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Standard Test Methods for Determining Hermeticity of Electron Devices with a Helium Mass Spectrometer Leak Detector[1]

This standard is issued under the fixed designation F 134; 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.

ε1 NOTE—Figures 1 and 2 were editorially renumbered in August 1988.

1. Scope

1.1 These test methods cover procedures for detecting leaks and measuring leak size in electron devices and associated parts with a helium mass spectrometer leak detector.

1.2 *Method A, Helium Leak Test,* may be conducted on parts with an internal cavity which either contains gas other than helium (such as air or nitrogen) or is evacuated.

1.2.1 The measured leak rate is a function of internal free volume, conditioning pressure and time, and the delay time between pressurizing and testing as well as the leak size. In general, if molecular flow is assumed, leak size can be calculated from the measured leak rate. Both the upper and lower limits of detectability depend on conditions of the measurement and so no single range of applicability can be specified for the method.

1.2.1.1 The smallest detectable leak size (see 5.7) depends primarily on the internal free volume, the product of conditioning pressure and time, and the sensitivity of the leak detector.

1.2.1.2 The largest detectable leak size (see 5.2) depends primarily on the internal free volume, and the delay time between conditioning and testing, and, to a lesser extent, on the conditioning pressure and the sensitivity of the leak detector.

1.2.1.3 The method may be applied to detect leaks with leak size between the smallest and the largest detectable leak size. In practice, a value of the maximum acceptable leak size (see 5.5) is agreed upon between the parties to the test and the conditions of the test are established by adjusting the product of conditioning pressure and time so that this leak size is greater than the smallest detectable leak size. Then leaks greater than this can be detected unless they exceed the largest detectable leak size. To detect leaks larger than the largest detectable leak size, other procedures must be employed (Note 1).

1.2.2 If a quantitative measure of leak rate is required parts must be tested singly. Batch testing for a leak is permissible (see 11.1.6).

1.2.3 For repetitive or routine testing of devices of a fixed volume under fixed conditions, a go, no-go test can be established based on the measured leak rate.

1.3 *Method B, Helium Tracer Probe Test,* is used to locate actual leakage sites. Leaks in the range 10^0 to 10^{-8} atm·cm³/s can be detected.

1.3.1 This method can be applied both to electron devices and to other parts such as terminals which can be attached to an evacuated chamber.

1.3.2 Under conditions in which the blanket of helium surrounding the leak approaches a pressure of 1 atm, the measured leak rate determined by this method approaches the leak size.

NOTE 1—Alternative methods for determining hermeticity of electron devices may be found in Practices F 97 and Recommended Practices F 98 (see 2.1).

1.4 These test methods are not appropriate for use on grease-filled devices.

1.5 Method A cannot be used on devices for which the specified conditioning pressure would exceed the component rating.

1.6 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

F 78 Method for Calibration of Helium Leak Detectors by Use of Secondary Standards[2]

F 97 Practices for Determining Hermeticity of Electronic Devices by Dye Penetration[2]

F 98 Recommended Practices for Determining Hermeticity of Electronic Devices by a Bubble Test[2]

3. Summary of Methods

3.1 *Method A*—Helium gas is forced under pressure into the completed part. The part under test is then transferred to a chamber connected to a helium mass spectrometer leak detector, and the rate of leakage of helium from the part is measured.

3.2 *Method B*—The part under test is attached to a helium mass spectrometer leak detector and evacuated. Helium gas is sprayed on the outside of the part from a fine

[1] These test methods are under the jurisdiction of Committee F-1 on Electronics and are the direct responsibility of Subcommittee F01.09 on Enclosures, Substrates and Films.

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[2] *Annual Book of ASTM Standards*, Vol 10.04.

nozzle. Leaks are identified by peak meter readings on the detector that occur as the nozzle is moved over the surface of the part.

4. Sigificance and Use

4.1 Contaminants that will reduce the effective life of electron devices may enter the case of the device through small leaks. These leaks are most frequently found at seals between parts made of the same or dissimilar materials but they may also result from porosity of a defective portion of the case.

4.2 There is no general agreement concerning the amount of leakage which is likely to be deleterious to a particular device. It is customary to specify a maximum acceptable leak size (see 5.5) below which the device is acceptable. This method may be used to establish that a particular sample device meets the specification requirements.

4.3 Since leaks may change with different ambient conditions, quantitative comparisons between test stations are not conclusive.

5. Definitions

5.1 *internal free volume, V* [cm^3]—within a device, the total volume that can contain a gas or vapor.

5.2 *largest detectable leak size, L_{max}* [$atm \cdot cm^3/s$]—the largest value of leak size in a package of a particular volume that gives a reading on a leak detector with a particular sensitivity when measured a particular time after the end of the conditioning period. An approximate relationship between the variables is as follows:

$$L_{max} \approx 0.0062 \, (V/t_2) \ln(2.69 \, L_{max} P_E / Q_{min}),$$

where:
P_E = conditioning pressure, atm,
t_2 = delay time, min, between conditioning and measurement, and the other quantities are defined in this section (Fig. 1).

5.3 *leak detector sensitivity, Q_{min}* [$atm \cdot cm^3/s$]—the value of measured leak rate that is four times the background leak rate of the leak detector (see 10.2). This quantity is affected by the surface absorption characteristics of the devices being tested in addition to the characteristics of the leak detector.

5.4 *leak size, L* [$atm \cdot cm^3/s$]—the quantity of dry air (dew point less than −25 C) in cubic centimetres that flows through an aperture or porous wall at 23 ± 3 C in 1 s with a pressure differential of 1 atm across the aperture or wall.

5.5 *maximum acceptable leak size, L_A* [$atm \cdot cm^3/s$]—the largest value of leak size that can be tolerated in parts deemed acceptable with respect to hermeticity. This value must be mutually agreed upon by parties to the test.

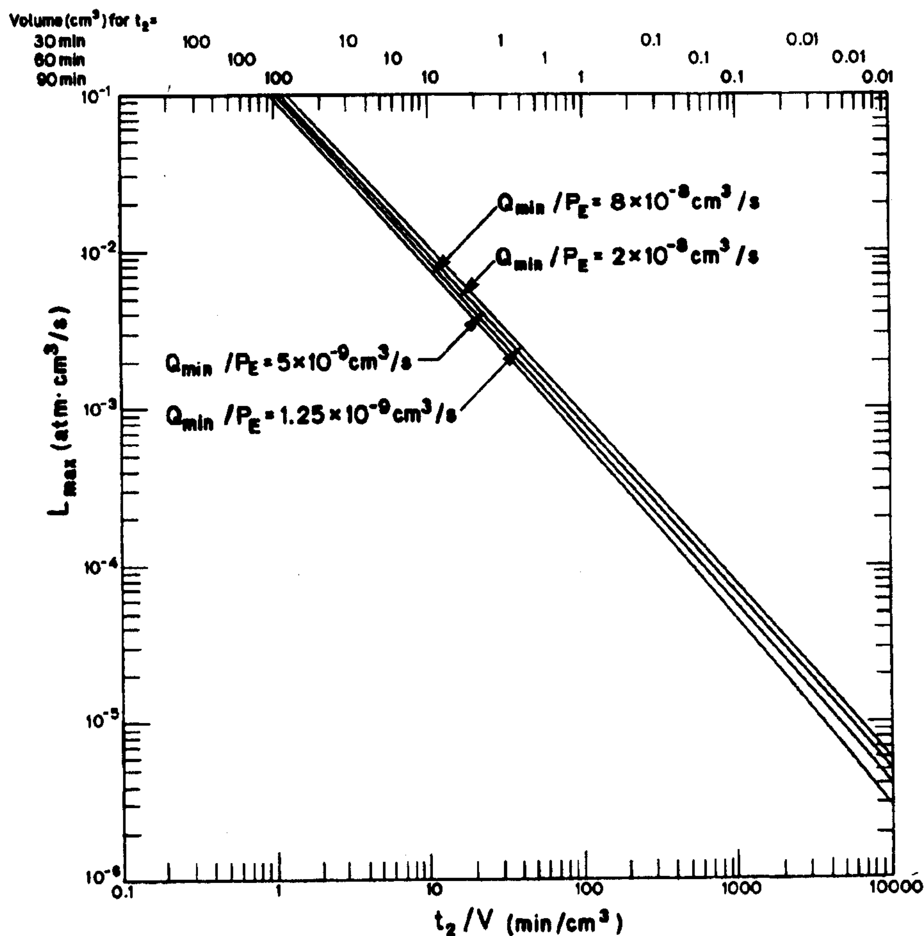

FIG. 1 Largest Detectable Leak

5.6 *measured leak rate, Q_m* [atm·cm³/s]—the quantity of helium in cubic centimeters that flows through an aperture or porous wall in 1 s as determined under specified conditions. Usually, leak rates measured under different conditions or by different methods cannot be compared unless flow mechanisms are assumed and corresponding leak sizes calculated.

5.7 *smallest detectable leak size, L_{min}* [atm·cm³/s]—the smallest value of leak size in a package of a particular volume that gives a reading on a leak detector with a particular sensitivity after conditioning in helium at a particular pressure for a particular time. An approximate relationship between the variables is as follows:

$$L_{min} \approx 0.0062 \sqrt{Q_{min} V / P_E t_1}$$

where:

P_E = conditioning pressure, atm,
t_1 = conditioning time, h, and

the other quantities are defined in this section (Fig. 2). Deviations from this relationship occur at large values of the ratio $P_E t_1 / V$ as shown by the shaded areas in Fig. 2. The deviations are greatest for small values of P_E. To obtain a value for the minimum detectable leak rate in these areas, the full relationship between L and Q_m should be employed (see 12.1.4).

6. Interferences

6.1 Helium leak testing following moisture-type environmental tests is unsatisfactory since small leaks may become clogged by the liquid. For this reason wet gross-leak tests such as the bubble test of Recommended Practices F 98 must follow helium leak testing.

6.2 Organic materials such as epoxy or paper on the surface of parts will cause erroneous readings when parts are tested according to Method A because of helium absorption on such materials.

6.3 Entrapment of helium in surface coatings, in minute pin-hole voids in solder surfaces, or between the parts under test and a mechanical attachment may produce false readings when the part is tested according to Method A. Parts with mechanical attachments, such as a radiator on a power transistor, should be checked either before the attachment is made or after it has been removed.

6.4 If an absorbent material is present in a device, absorption of moisture from the ambient by the material may retard the pump-down time of the helium mass spectrometer when the part is tested according to Method B.

6.5 Extraneous leakage indications may occur in Method B because of helium convection when the probe is at a point distant from the leak. An inert gas such as nitrogen may be directed lightly over the part under test to create a flow which flushes the helium away so that only the area immediately adjacent to the probe is tested.

7. Apparatus

7.1 *Helium Mass Spectrometer Leak Detector* with sensitivity of 4×10^{-8} atm·cm³/s or smaller (see 5.3, 10.2).

7.2 *Standard, Commercial, Calibrated Leak.*

7.3 *Method A:*

7.3.1 *Pressure Chamber* suitable for holding the components in an atmosphere of helium at the desired pressure (6 atm or less) for the required period of time. For testing devices with large internal volume, provision for evacuating the pressure chamber prior to the introduction of helium is desirable.

7.3.2 *Test Chamber* attached to the helium mass spectrometer leak detector with a high conductance line. To minimize sensitivity to background, this chamber shall be no larger than necessary to hold the normal volume of specimens.

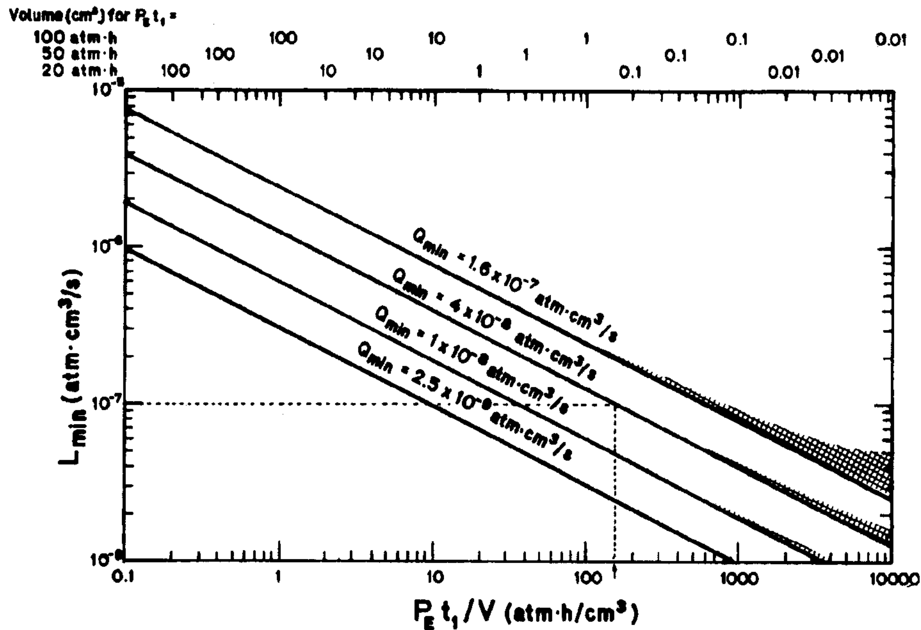

FIG. 2 Smallest Detectable Leak

7.3.3 *Balance* for determining the internal free volume of a device typical of that being measured, if it is necessary to measure package volume.

7.4 *Method B:*

7.4.1 *Hypodermic Needle* with flexible tubing which can be connected to a source of helium.

7.4.2 *Test Port* on the detection station so that the part under test may be attached to the helium mass spectrometer leak detector with a high conductance line and evacuated.

8. Material

8.1 *Helium Gas, Commercially Pure.*

8.2 *Nitrogen Gas, Commercially Pure* (Method B only).

9. Sampling

9.1 *Method A*—This test is usually conducted on a 100 percent basis. For determination that all devices in a lot do not have leaks exceeding a specified value, devices may be tested in groups. Increasing the number of devices in a group increases the risk of false indication due to absorption of helium on outside surfaces of the device case. If a leak in excess of the maximum acceptable leak size is found for a group of devices, the devices must be retested to identify the rejects (see 11.1.6).

9.2 *Method B*—This test is usually conducted on selected parts. This method of selection should be agreed upon in advance of the test.

10. Calibration

10.1 Calibrate the mass spectrometer leak detector in accordance with Method F 78. Record the meter reading obtained with the standard leak (see 7.2). Note and record the leak rate of the standard leak as furnished by the manufacturer.

10.2 (Method A Only) Determine the background leak rate as follows: Soak one or more non-leaking devices of the type under investigation in the pressure chamber at 2 atm (30 psig or 207 kPa, gage) or more (not to exceed 6 atm or 620 kPa, gage) for a time such that the time-pressure product is at least 20 atm·h. Transfer the part or parts under test to the test chamber attached to the helium mass spectrometer leak detector. Evacuate the test chamber and observe and record the meter reading of the leak detector. Calculate the measured leak rate according to 12.1.2 to obtain the background leak rate. The background leak rate must not exceed 10^{-8} atm·cm^3/s (Note 2); a lower value is desirable. Multiply the background leak rate by 4 to obtain the leak detector sensitivity, Q_{min}.

NOTE 2—Background leak rates higher than 10^{-8} atm·cm^3/s are indicative of leaks in the system (check O-ring seals and other sources of leaks and remeasure background leak rate after corrective action) or entrapped helium (flush with nitrogen and remeasure background leak rate). Since rubber and neoprene O-rings and tubing tend to release absorbed helium gradually, tubing of such materials should not be used and new O-rings should be shielded from direct contact with helium.

11. Procedure

11.1 *Method A*—Procedure 1 (for quantitative tests):

11.1.1 Establish the conditioning time and pressure.

11.1.1.1 Determine the internal free volume of the part or parts under test. Obtain this quantity from the supplier of the part or determine it as follows: Drill a small hole in the part, weigh, fill completely with water or other liquid of known density and reweigh. Calculate the internal free volume according to 12.1.1.

11.1.1.2 From Fig. 2, find the value of the quantity $P_E t_1/V$ for the appropriate leak detector sensitivity (see 10.2) and the agreed upon maximum acceptable leak size, L_A, by setting $L_{min} = L_A$. Then calculate the time-pressure product in atmosphere-hours by multiplying this value of the quantity $P_E t_1/V$ by the volume in cubic centimetres.

NOTE 3—For example, assume that $L_A = 1 \times 10^{-7}$ atm·cm^3/s. Extend a horizontal line until it meets the line for the value of L_{min}, here assumed to be 4×10^{-8} atm·cm^3/s. Then drop a line to the abscissa to find the value of $P_E t_1/V$, here 155 atm·h/cm^3. To test a device with internal volume of 0.5 cm^3, a pressure-time product of 77.5 atm·h or more must be used. To test a device with internal volume of 2 cm^3, a pressure-time product of 310 atm·h must be used.

11.1.2 Place the part or parts to be tested in the pressure chamber.

11.1.3 Increase the *partial pressure* of helium in the chamber to 2 atm (30 psia or 207 kPa absolute if the chamber is initially evacuated or 30 psig and 207 kPa gage if not evacuated) or more (not to exceed 6 atm or 620 kPa, gage) and maintain this pressure until 20 atm·h or time-pressure product determined in 11.1.1, whichever is greater, is reached. Record the time of the start of the pressurization to the nearest 1 min. Alternative exposure pressure and time may be employed if mutually agreed upon by parties to the test. **Caution**—The conditioning pressure must not exceed the component rating (see 1.5).

NOTE 4—Since molecular flow is assumed to be the mechanism of leakage for small leak sizes, and since this flow mechanism depends on the concentration of the tracer gas species regardless of the presence of other gases, the effective helium pressure may be increased by 1 atm simply by evacuating the pressure chamber and back filling with helium. This technique permits a corresponding reduction in exposure time.

11.1.4 Release the pressure. Note and record to the nearest 1 min the time of pressure release. Transfer the part or parts under test from the pressure chamber to the test chamber attached to the helium mass spectrometer leak detector.

11.1.5 Evacuate the test chamber and turn the mass spectrometer on. Observe and record the meter reading of the helium mass spectrometer leak detector. Note and record to the nearest 1 min the time of completion of the measurement. Complete testing within 30 min or within a mutually agreed upon time after the pressure has been released (see 5.2 or 12.1.4 for relationships between leak size, measured leak rate, and delay time between pressurizing and measuring).

11.1.6 Perform the calculations in 12.1.2, 12.1.3, and 12.1.4 to determine the leak size.

NOTE 5—The same value of Q_m may correspond to both a large and a small value of L. It is therefore sometimes necessary to determine by independent means which of the two is appropriate to the part under test. One way of doing this is to repeat the test with different values of t_1 or t_2, or both.

11.1.7 If more than one part has been tested, determine whether the leak size exceeds the acceptance limit for a single part. If it does, retest parts to identify the unacceptable units (see 9.1).

11.2 *Method A*—Procedure 2 (for go, no-go tests under fixed conditions on devices of a fixed volume):

11.2.1 Establish the conditions of the test for the volume by determining the minimum time-pressure product according to the procedure of 11.1.1. Use this or a larger value. Specify an appropriate delay time.

11.2.2 Determine the limits of the test range.

11.2.2.1 Determine the value of measured leak rate that corresponds to the maximum acceptable leak size, L_A, for the conditions of the test from the relationship in 12.1.4 with the substitution of L_A for L. Call this value Q_A. (If the minimum time-pressure product found in 11.2.1 is used, $Q_A = Q_{min}$; if a larger value is used, $Q_A > Q_{min}$.)

11.2.2.2 Determine the upper limit of the test, L_U by calculating the large leak size associated with Q_A from the relationship in 5.2 for the specified delay time and with this substitution of L_U and Q_A for L_{max} and L_{min}, respectively. Start with $L_U = 0.0062\ (V/t_2)$ and iterate until the desired accuracy (usually a few percent) is obtained. If $V/L_U t_1 > 2421$ calculate L_U from the relationship in 12.1.4 by means of an iterative procedure such as Newton's method.

11.2.3 Determine the measured leak rate according to the procedure in 11.1.2, 11.1.3, 11.1.4, and 11.1.5. Be certain that the conditioning pressure, conditioning time, and delay time are within 3 percent of the established values.

11.2.4 Interpret the results according to 12.1.5.

11.2.5 If more than one part has been tested and the measured leak rate exceeds the acceptance limit for a single part, retest parts to identify the unacceptable units.

11.3 *Method B:*

11.3.1 Seal the part to the test port on the helium mass spectrometer leak detector (see reference to O-rings and tubing in Note 2). Evacuate the part and turn the mass spectrometer on.

11.3.2 Connect the flexible tubing of the hypodermic needle to a source of helium gas and adjust the helium pressure so that the flow can barely be felt when the flow from the needle is directed on the operator's finger. The rate of helium flow is not critical; it may be increased if desired.

11.3.3 Direct the gas on suspected leak areas starting from the highest elevations of the part under test and working downward so that helium does not reach a leakage site remote from the probe by convection and thereby obscure localization (see 6.5).

NOTE 6—Alternatively, to detect a leak surround the part with helium. If a leak is indicated, locate its site by the procedure of 11.3.4.

11.3.4 To locate leak sites more precisely, flush the area with nitrogen, then, in still air, move the probe filled with helium around the suspected area. No flow of helium is needed.

11.3.5 Note leakage sites as indicated by peak meter readings on the detector. If the leakage site is near the sealing surface between the part under test and the test port, attempt to ensure that the specimen is actually the leaking member by breaking and remaking the seal, and retesting the region.

12. Calculations and Interpretation of Results

12.1 *Method A:*

12.1.1 Calculate the internal free volume of the device as follows if it has been determined experimentally (see 11.1.1.1):

$$V = (W_2 - W_1)/\rho,$$

where:

V = internal free volume, cm^3,
W_1 = initial mass of device, g,
W_2 = mass of filled device, g, and
ρ = density of filling fluid, g/cm^3.

12.1.2 Calculate the measured leak rate of the part or group of parts under test as follows:

$$\log Q_m = (\log R_i - (a/b)$$

where:

Q_m = measured leak rate of the part or parts under test, $atm \cdot cm^3/s$,
R_i = meter reading of helium mass spectrometer leak detector for part or parts under test minus leak detector background reading,
a, b = constants in the helium leak detector calibration line equation of $\log y = a + b \log \times$ determined in accordance with Method F 78.

An alternative procedure is

$$Q_m = R_i\ L_s/R_s$$

where L_s = leak rate of a standard leak with a value in the same decade as Q_m.

12.1.3 Calculate the actual exposure and delay times as follows:

$$t_1 = (T_r - T_s)/60$$
$$t_2 = T_c - T_r$$

where:

t_1 = exposure time, h,
t_2 = delay time, min,
T_s = clock time at start of pressurization,
T_r = clock time at release of pressure, and
T_c = clock time at completion of measurement.

12.1.4 Calculate the leak size of the device or devices as referred to air from the following (when devices are not tested individually the leak size found is an effective total leak size, see 11.1.6):[3]

$$Q_m = 2.69\ P_E L[1 - \exp(-9684\ Lt_1/V)]\ \exp(-161.4\ Lt_2/V)$$

where:

Q_m = measured leak rate, $atm \cdot cm^3/s$,
L = leak size, $atm \cdot cm^3/s$,
P_E = conditioning pressure, atm,
t_1 = conditioning time, h,
V = internal free volume, cm^3, and
t_2 = delay time, min.

12.1.5 Interpret go, no-go tests as follows: if the measured leak rate $Q_m > Q_A$, the device has a leak of size between L_A and L_U and is not acceptable. If $Q_m < Q_A$, the device either has an acceptably small leak size $L \leq L_A$ or is a gross leaker ($L \geq L_U$). An alternative test (Note 1) must be used to detect gross leaks.

12.2 *Method B*—Since this method is intended only to provide qualitative indications of leakage sites, no calculations are required.

13. Report

13.1 *Method A:*

[3] Howl, D. A., and Mann, C. A., "The Back-Pressurising Technique of Leak-Testing," *Vacuum*, VACUA, Vol 15, July 1965, pp. 347–352.

13.1.1 For quantitative tests on single devices the report shall include the following:

13.1.1.1 Identification of specimen,

13.1.1.2 Identification of helium mass spectrometer leak detector,

13.1.1.3 Leak rate of standard calibrated leak (L_s),

13.1.1.4 Meter reading obtained with the calibrated leak (R_s),

13.1.1.5 Leak detector sensitivity (Q_{min}),

13.1.1.6 Maximum acceptable leak size (L_A),

13.1.1.7 Internal free volume (V),

13.1.1.8 Exposure pressure (P_E),

13.1.1.9 Actual exposure time (t_1),

13.1.1.10 Delay time (t_2),

13.1.1.11 Meter reading obtained with device under test (R_i),

13.1.1.12 Measured leak rate (Q_m), and

13.1.1.13 Computed leak size (L).

13.1.2 For routine or go, no-go tests, the report shall include the following:

13.1.2.1 Identification of specimen,

13.1.2.2 Identification of helium mass spectrometer leak detector,

13.1.2.3 Maximum acceptable leak size (L_A),

13.1.2.4 Acceptance limit for measured leak rate (Q_A),

13.1.2.5 Upper limit of test (L_U), and

13.1.2.6 Measured leak rate (Q_m).

13.2 *Method B*—The report shall indicate whether Procedure 1 (11.3.2, 11.3.3) or Procedure 2 (11.3.4) was used and shall include a qualitative description of the location of leakage sites or, if no leakage sites were detected, an indication that the device is leaktight when tested according to this procedure.

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