

SEMI F1-90

SPECIFICATION FOR LEAK INTEGRITY OF TOXIC GAS PIPING SYSTEMS

1 Purpose

This document defines the leak testing requirements to provide a minimum acceptable level of safety for toxic gas piping systems used in semiconductor fabrication. It is also intended as an aid to the procurement and installation of equipment, materials, and services.

NOTE: Users of this specification are encouraged to submit suggested revisions or other comments to SEMI.

2 Scope

2.1 This specification applies to toxic gas piping systems used in semiconductor manufacturing facilities and comparable research and development areas. It includes testing requirements for complete systems, subsystems, and individual components. It states requirements for both the end user and manufacturer and establishes standard limits for acceptance and qualification.

2.2 The basis of these requirements is given in Appendix 2.

2.3 This specification is not a replacement for existing regulations. It is the responsibility of the user to ensure that piping systems covered by this specification comply with all applicable regulations.

3 Applicable Documents

The following documents of the issue in effect on the date of equipment purchase form a part of this specification to the extent referenced herein:

3.1 ASTM Standards¹

E 493 — Standard Test Methods for Leaks Using the Mass Spectrometer Leak Detector in the Inside-Out Testing Mode

E 498 — Standard Methods of Testing for Leaks Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Tracer Probe Mode

E 499 — Standard Methods of Testing Leaks Using the Mass Spectrometer Leak Detector in the Detector Probe Mode

3.2 Code of Federal Regulation Labor²

Title 29 — Part 1910

3.3 Other Standard³

TLV's^{®4} — Threshold Limit Values for Chemical Substances in the Work Environment Adopted by ACGIH

4 Terminology

4.1 *component* — an individual piece or a complete assembly of individual pieces, including industrial products that are manufactured as independent units, capable of being joined with other pieces or components. The typical components referred to by the specification are valves, fittings, regulators, gauges, instrument sensors, single lengths of tubing, several pieces of tubing welded together, and tubing welded to fittings.

4.2 *design pressure* — of a system or subsystem, the pressure at the most severe condition of coincident internal or external pressure and temperature expected during normal service. The maximum pressure expected in any portion of a system or subsystem is typically determined by the maximum adjustable setting of the last pressure regulator that supplies it, the supply pressure to the regulator, or the actuation pressure of any relief device incorporated.

4.3 *leakage, inboard* — leakage from outside to inside that occurs when the internal pressure is less than external pressure acting on a component.

4.4 *leakage, internal* — leakage that occurs within a component across a flow barrier, such as leakage across the seat of a closed valve.

¹ American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103

² United States Government Printing Office, Washington, D.C. 20402

³ American Conference of Governmental Industrial Hygienists, 6500 Glenway Ave., Building D7, Cincinnati, OH 45211

⁴ TLV is a registered trademark of the ACGIH.

4.5 *leakage, outboard* — leakage from inside to outside that occurs when the internal pressure is greater than the external pressure acting on a component.

4.6 *may* — a term indicating that a provision is neither required nor prohibited by this specification.

4.7 *rated pressure* — the manufacturer's recommended maximum allowable operating pressure at the manufacturer's rated temperature.

4.8 *shall* — a term indicating that a provision is a requirement of this specification.

4.9 *should* — a term indicating that a provision is recommended as good practice but is not a requirement of this specification.

4.10 *shutoff valve* — a valve that is designed for, and capable of, positive closure to prevent flow within a system. Typical shutoff valves include: manually actuated, power-actuated, or spring-actuated, fail-safe shutoff valves. Generally excluded are self-actuated valves such as check valves, pressure regulators, flow controllers, and other devices that are not intended to provide positive shutoff for safety isolation.

4.11 *subsystem* — an assembly of two or more components that is manufactured as a single entity. A subsystem must be combined with one or more additional components or subsystems to form a complete system.

4.12 *system* — an integrated structure of components and subsystems capable of performing, in aggregate, one or more specific functions. For the purpose of this specification, a system includes the gas source control subsystem, its connection to the gas source, the distribution piping, and the gas control subsystem within the process equipment.

4.13 *TLV* — Threshold Limit Value-Time Weighted Average (TLV-TWA) as defined by the American Conference of Governmental Industrial Hygienists.

4.14 *toxic gas* — a substance that is discharged into a piping system in gaseous form and that is defined as toxic or highly toxic in Title 29 of the Code of Federal Regulations, Section 1910.1200.

5 Ordering Information

5.1 Orders for equipment or services requiring leak testing in accordance with this specification shall include the following:

- a. This specification number and date of issue.
- b. Qualification test requirements as defined in the detailed specifications for the specific product being purchased (see Section 6.2).
- c. The design pressure to be used for internal and outboard leakage testing of systems (see Sections 7.3, 7.4) or subsystems (see Sections 8.3, 8.4).
- d. Whether certification of the qualification or acceptance tests and a report of test results is required (see Section 10).

6 General Requirements

6.1 *Acceptance Tests* — Acceptance tests are conducted on each component, subsystem, or system produced. They are the basis for acceptance or rejection by the purchaser.

6.2 *Qualification Tests* — Qualification tests are conducted on samples of production articles, not on each item produced. Their purpose is:

- a. To establish the performance rating of a product.
- b. To demonstrate that the acceptance tests are effective in revealing defects.
- c. To demonstrate that the acceptance testing is non-degrading to the product.

6.2.1 Qualification tests apply to components, subsystems or systems that are manufactured to a single design either in multiple quantities or one-of-a-kind single items.

6.2.2 Qualification tests to establish product leakage ratings shall use the methods and acceptance criteria of this specification. All other qualification tests shall be defined in the product specification. (See Section 5.1.)

6.3 *Personnel Qualification* — Personnel performing tests in accordance with this specification shall have suitable training and experience. Such personnel should, as a minimum,

- a. be trained and experienced in the use of mass spectrometer leak detectors,
- b. be familiar with the use of the ASTM test methods referenced by this specification, and
- c. be familiar with the operation and calibration of the specific equipment used in performing the tests.

6.4 Required Tests

6.4.1 Prior to initial operation, each component, sub-system, and system shall be tested in accordance with this specification.

6.4.2 If repairs or additions are made following the leakage tests, the affected portions of the system shall be retested.

6.5 Precautions

WARNING: Testing of systems, subsystems, or components with high pressure gas could cause explosive rupture of these items, with the resulting fragmentation causing death or serious injury. In addition, if a component of the system under test were to fail, an unrestricted supply of test gas could cause pressurization and rupture of the test enclosure. Such testing must never be performed without shielding that will protect the operator and other personnel in the event of equipment failure. The source of test gas should be provided with a suitable device that will limit or shut off the flow in the event of component rupture.

WARNING: Some elements of a piping system may not be designed for pressurization. Pressurization of such system elements could cause explosive rupture, with the resulting fragmentation causing death or serious injury. Such elements shall never be tested in a manner inconsistent with the manufacturer's specifications. Valves used to isolate these elements of systems must be rated for higher pressure and temperature than the proposed test environment.

6.5.1 When leakage tests are conducted at metal temperatures near the ductile-to-brittle transition temperature of the material, the possibility of brittle fracture shall be considered. The test temperature shall be considered when the choice of material is made in the original design.

6.5.2 Test gas pressure shall not exceed the manufacturer's pressure rating at the test temperature. Leakage tests shall be conducted at a temperature that is within the system design temperature and within the manufacturer's temperature rating of each component.

6.5.3 Gas leakage tests shall include a preliminary check at not more than 25 psig or 10% of design pressure, whichever is lower. The test pressure shall be

increased gradually in steps, with sufficient time at each step to equalize strains during the test and to check for leakage.

6.6 Test Preparation

6.6.1 All joints, including welds, shall be uninsulated, unpainted, and exposed for examination during the test. If hydrostatic or bubble emission tests are performed, they shall be done after the gas leakage tests.

6.6.2 Portions of a system that are not to be subjected to a leakage test shall be isolated during the test.

6.7 *Gas Mixtures* — Test gas mixtures shall be homogeneous, and the concentration of the minor component shall be accurate to within $\pm 10\%$.

6.8 *Interferences* — Mass spectrometer leak testing with helium can result in misleading indications due to high permeability of polymeric materials by helium. Permeation is often indicated by a delayed leakage indication and a continually rising apparent leakage rate. The test time must be sufficient to insure adequate sensitivity but short enough to avoid the effects of permeation. Helium tracer gas under pressure is absorbed by permeable materials, and subsequent desorption can inhibit later testing at sensitive levels. Outboard leakage tests must not be done until after inboard and internal leakage tests have been performed.

6.9 *Alternative Tests* — This specification defines standard acceptance test requirements (Sections 7 through 9). These are the preferred tests and shall be used whenever feasible. It is recognized that this specification applies to a broad range of products, from small and simple to large and complex. The alternative tests given in Appendix 1 may be used if the preferred tests are not feasible; the designer of the product shall establish the most effective test applicable to the product. The applicable test shall be described in the manufacturer's product information.

7 System Acceptance Test Requirements

7.1 *General* — Each system shall be tested by the manufacturer in accordance with the following requirements.

7.2 Inboard Leakage Test

7.2.1 Each system shall be tested for total inboard leakage.

7.2.2 *Test method* — ASTM E 498, Method A. System acceptance shall be based upon total system integrity in accordance with ASTM E 498, Article 6.8.

7.2.3 *Tracer gas* — 100% helium. The test procedure shall insure that the envelope is sufficiently well purged of air to minimize dilution of the helium.

7.2.4 *Maximum leakage rate* — 1×10^{-5} sccs of helium, total leakage of the enclosed system.

7.2.5 Systems that are too large to enclose in a single helium envelope may be tested in segments, with each segment treated as a subsystem. Each enclosed segment shall be tested to a maximum leakage rate of 1×10^{-6} sccs.

7.2.6 Portions of systems that cannot be entirely enclosed in a helium envelope shall be tested by the tracer probe method, ASTM E 498, Articles 6.1 through 6.7, to a maximum leakage rate of 1×10^{-7} sccs per leak point.

7.3 Internal Leakage Test

7.3.1 Each system shall be tested for internal leakage of each shutoff valve that isolates the toxic gas from the environment outside the systems during any operating or maintenance condition, or that separates incompatible gases (e.g., flammables and oxidizers).

7.3.2 *Test method* — ASTM E 498, Method A, modified as follows:

- a. The shutoff valve shall be closed and the inlet pressurized with tracer gas.
- b. The leak detector shall be connected to the closest point available to the valve outlet. The evacuated portion of the system shall be kept as small as practicable.

7.3.3 *Tracer gas* — 1% helium in nitrogen.

7.3.4 *Tracer gas pressure* — 100% of system design pressure (see Section 5.1).

7.3.5 *Maximum leakage rate* — 1×10^{-5} sccs indicated leakage of helium. The leakage rate shall apply to each individual shutoff valve and to the combined leakage rate of multiple valves in parallel circuits.

7.3.6 Interferences

7.3.6.1 For low pressure tests, 10 atmospheres or less, the system must be purged or evacuated to avoid diluting the tracer gas.

7.3.6.2 Long tubing lines or small diameter tubing at a valve inlet may require purging to insure that the tracer gas reaches the valve seat.

7.3.6.3 Conductance between the valve outlet and the leak detector must be adequate to insure test sensitivity. Restrictions such as a regulator or check valve between the valve outlet and the leak detector may require testing the shutoff valve before installing the downstream components.

7.4 Outboard Leakage Test

7.4.1 Each system shall be tested for total outboard leakage.

7.4.2 *Preferred test method* — ASTM E 493, Method B, modified as follows:

- a. The system shall be prefilled and maintained at constant pressure during the test.
- b. System acceptance shall be based upon measured leakage rate.

7.4.3 *Tracer gas* — 1% helium in nitrogen.

7.4.4 *Tracer gas pressure* — 100% of system design pressure (see Section 5.1).

7.4.5 *Maximum leakage rate* — $Q_L = 4.7 \times 10^{-4} \times TLV \times Q_v$, as defined in Appendix 2.

7.4.6 Systems that are too large to enclose in an evacuated chamber shall be tested by one of the alternative test methods defined in Appendix 1. The alternatives for testing systems are:

- a. A1, Detector Probe Test *plus* A2, Pressure Decay Test
- b. A3, Accumulation Test

8 Subsystem Acceptance Test Requirements

8.1 *General* — Each subsystem shall be tested by the manufacturer in accordance with the following requirements. If a subsystem is tested by the purchaser prior to installation in a complete system, it shall be tested in accordance with the requirements for systems, Section 7.

8.2 Inboard Leakage Test

8.2.1 Each subsystem shall be tested for total inboard leakage.