



Standard Test Methods for Leakage Measurement Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Hood Mode¹

This standard is issued under the fixed designation E 1603; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope

1.1 These test methods cover procedures for testing the sources of gas leaking at the rate of 4.4×10^{-14} moles/s (1×10^{-9} standard-cm³/s at 0°C) or greater. These test methods may be conducted on any object that can be evacuated and to the other side of which helium or other tracer gas may be applied. The object must be structurally capable of being evacuated to pressures of 0.1 Pa (approximately 10^{-3} torr).

1.2 Three test methods are described;

1.2.1 *Test Method A*—For the object under test capable of being evacuated, but having no inherent pumping capability.

1.2.2 *Test Method B*—For the object under test with integral pumping capability.

1.2.3 *Test Method C*—For the object under test as in Test Method B, in which the vacuum pumps of the object under test replace those normally used in the leak detector (LD).

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standard:*

E 1316 Terminology for Nondestructive Examination²

2.2 *Other Documents:*³

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing³

ANSI/ASNT CP-189 ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel³

3. Terminology

3.1 *Definitions*—For definitions of terms used in these test methods, see Terminology E 1316.

4. Summary of Test Methods

4.1 These test methods require a helium LD that can provide a system sensitivity of 10 % or less of the intended leakage rate to be measured.

4.2 *Test Method A*—This test method is used to helium leak test objects that are capable of being evacuated to a reasonable test pressure by the LD pumps during an acceptable length of time (Fig. 1). This requires that the object be clean and dry. Auxiliary vacuum pumps having greater capacity than those in the LD may be used in conjunction with them. The leak test sensitivity will be reduced under these conditions.

4.3 *Test Method B*—This test method is used to leak test equipment that can provide its own vacuum (that is, equipment that has a built-in pumping system) at least to a level of a few hundred pascals (a few torr) or lower. Refer to Fig. 2.

4.4 *Test Method C*—When a vacuum system is capable of producing internal pressures of less than 2×10^{-2} Pa (2×10^{-4} torr) in the presence of leaks, these leaks may be located and evaluated by the use of either a residual gas analyzer (RGA) or by using the spectrometer tube and controls from a conventional MSLD, provided that the leakage is within the sensitivity range of the RGA or MSLD under the conditions existing in the vacuum system. Refer to Fig. 3.

5. Personnel Qualification

5.1 It is recommended that personnel performing leak testing attend a dedicated training course on the subject and pass a written examination. The training course should be appropriate for NDT Level II qualification in accordance with Recommended Practice SNT-TC-1A or ANSI/ASNT Standard CP-189.

6. Significance and Use

6.1 *Test Method A*—This test method is the most frequently used in leak testing components. Testing of components is correlated to a standard leak, and the actual leak rate is measured. Acceptance is based on the maximum system allowable leakage. For most production needs, acceptance is based on acceptance of parts leaking less than an established, leakage rate, which will ensure safe performance over the

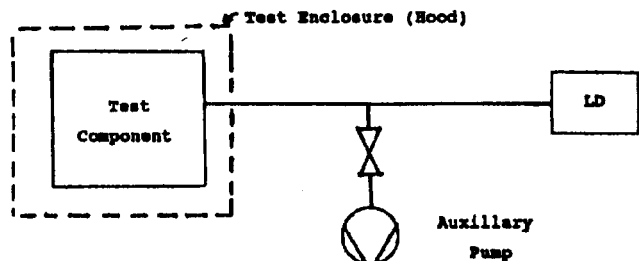


FIG. 1 Test Method A

¹ These test methods are under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and are the direct responsibility of Subcommittee E07.08 on Leak Testing Method.

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² *Annual Book of ASTM Standards*, Vol 03.03.

³ Available from American Society for Nondestructive Testing, 1711 Arlington Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

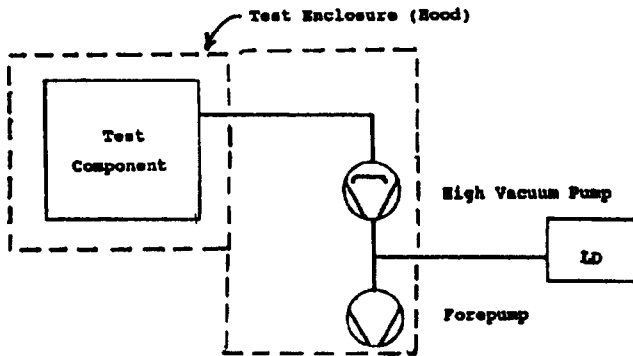


FIG. 2 Test Method B

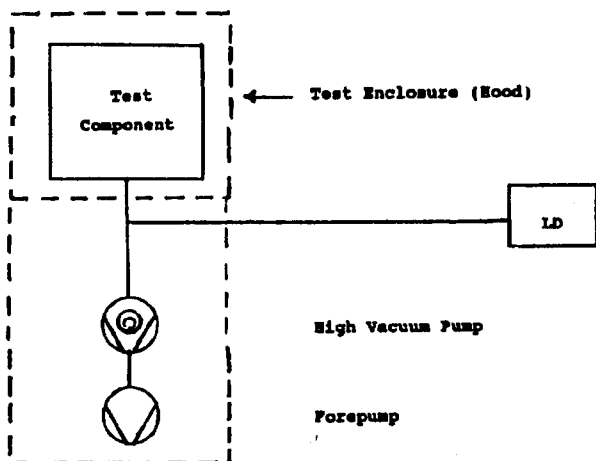


FIG. 3 Test Method C

projected life of the component. Care must be exercised to ensure that large systems are calibrated with the standard leak located at a representative place on the test volume. As the volume tends to be large ($>1 \text{ m}^3$) and there are often low conductance paths involved, a check of the response time as well as system sensitivity should be made.

6.2 Test Method B—This test method is used for testing vacuum systems either as a step in the final test of a new system or as a maintenance practice on equipment used for manufacturing, environmental test, or conditioning parts. As with Test Method A, the response time and a system sensitivity check may be required for large volumes.

6.3 Test Method C—This test method is to be used only when there is no convenient method of connecting the LD to the outlet of the high-vacuum pump. If a helium LD is used and the high-vacuum pump is an ion pump or cryopump, leak testing is best accomplished during the roughing cycle, as these pumps leave a relatively high percentage of helium in the high-vacuum chamber. This will limit the maximum sensitivity that can be obtained.

7. Interferences

7.1 Series leaks with an unpumped volume between them present a difficult if not impossible problem in helium leak testing. Although the trace gas enters the first leak readily enough since the pressure difference of helium across the first leak is approximately one atmosphere, it may take many

hours to build up the partial pressure of helium in the volume between the two leaks so that enough helium enters the vacuum system to be detected by the LD. This type of leak occurs frequently under the following conditions:

- 7.1.1 Double-welded joints and lap welds,
- 7.1.2 Double O-rings,
- 7.1.3 Threaded joints,
- 7.1.4 Ferrule and flange-type tubing fittings,
- 7.1.5 Casting with internal voids,
- 7.1.6 Flat polymer gaskets, and
- 7.1.7 Unvented O-ring grooves.

7.2 In general, the solution is proper design to eliminate these conditions; however, when double seals must be used, an access port between them should be provided for attachment to the LD. Leaks may then be located from each side of the seal. The access port can be sealed or pumped continuously after repair by a holding pump (large vacuum system).

7.3 Temporarily plugged leaks often occur because of poor manufacturing techniques. Water, cleaning solvent, plating, flux, grease, paint, etc. are common problems. These problems can be eliminated to a large extent by proper preparation of the parts before leak testing. Proper degreasing, vacuum baking, and testing before plating or painting are desirable.

7.4 The time constant for evacuation and for the rise of the helium signal is inversely proportional to the pumping speed and directly proportional to the volume being evacuated.

$$\tau = V/S$$

Low-conductance tubing, or any other flow impedance, can reduce the pumping speed of the system very significantly, thus extending the system response time constant. If such an impedance connects two volumes under test, a LD connection to each volume should be provided.

7.5 When unusually long pumping times are necessary, all of the connections not being tested should be protected from continuous exposure to the helium. This will reduce undesired high-helium background levels due to permeation of helium through the O-rings. This can be effected by double-seals (with evacuation of the space between), or sometimes by more informal shielding approaches.

TEST METHOD A—HELIUM LEAK TESTING OF COMPONENTS/SYSTEMS USING THE LD

8. Apparatus

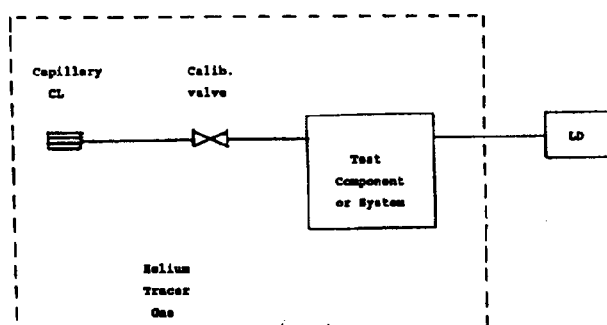
8.1 Leak Detector, having a minimum detectable leak rate as required by the test sensitivity.

8.2 Auxiliary Pumps, capable of evacuating the object to be tested to a low enough pressure that the LD may be connected.

8.3 Suitable Connector and Valves, to connect to the LD test port. Compression fitting and metal tubing should be used in preference to a vacuum hose.

8.4 Standard Leaks of Both Capsule Type (Containing Its Own Helium Supply) and Capillary Type, an actual leak that is used to simulate the reaction of the test system to a helium leak. The leak rate of the standard leak used for the system calibration shall be equal to or less than one half of the acceptance level (maximum permissible leakage rate). Temperature correction of the permeation capsule-type standard

Calibration Setup with a Capillary CL



Calibration Setup with a Capsule CL

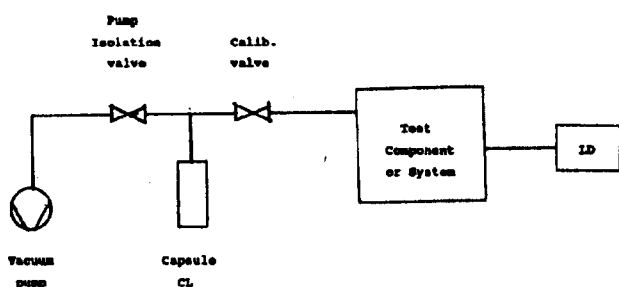


FIG. 4 Calibration Setups

leaks should be performed when the ambient temperature has a difference of 3°C (5°F) from the calibration temperature of the standard leak. The leakage rate error may become significant (>12 %) without temperature correction.

8.5 *Vacuum Gage*, to read the pressure before the LD is connected.

8.6 *Helium Tank and Regulator*, with attached helium probe hose and jet.

8.7 *Test Component/System Enclosure (Hood)*—Either a rigid structure or heavy plastic cover to contain and surround the test part totally in helium tracer gas.

9. Instrument Calibration

9.1 Attach the capsule leak to the LD and tune the LD to achieve the desired sensitivity scale in accordance with the manufacturer's instructions. Allow sufficient time for the flow rate from the capsule leak to equilibrate. The permeation-type capsule leak should be stored with the shutoff valve (if present) open, and the leak should be allowed to equilibrate to ambient temperature for several hours. Capillary-type capsule leaks should be stored with the shutoff valve closed to prevent unwanted decay of the reservoir pressure.

9.2 Adjust the LD readout to correspond to the temperature-corrected standard leak value in accordance with the manufacturers' instructions.

NOTE 1—Valve closures may be accomplished automatically on some LDs, and some counterflow-type MSLDs require continued use of the roughing pump during testing. Refer to the manufacturer's operating manual.

9.3 Disconnect the capsule standard leak from the LD and connect the test system to the LD.

10. System Calibration and Test Procedure

10.1 For small-volume tests (a few litres and less) or when the standard leak cannot be attached directly to the test component, the instrument calibration shall be used for the system calibration. The correction factor (CF) used to multiply the instrument calibration value for the system leak rate is one.

10.2 For large-volume systems, attach one of the standard leaks to the test system at a location that provides the lowest conductance path to the LD.

NOTE 2—If using a capsule leak, open the calibrated leak (CL) and pump isolation valves, and close the calibration valve. Turn on the CL vacuum pump. Refer to Fig. 4.

10.3 Evacuate the device to be tested until near equilibrium pressure is reached on the rough vacuum gage. Open the valve to the LD and check the background helium concentration. When the helium background is equal to or less than one half the acceptance level (maximum permissible leakage rate), close the valve(s) to the roughing pumps.

10.4 System Calibration or Procedure Qualification:

10.4.1 Record the helium background level.

10.4.2 Open the valve of the system standard leak (calibration valve) attached to the test component/system (Fig. 4).

NOTE 3—If using a capillary leak, apply helium of one atmosphere to the standard leak. For the capsule standard leaks, close the pump isolation valve immediately prior to opening the calibration valve.

10.4.3 Graph the LD response as a function of time until a steady-state condition is reached. Refer to Fig. 5.

10.4.4 Close the standard leak valve, and reduce the helium background of the test component/system to the same level as that obtained before system calibration. It may be necessary to open roughing pump valves and use the roughing pumps to expedite the reduction of the helium background.

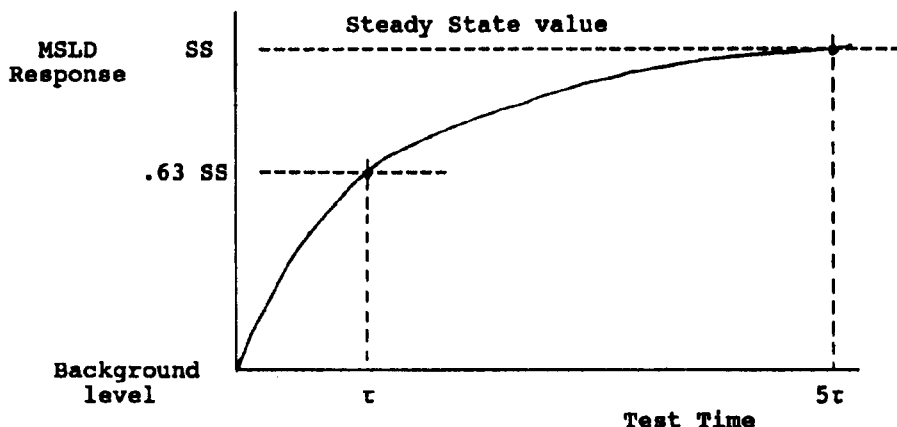
10.4.5 Calculate the LD CF for adjusting the instrument calibration reading to a system calibration reading. For tests on large-volume systems, the amplitude response of a leak in the system is less than the amplitude response from the instrument calibration standard leak.

10.4.5.1 This CF should be calculated at either the time at which a steady-state response (SS) is reached or at the time at which the LD response is 63 % of the change. This shall be the minimum test period. The formula for the CF at this test time is as follows:

$$CF = \frac{CL_c}{LR - BR}$$

where:

CL_c = temperature-corrected standard leak rate,



v = τ = system time constant
 τ = - v = Volume of test system
 s = s = Pumping speed of system
 τ = 63% of amplitude change caused by CL
 5τ = 99.9% of amplitude change (steady state condition)

FIG. 5 System Time Constant

LR = indicated LD reading (0.63 SS or SS) at the end of the test period (τ or 5τ respectively), and
 BR = background reading (initial reading).

10.5 Set the LD on the appropriate range.

10.6 Close the valves to the roughing pump(s) if they were opened to expedite the reduction of the helium background.

10.7 Fill the test component/system enclosure with helium or place the test part in the enclosure. Large enclosures should be purged sufficiently to remove the trapped air. For any concentration other than 100 % helium atmosphere, the system acceptance level should be adjusted for the reduced sensitivity.

10.8 Keep the test component/system in the test enclosure for the test period established in accordance with 10.4.5 and record the LD reading at the end of the period.

NOTE 4—The system time response may be longer than the instrument response time.

10.9 Calculate the system leakage by multiplying the LD reading by the CF to obtain the corrected system leakage. For tests in which a system calibration was not performed (that is, test volumes less than a few litres), use a CF of one.

10.10 Write a test report, or otherwise indicate the test results as required.

TEXT METHOD B—HELIUM LEAK TESTING OF VACUUM EQUIPMENT AND SYSTEMS THAT HAVE INTEGRAL PUMPING SYSTEMS OF THEIR OWN

11. Apparatus

11.1 Helium LD—Same apparatus as Section 8.

12. Preparation of Apparatus

12.1 Connect the inlet valve of the LD of the foreline of the object to be tested. If possible, insert a valve in the foreline between the mechanical pump and the LD connec-

tion. All connections should have as high a conductance as is practical.

12.2 Attach the standard leak to the vacuum chamber of the object to be tested and as far as practical from the inlet to the pumping system. Refer to Fig. 4.

12.3 Operate the equipment until equilibrium vacuum is reached in the vacuum chamber.

12.4 Slowly open the inlet valve to the LD. Do not allow the LD pressure to exceed the manufacturer's recommendations.

12.5 If the inlet valve can be opened fully without exceeding the safe LD operating pressure, close the equipment roughing pump valve slowly. If this valve can be closed completely, the maximum sensitivity of the test will be achieved.

13. Instrument Calibration

13.1 See Section 9.

14. System Calibration and Test Procedure

14.1 See Section 10.

TEST METHOD C—USE OF RGA OR OF HELIUM MSLD SPECTROMETER TUBE AND CONTROL IN LEAK TESTING (NO VACUUM SYSTEM IN THE LD)

15. Apparatus

15.1 RGA or MSLD and Controls, tuneable to the trace gas.

15.2 Standard Leak, of approximately the size of the minimum leak to be located.

15.3 Suitable Fitting and Isolating Valves, for attachment to the high-vacuum chamber.

15.4 Liquid Nitrogen Cold Traps, to be used if the system contains condensable vapors harmful to the RGA or the MSLD.

16. Preparation of Apparatus

16.1 Attach the RGA or the MSLD tube to the high-vacuum section of the test object to be tested. The connection should be located near the pumped end of the system and attached with as short and as large a diameter tube as practical. Maximum test sensitivity is obtained when the high-vacuum pumps are throttled, by means of the high-vacuum valve, so as to maintain as high a pressure in the volume under test as is safe for the LD. An isolation valve may be used between the detector and the system to allow servicing the detector without loss of vacuum in the system and to protect the detector from contamination when not in use. When a liquid nitrogen trap and isolating valve are both being used, the cold trap should be located between the test object and the isolating valve.

16.2 Attach a standard capillary or permeation leak to the system as far away from the pumps as possible, using the lowest conductance path. A small high-vacuum valve should be used between the standard leak and the system, and a dust cap should be provided for the capillary standard leak if it is

to be left in place. Refer to Fig. 4 for the calibration setup.

17. Instrument Calibration

17.1 See section 9.

18. System Calibration and Test Procedure

18.1 See Section 10.

19. Precision and Bias

19.1 *Precision*—The precision of these test methods will vary with each instrument and the sensitivity level of the leak test.

19.2 *Bias*—The bias of the leak test will be equal to that of the standard leak used for the system calibration when test conditions are the same as the system operating conditions.

20. Keywords

20.1 helium leak test; helium mass spectrometer leak test; hood leak test; leak testing; mass spectrometer leak test

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