_2CH_3$	
271	Butanol-1	3	C4H10O	$CH_3CH_2CH_2CH_2OH$	
336	Butanol-2	3	C4H10O	$CH_3CH_2CH(OH)CH_3$	
104	Butene	3	C4H8	$CH_3CH_2CH=CH_2$	1-Butene
107	Cisbutene	3	C4H8	$CH_3CH=CHCH_3$	Cis-2-Butene
207	Cyclobutane	3	C4H8	C_4H_8	Tetramethylene

SEMI Gas #	*Chemical Name*	*Category*	*Symbol*	*Formula*	*Synonym*
61	Cyclopropane	3	C3H6	C_3H_6	
208	Diazomethane	3	CH2N2	CH_2N_2	Acomethylene
338	Diethyl Ether	3	C4H10O	$C_2H_5OC_2H_5$	
73	Dimethyl Ether	3	C2H6O	CH_3OCH_3	Methylether
122	Dimethylpropane	3	C5H12	$(CH_3)_4C$	Neopentane
54	Ethane	3	C2H6	CH_3CH_3	
136	Ethanol	3	C2H6O	CH_3CH_2OH	
93	Ethyl Acetylene	3	C4H6	$CH_3CH_2C{\equiv}CH$	
291	Ethyl Formate	3	C3H6O2	$HCO_2C_2H_5$	Ethyl ester formic acid
174	Ethylbenzene	3	C8H10	$C_6H_5C_2H_5$	
38	Ethylene	3	C2H4	$CH_2{=}CH_2$	Ethene
45	Ethylene Oxide	3	C2H4O	C_2H_4O	Acetaldehyde
169	Ethyleneglycol	3	C2H6O2	$HOCH_2CH_2OH$	Ethanediol, Glycol
322	Formaldehyde	3	CH2O	CH_2O	H2CO; UN1198; BFV
335	Glycidol	3	C3H6O2	CH_2CHCH_2OH	1-Propanol, 2,3 epoxy
333	Glycol Methylene Ether	3	C3H6O2	$C_3H_6O_2$	1,3-Dioxolane
127	Hexane	3	C6H14	$CH_3(CH_2)_4CH_3$	
170	Hexanediol-1,6	3	C6H14O2	$HO(CH_2)_6OH$	Hexyleneglycol
111	Isobutane	3	C4H10	$(CH_3)_2CHCH_3$	2-Methylpropane
106	Isobutene	3	C4H8	$(CH_3)_2C{=}CH_2$	Isobutylene, Methylpropene
341	Isobutyl Alcohol	3	C4H10O	$(CH_3)_2CHCH_2OH$	
231	Isopentane	3	C5H12	$CH_3CH_2CH(CH_3)_2$	2-Methylbutane
187	Isopropal Alcohol	3	C3H8O	$(CH_3)_2CHOH$	2-Propanol
28	Methane	3	CH4	CH_4	
176	Methanol	3	CH4O	CH_3OH	Methyl Alcohol
292	Methyl Acetate	3	C3H6O2	$CH_3CO_2CH_3$	Methyl ester acetic acid; UN 1231
68	Methyl Acetylene	3	C3H4	$CH_3C{\equiv}CH$	Propyne
340	Methyl Isopropyl Ether	3	C4H10O	$(CH_3)_2CHOCH_3$	
305	Methyl methacrylate polymer	3	C5H8O2	$C_5H_8O_2$	Poly(methyl methacrylate)
339	Methyl Propyl Ether	3	C4H10O	$CH_3OC_3H_7$	
81	Methyl Vinyl Ether	3	C3H6O	$CH_3OCH{=}CH_2$	
120	Methylbutene	3	C5H10	$CH_3CH_2CCH_3{=}CH_2$	2-Methyl-1-Butene
177	Methylcyclohexane	3	C7H14	$CH_3C_6H_{11}$	Hexahydrotoluene
237	Octane	3	C8H18	$CH_3(CH_2)_6CH_3$	
179	o-Xylene	3	C8H10	$1,2\text{-}(CH_3)_2C_6H_4$	1,2-Dimethylbenzene
240	Pentane	3	C5H12	$CH_3(CH_2)_3CH_3$	
180	Phenol	3	C6H6O	C_6H_5OH	
89	Propane	3	C3H8	$CH_3CH_2CH_3$	

SEMI Gas #	Chemical Name	Category	Symbol	Formula	Synonym
69	Propylene	3	C3H6	$CH_3CH{=}CH_2$	Propene
319	Styrene	3	C8H8	C_8H_8	Ethenylbenzene; Un 2055
337	Tertiary Butyl Alcohol	3	C4H10O	$(CH_3)_3COH$	
182	Tetrahydrofuran	3	C4H8O	C_4H_8O	
181	Toluene	3	C7H8	$C_6H_5CH_3$	Methylbenzene
98	Transbutene	3	C4H8	$CH_3CH{=}CHCH_3$	
264	Xylene p-	3	C8H10	1,4-$(CH_3)_2C_6H_4$	1,4 Dimethyl Benzene
263	Xylene m-	3	C8H10	1,3-$(CH_3)_2C_6H_4$	1,3 Dimethyl Benzene
	6.4 Halogenated Hydrocarbons	4			
186	2,2 Dichloro 1,1,1 Trifluoroethane	4	C2HCl2F3	$CHCl_2$-CF_3	Freon 123, Suva 123
199	Bromochlorodifluoromethane	4	CBrClF2	$BrClCF_2$	
105	Bromotrifluoroethylene	4	C2BrF3	CF_2CFBr	
80	Bromotrifluoromethane	4	CBrF3	$BrCF_3$	F-13B1, R-13B1
200	Carbon Tetrabromide	4	CBr4	CBr_4	
101	Carbon Tetrachloride	4	CCl4	CCl_4	Tetrachloromethane
63	Carbon Tetrafluoride	4	CF4	CF_4	Tetrafluoromethane
46	Carbonyl Fluoride	4	CF2O	CF_2O	
172	Chlorobenzene	4	C6H5Cl	C_6H_5Cl	Chlorobenzol, Phenylchloride
203	Chlorodifluoroethane	4	C2H3ClF2	CH_3-CF_2Cl	R-142b
204	Chlorodifluoroethylene (FREON-1122)	4	C2HClF2	$CF_2{=}CHCl$	R-1122, FREON-1122
57	Chlorodifluoromethane	4	CHClF2	$CClHF_2$	F-22, R-22
71	Chloroform	4	CHCl3	$CHCl_3$	Trichloromethane
119	Chloropentafluoroethane	4	C2ClF5	$ClCF_2CF_3$	F-115, R-115
206	Chlorotrifluoroethylene (FREON-1113)	4	C2ClF3	$FCCl{=}CF_2$	R-1113, FREON-1113
74	Chlorotrifluoromethane	4	CClF3	$ClCF_3$	F-13, R-13
209	Dibromodifluoromethane	4	CBr2F2	Br_2CF_2	R-12B2, FREON-12B2
130	Dibromotetrafluorethane	4	C2Br2F4	BrF_2CCF_2Br	F-114B2, R-114B2
84	Dichlorodifluoromethane	4	CCl2F2	CCl_2F_2	F-12, R-12
210	Dichloroethylene	4	C2H2Cl2	$CH_2{=}CCl_2$	Vinylidene Chloride
211	Dichloroethylene -cis	4	C2H2Cl2	$CHCl{=}CHCl$	
191	Dichloroethylene -trans	4	C2H2Cl2	$CHCl{=}CHCl$	
65	Dichlorofluoromethane	4	CHCl2F	$CHCl_2F$	F-21, R-21
265	Dichloromethane	4	CH2Cl2	CH_2Cl_2	
125	Dichlorotetrafluoroethane	4	C2Cl2F4	F_3CCCl_2F	F-114, R-114
103	Difluorochloroethane	4	C2H3ClF2	CF_2ClCH_3	F-142B, R-142B
82	Difluoroethane	4	C2H4F2	CH_3CHF_2	Ethylidene Fluoride, R-152A
64	Difluoroethylene	4	C2H2F2	$CH_2{=}CF_2$	G-1132A,Vinylidenefluoride

SEMI Gas #	*Chemical Name*	*Category*	*Symbol*	*Formula*	*Synonym*
160	Difluoromethane	4	CH2F2	CH_2F_2	Methylene Fluoride
75	Ethyl Chloride	4	C2H5Cl	C_2H_5Cl	Chloroethane or Ethane, Chloro
221	Ethyl Fluoride (FREON 161)	4	C2H5F	CH_3CH_2F	Fluoroethane, R-161, FREON-161
222	Ethylene Dichloride	4	C2H4Cl2	$ClCH_2CH_2Cl$	1,2 Dichloroethane
223	Fluoroacetylene	4	C2HF	$FC\equiv CH$	
49	Fluoroform	4	CHF3	CHF_3	Trifluoromethane,F-23, R-23
137	Halothane	4	C2HBrClF3	$BrClHCCF_3$	
295	Heptafluoropropane	4	C3HF7	C_3HF_7	Freon 227
272	Hexafluoro Acetylacetone	4	C5H2F6O2	$C_5H_2F_6O_2$	
297	Hexafluoro butadiene-1,3	4	C4F6	CF_2=CF-CF=CF_2	Perfluorobutadiene-1,3;
267	Hexafluoro Propane	4	C3H2F6	$CH_2FCF_2CF_3$	1,1,1,2,2,3-Hexafluoropropane
270	Hexafluoro-2-Butyne	4	C4F6	$CF_3C\equiv CCF_3$	Bis(trifluoromethyl)acetylene
225	Hexafluoroacetone	4	C3F6O	$(CF_3)_2CO$	
192	Hexafluorobenzene	4	C6F6	C_6F_6	
296	Hexafluorocyclobutene	4	C4F6	C_4F_6	Perfluorocyclobutene
118	Hexafluoroethane	4	C2F6	F_3CCF_3	F-116, Perfluoroethane
138	Hexafluoropropylene	4	C3F6	$CF_3CF=CF_2$	Perfluoropropylene
286	Hexafluoropropylene oxide	4	C3F6O	C_3F_6O	Hexafluoroepoxypropane
323	Iodomethane	4	CH3I	CH_3I	Methyl iodide; Un 2644
44	Methyl Bromide	4	CH3Br	CH_3Br	Bromomethane
36	Methyl Chloride	4	CH3Cl	CH_3Cl	Chloromethane
33	Methyl Fluoride	4	CH3F	CH_3F	Fluoromethane
268	Methylene Bromide	4	CH2Br2	CH_2Br_2	UN 2664; Methyl dibromide
236	Octafluorobutane	4	C4F8	C_4F_8	
129	Octafluorocyclobutane	4	C4F8	$(CF_2)_4$	Perfluorocyclobutane
266	Octafluorocyclopentene	4	C5F8	$CF_2=C(CF_3)$-CF=CF_2	
155	Pentafluoroethane	4	C2HF5	CF_3CHF_2	F-125, R-125
288	Pentafluoropropanol	4	C3H3F5O	$C_2F_5CH_2OH$	Perfluorodihydropropanol
241	Perfluorobutane	4	C4F10	C_4F_{10}	
128	Perfluoropropane	4	C3F8	$CF_2(CF_3)_2$	
168	Tetrachloroethylene	4	C2Cl4	$Cl_2C=CCl_2$	Perchloroethylene
94	Tetrafluorethylene	4	C2F4	$F_2C=CF_2$	
156	Tetrafluoroethane	4	C2H2F4	CH_2FCF_3	R-134A, F-134A
83	Tribromomethane	4	CHBr3	$CHBr_3$	
112	Trichloroethane	4	C2H3Cl3	CH_3CCl_3	TCA, Methylchloroform
91	Trichlorofluoromethane	4	CCl3F	CCl_3F	F-11, R-11
126	Trichlorotrifluoroethane	4	C2Cl3F3	CF_2ClCCl_2F	F-113, R-113

SEMI Gas #	*Chemical Name*	*Category*	*Symbol*	*Formula*	*Synonym*
321	Trifluoromethylhypofluorite	4	CF4O	CF_4O	CF3OF; Hypofluorous acid
290	Trifluoropropane	4	C3H5F3	$C_3H_5F_3$	1,1,1-Trifluoropropane
56	Vinyl Bromide	4	C2H3Br	CH_2=CHBr	
55	Vinyl Chloride	4	C2H3Cl	CH_2=CHCl	Chloroethylene
51	Vinyl Fluoride	4	C2H3F	H_2C=CHF	
	6.5 Hydrides	5			
35	Arsine	5	AsH3	AsH_3	
244	Deuteriumsilane	5	SiD4	SiH_4^2	
58	Diborane	5	B2H6	B_2H_6	
217	Digermane	5	Ge2H6	Ge_2H_6	
97	Disilane	5	Si2H6	Si_2H_6	
43	Germane	5	GeH4	GeH_4	
24	Hydrogen Cyanide	5	HCN	HCN	
23	Hydrogen Selenide	5	H2Se	H_2Se	
22	Hydrogen Sulfide	5	H2S	H_2S	
229	Hydrogen Telluride	5	H2Te	H_2Te	
185	Methylsilane	5	CH6Si	CH_3SiH_3	Monomethylsilane
142	Pentaborane	5	B5H9	B_5H_9	
239	Pentaborane(11)	5	B5H11	B_5H_{11}	
31	Phosphine	5	PH3	PH_3	
39	Silane	5	SiH4	SiH_4	
245	Stibine	5	SbH3	SbH_3	
253	Tetrasilane	5	Si4H10	Si_4H_{10}	
328	Trisilane	5	Si3H8	Si_3H_8	Silicopropane; Trisilicane; H_8Si3
	6.6 Halogens, other than Fluorine	6			
21	Bromine	6	Br2	Br_2	
19	Chlorine	6	Cl2	Cl_2	
	6.7 Halides, other than Fluorides	7			
193	Arsenic Tribromide	7	AsBr3	$AsBr_3$	
216	Arsenic Trichloride	7	AsCl3	$AsCl_3$	
196	Arsenic Triiodine	7	AsI3	AsI_3	
79	Boron Tribromide	7	BBr3	BBr_3	
70	Boron Trichloride	7	BCl3	BCl_3	
201	Chlorine Dioxide	7	ClO2	ClO_2	
205	Chlorosilane	7	SiH3Cl	SiH_3Cl	
67	Dichlorosilane	7	SiH2Cl2	SiH_2Cl_2	
113	Germanium Tetrachloride	7	GeCl4	$GeCl_4$	Tetrachlorogermane

SEMI Gas #	*Chemical Name*	*Category*	*Symbol*	*Formula*	*Synonym*
10	Hydrogen Bromide	7	HBr	HBr	
11	Hydrogen Chloride	7	HCl	HCl	
17	Hydrogen Iodide	7	HI	HI	
183	Methyltrichlorosilane	7	CH3Cl3Si	CH_3SiCl_3	MTS
238	Oxygen Dichloride	7	OCl2	OCl_2	
60	Phosgene	7	CCl2O	CCl_2O	Carbonyl Chloride
102	Phosphorus Oxychloride	7	POCl3	$POCl_3$	
193	Phosphorus Trichloride	7	PCL3	PCl_3	
278	Silicon Tetrabromide	7	Br4Si	Br_4Si	SiBr4; Tetrabromosilane
108	Silicon Tetrachloride	7	SiCl4	$SiCl_4$	Tetrachlorosilane
189	Sulfur Monochloride	7	S2Cl2	S_2Cl_2	
248	Tetrachlorodiborane	7	B2Cl4	B_2Cl_4	
145	Tin Tetrachloride	7	SnCl4	$SnCl_4$	Tetrachlorostannane
114	Titanium Tetrachloride	7	TiCl4	$TiCl_4$	
254	Titanium Tetraiodide	7	TiI4	TiI_4	
255	Tribromostibine	7	SbBr3	$SbBr_3$	
147	Trichlorosilane	7	SiHCl3	$SiHCl_3$	
256	Trichlorostibine	7	SbCl3	$SbCl_3$	
	6.8 Fluorine and Fluorides	8			
226	Aluminum Trifluoride	8	AlF3	AlF_3	
96	Arsenic Pentafluoride	8	AsF5	AsF_5	
195	Arsenic Trifluoride	8	AsF3	AsF_3	
48	Boron Trifluoride	8	BF3	BF_3	
116	Bromine Pentafluoride	8	BrF5	BrF_5	
76	Bromine Trifluoride	8	BrF3	BrF_3	
202	Chlorine Pentafluoride	8	ClF5	ClF_5	
77	Chlorine Trifluoride	8	ClF3	ClF_3	
232	Difluoroamidogen	8	NF2	NF_2	
134	Difluorosilane	8	SiH2F2	SiH_2F_2	
326	Disilane Hexafluoride	8	SiF6	SiF_6	F_6Si_2; Hexafluorodisilane
18	Fluorine	8	F2	F_2	
327	Fluoro Silane	8	SiH3F	SiH_3F	H_3FSi
99	Germanium Tetrafluoride	8	GeF4	GeF_4	Tetrafluorogermane
12	Hydrogen Fluoride	8	HF	HF	
115	Iodine Pentafluoride	8	IF5	IF_5	
124	Molybdenum Hexafluoride	8	MoF6	MoF_6	
53	Nitrogen Trifluoride	8	NF3	NF_3	
41	Oxygen Difluoride	8	OF2	OF_2	

SEMI Gas #	*Chemical Name*	*Category*	*Symbol*	*Formula*	*Synonym*
72	Perchloryl Fluoride	8	ClO3F	ClO_3F	
143	Phosphorus Pentafluoride	8	PF5	PF_5	
62	Phosphorus Trifluoride	8	PF3	PF_3	
243	Rhenium Hexafloride	8	ReF6	ReF_6	
325	Selenium Hexafluoride	8	SeF6	SeF_6	UN 2194; Selenium fluoride
88	Silicon Tetrafluoride	8	SiF4	SiF_4	
110	Sulfur Hexafluoride	8	SF6	SF_6	
86	Sulfur Tetrafluoride	8	SF4	SF_4	
87	Sulfuryl Fluoride	8	SO2F2	SO_2F_2	
247	Tellurium Hexafluoride	8	TeF6	TeF_6	
249	Tetrafluorodiborane	8	B2F4	B_2F_4	
157	Tetrafluorohydrazine	8	N2F4	F_2NNF_2	Dinitrogen Tetrafluoride
261	Trifluorosilane	8	SiHF3	$SiHF_3$	
121	Tungsten Hexafluoride	8	WF6	WF_6	
123	Uranium Hexafluoride	8	UF6	UF_6	
324	Xenon difluoride	8	XeF2	XeF_2	F_2Xe; Xenon fluoride
	6.9 Organo-metallic and Siloxanes	9			
212	Dichlorodimethylsilane	9	C2H6SiCl2	$(CH_3)_2SiCl_2$	
188	Diethoxy Dimethyl Silane	9	C6H16O2Si	$(C_2H_5O)_2Si(CH_3)_2$	
154	Diethylsilane	9	C4H12Si	$(C_2H_5)_2SiH_2$	
214	Diethylzinc	9	C4H10Zn	$Zn(C_2H_5)_2$	
300	Dimethoxydimethyl silane	9	C4H12O2Si	$(CH_3O)_2Si(CH_3)_2$	KBM 22
284	Dimethyl Selenide	9	C2H6Se	C_2H_6Se	(CH3)2Se; Selenium dimethyl
164	Dimethylaluminum-hydride	9	C2H7Al	$(CH_3)_2AlH$	DMAH
218	Dimethylcadmium	9	C2H6Cd	$(CH_3)_2Cd$	
219	Dimethylsilane	9	C2H8Si	$(CH_3)_2SiH_2$	
220	Dimethyltellurium	9	C2H6Te	$(CH_3)_2Te$	
135	Dimethylzinc	9	C2H6Zn	$(CH_3)_2Zn$	
285	Ethoxy Silane	9	C2H8OSi	C_2H_8OSi	
224	Fluorotriethoxysilane	9	C6H15OSiF	$(C_2H_5O)_3SiF$	
139	Hexamethyldisilane	9	C6H18Si2	$(CH_3)_3Si_2(CH_3)_3$	HMDSi, HMDS
227	Hexamethyldisilazane	9	C6H19Si2N	$(CH_3)_6Si_2NH$	
228	Hexamethyldisiloxane	9	C6H18Si2O	$(CH_3)_6Si_2O$	
279	Tantalum (V) Ethoxide	9	C10H25O5Ta	$C_{10}H_{25}O_5Ta$	Ta(Oet)5
274	TEAsat	9	C6H15O4As	$(C_2H_5O)_3AsO$	
161	Tertiarybutylarsine	9	C4H11As	$C(CH_3)_3AsH_2$	TBA
162	Tertiarybutylphosphine	9	C4H11P	$C(CH_3)_3PH_2$	TBP
144	Tetraethoxysilane	9	C8H20O4Si	$(C_2H_5O)_4Si$	TEOS

SEMI Gas #	***Chemical Name***	***Category***	***Symbol***	***Formula***	***Synonym***
316	Tetraethyl lead	9	C8H20Pb	$(C_2H_5)_4Pb$	Plumbane, tetraethyl; UN1649
317	Tetraethyl silane	9	C8H20Si	$C_8H_{20}Si$	Tetraethylsilane
315	Tetraethylgermane	9	C8H20Ge	$(C_2H_5)_4Ge$	(C2H5)4Ge; Germanium tetraethyl
282	Tetrakis (diethylamino) titanium	9	C16H40N4Ti	$C_{16}H_{40}N_4Ti$	
318	Tetrakis (dimethylamino) titanium	9	C8H24N4Ti	$C_8H_{24}N_4Ti$	
301	Tetramethoxy Silane	9	C4H12O4Si	$(CH_3O)_4Si$	Silicic Acid (H4SiO4)
299	Tetramethoxygermanium	9	C4H12GeO4	$(CH_3O)_4Ge$	Ge(OMe)4
302	Tetramethyl Lead	9	C4H12Pb	$(CH_3)_4Pb$	(CH3)4Pb; Plumbane, tetramethyl;
252	Tetramethyl Tin	9	C4H12Sn	$(CH_3)_4Sn$	
158	Tetramethylcyclotetra-siloxane	9	C4H16Si4O4	$(CH_3)_4H_4(SiO)_4$	TMCTS
250	Tetramethylgermanium	9	C4H12Ge	$(CH_3)_4Ge$	
251	Tetramethylsilane	9	C4H12Si	$(CH_3)_4Si$	
194	Titanium Tetraisopropoxide	9	C12H28O4Ti	$Ti(OC_3H_7)_4$	
146	Tributylaluminum	9	C12H27Al	$(CH_3CH_2CH_2CH_2)_3Al$	TBAl
307	Triethoxy Arsine	9	C6H15AsO3	$(C_2H_5O)_3As$	Triethyl ester arsenous acid
312	Triethoxy Silane	9	C6H16O3Si	$(C_2H_5O)_3SiH$	
308	Triethoxyborane	9	C6H15BO3	$(C_2H_5O)_3B$	Boron triethoxide;
311	Triethoxyphosphine	9	C6H15O3P	$(C_2H_5O)_3P$	Triethyl phosphite; UN2323
306	Triethyl Arsine	9	C6H15As	$(C_2H_5)_3As$	Arsine; Triethylarsenic
313	Triethyl Silane	9	C6H16Si	$(C_2H_5)_3SiH$	(C2H5)3SiH;
257	Triethylaluminum	9	C6H15Al	$(C_2H_5)_3Al$	
258	Triethylantimony	9	C6H15Sb	$(C_2H_5)_3Sb$	
163	Triethylborate	9	C6H15O3B	$B(OC_2H_5)_3$	TEB, Triethoxyborane
148	Triethylgallium	9	C6H15Ga	$(C_2H_5)_3Ga$	TEGa
309	Triethylindium	9	C6H15In	$(C_2H_5)_3In$	Indium triethyl
262	Triisobutylaluminum	9	C12H27Al	$(C_4H_9)_3Al$	
287	Trimethoxy Silane	9	C3H10O3Si	$C_3H_{10}O_3Si$	
131	Trimethoxyborine	9	C3H9BO3	$B(OCH_3)_3$	TMB, Trimethylborate
190	Trimethyl Silane	9	C3H10Si	$(CH_3)_3SiH$	
149	Trimethylaluminum	9	C3H9Al	$Al(CH_3)_3$	TMA, TMAl
150	Trimethylantimony	9	C3H9Sb	$(CH_3)_3Sb$	Trimethylstibene
151	Trimethylarsenic	9	C3H9As	$(CH_3)_3As$	Trimethylarsine, TMAs
277	Trimethylborane	9	C3H9B	$(CH_3)_3B$	
152	Trimethylgallium	9	C3H9Ga	$Ga(CH_3)_3$	TMGa
153	Trimethylindium	9	C3H9In	$(CH_3)_3In$	TMIn
133	Trimethylphosphite	9	C3H9PO3	$(CH_3O)_3P$	TMPi, Trimethoxyphosphine

SEMI Gas #	Chemical Name	Category	Symbol	Formula	Synonym
132	Trimethylphosphorus	9	C3H9P	$(CH_3)_3P$	Trimethylphosphine, TMP
303	Trimethylvinylsilane	9	C5H12Si	$C_5H_{12}Si$	Vinyltrimethylsilane
	6.10 Oxygen and Oxides and Sulfides	10			
8	Air	10	Air		
25	Carbon Dioxide	10	CO2	CO_2	
40	Carbon Disulfide	10	CS2	CS_2	
9	Carbon Monoxide	10	CO	CO	
34	Carbonyl Sulfide	10	COS	COS	
298	Diethyl Sulfide	10	C4H10S	$C_4H_{10}S$	UN2375; Ethyl sulfide;
230	Iron Carbonyl	10	C5O5Fe	$Fe(CO)_5$	
47	Methyl Mercaptan	10	CH4S	CH_3SH	
140	Nickel Carbonyl	10	C4O4Ni	$Ni(CO)_4$	
15	Oxygen	10	O2	O_2	
30	Ozone	10	O3	O_3	
32	Sulfur Dioxide	10	SO2	SO_2	
246	Sulfur Trioxide	10	SO3	SO_3	
273	Tungsten Hexacarbonyl	10	C6O6W	$W(CO)_6$	
20	Water Vapor	10	H2O	H_2O	
	6.11 Nitrogen and Nitrogen Compounds	11			
173	Acetonitrile	11	C2H3N	CH_3CN	
276	Acrylonitrile	11	C3H3N	$CH_2=CHCN$	Acrylon; Propenenitrile
29	Ammonia	11	NH3	NH_3	
198	Borazine	11	B3N3H6	$H_3B_3N_3H_3$	
59	Cyanogen	11	C2N2	NCCN	Oxalodinitrile
37	Cyanogen Chloride	11	ClCN	ClCN	
213	Diethylamine	11	C4H11N	$(C_2H_5)_2NH$	
85	Dimethylamine	11	C2H7N	$(CH_3)_2NH$	
166	Dimethylethylaminealane	11	C4H14NAl	$(CH_3)_2C_2H_5NAlH_3$	DMEAA
281	Diphenylmethan-4,4' -diisocyanat	11	C15H10N2O	$C_{15}H_{10}N_2O$	UN2489
280	Diphenylmethylenediamine	11	C13H14N2	$C_{13}H_{14}N_2$	
275	Hafnium Tetranitrate	11	HfN4O12	$Hf(NO_3)_4$	
50	Hydrazine	11	N2H4	H_2NNH_2	
269	Hydrazoic Acid	11	HN3	HN_3	
52	Methylamine	11	CH5N	CH_3NH_2	Amino Methane
233	Monoethylamine	11	C2H7N	$C_2H_5NH_2$	
234	Monomethyl Hydrazine	11	CH6N2	$CH_3N_2H_3$	
16	Nitric Oxide	11	NO	NO	

SEMI Gas #	Chemical Name	Category	Symbol	Formula	Synonym
13	Nitrogen	11	N2	N_2	
26	Nitrogen Dioxide	11	NO2	NO_2	
95	Nitrogen Tetroxide	11	N2O4	N_2O_4	Dinitrogenoxide
78	Nitrogen Trioxide	11	N2O3	N_2O_3	
235	Nitromethane	11	CH3NO2	CH_3NO_2	
141	Nitrosyl Chloride	11	NOCl	NOCl	
27	Nitrous Oxide	11	N2O	N_2O	
293	Propenamine	11	C3H7N	C_3H_7N	Allylamine; UN2334
304	Pyridine	11	C5H5N	C_5H_5N	Azabenzene; Azine
320	Triallylamine	11	C9H15N	$C_9H_{15}N$	
310	Triethylamine	11	C6H15N	$(C_2H_5)_3N$	UN 1296; Ethanamine;
260	Trifluoroacetonitrile	11	C2F3N	F_3CCN	
109	Trimethylamine	11	C3H9N	$(CH_3)_3N$	Methylamine
165	Trimethylaminealane	11	C3H12AlN	$(CH_3)_3NAlH_3$	TMAA
314	Trimethylisoxazole	11	C6H9NO	CH_3CH=CHCH=C $HCONH_2$	3,4,5-Trimethylisoxazole
	6.12 Acids	12			
283	Acetic acid	12	C2H4O2	CH_3COOH	Ethanoic acid; UN 2789;
289	Acrylic acid	12	C3H4O2	$C_3H_4O_2$	2-Propenoic acid
167	Nitric Acid	12	HNO3	HNO_3	
334	Propanoic acid	12	C3H6O2	$CH_3CH_2CO_2H$	Propionic acid
171	Sulfuric Acid	12	H2SO4	H_2SO_4	
259	Trifluoroacetic Acid	12	CF3CO2H	CF_3CO_2H	
294	Trimethyl Ester Phosphoric acid	12	C3H9O4P	$C_3H_9O_4P$	Methyl phosphate
	6.13 Other	13			
329	Mercury	13	Hg	Hg	UN2809
330	Zinc	13	Zn	Zn	UN 1383

NOTICE: SEMI makes no warranties or representations as to the suitability of the guidelines 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 F80-1103
TEST METHOD FOR DETERMINATION OF GAS CHANGE/PURGE EFFICIENCY OF GAS DELIVERY SYSTEM

This test method was technically approved by the Global Facilities Committee and is the direct responsibility of the Japanese Facilities Committee. Current edition approved by the Japanese Regional Standards Committee on August 8, 2003. Initially available at www.semi.org October 2003; to be published November 2003.

1 Purpose

1.1 This document is a guide to a test method to determine gas change/purge efficiency of gas delivery system.

2 Scope

2.1 It covers both conventional metal face sealing and surface mount gas delivery systems.

2.2 The test method applies to all type of high purity gas delivery systems used in semiconductor manufacturing facilities and comparable research and development areas.

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 All components must meet quality requirements as established and controlled by manufacturers prior to testing (e.g., dimensional, functional, etc.).

3.2 Care should be exercised in handling of components to maintain manufacturer's specifications.

4 Referenced Standards

None.

5 Terminology

5.1 *Abbreviations and Acronyms* (See Figure 1.)

5.1.1 *APIMS* — Atmospheric Pressure Ionization Mass Spectrometer

5.2 *Definitions*

5.2.1 *purge efficiency* — the ratio of process gas concentration before and after the purge event.

5.2.2 *required concentration* — a concentration that a user of the gas delivery system required.

6 Condition

6.1 Test shall be performed at 22° C ± 4° C.

6.2 Test gas shall be used for measuring equipment and shall not be adsorptive gas. Two gases shall be used as the test gases. They are indicated as Gas A and Gas B in this test method.

6.3 APIMS or measuring equipment that has a low detectable limit and has a good response capability of gas densitometer.

NOTE 1: APIMS is widely used for this type of measurement.

NOTE 2: Qmass is not considered as a recommended option as the following reasons; (1) Special sampling valve needs to be installed on the testing equipment. (2) Detectable limit of Qmass is high.

NOTE 3: An oximeter is not considered as a recommended option because it does not have enough capability of response.

6.4 Flow rate of each gas for this test shall be determined by a mass flow controller of the System Under Test and a capability of the measuring equipment.

7 Procedure

7.1 *Case (1)* — This is the test method in consideration of purge line in the gas delivery system.

7.1.1 A recommended test flow schematic is shown in Figure 2.

7.1.2 The test is to evaluate a purge efficiency of gas delivery systems by using its process line and purge line.

7.1.3 Set each component for the following condition before starting the test. APV1, APV2, APV3, APV4, and APV5 are closed condition. Rest of the components in the System Under Test are open condition. Supply Gas A to the upstream of APV1. Supply Gas B to the upstream of APV2. (See Figure 2.)

7.1.4 Open APV5 and flow Gas A from Bypass line. (1) Close PV3, open APV3, and vacuum the System Under Test. (2) (See Figure 3.)

7.1.5 Open APV2 and flow Gas B from the Purge line. When flowing, close APV3 and fill the line with Gas B up to PV2. Then, close PV2. Gas B also fills the line downstream of PV2. Open APV3, vacuum inside of the line, and vent Gas B. Then, close APV3. (3) (See Figure 4.)

7.1.6 (a) Open APV1 and flow Gas A from the Process line. (b) Close PV1, open APV3 and vacuum the process line. Then, Close APV3, open and close PV1, and open APV3. (c) Repeat this operation (b) 3 times and close APV3 to sufficiently fill process line with Gas A. (4) (See Figure 5.)

7.1.7 Close APV5. Then open APV4 and flow Gas A to the System Under Test. Measure the concentration of Gas A by measuring equipment. (See Figure 6.)

7.1.8 Close PV1, open PV2 and flow Gas B to the System Under Test. The measuring equipment continuously monitors the Gas A concentration. Record the time to achieve required concentration for Gas A from the start of flowing Gas B. (See Figure 7.)

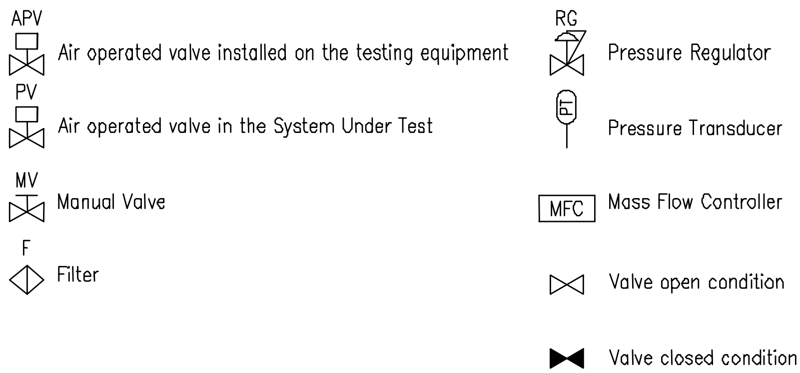


Figure 1
Abbreviations and Symbols

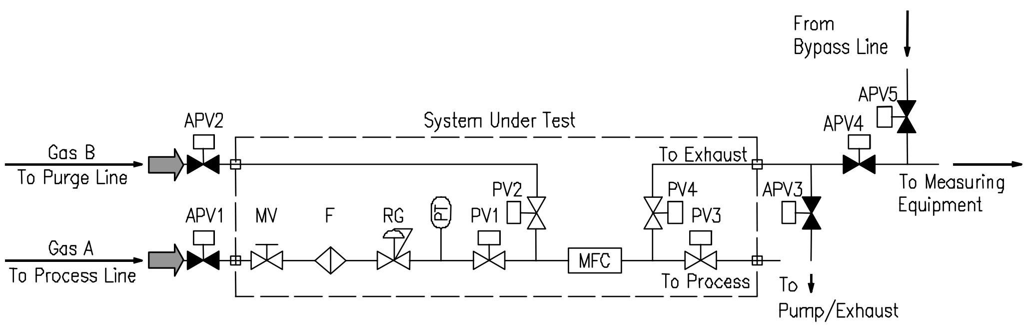


Figure 2
Gas Change/Purge Efficiency Test Schematic Case 1

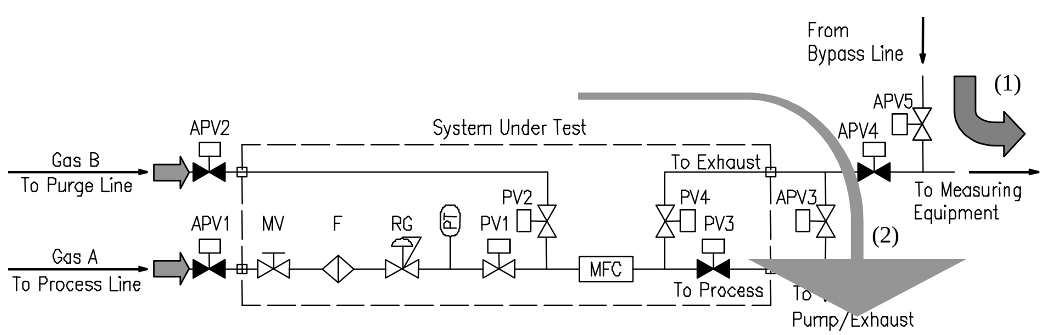


Figure 3
Procedure 7.1.4

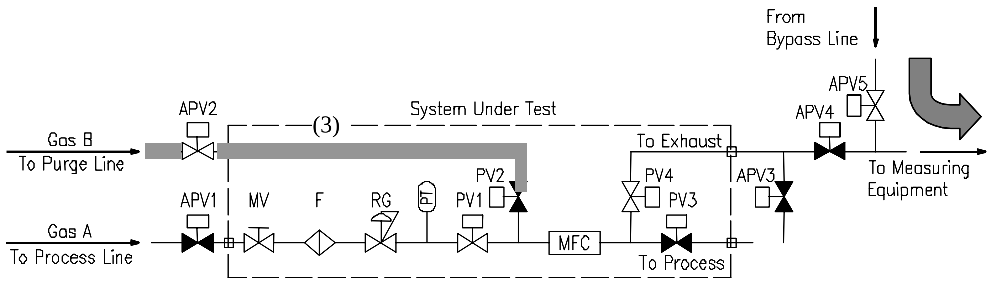


Figure 4
Procedure 7.1.5

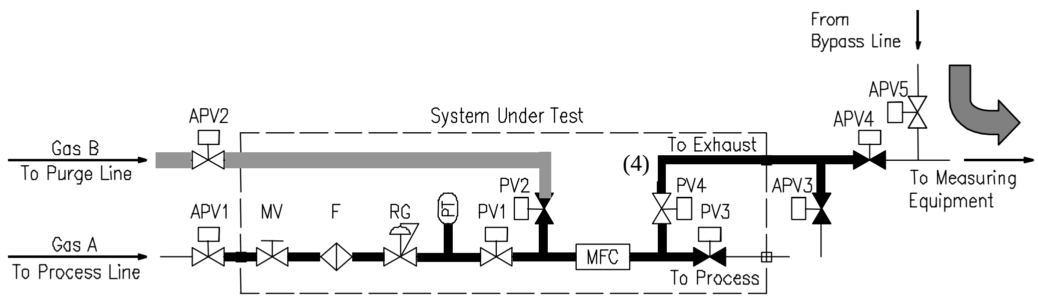


Figure 5
Procedure 7.1.6

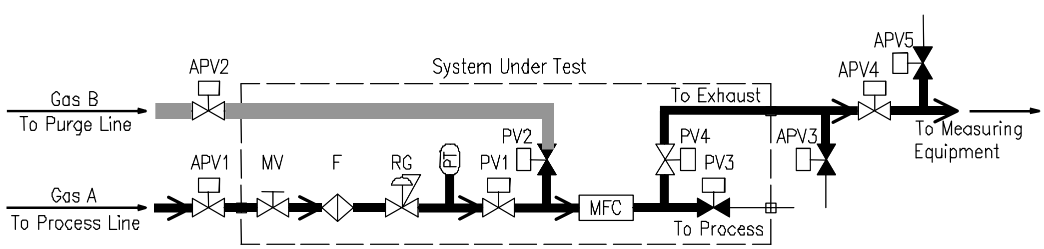


Figure 6
Procedure 7.1.7

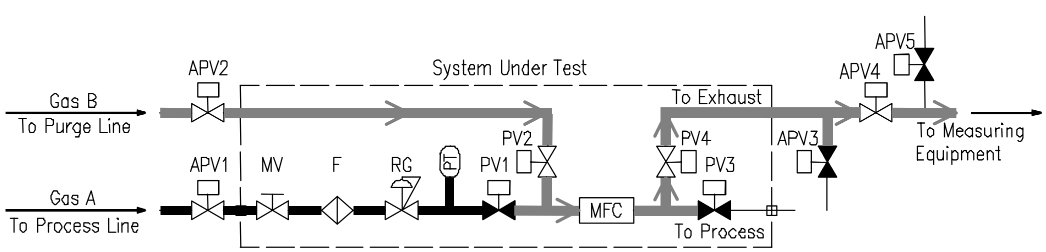


Figure 7
Procedure 7.1.8

7.2 *Case (2)* — This is the test method in consideration of gas change in the gas delivery system.

7.2.1 A recommended test flow schematic is shown in Figure 8.

7.2.2 The test is to evaluate a gas change performance in the gas delivery systems by using process line.

7.2.3 Set each component for the following condition before starting the test. APV1, APV2, APV3, APV4, and APV5 are closed condition. Rest of the components in the System Under Test are open condition. Supply Gas A to the upstream of APV1. Supply Gas B to the upstream of APV2. (See Figure 8.)

7.2.4 Open APV5 and flow Gas A from Bypass line. (1) Close PV2 and PV4, open APV3, and vacuum the System Under Test. (2) (See Figure 9.)

7.2.5 (a) Close APV3, open APV1, and flow Gas A to process line. (b) Close APV1, open APV3, and vacuum process line. Then, close APV3, open and close APV1, and open APV3. (c) Repeat this operation (b) 3 times and close APV3 to sufficiently fill process line with Gas A. (3) (See Figure 10.)

7.2.6 Open APV1and close APV5. Then open APV4 and flow Gas A to the System Under Test. Measure the concentration of Gas A by measuring equipment. (See Figure 11.)

7.2.7 Close APV1, open APV2, and flow Gas B to the System Under Test. The measuring equipment continuously monitors the Gas A concentration. Record the time to achieve required concentration for Gas A from the start of flowing Gas B. (See Figure 12.)

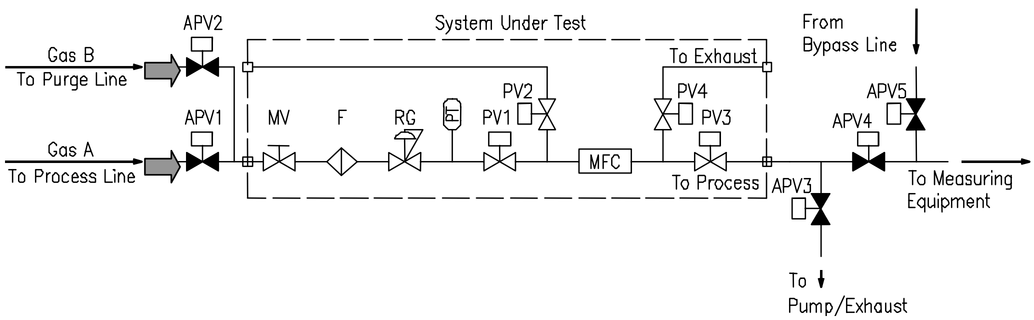


Figure 8
Gas Change/Purge Efficiency Test Schematic Case 2

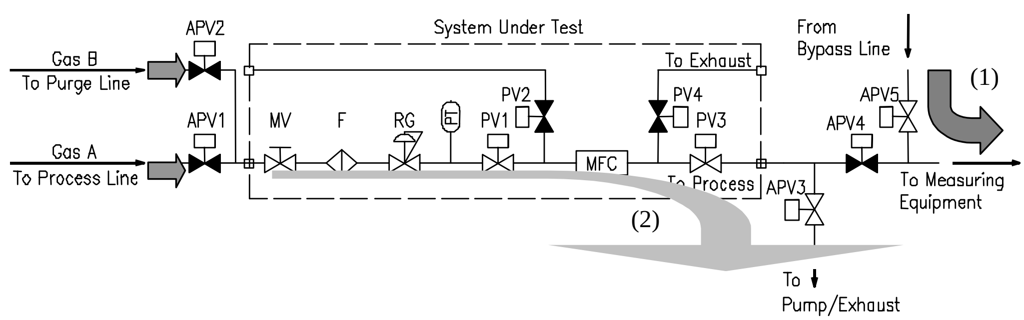


Figure 9
Procedure 7.2.4

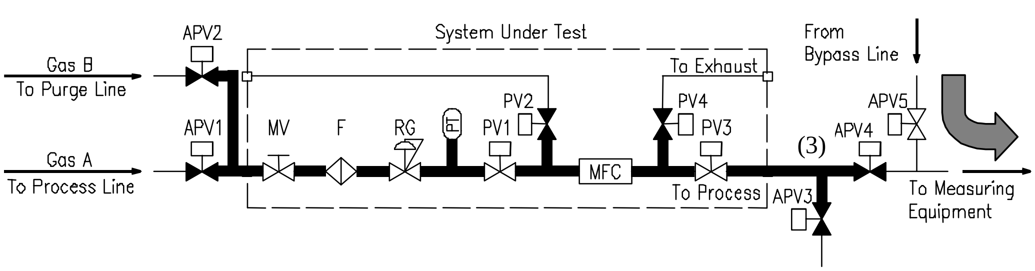


Figure 10
Procedure 7.2.5

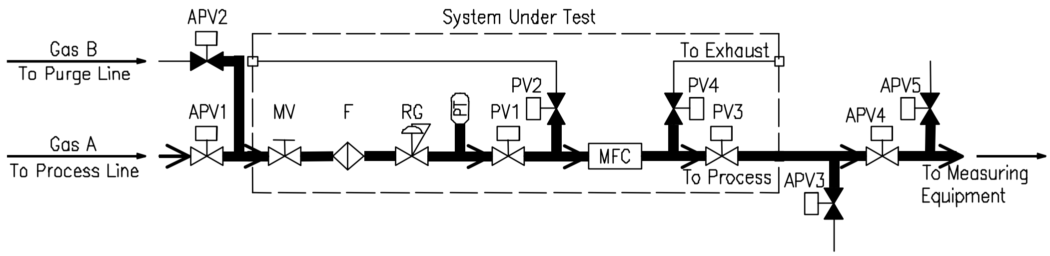


Figure 11
Procedure 7.2.6

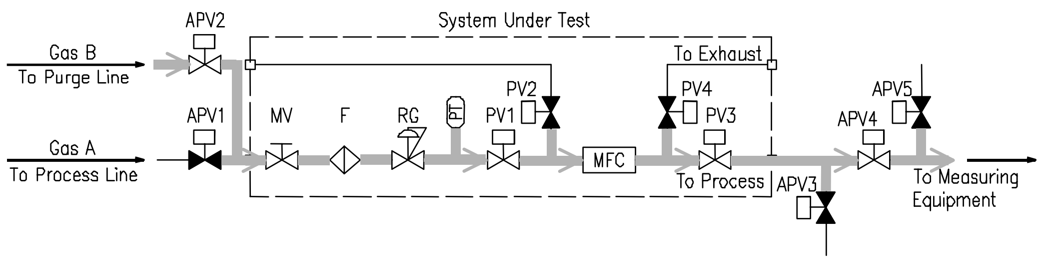


Figure 12
Procedure 7.2.7

8 Reporting Results

8.1 The following items shall be stated on the test report.

- Test date and time,
- Name of an operator,
- Test temperature,
- Flow rate of Gas A and Gas B,
- Name of Gas A and Gas B,
- Pressure of Gas A and Gas B,
- Name of the measuring equipment and model,
- Measuring condition of the measuring equipment (ex. APIMS: Scan time, Mass range, and measuring range),
- Minimum detectable limit of the measuring equipment, and
- Relationship between gas concentration and test time.

SEMI F81-1103
SPECIFICATION FOR VISUAL INSPECTION AND ACCEPTANCE OF GAS TUNGSTEN ARC (GTA) WELDS IN FLUID DISTRIBUTION SYSTEMS IN 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 September 3, 2003. Initially available at www.semi.org October 2003; to be published November 2003.

1 Purpose

1.1 The purpose of this specification is to provide visual inspection and acceptance criteria for gas tungsten arc (GTA) welds of stainless steel and other corrosion resistant metals and alloys (CRAs) in fluid (liquid or gas) distribution systems in semiconductor manufacturing applications. These criteria are meant to ensure that welds are of sufficient quality to provide the required system purity, weld integrity, and weld strength for use in semiconductor manufacturing applications.

2 Scope

2.1 This specification defines inspection and acceptance criteria for GTA autogenous butt joint welds of stainless steel and other CRAs in fluid distribution systems. The fluid distribution system includes tubing, pipe, fittings, valves, subassemblies and components that contain and distribute fluid.

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 The stainless steels covered by this specification are limited to the austenitic and superaustenitic grades of stainless steel.

3.2 Corrosion resistant metals and alloys covered by this specification are limited to solid solution grades of nickel alloys and solid solution grades of titanium alloys.

3.3 This specification applies only to autogenous GTA circumferential butt joint welds performed on fluid distribution system components 6 inches (150 mm) or less in diameter.

3.4 This specification applies only to automatic, mechanized, or machine GTA welding processes.

3.5 This specification applies only to welds performed with no fillers and no fluxes.

3.6 This specification does not apply to pressure vessel or process chamber welds.

4 Referenced Standards

NOTE 1: The following documents become part of the guide to the extent that they are included herein.

4.1 *SEMI Standard*

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

4.2 *ASME Standard*[1]

BPE — Bioprocessing Equipment Standard

4.3 *AWS Standard*[2]

AWS QC-1 — Standard for AWS Certification of Welding Inspectors

AWS A3.0 — Standard Welding Terms and Definitions

4.4 *ASNT Standard*[3]

ASNT SNT-TC-1A — Guideline to Personnel Qualification and Certification in NDT

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

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

2 American Welding Society, 550 NW LeJeune Road, P.O. Box 351040, Miami, Florida 33135

5 Terminology[3]

5.1 *Definitions*

5.1.1 *angular misalignment* — the condition that exists when the tubing angle is unintentionally changed at the weld.

5.1.2 *autogenous weld*(2) — a fusion weld made without filler metal.

5.1.3 *automatic arc welding downslope* — the time during which the welding current is reduced continuously from the final level until the arc is extinguished.

5.1.4 *axial misalignment* — the offset caused by tubing being in line but not centered at the weld.

5.1.5 *backing gas* — an inert gas (or gas mixture) on the interior of the weld joint used to prevent or reduce formation of oxides and other detrimental surface substances during welding, and to provide pressure for weld profile.

5.1.6 *bead*(2) — non-standard term for *weld bead.*

5.1.7 *bead overlap* — in a pulsed weld the amount of coverage of a weld pulse of the previous weld pulse, usually measured in percentage of the diameter of the pulse.

5.1.8 *bead variation* — the amount of change of ID bead width from one area to another.

5.1.9 *bead width* — the width of the weld bead on the ID, normally measured in units of *T*, where *T* is the nominal tube wall thickness.

5.1.10 *center line shrinkage* — a profile-reducing defect or discontinuity normally formed by shrinkage during solidification.

5.1.11 *color line* — acceptance criteria of the maximum amount of discoloration allowed on the weld or adjacent surfaces.

5.1.12 *color* — the darkness of the oxidation of the weld or adjacent surfaces. Non-standard term for *discoloration.*

5.1.13 *concavity*(3) — a condition in which the surface of a weld is depressed relative to the surface of the tube or pipe. Concavity is measured as a maximum distance from the outside or inside diameter surface of a weld along a line perpendicular to a line joining the weld toes.

5.1.14 *convexity*(3) — a condition in which the surface of a weld is extended relative to the surface of the tube or pipe. Convexity is measured as a maximum distance from the outside or inside diameter surface of a weld along a line perpendicular to a line joining the weld toes.

5.1.15 *coupon* — weld sample which is opened for inspection to insure that the weld meets specifications.

5.1.16 *coupon-in* — first coupon prior to production welding of butt weld joint.

5.1.17 *coupon-out* — last coupon after production welding of butt weld joint ends.

5.1.18 *discoloration*(3) — any change in surface color from that of the base metal. Usually associated with *oxidation* occuring on the weld and heat affected zone on the outside and inside diameter of the weld joint as a result of heating the metal during welding. Colors may range from pale bluish-gray to deep blue, and from pale straw color to a black crusty coating.

5.1.19 *downslope* — see *automatic arc welding downslope.*

5.1.20 *dross*(2) — non-standard term for *slag.*

5.1.21 *electrode*(2) — non-standard term for *tungsten electrode.*

5.1.22 *enclosed weld head* — weld head in which the weld joint is held and welded within a closed chamber containing a shielding purge gas.

5.1.23 *encroachment* — non-standard term for ID *convexity.*

5.1.24 *examiner* — a person who performs examination of a particular object, or evaluates an operation, for compliance to a given standard. The examiner performs quality control for the manufacturer, fabricator, or erector.

5.1.25 *fluid*(1) — liquid or gas.

5.1.26 *gas*(1) — the fluid form of a substance in which it can expand indefinitely and completely fill its container; form that is neither liquid or solid.

5.1.27 *gas tungsten arc welding (GTAW)*(3) — an arc welding process that uses an arc between a tungsten electrode (nonconsumable) and the weld pool. The process is used with a shielding gas.

5.1.28 *halo* — non-standard term for *discoloration* resulting from welding procedure.

5.1.29 *haze* — non-standard term for *discoloration* resulting from welding procedure.

3 The terminology has been derived from the following sources:

(1) Webster's New World College Dictionary Fourth Edition

(2) ANSI/AWS A3.0 Standard Welding Terms and Definitions

(3) ASME BPE Bioprocessing Equipment Standard

5.1.30 *heat tint/color* — non-standard term for *discoloration* resulting from welding procedure.

5.1.31 *heat-affected zone (HAZ)*(2) — the portion of the base metal whose mechanical properties or microstructure have been altered by the heat of welding.

5.1.32 *inclusion*(2) — entrapped foreign solid material, such as slag, flux, tungsten, or oxide.

5.1.33 *inert gas* — a gas that normally does not combine chemically with materials. A protective atmosphere.

5.1.34 *inspector* — a person who verifies that all required examinations and testing have been completed, and who inspects the assembly to the extent necessary to be satisfied that it conforms to all applicable examination requirements. The inspector performs quality assurance for the owner. The inspector is designated by the owner and shall be the owner, an employee of the owner, an employee of an engineering or scientific organization, or of a recognized insurance or inspection company acting as the owner's agent.

5.1.35 *lathe welding* — automatic or machine welding of tubes or pipes in which the electrode is stationary and the weld joint rotates. Lathe welding as defined here is a fusion process without the addition of filler.

5.1.36 *liquid*(1) — having its molecules moving freely with respect to each other so as to flow readily, unlike a solid, but because of cohesive forces not expanding infinitely like a gas.

5.1.37 *liquid cylinder* — often referred to as a dewar, an insulated and pressure controlled metal cylinder used to store fluids in their liquid form.

5.1.38 *meandering*(3) — of or pertaining to a weld bead that deviates from side to side across the weld joint rather than tracking the joint precisely.

5.1.39 *orbital welding*(3) — automatic or machine welding of tubes or pipes in-place with the electrode rotating (or orbiting) around the work. Orbital welding, as it applies to this standard, is a fusion process without the addition of filler.

5.1.40 *oxidation*(3) — the formation of an oxide layer on a metal surface. When excessive oxidation occurs as a result of welding, it is visible as *discoloration.*

5.1.41 *oxide island* — non-standard term for *slag.*

5.1.42 *pressure cylinder* — a metal cylinder used to store gases under pressure.

5.1.43 *profile defect* — any defect or discontinuity that reduces the wall thickness below that of the parent metal.

5.1.44 *pulsed gas tungsten arc welding* — a gas tungsten arc welding process variation in which the current is varied in regular intervals.

5.1.45 *purge gas* — an inert gas (or gas mixture) used to displace the ambient atmosphere from the inside (ID) of the weld joint.

5.1.46 *purge* — the application of an inert gas (or gas mixture) to the OD or ID surface of the weld joint to displace non-inert atmospheric gases.

5.1.47 *root* — non-standard term for *root surface.*

5.1.48 *root surface*(2) — the exposed surface of a weld opposite the side from which the welding was done.

5.1.49 *rotation delay* — time delay between when the arc is initiated and the rotor begins to turn.

5.1.50 *shield gas* — inert gas (or gas mixture) that protects the electrode and molten puddle from atmosphere and provides the required arc characteristics.

5.1.51 *slag*(2) — a non-metallic product resulting from the mutual dissolution of non-metallic impurities in some welding processes.

5.1.52 *tack weld*(2) — a weld made to hold the parts of a weldment in proper alignment until the final welds are made.

5.1.53 *tail-out*(2) — non-standard term for *automatic arc welding downslope.*

5.1.54 *tungsten* — non-standard term for *tungsten electrode.*

5.1.55 *tungsten electrode*(2) — a component of the electrical circuit that terminates at the arc, molten conductive slag, or base metal. A non-filler electrode made principally of tungsten and used in arc welding.

5.1.56 *undercut*(2) — a groove adjacent to the base metal at the edge of the weld left unfilled by weld metal.

5.1.57 *underfill*(2) — a groove weld condition in which the weld face or root surface is below the adjacent surface of the base metal.

5.1.58 *weld bead*(2) — a weld resulting from a weld pass.

5.1.59 *weld level* — a segment or portion of a weld schedule in which one or more weld parameters can be changed independently; part of a weld sequence.

5.1.60 *weld sequence* — a series of steps executed by the welding power supply to make a particular orbital weld.

5.1.61 *welder* — a person who does welding (sometimes used to refer to a welding machine or power supply).

5.1.62 *welding equipment* — power supply, weld heads, torches, and associated cables and accessories used for welding.

5.1.63 *welding operator* — a person who welds with an orbital or machine welding system.

6 Ordering Information

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

6.1.1 Purchase order number

6.1.2 Reference to applicable specifications

6.1.3 Documentation and certification requirements

6.1.3.1 Disposition of documentation and coupons

6.1.3.2 Disposition of nonconforming product

6.1.4 Inspection methods and tools

6.1.4.1 Qualifications for inspector/examiner; for example, ASNT SNT-TC-1A or AWS QC-1

6.1.4.2 % level inspection for quality assurance or quality control

7 Requirements

7.1 Welds shall be produced in conformance with the procedures and requirements outlined in SEMI F78 "Practice for Gas Tungsten Arc (GTA) Welding of Fluid Distribution Systems in Semiconductor Manufacturing Applications." All weld beads shall conform to the following specifications:

7.1.1 All welds shall exhibit complete penetration around the entire internal surface. Penetration and bead width shall be uniform throughout the entire weld.

7.1.2 Welds shall have no visible surface cracks, porosity or inclusions under magnification. (Refer to Section 8.1 of this standard.) See also Section 7.1.9.

7.1.3 No profile defect reducing the minimum wall thickness T_{min} below that of the parent metal is permitted at any point in the weld (Figure 1). Undercut and centerline shrinkage shall not be accepted. ID concavity is not permitted.

7.1.4 Outer diameter (OD) concavity shall not exceed 10% of the nominal tube wall thickness T on tubing 1 in. (25 mm) and larger. No OD concavity is allowed on tubing under 1 in. (25 mm) OD convexity shall not exceed 10% of the nominal wall thickness T (Figure 2).

7.1.5 Inner diameter (ID) convexity shall not exceed 10% of the nominal wall thickness T (Figure 3).

7.1.6 Minimum ID weld bead width shall be 1.0 times the nominal wall thickness T. Maximum ID bead width shall be 2.5 times the nominal wall thickness T.

7.1.7 In any individual weld, maximum ID bead width shall not exceed 1.25 times the minimum bead width (Figure 4).

7.1.8 ID and OD weld bead meander shall not exceed 35% of the nominal wall thickness T (Figure 5).

7.1.9 The ID weld root surface shall have no porosity, inclusions or slag when viewed without magnification. A small slag inclusion at the end of the downslope, with a diameter less that 10% of the nominal wall thickness T, that does not affect weld integrity may be acceptable.

7.1.10 The OD weld face width shall be a minimum of two (2) times the nominal wall thickness T.

7.1.11 Weld bead overlap (the percentage of the first weld pulse that is covered by the subsequent weld pulse) shall be at a minimum 80% on the OD and 70% on the ID along the complete length except the downslope (Figure 6).

7.1.12 Tack welds must be totally consumed and undetectable in or around the OD or ID weld bead (Figure 7).

7.1.13 The OD weld face shall be free of oxidation except a light straw color is permissible. Light external oxidation may be removed with a stainless steel wire brush immediately after welding unless prohibited by the end user.

7.1.14 There shall be no visible discoloration on the tube ID or weld ID when viewed under a bright fluorescent light without magnification (HP and UHP systems only). Above 2 in. (50 mm) in diameter, a slight blue color may be acceptable.

7.1.15 Axial misalignment shall not exceed 10% of the nominal wall thickness T (Figure 8).

7.1.16 Angular misalignment shall not exceed ± ½ degree (1/8 in. per foot or 10 mm per m) (Figure 9).

7.1.17 The weld downslope must be present and of sufficient length to prevent a crater at the end of the weld. The distance between the ID downslope and the OD downslope shall be a minimum of 3 times the nominal wall thickness T (Figure 10).

8 Inspection Tools and Methods

8.1 Acceptable tools, magnification, and illumination shall be specified and agreed upon between the supplier and purchaser, per Section 6.1.4 of this document.

8.2 Examples of acceptable tools, magnification, and illumination include, but are not limited to, the following:

8.2.1 *Tools* — sight pipe; rigid borescope; calipers; v-blocks; dial indicators; comparators

8.2.2 *Magnification* — magnifying glass; optical microscope (2 to 40×)

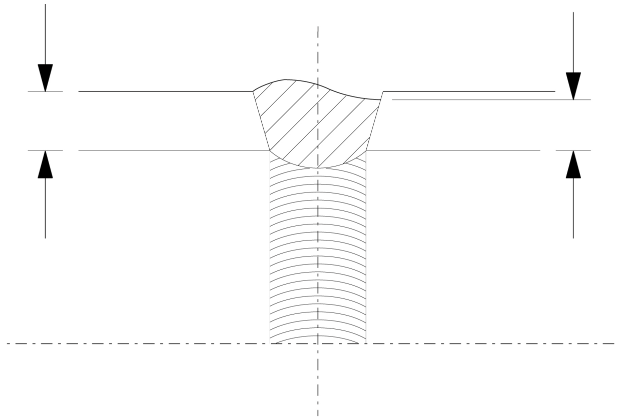
8.2.3 *Illumination* — flashlight; bright fluorescent light; natural (ambient) light; white paper (for background illumination)

8.3 All tools shall be used without damaging or contaminating the wetted surface of production weldments. Tools may touch the wetted surface of coupons.

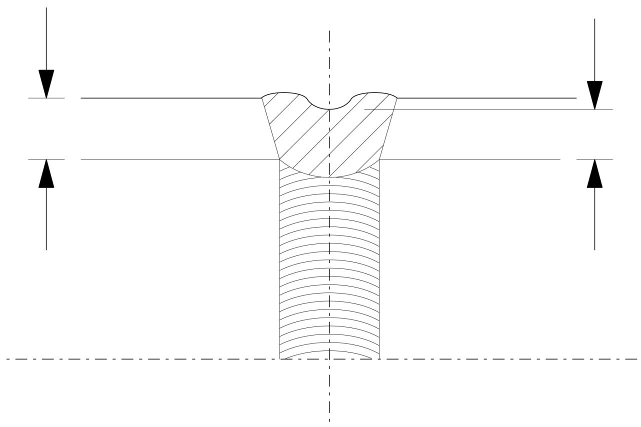
9 Certification

9.1 Upon request of the purchaser in the contract or order, a manufacturer' s or supplier' s certification that the product was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

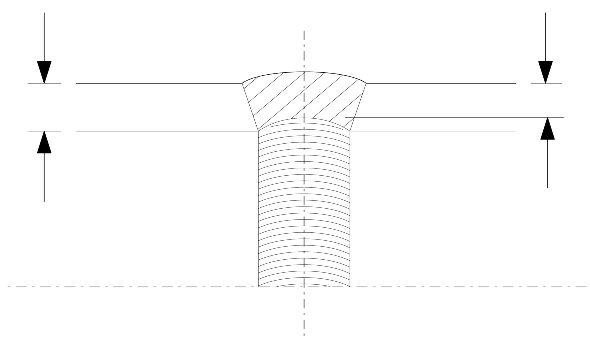
9.2 If desired, the supplier and purchaser may agree that the product shall be certified as "capable of meeting" certain requirements. In this context, "capable of meeting" shall signify that the supplier is not required to perform the appropriate tests. However, if the purchaser performs the test(s) and the product fails to meet the requirement(s), the product may be subject to rejection.



(a) Undercut

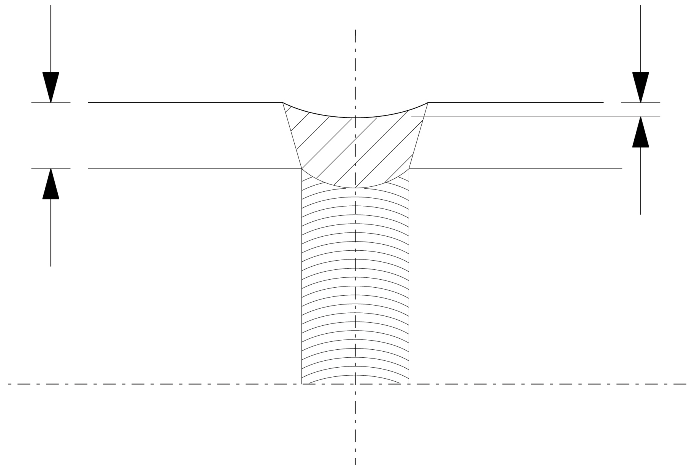


(b) Center line shrinkage

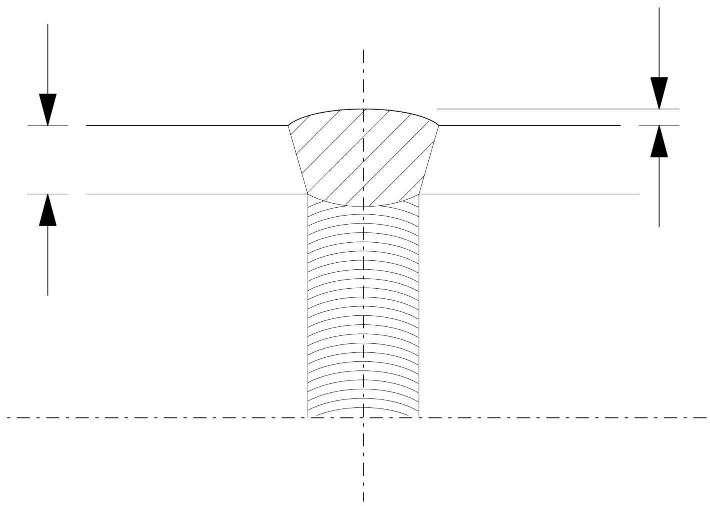


(c) ID concavity

Figure 1
Rejectable Profile Defects



(a) OD concavity



(b) OD convexity

Figure 2
OD Concavity and OD Convexity

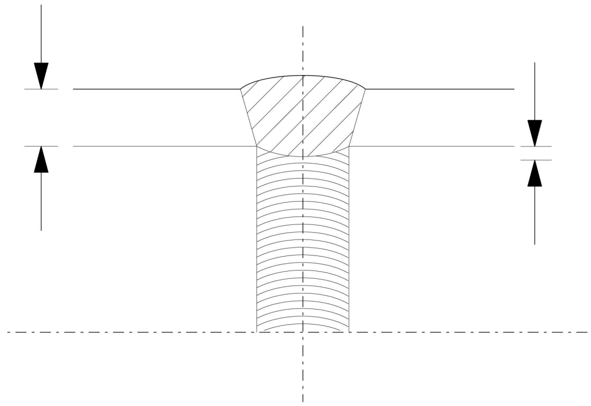


Figure 3
ID Convexity

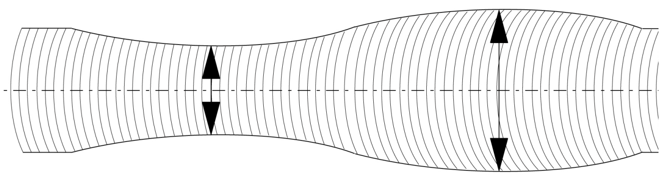


Figure 4
Weld Width Variation

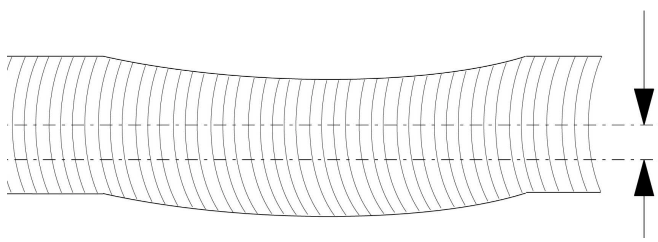


Figure 5
Weld Bead Meander

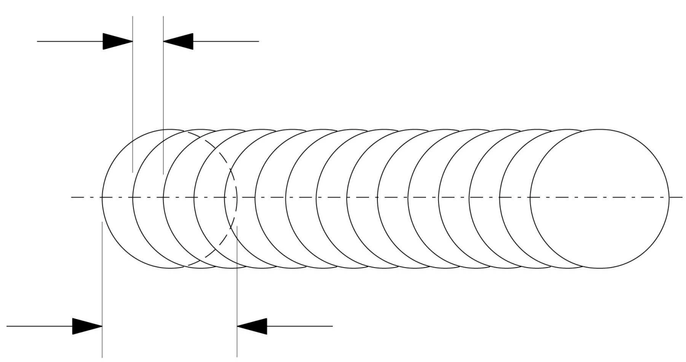


Figure 6
Bead Overlap

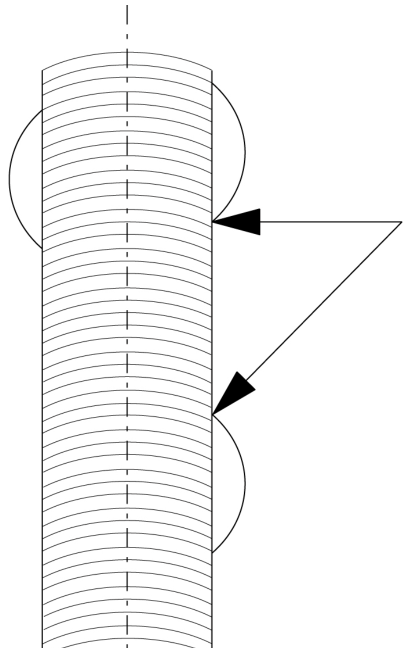


Figure 7
Unconsumed Tack Welds

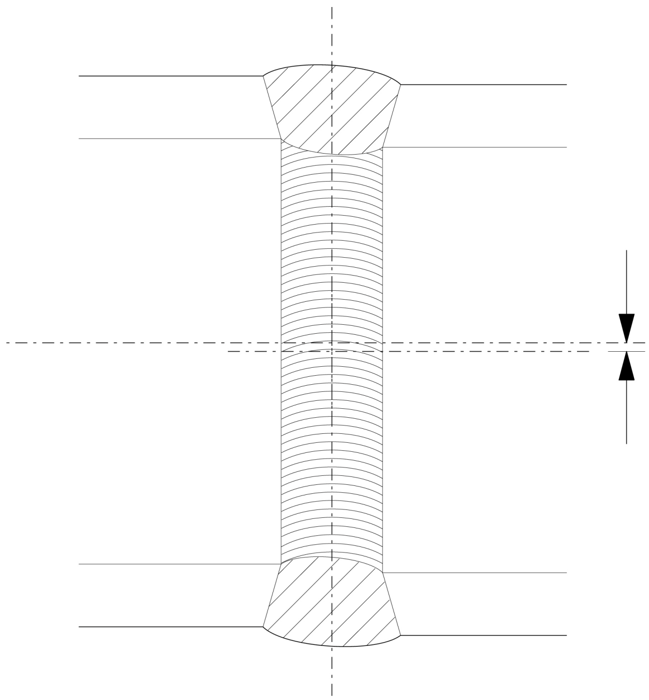


Figure 8
Axial Misalignment

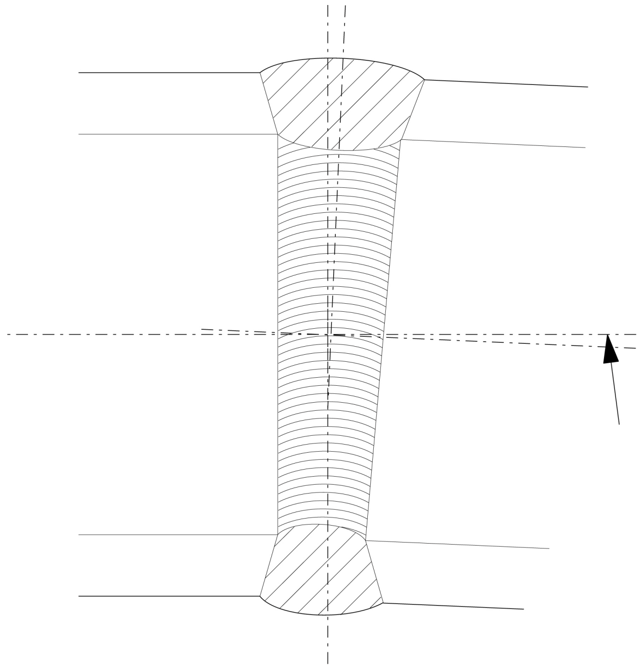


Figure 9
Angular Misalignment

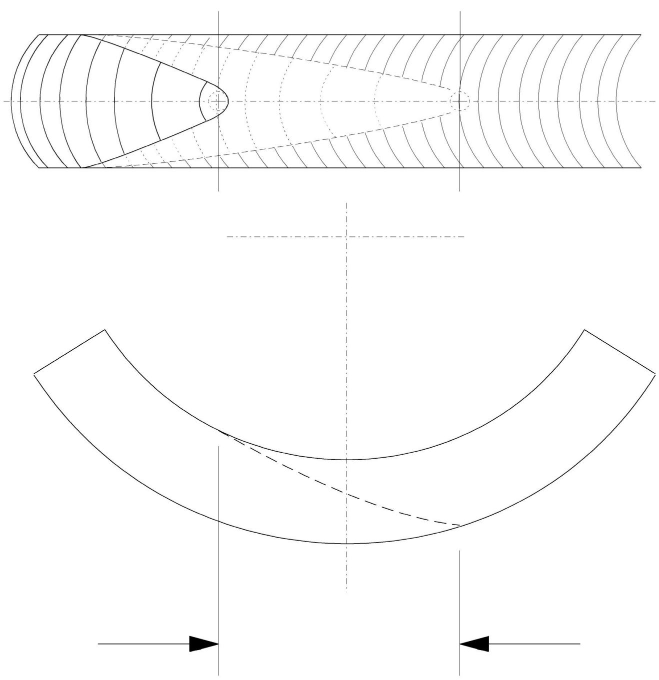


Figure 10
Downslope

SEMI F82-0304
SPECIFICATION FOR DIMENSION OF MASS FLOW CONTROLLER / MASS FLOW METER FOR 1.125 INCH TYPE SURFACE MOUNT GAS DISTRIBUTION SYSTEMS

This specification was technically approved by the Global Gases Committee and is the direct responsibility of the Japanese Gases & Facilities Committee. Current edition approved by the Japanese Regional Standards Committee on November 20, 2003. Initially available at www.semi.org February 2004; to be published March 2004.

1 Purpose

1.1 This standard establishes the properties and physical dimensions of mass flow controllers and mass flow meters for 1.125 inch type surface mount gas distribution systems.

2 Scope

2.1 This document includes common requirements, layout, size, detailed specifications, and dimensions of the components.

2.2 This standard applies to all mass flow controllers and mass flow meters. The components are mounted on substrates with fasteners accessible from the top.

2.3 This standard only applies to components, which control flow of ≤ 50 slm nitrogen equivalent at 308 kPa (44.7 psia). This standard also only applies to components with operating pressures less than 3445 kPa (500 psia) at 20°C.

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

3 Limitations

3.1 This standard only addresses the component; it does not address the seals, the sealing system, or the assembly process and does not guarantee the performance of the sealing system. The user should be aware that gas delivery system performance and sealing system performance are addressed elsewhere in the SEMI standards.

3.2 The user should be aware that alternative technologies are commercially available.

3.3 International, national, and local codes, regulations, and laws should be consulted to ensure that the equipment meets regulatory requirements in each location of use.

4 Referenced Standards

4.1 *SEMI Standards*

SEMI E49.9 — Guide for Ultrahigh Purity Gas Distribution Systems in Semiconductor Manufacturing Equipment

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

4.2 *ASME Standards*[1]

ASME Y14.5 — Dimensioning and Tolerancing

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

5 Terminology

5.1 *Definitions*

5.1.1 *components for surface mount* — a gas distribution system component having inlets and outlets located on the bottom of the component with the attachment mechanism accessible from the top.

5.1.2 *Ra* — roughness average. The arithmetic average of the absolute values of the measure profile height deviations taken within the sampling length and measured from the graphical centerline.

5.1.3 *two fastener configuration* — the component has two fasteners per sealing point. The sealing point is located in the middle of the two fasteners.

6 Common Requirements

6.1 *Dimensional Requirements* — All components shall meet the requirements outlined in Figure 1. All geometric dimensioning and tolerancing complies with ASME Y14.5 and/or the applicable ISO standard.

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

NOTE 1: All dimensions are in millimeters unless otherwise noted.

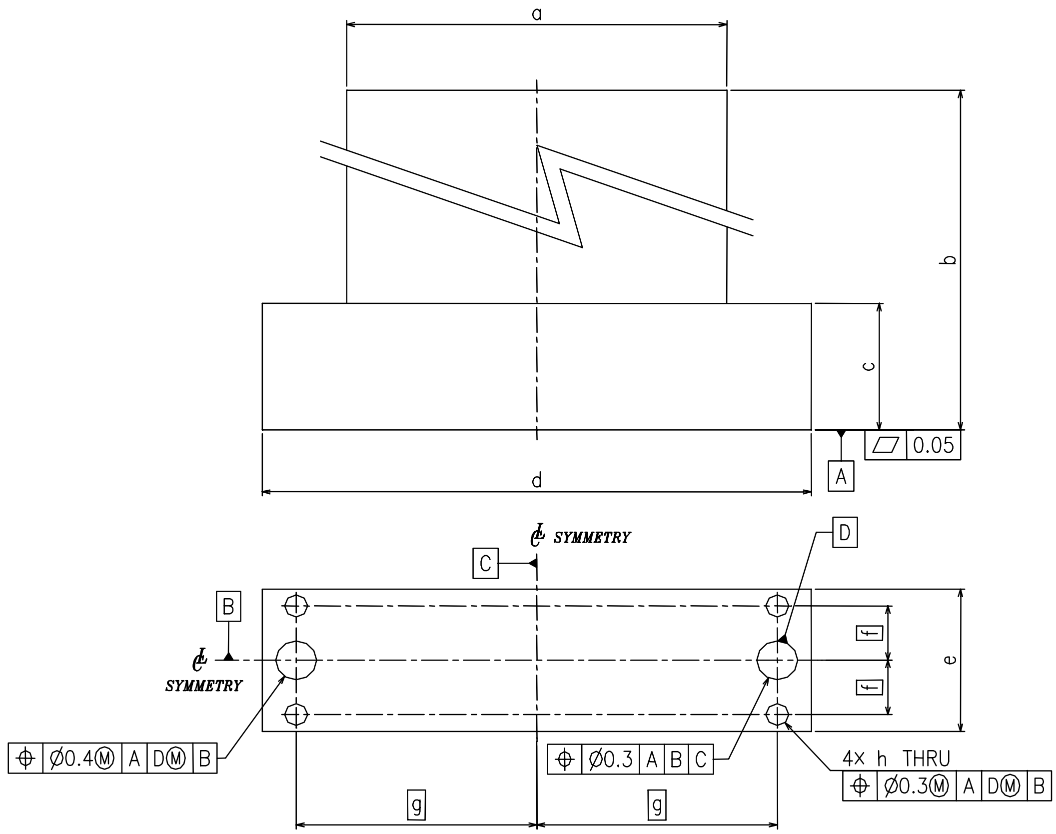
NOTE 2: The through hole of the sealing port will be elliptical if the through hole is drilled at an angle. In this case, the diameter shall apply to the major diameter of the ellipse.

6.2 *Material* — The material used to manufacture the base of the components shall comply to SEMI F20 with the exception that the sulfur content shall comply to SEMI E49.9.

NOTE 3: SEMI E49.9 was withdrawn. However, a ballot to combine E49.8 and E49.9 in one single standard was submitted for SEMICON West 2003.

6.3 *Burrs and Sharp Edges* — Unless specifically noted on the drawing, remove all burrs and sharp edges.

6.4 *Displays* — Removable displays shall stay within the maximum envelope of the base of the component. They shall be movable or removable such that they do not interfere with the access of the mounting fasteners from above.



a	*b*	*c*	*d*	*e*	*f*	*g*	*h*
82.7 MAX	127 MAX	25.4 ±0.5	105 ±0.5	28.6 + 0.3/-0.5	10.9	46	ϕ4.4 ±0.1

UNIT: [mm]

Figure 1
All Components

7 Related Documents

7.1 *ISO Standards*[2]

ISO 406 — Technical Drawings - Tolerancing of Linear and Angular Dimensions

ISO 1101 — Technical Drawings - Geometrical Tolerancing - Tolerancing of Form, Orientation, Location, and Run-Out - Generalities, Definitions, Symbols, and Indications on Drawings.

ISO 1660 — Technical Drawings - Dimensioning and Tolerancing of Profiles

ISO 2692 — Technical Drawings - Geometrical Tolerancing - Maximum Material Principle

ISO 6507 — Metallic Materials - Vickers Hardness Test

ISO 8015 — Technical Drawings - Fundamental Tolerancing Principles

2 ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Genevè 20, Switzerland. http://www.iso.ch

RELATED INFORMATION 1
EXAMPLES OF SEAL DESIGNS FOR 1.125 INCH TYPE SURFACE MOUNT COMPONENTS

NOTICE: This related information is not an official part of SEMI F82 and was derived from the work of the originating task force. This related information was approved for publication by full ballot procedures. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 Design Example 1

R1-1.1 *Seal Design* — See Figure R1-1.

R1-1.2 *Surface Hardness* — The sealing surface (the bottom of the counterbore) has a minimum hardness of 170 Vickers. The hardness may be tested per ISO 6507.

R1-1.3 *Surface Roughness* — The sealing surface (the bottom of the counterbore) has a surface roughness of 0.25 micrometers Ra max. The surface roughness may be tested per SEMI F37-0299.

R1-1.4 *Surface Scratches* — The sealing surface (the bottom of the counterbore) is without any lateral scratches which are visible to non-magnified normal vision.

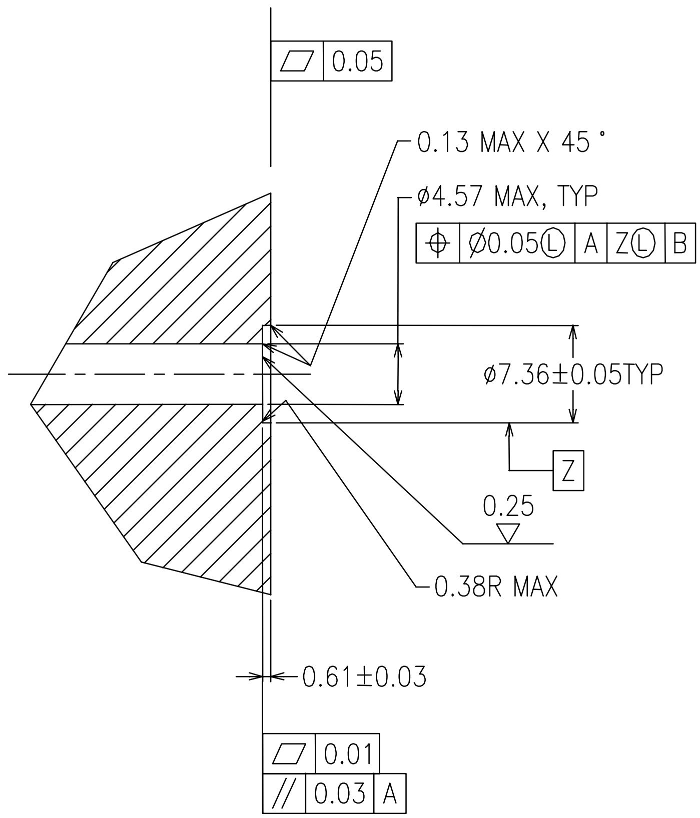


Figure R1-1
Design Example 1