

**SEMASPEC Test Method for
Determination of Helium Leak Rate
for Gas Distribution System
Components**

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Abstract: This SEMASPEC describes the SEMATECH test methods for leak testing components being considered for installation into a high-purity gas distribution system using a helium mass spectrometer leak detector. Application of this test method is expected to yield comparable data among components tested for the purposes of qualification for installation.

This document is in development as an industry standard by Semiconductor Equipment and Materials International (SEMI). When available, adherence to the SEMI standard is recommended.

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1. Introduction

Semiconductor cleanrooms are serviced by high-purity gas distribution systems. This document presents a test method that may be applied for the evaluation of one or more components considered for use in such systems.

1.1 *Purpose*

1.1.1 The purpose of this document is to define a method for testing components being considered for installation into a high-purity gas distribution system. Application of this test method is expected to yield comparable data among components tested for purposes of qualification for this installation.

1.1.2 This procedure describes a qualification test method for leak testing using a helium mass spectrometer for ultra-high-purity components of gas distribution systems in semiconductor manufacturing facilities.

1.2 *Scope*—This helium leak test method is to be used for gas distribution system components such as valves, filters, regulators, and other piping specialties.

1.3 *Limitations*

1.3.1 Do not perform an across-the-seat leak test or inboard leak test after an outboard leak test because of helium saturation of nonmetallic materials used in some components. Also, do not perform an inboard leak test after an across-the-seat leak test.

1.3.2 This method is written with the assumption that the operator understands the use of the apparatus at a level equivalent to six months of experience performing helium leak tests.

1.3.3 This test does not require the use of a cleanroom. If subsequent tests require maintaining the cleanliness of the component, the test can be performed in a cleanroom.

1.3.4 It is recognized that temperature variations may affect helium leak performance. However, this test method does not address this effect.

2. Reference Documents

2.1 Semiconductor Equipment and Materials International. "Guideline for Determining and Describing Mass Flow Controller Leak Rates," SEMI Standard E16-90. 1990 *SEMI International Standards*, v.2A. 1990.

2.2 Semiconductor Equipment and Materials International. "Product Performance Safety Guidelines, S2-91. 1991 *SEMI Facility Standards and Safety Guidelines*. 1991.

3. Terminology

- 3.1 *acceptance test*—testing of components as they are fabricated in the manufacturer's shop, prior to shipment to the job site; e.g., testing of components such as valves as they come off the production line. Acceptance testing is not addressed in this document.

[Note: The purpose of acceptance testing is to provide a quick check to ensure that the components have been assembled properly.]

- 3.2 *across-the-seat test*—testing for leaks across the internal seal of the test component (for example, from one side of the valve seat to the other).

- 3.3 *inboard test*—testing for internal leaks from outside to inside of the test component when the external pressure is greater than the internal pressure within the test component.

[Note: Inboard leak tests are the easier tests to conduct, but are typically not indicative of the normal operating conditions of a component. These types of components normally do not operate with an internal pressure less than the external environmental pressure. It is difficult to relate the significance of an inboard leak to the performance of the component when under normal internal pressure. Also, the internal collapsing forces created by the higher external pressure may mask some leaks which would exist when the component is subjected to internal pressure. As a result, it is recommended that testing not be limited to inboard tests.]

- 3.4 *leak*—a path (or paths) in a sealed system that will pass helium when a partial pressure differential exists.

[Note: A partial pressure differential can exist for helium even though a total gas pressure differential may not exist. There are two major leak mechanisms, either a mechanical passage or a material through which gas can diffuse or permeate. In a real system, a leak may have both mechanisms operating in parallel.]

- 3.5 *measured leak rate*—the rate of leakage of a given system measured under specified conditions and employing a specified test gas—in this case, helium.

[Note: For the purposes of comparison with rates determined by other methods of testing, measured leak rates must be converted to equivalent standard leak rates.]

The measured leak rate shall be corrected to standard leak rate by multiplying by the

$$\text{Standard Leak Rate} = \frac{[101.3 \text{ kPa (1 atm)} \times \text{measured leak rate}]}{[\text{actual He absolute pressure}]}$$

ratio of 101.3 kPa to the absolute value of the pressurizing helium, as explained in 3.3.

- 3.6 *outboard test*—testing for external leaks from inside to outside of the test component when the external pressure is less than the internal pressure of the test component.

[Note: Outboard leak testing evaluates the test component under conditions which more typically simulate the actual environment in which the component will operate, that

being with the test component exposed to an internal operating pressure greater than the external environmental pressure.]

- 3.7 *psi*—pounds per square inch.
- 3.8 *psia*—pounds per square inch absolute.
- 3.9 *psid*—pounds per square inch differential.
- 3.10 *psig*—pounds per square inch gauge.
- 3.11 *qualification tests*—extensive, closely controlled tests which completely analyze the characteristics of a component. These tests are performed in order to qualify a component for use in a high purity installation.
- 3.12 *scfm*—standard cubic feet per minute.
- 3.13 *slpm*—standard liters per minute.
- 3.14 *standard conditions*—101.3 kPa, 0.0 °C (14.73 psia, 32 °F).
- 3.15 *standard leak rate*—the quantity of helium at 22 °C (70 °F) and 101.3 kPa (1 atm) flowing through a leak when the partial pressure of helium on the high pressure side is 101.3 kPa and the pressure on the low pressure side is below 2 Pa ($2 \cdot 10^{-4}$ torr). Calculated test component leak rate shall be expressed in the following units:

Pa–ml/s (He) [atm–ml/sec (He)] = Pascal milliliters per second, helium (atmospheric cubic centimeters per second, helium)

[Note: The mass spectrometer helium leak detector is generally used for leak rate testing of high- and medium-level vacuum apparatus.]

4. Test Protocol

- 4.1 *Test Conditions*
 - 4.1.1 Precautions
 - 4.1.1.1 This test method may involve hazardous materials, operations, and equipment. This test method does not purport to address the safety considerations associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations before using this method.
 - 4.1.1.2 Components with manufacturer's directions specifically indicating unsuitability for vacuum service should not be subjected to the inboard helium and across-the-seat leak tests.
 - 4.1.2 The use of gas mixtures reduces the sensitivity of the leak test. Leak testing shall be done with 100% helium. See Section 4.2.1.
 - 4.1.3 Temperature is to be maintained between 18 °C (64 °F) and 26 °C (78 °F).
- 4.2 *Apparatus*
 - 4.2.1 Materials—Filtered UHP (ultra-high purity) grade helium is required. Filtration to 0.02 µm is recommended.
 - 4.2.2 Instrumentation

- 4.2.2.1 The helium mass spectrometer shall have a sensitivity at least equal to or preferably greater than the specified leak rating of the test component. If the actual leak rate is to be reported, the sensitivity shall have to be five times greater than the leak to be measured. If the sensitivity is not five times greater, the actual leak rate may be reported only if the sensitivity of the detector is also reported.
- 4.2.2.2 *Calibration*—Verify the proper operation of the leak detector by conducting a helium sensitivity test using the calibrated leak provided by the leak detector manufacturer. Conduct this calibration check prior to the test series (or at a minimum, daily) as well as at the termination of the test sequence.
- 4.2.3 Setup and Schematic

A test stand for determining the helium leak rate of automatic valves is to be constructed according to the schematic drawings shown in Figures 1 to 3. A recommended test apparatus which can be used to conduct all three helium leak tests is shown in Figure 4 (Section 5). Dimensions between the components and a list of parts that can be used to assemble the recommended test apparatus is presented in Table 1. Nitrogen gas supply from a liquid nitrogen source is filtered by a 0.01 μm filter before it is delivered to the test valve through the isolation valve. The test valve is isolated between two isolation valves to allow for pressurization of the test component during cycling and leak testing. Helium gas needed for leak testing is provided from an ultra high purity helium gas cylinder.

The test component is installed inside a Pyrex bell jar placed above a SS base plate to provide a leak-tight enclosure required for both the inboard and outboard helium leak tests. Ports are provided in the base plate for the inlet and outlet lines of the test component, for the actuator line, and for a port for the actuator exhaust to release the exhaust outside the bell jar. The base plate is sealed to the bell jar by a rubber gasket during outboard leak testing of the test component.

Both the inlet and outlet pressures are measured immediately upstream and downstream of the test valve by two electronic pressure transducers. These pressure transducers are connected to two digital readouts to display inlet and outlet pressures. Electronic readouts are connected to a dual channel strip chart recorder to continuously monitor the inlet and outlet pressures. A thermocouple is connected to a digital readout unit to directly display and read the ambient temperature.

As shown in Figure 1, the nitrogen gas supply is shut off before helium is delivered to either pressurize the test component for outboard leak testing or for spraying helium around the test specimen for inboard leak testing. A helium leak detector that can measure helium leak rates down to 2×10^{-11} atm-cc/s (He) is to be used for leak measurements.

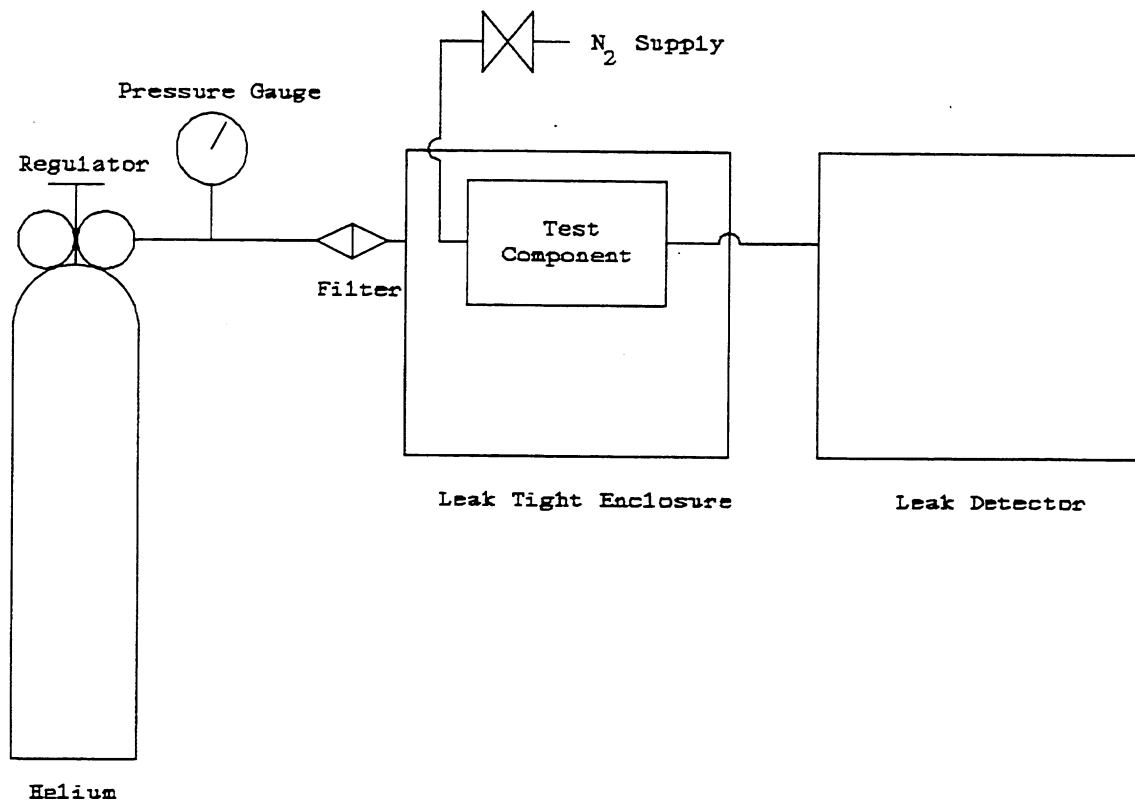


Figure 1 Inboard Helium Leak Test Schematic

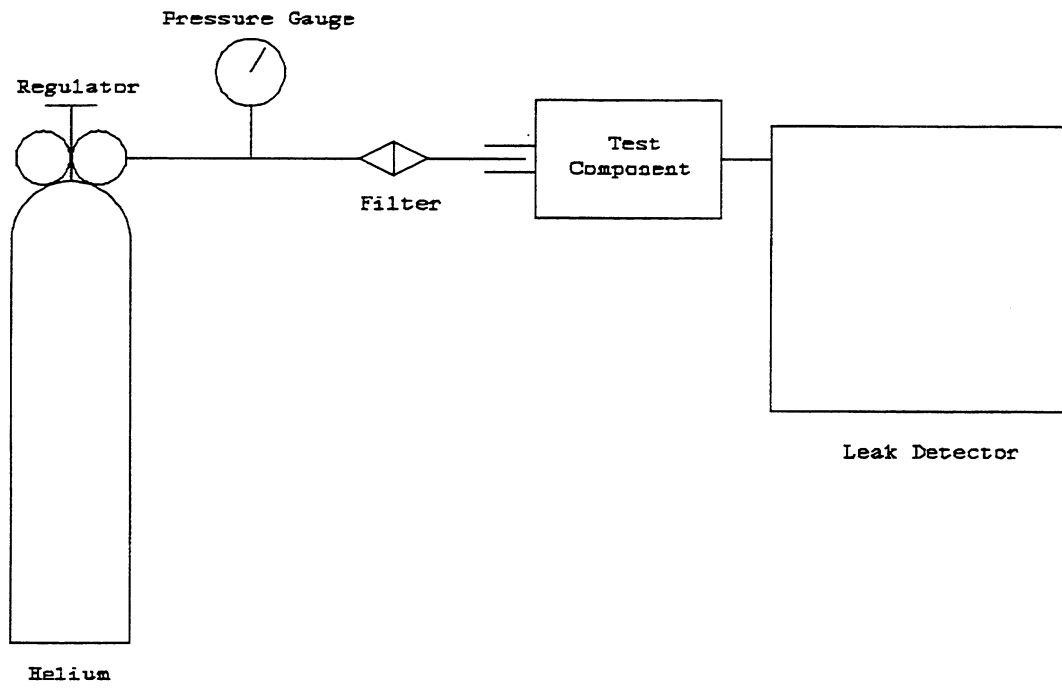


Figure 2 **Across-the-Seat Helium Leak Test Schematic**

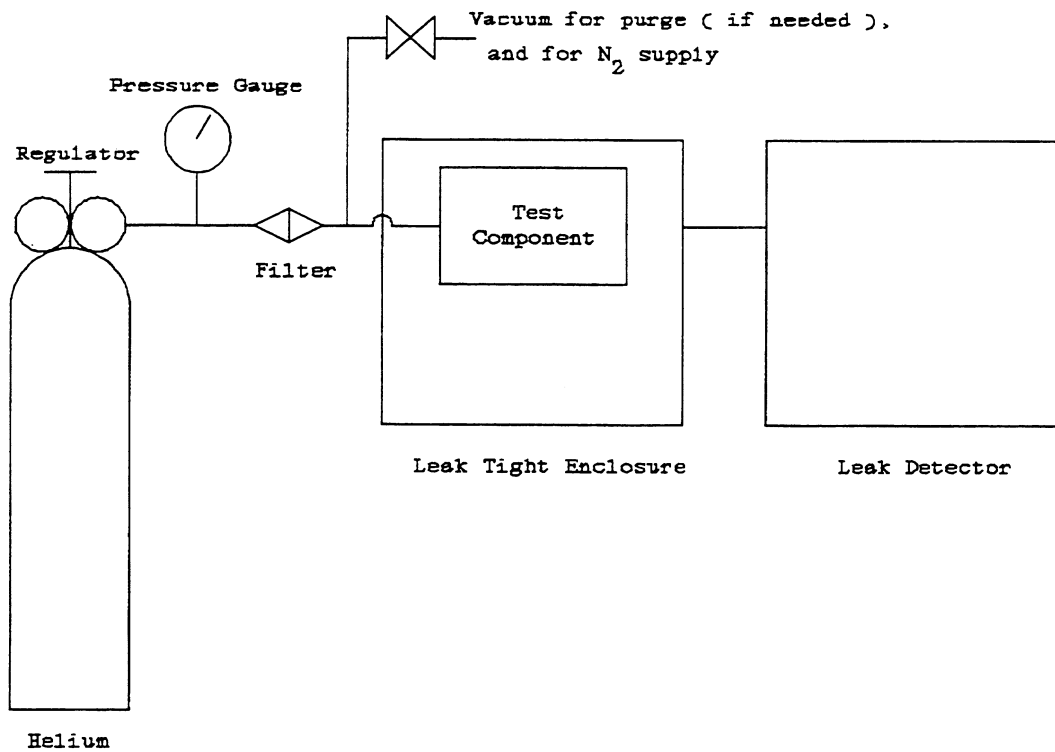


Figure 3 Outboard Helium Leak Test Schematic

4.3 *Test Procedures*

4.3.1 Inboard Leak Test—see Figure 1.

4.3.1.1 Connect one end of the test component to the leak detector with the opposite end sealed. For regulators and valves, open the component. Start the vacuum system of the leak detector and draw the test component down to the operating vacuum of the leak detector, typically a test pressure of about 2 Pa ($2 \cdot 10^{-4}$ torr).

4.3.1.2 Check for gross leaks (greater than $1 \cdot 10^{-7}$ atm cm³/sec) by spraying a small stream of helium around each point of possible leak source. Any gross leaks will be identified by a rapid rise in helium indication on the leak detector. An increase greater than one order of magnitude in indicated helium (for example, a rise from 10^{-8} to 10^{-7} atm cm³/sec) within a few seconds indicates a gross leak.

4.3.1.3 For leak rates less than $1 \cdot 10^{-7}$ atm cm³/sec, install the component into a confined environment like a gas-tight bag or other enclosure to isolate the various possible leak sources so that they can be tested independently (see Figure 1).

4.3.1.4 Continually purge the gas-tight enclosures for components not under test with nitrogen. Introduce helium into the bag or enclosure around the joint to be tested until it fully displaces the nitrogen present. Monitor the leak rate for a minimum of 15 seconds.

4.3.1.5 Repeat step 4.3.1.4 for each enclosed component.

4.3.2 Across-the-Seat Leak Test—see Figure 2.

4.3.2.1 Attach the outlet port of the test component to the mass spectrometer and leave the inlet port open to the atmosphere with the component tightly closed.

[Note: Obviously, this test can only be performed on components such as valves and regulators, which have seats.]

4.3.2.2 For regulators, using some type of needle tip to inject the helium more accurately, spray helium into the inlet port of the regulator for a minimum of 15 seconds.

[Note: A low pressure inlet condition is felt to represent a worst case test based on current designs.]

For valves, pressurize the inlet port of the valve to the maximum operating pressure of the valve. Observe the leak rate for 15 seconds.

[Note: A high pressure inlet condition is felt to represent a worst case test based on current designs.]

4.3.2.3 Conduct the same across-the-seat test in the reverse direction. Attach the inlet port of the test component to the mass spectrometer and introduce helium into the outlet port. Repeat step 4.3.2.2.

- 4.3.3 Outboard Leak Test—see Figure 3.
- 4.3.3.1 Install the component into a vacuum chamber. For regulators and valves, open the component. A leak tight gas flow passage must extend from the test component to the exterior of the vacuum chamber.
- 4.3.3.2 Connect the leak detector to the vacuum chamber and evacuate the chamber to the vacuum level necessary for proper operation of the leak detector, typically about 2 Pa ($2 \cdot 10^{-4}$ torr).
- 4.3.3.3 Evacuate the test component or use a cyclic pressurize/depressurize purge technique of 10 cycles to remove all residual non-helium gases.
- 4.3.3.4 Pressurize the test component with helium up to the maximum operating pressure (as specified by the manufacturer) for the component.
- 4.3.3.5 Maintain the test condition for one minute. A longer test time can result in permeation of nonmetallic parts of the component. Record the measured leak rate.
- 4.4 *Data Analysis*
- 4.4.1 Complete Table 2. (See Section 5.)
- 4.4.2 Calculate the standard leak rate. Refer to Section 3.5.

5. Illustrations

5.1 For schematic diagrams of the inboard helium leak test, the across-the-seat helium leak test, and the outboard helium leak test, see Figures 1, 2, and 3 in Section 4.2.3.

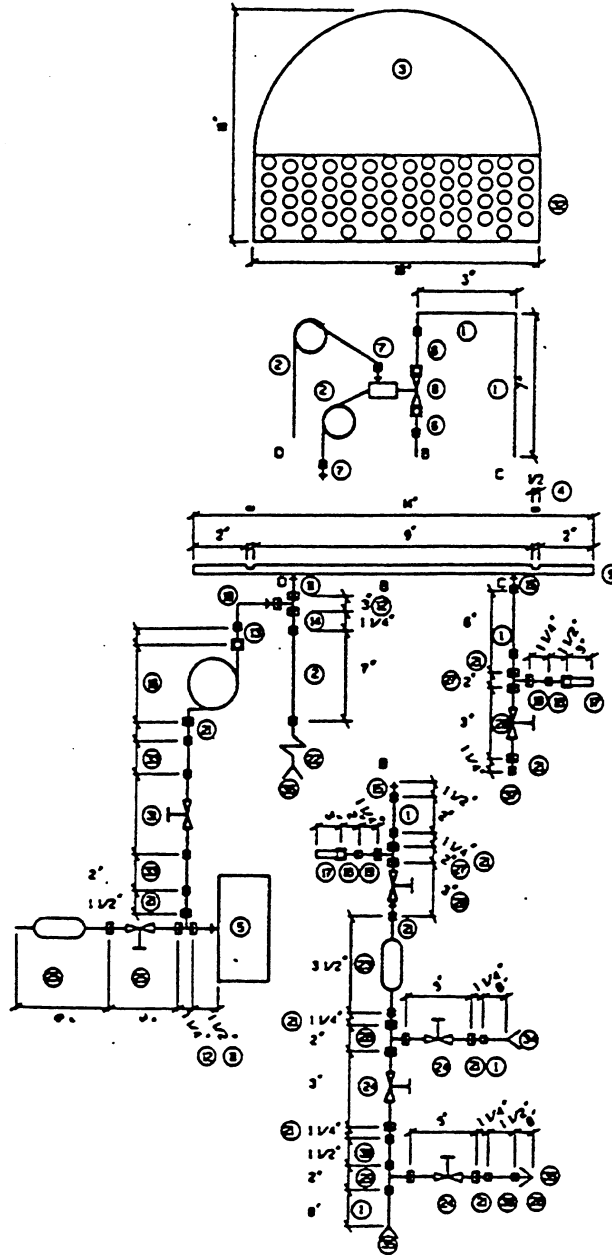


Figure 4 Schematic Diagram of the Recommended Test Apparatus

Table 1 Helium Leak Test

Component Identification	_____	
Test Number	_____	
Date	_____	
Operator Name	_____	
Maximum Rated Pressure (MRP)	_____	kPa
Helium Concentration (100% Recommended)	_____	%
Inboard Leak Test		
Gross Leaks by Helium Spray	Yes _____	No _____
Pressure in Component and Leak Detector	_____	Pa
Measured Leak Rate	_____	ml/sec.
Standard Leak Rate (calculated)	_____	ml/sec.
Across-The-Seat Leak test		
Pressure in Component and Leak Detector	_____	Pa
Measured Leak Rate	_____	ml/sec.
Standard Leak Rate (calculated)	_____	ml/sec.
Outboard Leak Test		
Evacuated Pressure of Component	_____	Pa
Pressure of Helium in Component (100% MRP)	_____	Pa
Measured Leak Rate	_____	ml/sec.
Standard Leak Rate (calculated)	_____	ml/sec.

APPENDIX
(Supplementary Information)

X1. Helium Leak Rate Test Method Apparatus

Table X1.1 Parts for the Recommended Helium Leak Rate Test Method Apparatus

Item number	Description
1	1/4 in. dia EP SS tube, Cross Process #50X0250035
2	1/8 in. dia EP SS tube
3	10 1/3 in. o.d. x 18 in. high Pyrex bell jar, Fisher Scientific #02628B
4	1/8 in. thick rubber gasket for bell jar, fabricated from sheet gasket material
5	Helium leak detector, Alcatel ASM 110 Turbo CL
6	1/4 in. tube to 1/4 in. VCR tube fitting, Swagelok #SS -4-VCR-6-400
7	1/8 in. tube to 10/32 mpt connector, fabricated
8	Test component
9	SS bell jar base, fabricated
10	1/4 in. mpt to 1/4 in. tube male elbow, Swagelok #SS -8M0-2-4RT
11	1/4 in. mpt to 1/4 in. mpt nipple, Cajon #SS -4-HN
12	1/4 in. fpt tee, Swagelok #SS -4-T
13	1/4 in. mpt to 1/4 in. tube male connector, Swagelok #SS -400-1-4
14	1/4 in. mpt to 1/8 in. tube male connector, Swagelok #SS -200-1-4
15	1/4 in. mpt to 1/4 in. tube male connector, Cajon ultratorr #SS -4-UT-1-2
16	6 ft SS flexible hose 1/4 in. fpt on each end
17	Pressure transducer, Omega #PX302-300GV
18	1/4 in. fpt to 1/4 in. WVCO connector, Swagelok #SS -4-WVCO-7-4
19	1/4 in. fpt to 1/4 in. VCO connector, Swagelok #SS -4-VCO-1-4
20	10,000 psi valve, Sno-Trik #SS-410-FP
21	1/4 in. tube to 1/4 in. mpt connector, Swagelok #SS -400-1-4
22	Four-way solenoid operated valve, W.W. Grainger #5A541
23	Point-of-use filter, Balston #type 9966 -07-65
24	1/4 in. mpt gate valve, Matheson #103
25	Calibrated helium leak tube, Alcatel #7732
26	1/8 in. plastic tubing
27	1/4 in. fpt street tee, Swagelok #SS -4-ST
28	1/4 in. tee, Swagelok #SS -4-S-T
29	1/4 in. female branch tee, Swagelok #SS -400-34TTF
30	1/4 in. to 1/8 in. tube reducing union, Swagelok #SS -400-6-2
31	Valve, Nupro #SS-4BG
32	Bell jar Shield, perforated aluminum sheet, McMaster-Carr #9282T24
33	1/4 in. tube nut union, fabricated
34	Nitrogen gas inlet
35	Helium gas inlet
36	Compressed air line for actuator
37	Exhaust/pumping port
38	Helium spray outlet

[Disclaimer: Products are identified with manufacturer's name solely for the purpose of defining products to be used in the construction of the recommended test apparatus. The use of manufacturer's name does not constitute an endorsement of their product. Equivalent products can be substituted without altering the function or quality of the test.]

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