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Standard Test Methods for Leaks Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Tracer Probe Mode[1,2]

This standard is issued under the fixed designation E 498; 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 reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 These test methods cover procedures for testing and locating the sources of gas leaking at the rate of 4.5×10^{-14} mol/s (1×10^{-9} Std cm ^{3}/s)[3] or greater. The test may be conducted on any object to be tested that can be evacuated and to the other side of which helium or other tracer gas may be applied.

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.

1.3 *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.* A specific hazard statement can be found in 19.2.

2. Referenced Documents

2.1 *ASTM Standards:*

E 1316 Terminology for Nondestructive Examinations[4]

2.2 *Other Documents:*

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing[5]

ANSI/ASNT CP-189 ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel[5]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this standard, see Terminology E 1316, Section E.

4. Summary of Test Methods

4.1 These test methods require a helium leak detector that is capable of detecting a leak of 4.5×10^{-15} mol/s (1×10^{-10} Std cm^3/s).[3]

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 leak detector pumps in an acceptable length of time. This requires that the object be clean and dry and usually no larger than a few cubic feet in volume. Also to cope with larger volumes or relatively“ dirty” devices, auxiliary vacuum pumps having greater capacity than those in the mass spectrometer leak detector (MSLD) may be used in conjunction with the MSLD. 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.

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, of course, that the leakage is within the sensitivity range of the RGA or MSLD under the conditions existing in the vacuum system.

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 according to Recommended

[1] These test methods are under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.08 on Leak Testing.

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[2] (Atmospheric pressure external, vacuum internal). This document covers the Tracer Probe Mode described in Terminology E 1316.

[3] The gas temperature is referenced to 0°C. To convert to another gas reference temperature, T_{ref}, multiply the leak rate by (T_{ref} + 273)/273.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

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Practice No. SNT-TC-1A of the American Society for Nondestructive Testing or ANSI/ASNT Standard CP-189.

6. Significance and Use

6.1 Test Method A is the most frequently used in leak testing components which are structurally capable of being evacuated to pressures of 0.1 Pa (approximately 10^{-3} torr). Testing of small components can be correlated to calibrated leaks, and the actual leak rate can be measured or acceptance can be based on a maximum allowable leak. For most production needs acceptance is based on acceptance of parts leaking less than an established standard which will ensure safe performance over the projected life of the component. Care must be exercised to ensure that large systems are calibrated with reference leak at a representative place on the test volume. Leak rates are determined by calculating the net gain or loss through a leak in the test part that would cause failure during the expected life of the device.

6.2 Test Method B 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 for conditioning parts. As the volume tends to be large, a check of the response time as well as system sensitivity should be made. Volume of the system in liters divided by the speed of the vacuum pump in L/s will give the response time to reach 63 % of the total signal. Response times in excess of a few seconds makes leak detection difficult.

6.3 Test Method C is to be used only when there is no convenient method of connecting the leak detector to the outlet of the high vacuum pump. If a helium leak detector 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 obscure all but large leaks, and the trace gas will quickly saturate the pumps.

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 MSLD. 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 Casings with internal voids.

7.1.6 Flat polymer gaskets.

7.1.7 Unvented O-ring grooves.

7.2 In general, the solution is in 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 MSLD. Leaks may then be located from each side of the seal and after repair, the access port can be sealed or pumped continuously by a “holding” pump (large vacuum systems).

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

7.4 In a device being tested, capillary tubing located between the leak and the leak detector can make leak testing extremely difficult as test sensitivity is drastically reduced and response time increased. If there is a volume at each end of the capillary, each such volume should be attached to the leak detector during testing. If this is impossible, the device should be surrounded with a helium atmosphere while attached to the leak detector for a long time to assure leak tightness. When unusually long pumping times are necessary, the connections to the leak detector (and all other auxiliary connections) that are exposed to the helium should be double-sealed and the space between the seals evacuated constantly by a small auxiliary roughing pump to avoid allowing helium to enter the system through seals that are not a part of the device to be tested.

TEST METHOD A—HELIUM LEAK TESTING OF SMALL DEVICES USING THE MSLD

8. Apparatus

8.1 *Helium Mass Spectrometer 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 so that the MSLD may be connected.

NOTE 1—If the object under test is small and clean and the MSLD has a built-in roughing pump, the auxiliary pumps are not required.

8.3 *Suitable Connectors and Valves*, to connect to the MSLD test port. Compression fittings and metal tubing should be used in preference to vacuum hose.

8.4 *Standard Leaks of Both Capsule Type (Containing its own Helium Supply) and Capillary Type (an Actual Leak which is Used to Simulate the Reaction of the Test System to Helium Spray)*—The leak rate from the capsule-type leak should be adequate to demonstrate the minimum allowable sensitivity of the MSLD. The capillary type should be slightly smaller than the test requirement.

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

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

9. Calibration of MSLD

9.1 Attach the capsule leak to the MSLD and tune the MSLD to achieve maximum sensitivity in accordance with the manufacturer’s instruction. Allow sufficient time for the flow rate from the capsule leak to equilibrate. The 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.

10. Procedure

10.1 Evacuate the device to be tested until near equilibrium pressure is reached on the rough vacuum gage. Open the valve to the leak detector and close the valve to the roughing pumps.

NOTE 2—This procedure will be automatic where the device is relatively small and clean and where an automatic MSLD is used without external pumps. Do not allow the pressure in the spectrometer tube to exceed the manufacturer's recommendation. This means in some cases that the MSLD inlet valve can only be partially opened. Maximum test sensitivity will be achieved with the inlet valve completely open and the auxiliary pump valve completely closed. However, testing at reduced sensitivity levels can be done as long as the inlet valve can be opened at all.

10.2 Adjust the helium probe jet so that a small flow of helium is coming from the tip.

10.3 Set the leak detector on the appropriate lowest range.

10.4 Pass the tip of the helium probe by the end of the standard capillary leak at a rate similar to the scan rate at which the object under test will subsequently be tested. Note the deflection of the leak detector output meter. If the probing rate is increased, the test sensitivity will be decreased, and if the probing rate is decreased, the test sensitivity will be increased. Consequently, when a leak is indicated during leak testing, it will be necessary to move the probe slowly backward until a maximum signal occurs. The approximate leak size can be determined by multiplying the size of the standard leak by the maximum reading obtained from the located leak and dividing by the maximum reading obtained when the helium was applied directly to the standard leak.

10.5 Starting at the most suspect part of the object to be tested, spray the smallest amount of helium on the part that will give a signal when sprayed on the capillary leak. If there are drafts, work up opposite to the direction of air flow.

10.6 When a leak is pinpointed, it should be first evaluated if desired, then sealed either permanently (preferable) or temporarily in such a manner as to allow repair at a later time, before proceeding to look for additional leaks. If the leak is so large that the MSLD output saturates (that is, goes to the top of the highest range), it can be evaluated by reducing the sensitivity of the test until the signal from the standard leak is barely readable. This can be done by opening the roughing valve and partially closing the MSLD inlet valve or by reducing the sensitivity of the leak detector itself if more convenient. If the unknown leak still produces an off-scale signal, it will be necessary to use a larger standard leak and far less test sensitivity or to use a reduced percentage of helium in the probe. (For instance, a probe gas concentration of 1 % helium and 99 % nitrogen would reduce the apparent sensitivity by a factor of 100.)

10.7 After the first leak has been found and sealed, the same technique is continued until all leaks have been similarly treated.

10.8 After all leaks have been found and repaired, it is desirable to enclose the entire device in a helium envelope (which can be a plastic bag or a large bell jar) to determine the total device integrity.

10.9 This step could also be done first and would eliminate the necessity for probing if no leakage is shown. However, if there are any materials in the device that are pervious to helium, doing this step first may build up the helium background to such a degree that subsequent probing would be insufficiently sensitive.

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

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

11. Apparatus

11.1 *Helium MSLD*—Same apparatus as Section 8.

12. Calibration of MSLD

12.1 See Section 9.

13. Preparation of Apparatus

13.1 Connect inlet valve of MSLD to foreline of object to be tested. If possible, insert a valve in the foreline between the mechanical pump and the MSLD connection. All connections should have as high a conductance as is practical.

13.2 Attach the standard capillary leak to the vacuum chamber of the object to be tested and as far as practical from the inlet to the pumping system.

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

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

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

14. 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 MSLD)

15. Apparatus

15.1 *RGA or MSLD* and controls tuneable to the trace gas.

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

15.3 *Suitable Fittings and Isolating Valve*, for attachment to the high vacuum chamber.

15.4 *Liquid Nitrogen Traps*, to be used if the system contains 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 leak 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. Minimum test sensitivity is obtained when the high-vacuum pumps are throttled, by means of the highvacuum valve, so as to maintain as high a pressure in the volume under test as is

safe for the MSLD. If two diffusion pumps are used in series on the system and the intermediate pressure is less than 1×10^{-2} Pa (approximately 1×10^{-4} Torr), the detector should be attached between the two pumps for maximum sensitivity. 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. A liquid nitrogen trap should be used between the detector and the system if vapors harmful to the detector are present in the system.

16.2 Attach the standard capillary leak to the system as far away from the pumps as possible. A small high-vacuum valve should be used between the standard leak and the system and a dust cap should be provided for the standard leak if it is to be left in place.

17. Calibration

17.1 See Section 9.

18. Test Procedure

18.1 Evacuate the object to be tested and the MSLD until equilibrium pressure is reached.

18.2 Turn on the MSLD and allow it to stabilize in accordance with the manufacturer's instructions.

18.3 Apply trace gas to the leak. Surround the leak with trace gas at small constant flow, but do not pressurize.

18.4 When equilibrium pressure of the trace gas is reached as shown by the MSLD output reading becoming stable after rising when trace gas was first applied, use the tuning adjustments of the MSLD to peak the signal in accordance with the manufacturer's instructions.

18.5 If trace gas is undetectable, and there is a valve between the pumps and the object to be tested, gradually close the valve until a reasonable signal is observed. Check by removing the trace gas from the leak. If the output drops when trace gas is removed and rises when trace gas is applied, leaks of the size of the standard leak and larger can be detected by applying trace gas to suspect joints in the system for a similar length of time. If a very substantial signal is obtained from the standard leak, smaller leaks may also be detected. (For example, if an output reading of 1000 divisions is obtained from a 4.5×10^{-11} mol/s (1×10^{-6} Std cm^3/s)[3] calibrated leak in 10 s, then a reading of 10 divisions will be obtained from a 4.5×10^{-13} mol/s (1×10^{-8} Std cm^3/s).[3]

18.6 Starting at the top of the system and working down (if the trace gas is lighter than air) probe all suspect areas with trace gas, dwelling as long at each point as it took to obtain unambiguous results from the standard leak. Repair or isolate each leak as it is located to prevent spurious indications from trace gas drifting away from the area being probed.

18.7 When the high-vacuum section of the system has been tested, the diffusion pump, foreline hardware, and the mechanical pumps can be tested by probing, although the response time will be greater and the test sensitivity will be lower. Do not probe the exhaust of the mechanical pump since the trace gas will become entrapped in the pump, causing long-lasting background problems.

18.8 Write a test report or otherwise indicate test results as required.

19. Precision and Bias

19.1 *Precision*—Replicate tests by the same operator for Test Method A should not be considered suspect if no more than 0.1 % of the previously accepted devices are found to be rejects. If leak rates are recorded, test results should be considered suspect if leaks of 4.5×10^{-12} to 4.5×10^{-9} mol/s (10^{-7} to 10^{-4} Std cm^3/s)[3] vary by more than ±10 %. Leak rates smaller than 4.5×10^{-12} mol/s (1×10^{-7} Std cm^3/s)[3] should be considered suspect if they vary by more than ±25 %.

19.2 *Bias*—Bias for measurement of leaks are typically ± 25 % for leaks in the range of 4.5×10^{-12} to 4.5×10^{-9} mol/s (10^{-7} to 10^{-4} Std cm^3/s).[3] Bias will increase for smaller leaks unless the test permits enclosing the device being tested with a known concentration of helium. Replicate tests made by another facility for Test Method A should not be considered suspect if less than 1 % of the previously accepted parts are found to be rejects. (**Caution**: Spraying helium from a valved tube will dilute the helium entering the leak with air causing a substantial change in bias).

20. Keywords

20.1 bell jar leak test; bomb mass spectrometer leak test; helium lead testing; helium leak test; leak testing; mass spectrometer leak testing; sealed object mass spectrometer leak test

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