Designation: E499/E499M – 11 (Reapproved 2017)

Standard Practice for Leaks Using the Mass Spectrometer Leak Detector in the Detector Probe Mode[1,2]

This standard is issued under the fixed designation E499/E499M; 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 standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This practice covers procedures for testing and locating the sources of gas leaking at the rate of 1×10^{-7} Pa m^3/s (1×10^{-8} Std cm^3/s)[3] or greater. The test may be conducted on any device or component across which a pressure differential of helium or other suitable tracer gas may be created, and on which the effluent side of the leak to be tested is accessible for probing with the mass spectrometer sampling probe.

1.2 Two test methods are described:

1.2.1 *Test Method A*—Direct probing, and

1.2.2 *Test Method B*—Accumulation.

1.3 *Units*—The values stated in either SI or std-cc/sec units are to be regarded separately as standard. The values stated in each system may not be exact equivalents: therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[4]

E1316 Terminology for Nondestructive Examinations

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 E1316, Section E.

4. Summary of Practice

4.1 Section 1.8 of the Leakage Testing Handbook[6] will be of value to some users in determining which leak test method to use.

4.2 The test methods covered in this practice require a leak detector with a full-scale readout of at least 1×10^{-6} Pa m^3/s (1×10^{-7} Std cm^3/s)[3] on the most sensitive range, a maximum 1-min drift of zero and sensitivity of ±5 % of full scale on this range, and ±2 % or less on others (see 7.1). The above sensitivities are those obtained by probing an actual standard leak in atmosphere with the detector, or sampling, probe, and *not* the sensitivity of the detector to a standard leak attached directly to the vacuum system.

4.3 *Test Method A, Direct Probing* (see Fig. 1), is the simplest test, and may be used in parts of any size, requiring only that a tracer gas pressure be created across the area to be tested, and the searching of the atmospheric side of the area be with the detector probe. This test method detects leakage and

[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.08 on Leak Testing Method.

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[2] (Atmospheric pressure external, pressure above atmospheric internal). This document covers the Detector Probe Mode described in Guide E432.

[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] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[5] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[6] Marr, J. William, "Leakage Testing Handbook," prepared for Liquid Propulsion Section, Jet Propulsion Laboratory, National Aeronautics and Space Administration, Pasadena, CA, Contract NAS 7-396, June 1961.

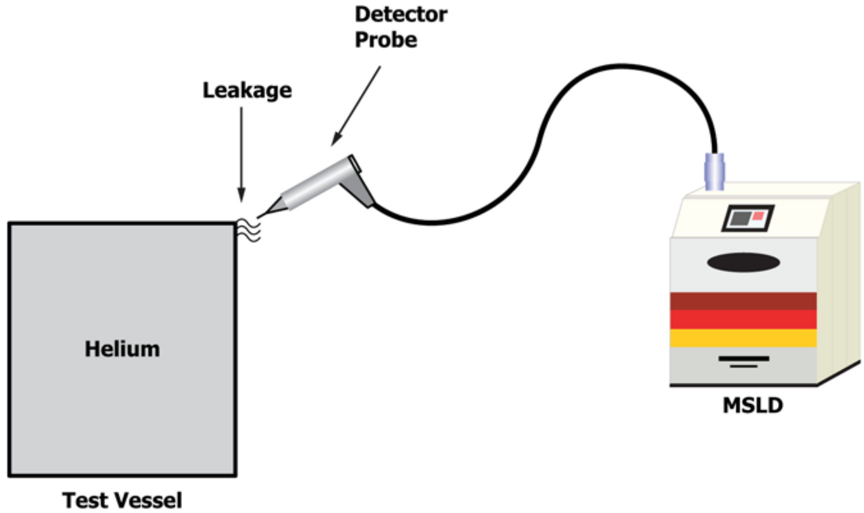
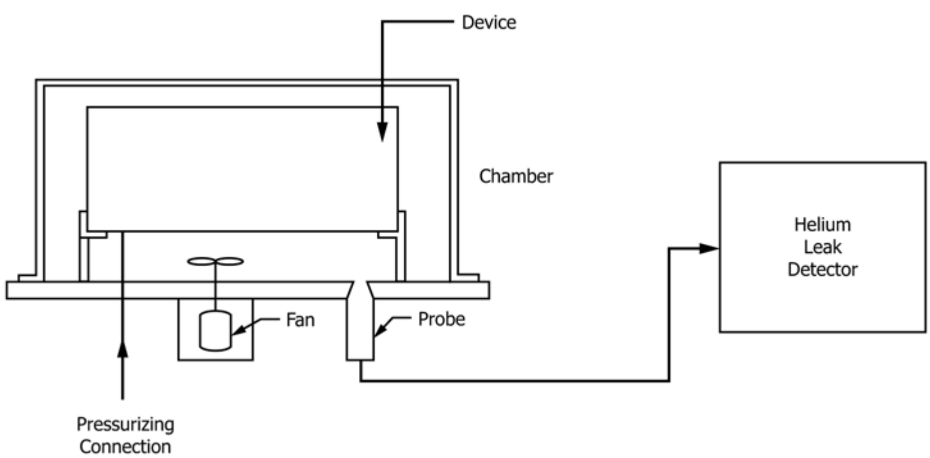
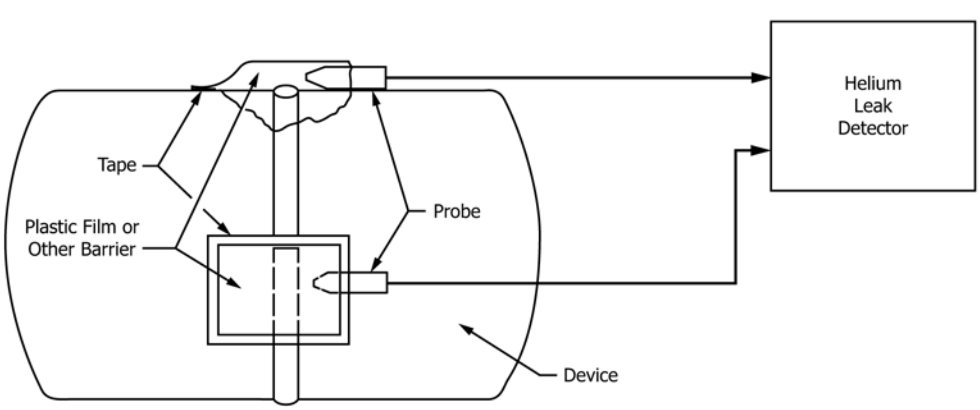


FIG. 1 Method A



a) Accumulation Leak Test, Complete Device in Chamber



b) Accumulation Leak Test, Flexible Shroud over a Small Portion of Device

FIG. 2 Method B

its source or sources. Experience has shown that leak testing down to 1×10^{-5} Pa m^3/s (1×10^{-6} Std cm^3/s)[3] in factory environments will usually be satisfactory if reasonable precautions against releasing gas like the tracer gas in the test area are observed, and the effects of other interferences (Section 6) are considered.

4.4 *Test Method B, Accumulation Testing* (see Fig. 2), provides for the testing of parts up to several cubic metres in volume as in Fig. 2(a) or in portions of larger devices as in Fig. 2(b). This is accomplished by allowing the leakage to accumulate in the chamber for a fixed period, while keeping it well mixed with a fan, and then testing the internal atmosphere for an increase in tracer gas content with the detector probe. The practical sensitivity attainable with this method depends primarily on two things: first, on the volume between the chamber and the object; and second, on the amount of outgassing of tracer gas produced by the object. Thus, a part having considerable exposed rubber, plastic, blind cavities or threads cannot be tested with the sensitivity of a smooth metallic part. The time in which a leak can be detected is directly proportional to the leak rate and inversely proportional to the volume between the chamber and the part. In theory, extremely small leaks can be detected by this test method; however, the time required and the effects of other interferences limit the practical sensitivity of this test method to about 1×10^{-7} Pa m^3/s (1×10^{-8} Std cm^3/s)[3] for small parts.

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 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 frequently used to test large systems and complex piping installations that can be filled with a trace gas. Helium is normally used. The test method is used to locate leaks but cannot be used to quantify except for approximation. Care must be taken to provide sufficient ventilation to prevent increasing the helium background at the test site. Results are limited by the helium background and the percentage of the leaking trace gas captured by the probe.

6.2 Test Method B is used to increase the concentration of trace gas coming through the leak by capturing it within an enclosure until the signal above the helium background can be detected. By introducing a calibrated leak into the same volume for a recorded time interval, leak rates can be measured.

7. Interferences,

7.1 *Atmospheric Helium*—The atmosphere contains about five parts per million (ppm) of helium, which is being continuously drawn in by the detector probe. This background must be "zeroed out" before leak testing using helium can proceed. Successful leak testing is contingent on the ability of the detector to discriminate between normal atmospheric helium, which is very constant, and an increase in helium due to a leak. If the normally stable atmospheric helium level is increased by release of helium in the test area, the reference level becomes unstable, and leak testing more difficult.

7.2 *Helium Outgassed from Absorbent Materials*—Helium absorbed in various nonmetallic materials (such as rubber or plastics) may be released during the test. If the rate and magnitude of the amount released approaches the amount released from the leak, the reliability of the test is decreased. The amount of such materials or their exposure to helium must then be reduced to obtain a meaningful test.

7.3 *Pressurizing with Test Gas*—In order to evaluate leakage accurately, the test gas in all parts of the device must contain substantially the same amount of tracer gas. When the device contains air prior to the introduction of test gas, or when an inert gas and a tracer gas are added separately, this may not be true. Devices in which the effective diameter and length are not greatly different (such as tanks) may be tested satisfactorily by simply adding tracer gas. However, when long or restricted systems are to be tested, more uniform tracer distribution will be obtained by first evacuating to less than 100 Pa (a few torr), and then filling with the test gas. The latter must be premixed if not 100 % tracer.

7.4 *Dirt and Liquids*—As the orifice in the detector probe is very small, the parts being tested should be clean and dry to avoid plugging. Reference should be frequently made to a standard leak to ascertain that this has not happened.

8. Apparatus,

8.1 *Helium Leak Detector,* equipped with atmospheric detector probe. To perform tests as specified in this standard, the detector should be adjusted for testing with helium and should have the following minimum features:

8.1.1 *Sensor Mass Analyzer.*

8.1.2 *Readout,* analog or digital.

8.1.3 *Range (linear)*—A signal equivalent to 1×10^{-5} Pa m^3/s (1×10^{-6} Std cm^3/s)[3] or larger must be detectable.

8.1.4 *Response time,* 3 s or less.

8.1.5 *Stability of Zero and Sensitivity*— A maximum variation of ±5 % of full scale on the most sensitive range while the probe is active; a maximum variation of ±2 % of full scale on other ranges for a period of 1 min.

NOTE 1—Variations may be a function of environmental interferences rather than equipment limitations.

8.1.6 *Controls:*

8.1.6.1 *Range,* preferable in scale steps of 10×.

8.1.6.2 *Zero,* having sufficient range to null out atmospheric helium.

8.2 *Helium Leak Standard*—To perform leak tests as specified in this standard (system calibration), the leak standard should meet the following minimum requirements:

8.2.1 *Ranges*—1×10^{-2} to 1×10^{-6} Pa m^3/s (10^{-3} to 10^{-7} Std cm^3/s)[3] full scale calibrated for discharge to atmosphere.

8.2.2 *Adjustability*—Adjustable leak standards are a convenience but are not mandatory.

8.2.3 *Accuracy,* ±15 % of full-scale value or better.

8.2.4 *Temperature Coefficient,* shall be stated by manufacturer.

8.3 *Helium Leak Standard,* as in 8.2 but with ranges of 1×10^{-5} Pa m^3/s or 1×10^{-8} Pa m^3/s (10^{-6} or 10^{-9} Std cm^3/s) full scale calibrated for discharge to vacuum shall be used for instrument calibration.[3]

8.4 *Other Apparatus*—Fixtures or other equipment specific to one test method are listed under that test method.

9. Material

9.1 *Test Gas Requirements:*

9.1.1 To be satisfactory, the test gas shall be nontoxic, nonflammable, not detrimental to common materials, and inexpensive. Helium, or helium mixed with air, nitrogen, or some other suitable inert gas meets the requirements. If the test specification allows leakage of 1×10^{-4} Pa m³/s (1×10^{-5} Std cm³/s)[3] or more, or if large vessels are to be tested, consideration should be given to diluting the tracer gas with another gas such as dry air or nitrogen. This will avoid excessive helium input to the sensor and in the case of large vessels, save tracer gas expense (Note 2).

9.1.2 *Producing Premixed Test Gas*—If the volume of the device or the quantity to be tested is small, premixed gases can be conveniently obtained in cylinders. The user can also mix gases by batch in the same way. Continuous mixing using calibrated orifices is another simple and convenient method when the test pressure does not exceed 50 % of the tracer gas pressure available.

NOTE 2—When a vessel is not evacuated prior to adding test gas, the latter is automatically diluted by one atmosphere of air.

9.2 *Liquid Nitrogen,* or other means of cold trap refrigeration as specified by the maker of the leak detector.

10. Calibration,

10.1 The leak detectors used in making leak tests by these test methods are not calibrated in the sense that they are taken to the standards laboratory, calibrated, and then returned to the job. Rather, the leak detector is used as a comparator between a leak standard (8.2) (set to the specified leak size) which is part of the instrumentation, and the unknown leak. However, the sensitivity of the leak detector is checked and adjusted on the job so that a leak of specified size will give a readily observable, but not off-scale reading. More specific details are given in Section 11 under the test method being used. To verify sensitivity, reference to the leak standard should be made before and after a prolonged test. When rapid repetitive testing of many items is required, refer to the leak standard often enough to ensure that desired test sensitivity is maintained.

11. Procedure

11.1 *General Considerations:*

11.1.1 *Test Specifications*—A testing specification shall be in hand. This shall include:

11.1.1.1 The gas pressure on the high side of the device to be tested; also on the low side if it need differ from atmospheric pressure.

11.1.1.2 The test gas composition, if there is need to specify it.

11.1.1.3 The maximum allowable leak rate in standard cubic centimetres per second.

11.1.1.4 Whether the leak rate is for each leak or for total leakage of the device.

11.1.1.5 If an "each leak" specification, whether or not other than seams, joints, and fittings needs to be tested.

11.1.2 *Safety Factor*—Where feasible, it should be ascertained that a reasonable safety factor has been allowed between the actual operational requirements of the device and the maximum specified for testing. Experience indicates that a factor of at least 10 should be used when possible. For example, if a maximum total leak rate for satisfactory operation of a device is 5×10^{-5} Pa m³/s (5×10^{-6} Std cm³/s)[3], the test requirement should be 5×10^{-6} Pa m³/s (5×10^{-7} Std cm³/s)[3] or less.

11.1.3 *Test Pressure*—The device should be tested at or above its operating pressure and with the pressure drop in the normal direction, where practical. Precautions should be taken so that the device will not fail during pressurization, or that the operator is protected from the consequences of a failure.

11.1.4 *Disposition or Recovery of Test Gas*—Test gas should never be dumped into the test area if further testing is planned. It should be vented outdoors or recovered for reuse if the volume to be used makes this worthwhile.

11.1.5 *Detrimental Effects of Helium Tracer Gas*—This gas is quite inert, and seldom causes any problems with most materials, particularly when used in gaseous form for leak testing and then removed. When there is a question as to the compatibility of the tracer with a particular material, an authority on the latter should be consulted. This is particularly true when helium is sealed in contact with glass or other barriers that it may permeate.

11.1.6 *Correlation of Test Gas Leakage with Other Gases or Liquids at Different Operating Pressures:*

11.1.6.1 Given the normal variation in leak geometry, accurate correlation is an impossibility. However, if a safety factor of ten or more is allowed, in accordance with 11.1.2, adequate correlation for gas leakage within these limits can usually be obtained by assuming viscous flow and using the equation:

$$Q_2 = (Q_1 N_1 / N_2)\left[(P_2^{\,2} - P_1^{\,2})/(P_4^{\,2} - P_3^{\,2})\right]$$

where:

Q_2 = test leakage, Pa·m³/s (standard cm³/s),
Q_1 = operational leakage, Pa·m³/s (standard cm³/s),
N_2 = viscosity of test gas (Note 3),
N_1 = viscosity of operational gas (Note 3),
P_2, P_1 = absolute pressures on high and low sides at test, and
P_4, P_3 = absolute pressures on high and low sides in operation (Note 4).

11.1.6.2 Experience has shown that, at the same pressures, gas leaks smaller than 1×10^{-4} Pa m³/s (1×10^{-5} Std cm³/s)[3] will not show visible leakage of a liquid, such as water, which evaporates fairly rapidly. For slowly evaporating liquids such as lubricating oil, the gas leakage should be another order of magnitude smaller, 1×10^{-5} Pa m³/s (1×10^{-6} Std cm³/s).[3] See Santeler and Moller[7] for further discussion of this topic.

NOTE 3—Viscosity differences between gases are a relatively minor effect and can be ignored if desired.

NOTE 4—It will be observed from this equation that the leakage increases at a rate considerably greater than that of the pressure increase. For this reason it is often desirable to increase the sensitivity of the test by

[7] Santeler, D. J., and Moller, T. W., "Fluid Flow Conversion in Leaks and Capillaries," *Vacuum Symposium Transactions* , Pergamon Press, London, 1956, p 29. Also General Electric Company Report R56GL261.

testing at the maximum safe pressure for the part. Increased sensitivity may even be obtained with the same amount of helium by increasing the pressure with another less expensive gas, such as air.

11.2 *Test Method A* (refer to 4.3 and Fig. 1):

11.2.1 *Apparatus:*

11.2.1.1 *Test Specification.*

11.2.1.2 *Helium Leak Detector,* with atmospheric detector, sampling probe.

11.2.1.3 *Helium Leak Standard,* discharge to atmosphere. Size equal to helium content of maximum leak rate per specification.

11.2.1.4 *Helium Leak Standard,* discharge to vacuum. Size: anywhere between 1×10^{-5} Pa m^3/s (1×10^{-6} Std cm^3/s)[3] and 1×10^{-8} Pa m^3/s (1×10^{-9} Std cm^3/s),[3] unless otherwise specified by maker of leak detector.

11.2.1.5 *Test Gas,* at or above specification pressure.

11.2.1.6 *Pressure Gauges, Valves, and Piping,* for introducing test gas, and if required, vacuum pump for evacuating device.

11.2.1.7 *Liquid Nitrogen,* if required.

11.2.2 *Procedure:*

11.2.2.1 Set helium leak standard at maximum helium content of specification leakage. The value of the standard leak to be used is determined by the following formula:

$$CL = LR_{acc} \times \%C/100 \quad (1)$$

where:

CL = leakage rate of system standard leak (Pa m^3/s or std cm^3/s)

LR_{acc} = acceptance level (maximum permissible leakage rate)

$\%C$ = percentage concentration of tracer gas.

Example:

Max leak rate: 1×10^{-3} Pa m^3/s (1×10^{-4} Std cm^3/s).[3] Test gas: 1 % helium in air. Set standard at 1×10^{-3} Pa m^3/s (1×10^{-4} Std cm^3/s)[3] $\times 0.01 = 1 \times 10^{-5}$ Pa m^3/s (1×10^{-6} Std cm^3/s).[3]

11.2.2.2 Start detector, warm up, fill trap with liquid nitrogen if required, and adjust in accordance with manufacturer's instructions, using leak standard 11.2.1.4 attached to vacuum system.

11.2.2.3 Attach atmospheric detector probe to detector sample port in place of leak standard and open valve of detector probe, if adjustable type is being used, to maximum inlet pressure under which the detector will operate properly.

11.2.2.4 Rezero detector to compensate for atmospheric helium, if desired.

11.2.2.5 With orifice of leak standard (11.2.1.3) in a horizontal position, hold the tip of the detector probe directly in line with and 1.5 ± 0.5 mm (0.06 ± 0.02 in.) away from the end of the orifice, and observe reading (Note 5).

11.2.2.6 Remove probe from standard leak and note minimum and maximum readings due to atmospheric helium variations or other instabilities.

11.2.2.7 If 11.2.2.6 is larger than 30 % of 11.2.2.5, take steps to reduce the helium added to the atmosphere, or to eliminate other causes of instability. If this cannot be done, testing at this level of sensitivity may not be practical.

11.2.2.8 System calibration shall be performed prior to, upon completion of, and during testing at intervals not to exceed 1 h. Failure of a calibration check to obtain the same or greater response as the previous check shall require that an evaluation or retest of all tested parts or areas examined be performed.

11.2.2.9 Evacuate (if required) and apply test gas to device at specified pressure and concentration.

11.2.2.10 *Probe Areas Suspected of Leaking*— Probe shall be held on or not more than 1 mm (0.04 in.) from the surface of the device, and moved not faster than 20 mm/s (0.8 in./s). If leaks are located which cause a "reject" indication they must be repaired before making final acceptance test.

11.2.2.11 Maintain an orderly procedure in probing the required areas, preferably identifying them as tested, and plainly indicating points of leakage.

11.2.2.12 At completion of the test evacuate or purge test gas from the device, if required.

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

NOTE 5—If necessary to obtain a reasonable instrument deflection, adjust range, rezero if necessary, and reapply sampling probe to leak standard.

11.3 *Test Method B* (refer to 4.4 and Fig. 2):

11.3.1 *Apparatus*—Same as for Test Method A, except that equipment for enclosing all or part of the item to be tested is required as shown in Fig. 2. The size of the helium leak standard will normally be in the range of 1×10^{-6} to 1×10^{-7} Pa m^3/s (10^{-7} to 10^{-8} Std cm^3/s).[7]

11.3.2 *Procedure:*

11.3.2.1 *Set-up*—Same as 11.2.2.1 – 11.2.2.7, Test Method A, except that somewhat larger variations in atmospheric helium can be tolerated due to the isolation of the part during test.

11.3.2.2 *Sensitivity Setting*—In general, it will be advantageous to use the maximum stable sensitivity setting on the leak detector, in order to reduce the accumulation time to a minimum.

11.3.2.3 Insert the part to be tested (unpressurized), the leak standard (11.2.1.3), and the detector probe in the Fig. 2 enclosure. Stratification of the tracer gas shall also be taken into consideration.

11.3.2.4 Note the rate of increase of detector indication.

11.3.2.5 Remove the leak standard, pressurize the part with test gas, and again note rate of rise, if any. If 11.3.2.5 exceeds 11.3.2.4, reject part.

11.3.2.6 Remove the part from the enclosure and purge out any accumulated helium.

11.3.2.7 Evacuate or purge test gas from the part, if required.

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

12. Keywords

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