METHOD 1071.14

HERMETIC SEAL

1. Purpose. The purpose of this test method is to determine the hermeticity of semiconductor devices with designed internal cavities.

2. Terms and definitions.

2.1 Standard leak rate. The quantity of dry air at 25°C in atmosphere cubic centimeters flowing through a leak or multiple leak paths per second when the high pressure side is at 1 atmosphere (765 mm Hg absolute) and the low pressure side is at a pressure of not greater than 1 mm Hg absolute. Standard leak rate shall be expressed in units of atmosphere cubic centimeters per second of air (atm cc/s Air).

2.2 Standard leak rate condition. The leak rate of air in atmosphere cubic centimeters per second of air (atm cc/s Air) flowing through a leak or multiple leak paths when the device is exposed to ambient room air.

2.3 Equivalent standard leak rate. The equivalent standard leak rate (L) of a package, is calculated by converting the measured leak rate of the device under test (defined in 2.5) to the standard leak rate (defined in 2.1),using the leak rate conversion factors listed in 2.7. The equivalent standard leak rate shall always be expressed in units of atmospheric cubic centimeters per second of air (atm cc/s Air).

2.4 Measured leak rate. The measurement of gaseous leakage obtained from a leak detection test system for a package under test. The measured leak rate shall be expressed in units of atmospheric cubic centimeters per second (atm cc/s) for the tracer gas being used by the leak detection test system (e.g., ^{85}Kr and He). All measured leak rates shall be converted to equivalent standard leak rates (atm-cc/sec Air) using the leak rate conversion factors listed in 2.7.

a. For all test conditions:
L is the maximum leak rate limit (atm cc/s Air) for a package, and it defines the pass/fail criterion for equivalent standard leak rates obtained during testing (see 10.2.2).

b. For test conditions H_1/H_2 and CH_1/CH_2:
R_1 is the calculated maximum leak rate allowable (atm-cc/sec He) for the device to be tested. R_1 shall be calculated using equation 3 (see 10.2.1.2). Equation 3a (see 10.2.1.2) shall be used to calculate R_1 for tracer gases other than Helium. R is the quantitative measured leak rate of the device (atm-cc/sec He), and shall be compared to R_1 for pass/fail determination.

c. For test conditions G_1 and G_2:
Qs is the calculated maximum leak rate allowable (atm-cc/sec ^{85}Kr) for the device to be tested. Qs shall be calculated using equation 1 (see 9.2). Q is the quantitative measured leak rate of the device (atm-cc/sec ^{85}Kr); see equation 2 (see 9.5), and shall be compared to Qs for pass/fail determination.

d. For test conditions L_1 and L_2:
L_2 is the calculated maximum leak rate allowable (atm-cc/sec He) for the device to be tested (see table 1071–VII). The helium leak rate shall be calculated using the equation in 13.2, and shall be compared to L_2 for pass/fail determination.

For purposes of comparison with rates determined by other methods of testing, all measured leak rates shall be converted to the equivalent standard leak rates, (converted to air equivalents at the standard leak rate condition).

2.5 Hermetic seal. A hermetic seal is one in which the gas or gases contained in the internal free volume of the sealed package shall not escape or be exchanged with any gas, vapor or liquid contained in the environment external to the sealed package, within the leak rate ranges detectable by this test method. For the purpose of this test method, a hermetically sealed device shall meet the requirements herein.

2.6 Air leak rate ranges.

Gross leak rate range:	Equivalent standard leak rates greater than 5×10^{-6} atm-cc/sec (air).
Fine leak rate range:	Equivalent standard leak rates less than 5×10^{-6} atm-cc/sec (air).
Fine-leak-rate ratios for krypton:	(atm-cc/sec (Kr) x 1.712) = atm-cc/sec (air).
Fine-leak-rate ratios for krypton:	atm-cc/sec (Kr) x 4.61 = atm-cc/sec (He).
Fine-leak-rate ratios for helium:	atm-cc/sec (air) value shall be calculated using the atm-cc/sec (He) value and back calculating through the Howl Mann equation (Equation 3, see 10.2.1.2).
Fine-leak-rate ratios for helium:	atm-cc/sec (He) x .217 = atm-cc/sec (Kr).

2.7 Fine leak failure criteria. The failure criteria in 10.2.2 in atm-cc/sec (air) shall apply for all dry gas leak test procedures in this test method.

2.8 Testing limitations. The history of device leak rate testing shall be maintained on travelers accompanying devices. Devices that have previously been subjected to bubble tests will not yield reliable test results when subjected to dry gas HMS leak testing. The radioisotope fine leak test condition G_1 can be used with the test sensitivity extended 1 order of magnitude. The leak rate detected of any device previously exposed to any liquid media (e.g. fluorocarbons) will be assumed to be one or two orders of magnitude larger than measured. It is important to note that fluorocarbon residues introduces "surface-sorption" problems that affect the standard testing procedures and may not be removable from device surfaces such as porosities and leak paths.

NOTE: The leak rate measurements are not necessarily performed with a one atmosphere differential, as implied by the standard leak rate. The equivalent conversion represents gas medium only.

2.9 Internal free cavity volume. The internal volume of a device less the area/volume of the die, die attach material, internal conformal coating, and any other internally applied materials. The internal free volume of a device shall be accurately measured to establish the required equivalent standard leak rate (L) failure criteria specified in 10.2.2.

2.10 Wait time. The time between the removal of the device (or batch of devices) from pressurization to the beginning of device testing (or the first device of the batch).

2.11 Dwell time. The maximum time allowed from the removal of the device (or batch of devices) from pressurization to the completion of device testing (or the last device of the batch). Dwell time includes the wait time.

3. Test conditions.

3.1 Gross leak test conditions. The following test conditions should be specified for gross leak testing:

a. Test condition A (see 4): Radioisotope wet gross leak test.

b. Test condition B (see 5): Radioisotope dry gross leak test.

c. Test condition C (see 6 and 17.e): Liquid perfluorocarbon gross leak.

d. Test condition D (see 7 and 17.e): Bubble test.

e. Test condition E (see 8): Penetrant dye gross leak.

f. Test condition J (see 11): Weight gain gross leak.

g. Test condition K (see 12): Fluorocarbon vapor detection gross leak.

h. Test condition L_1 (see 13): Optical gross leak.

i. Test condition G_2 (see 9.6): Radioisotope gross/fine combination.

j. Test conditions CH_1 and CH_2 (see 10 and 15): Cumulative helium gross/fine combination.

k. Test conditions H_1 and H_2 (see 10): Helium fine leak test.

l. Test condition G_t (see 3.3 and 14): Radioisotope thermal leak test.

m. Test condition H_3 (see 16): Combined He/O_2 dry gross leak and He fine leak.

3.2 Fine leak test conditions. The following test conditions should be specified for fine leak testing:

a. Test condition G_1 (see 9), radioisotope fine leak test or G_2 (see 9.6) fine/gross combination leak test.

b. Test conditions H_1 and H_2 (see 10): Tracer gas (helium) leak test.

c. Test conditions CH_1 and CH_2 (see 10): Cumulative helium gross/fine combination.

d. Test condition L_2 (see 13): Optical combined fine/gross leak .

e. Test condition H_3 (see 16): Combined He/O_2 dry gross leak and He fine leak.

3.3 Radioisotope thermal leak test (see 14). Test condition G_t should be used for radioisotope thermal leak testing.

3.4 Fine and gross leak test procedures. Unless otherwise specified by applicable performance specification sheet, tests shall be conducted in accordance with table 1071–I. When specified (see 15 herein) measurements after test shall be conducted following the leak test procedures. Where bomb pressure specified exceeds the device package capability, alternate pressure, exposure time, and dwell time conditions shall be used provided they satisfy the leak rate, pressure, and time relationships which apply and provided no less than 30 psia (207 kPa) bomb pressure is applied in any case, or for condition L_1, a minimum 10 psia (69 kPa) differential test pressure is applied.

Fine and gross leak tests shall be conducted in accordance with the requirements and procedures of the specified test condition. Testing order shall utilize only the all-dry gas tests first, followed by any liquid immersion gross leak test (i.e.; the option to use the radioisotope gross, fine, or gross/fine combination leak test conditions B, G_1, and G_2 (respectively), may be used together, or in succession, as long as the minimum test requirements are met). The radioisotope dry gas gross leak test B or G_2 may be used for gross leak testing prior to any dry gas fine test. The optical gross leak test, L_1, is an all-dry gas test and can be used before any fine leak test. If any other gross leak test is used, (test conditions A, C, D, E, F, J, or K), the sequence of testing shall use the dry gas fine leak test first, followed by the gross leak test, except in accordance with 14, note 1. When batch testing (more than one device in the leak detector at one time) is used in performing test condition H_1, H_2, and CH a reject condition occurs, it shall be noted as a batch failure. Each device with a cavity greater than 0.5 cm^3 may then be tested individually one time for acceptance if all devices in the batch are retested within the dwell time used to determine the pass/fail point. Devices with cavity less than 0.5 cm^3 shall be measured within ten minutes or re-pressurized and then re-read. For condition G_1 only, devices may be batch tested for acceptance provided, if a reject occurs, all remeasuring of parts individually is completed within 30 minutes after removal from the tracer gas pressurization chamber. For condition G_2 only, devices may be batch tested for acceptance provided, if a reject occurs, all remeasuring of parts individually is completed within 10 minutes after removal from the tracer gas pressurization chamber. For condition K only, devices that are batch tested, and indicate a reject condition, may be retested individually one time using the procedure of 12.2 herein, except that repressurization is not required if the devices are immersed in detector fluid within 20 seconds after completion of the first test, and they remain in the bath until retest. For condition CH only, devices that are batch tested, and indicate a fine leak reject condition, may be retested individually if they are retested within the dwell time used to determine the pass/fail point using the Howl-Mann equation. For CH_1 and CH_2 only, devices which are batch tested, and indicate a gross leak reject condition, may be retested individually if they are retested within the dwell time used to determine the pass/fail point using the Howl-Mann equation or the devices can be re-bombed with helium for at least 60 seconds and then retested.

TABLE 1071–I. Required test sequence.

Volume (cm^3)	Fine leak condition	Gross leak condition
≤ 0.4	G_1, G_2, H_1, H_2, CH_1, CH_2, L_2	CH_1, CH_2, A, B, C, E, G_2, J, K, L_1 1/ 2/
> 0.4	G_1, G_2, H_1, H_2, CH_1, CH_2, L_2	CH_1, CH_2, A, B, C, D, E, K, L_1 3/
> 0.4	CH_1, CH_2, J, L_2 4/	CH_1, CH_2, J, L_1 4/

1/ Condition B and G_2 may be used for small cavity devices that contain approved getting material.
2/ Condition J cannot be used for packages whose internal volume is < 0.001 cm^3.
3/ Condition D cannot be used for packages whose internal volume is ≤ 0.05 cm^3.
4/ Condition J may be used as a single test for devices with an internal cavity volume of > 0.4 cm^3 provided the specified requirements can be satisfied by a leak rate of 1 x 10^{-6} atm-cc/sec (air).

4. Test condition A – radioisotope wet gross leak test. Designed for packages with internal free cavity volume less than 0.05 cm^3. This test condition may be used for larger packages to detect larger leak paths. This test condition is not intended to replace visual inspection for sealing defects.

4.1 Apparatus. The apparatus required for test condition A shall be as follows:

a. Radioactive tracer gas pressurization console.

b. Counting station equipment consisting of a scintillation crystal, photomultiplier tube, preamplifier, ratemeter, and ^{85}Kr reference standards. The counting station shall be of sufficient sensitivity to determine through the device wall, the radiation level of any ^{85}Kr tracer gas present within the device. The counting station detector shall have a minimum detectability of 500 cpm of ^{85}Kr above ambient background. The function of scintillation-crystal/ratemeter shall be verified at least once every working shift using ^{85}Kr reference standards and following the equipment manufacturer's instruction. A record of proper function shall be maintained with a recorded measured value and operator sign off.

c. A container of sufficient volume to allow the devices to be covered with red-dye-penetrant solution, evacuated, and subjected to air pressure in the same container.

d. Solutions:

(1) Red dye penetrant solution:
95.45 percent by volume petroleum hydrocarbon mineral oil (CAS NUMBER 64742-54-7),
1.8 percent by volume C.I. solvent red 164 (CAS NUMBER 92257-31-3),
2.7 percent by volume hydrotreated light napthenic petroleum distillates (CAS NUMBER 64742-53-6),
.04 percent by volume xylene (CAS NUMBER 1330-20-7),
.01 percent by volume ethylbenzene (CAS NUMBER 100-41-4).

(2) The red dye penetrant solution shall be kept clean and free of contaminants (including wash solvents). The solutions shall be tested and approved by the equipment manufacturer to ensure maximum gettering capability. The equipment manufacturer shall provide a test procedure to be used to verify the efficiency of the solution for both ^{85}Kr gettering and visual detectability (see 4.3). This procedure can also be used to verify that the red dye penetrant solution is maintaining efficiency and has not become contaminated.

(3) The solvent for washing the devices after immersion shall be acetone.

e. A tracer gas consisting of a mixture of ^{85}Kr and air. The concentration of ^{85}Kr in air shall be no less than 100 microcuries per atmospheric cubic centimeter (µCi per atm-cc). This value shall be determined at least once each 30 days, following manufacturer's procedure, and recorded in accordance with the calibration requirements of the general test method standard MIL–STD–750. The specific activity may be measured automatically by the equipment during cycling of the equipment. However, it is recommended that an analytical sample of the gas be measured at least annually for low use systems and semiannually for high use systems.

4.2 Procedure. The following four steps shall be followed.

Step 1: The devices shall be immersed in the red dye penetrant solution and evacuated to a pressure of 100 mm of Hg or less for 10 minutes and then pressurized with air for 10 minutes minimum at 45 psia (310 kPa) minimum. The devices shall be removed from the red dye penetrant solution and placed in a fine-screen basket and flushed with acetone by applying a fine-spray of acetone to remove the surface film of the solution. It is recommended that the devices in the fine-screen basket be held over funnel, with the funnel inserted into a large Erlenmeyer flask, (thus minimizing the acetone vapors released into the room). Do not allow any acetone to contaminate the red dye penetrant solution. Immediately following the wash, the devices shall be emptied onto a white surface (such as paper towels), and examined carefully for evidence of red dye penetrant solution exiting from any leaking devices. Any devices with red dye penetrant solution leaking from them shall be rejected as gross leakers.

Step 2: The devices shall then be placed in the radioisotope pressurization tank, (with all excess free volume displaced with aluminum filler blocks), and the tank evacuated to a pressure of 0.5 mm of Hg. The devices shall then be pressurized to a minimum of three atmospheres absolute pressure of ^{85}Kr/air mixture for 12 minutes minimum. The gas mixture shall then be transferred to storage until a pressure of 2.0 mm of Hg maximum exists in the tank. This transfer shall be completed in 2 minutes maximum. The tank shall then be filled with air, and the devices immediately removed from the tank and measured within 5 minutes after gas exposure, with a scintillation “well” crystal equipped counting station. It is recommended that batch sizes be kept small enough to allow all devices to be measured within 5 minutes. Any device indicating 500 counts per minute (cpm) or greater above the ambient background of the counting station shall be considered a gross leaker. If all of the devices cannot be measured within 5 minutes, they shall be retested starting at the beginning of step 2.

Step 3: Failing devices may cross contaminate compliant devices with red dye penetrant solution. Devices which contain red dye penetrant solution may effervesce after being pressurized with ^{85}Kr and may lose the ^{85}Kr trapped within them. The devices shall be emptied onto a white surface (such as paper towels), and examined carefully for any red dye penetrant solution exiting from any leaking devices. Any devices with red dye penetrant solution leaking from them shall be rejected as gross leakers. Gross leak failures with a internal free cavity volume less than 0.05 cm^3 shall be visually inspected at 30X to confirm that the red dye penetrant solution is actually leaking from the device.

Step 4: If any devices are rejected by steps 1 through 3, the procedure (starting with step 2) shall be repeated until no more gross leakers are found.

4.3 Procedure for verifying ^{85}Kr gettering efficiency.

Step 1: Gather five samples of each package. Each sample shall be tested separately. A separate test sequency shall be performed for each package.

Step 2: Drill a .020 inch (0.51 mm) hole in the lid of the package samples.

Step 3: Immerse the samples in test solution and evacuate to near complete vacuum for ten minutes (min).

Step 4: Pressurize the samples at 75 psia (while immersed in the test solution) for ten minutes.

Step 5: Remove the samples and place in a screen basket and wash with a fine acetone spray per the requirements of MIL-STD-750-1, test method 1071, paragraph 4.2, step 1.

Step 6: Place each sample in the ^{85}Kr pressurization system, and perform a gross leak test using the following conditions:

Bomb pressure = 75 psia
Bomb time = 12 minutes
Vent = 2 mmHg

Step 7: Remove the samples and perform ^{85}Kr reading in a well crystal counting station using a slow time constant.

Step 8: Re-read the samples at two minutes, four minutes, six minutes, eight minutes and ten minutes (total of six measurements per sample).

Step 9: Each sample shall read 500 C/M above background for at least ten minutes.

5. Test condition B – radioisotope dry gross leak. This test shall be used to test devices that internally contain some ^{85}Kr absorbing or adsorbing medium, such as electrical insulation, organic, or molecular sieve, or approved gettering material. If the device does not contain any adsorbing medium this can only be used on parts with 0.1 cc internal free volume or larger, or that can demonstrate that the following requirements are met:

a. A .005 inch (0.13 mm) diameter hole shall be made in a representative unit of the devices to be tested.

b. The device shall be subjected to this test condition and removed from the pressurization tank immediately after the tank is vented to atmosphere, and measured in the counting station. A net reading indicating 500 cpm or greater is considered a reject. The device shall remain a reject for a minimum of 10 minutes after removal from the pressurization tank. If the device does not fail, this test may not be used.

5.1 Apparatus. The apparatus required for test condition B shall be as follows:

a. Radioactive tracer gas pressurization console containing ^{85}Kr/air mixture.

b. Counting equipment consisting of a scintillation crystal, photomultiplier tube, preamplifier, ratemeter, and ^{85}Kr reference standards. The counting station shall be of sufficient sensitivity to determine through the device wall the radiation level of the ^{85}Kr tracer gas present within the device.

(1) A "well type" counting station with a minimum sensitivity of 10,000, cpm per µCi of ^{85}Kr tracer gas and a minimum detectable count rate of 500 cpm above background level.

(2) A "flat top" counting station with a minimum sensitivity of 4,500, cpm per µCi of ^{85}Kr tracer gas and a minimum detectable count rate of 500 cpm above background level.

(3) A "tunnel" couting station with a minimum sensitivy of 4,500, cpm per µCi of ^{85}Kr tracer gas and a minimum detectable count rate of 500 cpm above background level.

c. A tracer gas consisting of a mixture of ^{85}Kr and air. The concentration of ^{85}Kr in air shall be no less than 100 µCi per atm-cc. This value shall be determined at least once each 30 days, following manufacturer's procedure, and recorded in accordance with the calibration requirements of the general test method standard MIL–STD–750. The specific activity may be measured automatically by the equipment during cycling of the equipment. However, it is recommended that an analytical sample of the gas be measured annually for low use systems and semiannually for high use production systems.

d. ESD protective tubes (plastic or aluminum) shall be utilized to ensure the system is ESD safe when using the “well type”counting station.

e. All calibration records (e.g. daily, monthly, voltage crystal plateau graphs, and Certificates of Conformance for ^{85}Kr reference standards, specific activity, etc.) shall be maintained and made available to the qualifying activity.

f. The crystal voltage plateau graph shall be performed and documented semiannually. Care should be taken when performing crystal voltage plateau measurements. Potential exposure to high voltage and potentiometer disturbance must be taken into consideration. Disturbance of the potentiometers may require the ratemeter to be repaired.

5.2 Procedure. The devices shall be placed in a radioactive tracer gas pressurization tank, (with aluminum filler blocks placed in the tank to displace all unneeded free volume), and the tank shall be evacuated to a pressure not to exceed 66.7 Pa (0.5 torr). The devices shall then be subjected to a minimum of 30 psia (207 kPa) of ^{85}Kr/air gas mixture for 2 minutes (.04 hours). For devices that have pressure limits less than 30 psia (207 kPa), the pressure limit shall be specified and not exceeded. The gas mixture shall then be transferred to storage until a pressure of 266.7 Pa (2.0 torr) maximum exists in the pressurization tank. This gas transfer shall be complete in 3 minutes maximum. The tank shall then be backfilled with air. The devices shall then be removed from the tank and measured within 10 minutes after gas exposure, with a scintillation-crystal-equipped counting station. Any device indicating 500 cpm, or greater, above the ambient background of the counting station shall be considered a gross leak failure. If the devices are not all measured at the end of 10 minutes from removal from the pressurization chamber, the remaining device shall be returned to the pressurization chamber and re-pressurized to a minimum of 30 psia (207 kPa) for a minimum of 2 minutes (.04 hours), and then measured at the counting station within 10 minutes.

5.2.1 Pre-gross leak test. To conserve the ^{85}Kr/air gas mixture, a pre-gross leak test may be performed prior to the gross leak test to remove devices exhibiting significant leakage. The pre-gross leak test shall implement all required bombing conditions as stated in 5.2, except soak time may be reduced to 36 seconds (.01 hours) minimum.

9. Test condition G_1 – radioisotope fine leak.

9.1 Apparatus. Apparatus for this test shall be as in 5.1.

9.2 Testing parameters. The bombing pressure and soak time shall be determined in accordance with the following equation:

Equation (1): $$Q_S = \frac{R}{SKTP\bar{t}}$$

The parameters of equation (1) are defined as follows:

Q_S = The maximum leak rate allowable, in atm cc/sec (Kr), for the devices to be tested. (This value is the equivalent ^{85}Kr measured leak rate equal to the allowable "L" value (atm cc/sec (air)) in 10.2.2).

R = Counts per minute above the ambient background after pressurization if the device leak rate were exactly equal to Q_S. This is the reject count above the background of both the counting equipment and the component, if it has been through prior radioactive leak tests.

S = The specific activity, in µCi per atm-cc, of the ^{85}Kr tracer gas in the pressurization system.

K = The overall counting efficiency of the scintillation crystal in counts per minute per microcurie of 85Kr in the internal void of the specific component being evaluated. This factor depends upon component configuration and dimensions of the scintillation crystal. The counting efficiency shall be determined in accordance with 9.3.2.

T = Soak time, in hours, that the devices are to be pressurized.

P = $P_e2 – P_i2$, where P_e is the pressure in atmospheres absolute, and P_i is the original internal pressure of the devices in atmospheres absolute. The bombing pressure (P_e) may be established by specification or, if a convenient soak time (T) has been established, the pressure (P_e) can be adjusted to satisfy equation (1).

t = Conversion of hours to seconds and is equal to 3,600 seconds per hour.

NOTE: The complete version of equation (1) contains a factor $(P_O^2 – (\Delta P)^2)$ in the numerator which is a correction factor for elevation above sea level. P_O is sea level pressure in atmospheres absolute and ΔP is the difference in pressure, in atmospheres between the actual pressure at the test station and sea level pressure. For the purpose of this test method, this factor has been dropped.

9.3 Determination of specific activity (S) and counting efficiency (K–factor).

9.3.1 Determination of specific activity of ^{85}Kr mixture.

a. The specific activity S is the concentration of the ^{85}Kr/air mixture in the radioisotope pressurization system. This concentration is measured in µCi per atm-cc/sec of ^{85}Kr/air mixture.

b. The specific activity must be maintained at 100 µCi per atm-cc/sec (minimum).

c. The specific activity must be determined at least monthly, either by gas sample or automatically by the equipment.

d. The specific activity must be measured at least semi-annually for high usage machines and annually for low usage machines, by sampling the gas following the manufacturer's procedure.

9.3.2 Determination of counting efficiency (K–factor). The counting efficiency K–factor of equation (1) shall be determined as follows:

a. A representative unit of the device type being tested shall have a known microcurie content of ^{85}Kr placed in the internal void of the device.

b. The counts per minute from the representative unit shall be measured in the shielded scintillation crystal of the counting station in exactly the same position as the actual samples will be measured. From this value, the counting efficiency, in counts per minute per microcurie (cpm per µCi), shall be calculated.

c. The K–factor, is the efficiency of measurement of radioactive ^{85}Kr tracer gas within a device using a scintillation crystal as a detector. The K–factor must be determined for the combination of both the scintillation crystal detection system that is to be used for the measurement and for the specific geometry of the device to be tested. This is done using a device 'sample' of the same geometric configuration as the device to be tested. The geometric center of the cavity, or its internal void, is the point called the "center of mass" of the radioactive gas being measured. The location of the center of mass is the point referred to for the k-factor of the device as it is positioned in each of the scintillation crystal detection systems described in 9.3.2.1, 9.3.2.2, and 9.3.2.3.

d. The equipment manufacturer may be able to provide K-factor data for most devices.

e. A list of K–factors for all devices shall be maintained for each crystal used.

9.3.2.1 K–factor for a scintillation "well–crystal".

a. A representative sample, consisting of a device with the same geometric configuration as the test sample device(s), shall be used to determine the K–factor. This representative sample shall have an accurately known micro-curie content of ^{85}Kr placed within its internal void.

b. The counts per minute from the representative sample shall be measured in the well of the shielded scintillation crystal of the counting station. The sample device should be in the exact position as test devices will be tested. If not, then the sample device shall be located at a height not to be exceeded by any device tested (see note below). From this measured value, the counting efficiency, in counts per micro-curie shall be calculated for that device/crystal system.

c. A scintillation "well crystal" shall have an efficiency of at least 10,000 cpm per µCi.

NOTE: The counting efficiency of the scintillation well crystal is reduced systematically at higher locations within the crystal's well. The K–factor for the sample at the bottom of the well crystal will be the greatest. If a device is placed on top of other devices such as in testing multiple devices simultaneously, then the top device will have the least measured K–factor effect. Thus, the measured K–factor, determination using the sample device located other than at the bottom of the crystal's well, determines the maximum height to be allowed for the actual test. This height shall be established and shall not be exceeded by any actual test device, including any one of the multiple devices being simultaneously tested.

9.3.2.2 K–factor for a scintillation "flat–top crystal".

a. A representative sample consisting of a device with the same geometric configuration as the test sample device(s) shall be used to determine the K–factor. This representative sample shall have an accurately known micro-curie content of ^{85}Kr placed in the internal void of the device.

b. The counts per minute from the representative sample shall be measured on the shielded scintillation crystal of the counting station. The sample must be in the exact position as the actual test devices will be tested. The K–factor for the sample shall be measured with the sample placed flat in a position centered to the main body of the crystal. Some flat-top crystals are solid cylinders of approximately 3 inches (76.2 mm) diameter, and the device sample is placed on the cylinder in the same manner, as mentioned. From this measured value, the counting efficiency, in counts per minute per micro-curie shall be calculated for that device/crystal system.

c. A "flat top" crystal should have a minimum sensitivity of 4,500 cpm per µCi.

9.3.2.3 Dynamic K–factor measurement with a scintillation-crystal.

a. A representative sample consisting of a device with the same geometric configuration as the test sample device(s) shall be used to determine the K–factor. This representative sample shall have an accurately known microcurie content of ^{85}Kr placed within its internal void.

b. A crystal, (or crystals), can be used for dynamic testing of devices passing over or through the crystal(s). This configuration is commonly used in high volume testing. The K–factor must be determined in the 'dynamic condition', which will establish a K–factor value, (usually less than in a static condition with the device standing at the center of the tunnel.) The representative sample is measured dynamically, as it passes through the crystal. This establishes the maximum reading achievable for the sample. From this measured value, the counting efficiency, in counts per minute per micro-curie shall be calculated. This K–factor determination is most commonly determined by the equipment manufacturer.

9.3.3 General. The K–factor for each geometric configuration is determined and used for testing. As a convenience, the same K–factor may apply to similar geometric configurations. This allows the same K–factor to be used for multiple devices, as long as the same test procedure and equipment is used, and the devices are measured using the same measurement system, (9.3.2, 9.3.2.1, 9.3.2.2, and 9.3.2.3).

It should be noted that state-of-the-art scintillation crystals are only capable of detecting (measuring) a maximum reading of 16,000 to 18,000 cpm from the emission from one microcurie of ^{85}Kr contained within the cavity of a device. Those values are limited by the total radiation emitted from ^{85}Kr; the mass of the sodium iodide crystal body; the physical proximity of the device to that crystal; and the materials of construction of the device. Most microcircuits and semiconductor devices have a K–factor of 14,000 to 16,000 cpm per µCi.

The efficiency of the counting station should be checked once every shift using a traceable ^{85}Kr reference sample. This is a functional test that assures the counting station is measuring within the tolerance of the scintillation crystal. Most "well-type" scintillation crystal will have an efficiency of 13,000 to 14,000 cpm per µCi. The reference standard should be corrected for half-life monthly and the measurements should be within ±10 percent of the established crystal efficiency.

9.4 Evaluation of surface sorption. All device encapsulations consisting of glass, metal, substrate and chip coatings, and ceramic or combinations thereof, that also include external coatings and external sealants or labels, shall be evaluated for surface sorption of ^{85}Kr before establishing the leak test parameters. Representative samples with the questionable surface material shall be subjected to the predetermined pressure and time conditions established for the device configuration as specified by 9.2. The samples shall then be measured at the counting station every 10 minutes, with count rates noted, until the count rate becomes asymptotic with time. (This is the point in time at which surface sorption is no longer a problem.) This time lapse shall be noted and shall determine the "wait tie" specified in 9.5.

9.5 Procedure. The devices shall be placed in the radioactive tracer gas pressurization tank. The tank may be partially filled with inert material *(*aluminum filler blocks), to reduce machine cycle time and increase the efficiency of the system*.* The tank shall be evacuated to 66.7 Pa (0.5 torr). The devices shall be subjected to a minimum of 30 psia (207 kPa) of ^{85}Kr/air mixture for a minimum of 12 minutes. Actual pressure and soak time shall be determined in accordance with 9.2. The R value in counts per minute shall not be less than 500 above background.

The ^{85}Kr/air gas mixture shall be transferred to storage until 66.7 Pa (0.5 torr) pressure exists in the pressurization tank. The storage cycle shall be completed in 3 minutes maximum as measured from the end of the bombing cycle or from the time the tank pressure reaches 60 psia (414 kPa) if a higher bombing pressure is used. The tank shall then immediately be backfilled with air. The devices shall then be removed from the tank and measured with a scintillation-crystal-equipped counting station. Device encapsulations that come under the requirements of 9.4 shall be exposed to ambient air for a time not less than the "wait time" determined by 9.4. The time between removal from the pressurization chamber and test should be completed within one hour, for devices less than 0.5 cm^3, or within three hours, for devices greater than 0.5 cm^3. Device encapsulations that do not come under the requirements of 9.4 may be tested without a "wait time".

If the devices are tested in the well-crystal with the crystal-well shielded with a lead-plug while measuring the device, and a background of approximately 500 cpm is achievable when the Ratemeter is in the "slow-time-constant" position; then reject values R of a minimum of 250 cpm (net) above background while using a lead plug, may be measured for rejection of devices in high sensitivity testing. The counting station shall be checked to verify functional accuracy at least once every shift using a ^{85}Kr reference standard and following the equipment manufacturer's procedure. The verification of acceptable readings shall be documented and recorded for each scintillation detection system (well, tunnel, flat top) prior to performing testing. A reference log shall be maintained for each counting station. The actual value of the functional check performed each shift, shall be recorded and signed off by operator.

The actual leak rate of the component shall be calculated with the following equation:

Equation (2): $$Q = \frac{\text{(Actual readout in net counts per minute)} \times Q_S}{R}$$

Where Q = actual leak rate in atm-cc/sec (^{85}Kr), and Q_S and R are defined in 9.2.

9.5.1 Failure criteria. Unless otherwise specified, devices that exhibit a leak rate equal to or greater than the test limits of table 1071–IV shall be considered as failures. These limits are the ^{85}Kr equivalents for the air leak rates that are needed to provide a minimum exchange with atmosphere in 1 year.

TABLE 1071–IV. Test limits for radioisotope fine leak method.

Volume of package cm^3	Failure criteria for L atm-cc/sec (air)	^{85}Kr reject level Q_S atm-cc/sec (Kr)
≤ 0.002	5×10^{-10}	2.9×10^{-10}
>0.002 ≤ 0.02	1×10^{-9}	5.8×10^{-10}
>0.02 ≤ 0.5	5×10^{-9}	2.9×10^{-9}
> 0.5	1×10^{-8}	5.8×10^{-9}

9.5.2 Quantitative (read and record) leak rate procedure. Devices subjected to the radioisotope fine leak procedure can be measured quantitatively for accurate leak rates following the procedure in 9.5. This procedure is usually applied to devices with internal cavities greater than 0.1 cm^3, with leak rates less than 10^{-6} atm-cc/sec (air). Special techniques must be followed for devices with external organic materials. The shielding plug shall be placed over the scintillation crystal and the background reading determined for the crystal. The devices are then measured at the scintillation crystal counting station using the "slow-time-constant" on the Ratemeter. The devices are then measured one device at a time, reading the counts per minute very carefully with the shielding plug placed over the opening of the crystal to minimize the environmental background radiation. The ‘net’ counts per minute reading is determined for the DUT by subtracting the background reading from the reading of the DUT. The counting station calibration must be checked at least once every shift using a ^{85}Kr reference standard following equipment manufacturer's procedure" and the actual value shall be recorded and signed off by operator.

The reading in cpm must be verified as stable. The device must be measured for surface beta reading to assure that there is no external ^{85}Kr gas absorbed onto the part. If surface beta readings are found, the device must be placed in vacuum for 5 minute intervals (for devices with greater than 0.5 cm^3 internal volumes), or, (for devices with less than 0.5 cm^3 internal volume), allowed to stand in ambient atmosphere until the Beta readings dissipate. The ^{85}Kr readings must remain stable for 24 hours for devices with greater than 0.5 cm^3 internal volumes, and for at least 4 hours for devices with less than 0.5 cm^3 internal volumes.

The quantitative leak rate of the device, Q, shall be calculated as follows, (using Equation (2):

$$Q = \frac{\text{(Net reading of DUT in counts per minute)}}{\text{"R"}} \times Q_S = \text{leak rate atm-cc/sec (Kr)}$$

The quantitative leak rate Q shall be converted to the equivalent atm-cc/sec (air) leak rate by multiplying the Q leak rate by a factor of 1.712.

NOTE 1: The exact internal volume of the device and the date code, if the device is to be subjected to further studies such as IGA.

NOTE 2: The history of the prior tests to which the device may have been subjected, i.e. fluorocarbon bubble tests, etc. (as the fluorocarbon fluid will skew the measured leak rate.

NOTE 3: When a group of the same lot of devices has been subjected to this procedure, it is suggested that at least one of the devices be subjected to 24 hours in vacuum with periodic readings taken to verify the slope of the loss of ^{85}Kr gas from the device. Those readings should show a linear ^{85}Kr loss for a molecular flow fine leak, unless the device has been previously subjected to fluorocarbon fluids. A non-linear slope also indicates that the measured leak rate is probably greater than measured.

9.6 Test conditions G_2 – radioisotope gross/fine combination.

9.6.1 Apparatus. The apparatus required for test conditions G_2 shall be in accordance with 5.1.

9.6.2 Testing parameters. The bombing pressure and soak time shall be in accordance with 9.2.

9.6.3 Determination of counting efficiency (K–factor). The determination of counting efficiency K–factor shall be in accordance with 9.3.

9.6.4 Evaluation of surface sorption. The evaluation of surface sorption shall be in accordance with 9.4.

9.6.5 Procedure G_2 combination gross/fine test. The devices shall be placed in a radioactive gas pressurization chamber. The pressurization chamber shall be filled with inert material (aluminum filler blocks), to reduce cycle time and make the test more efficient. The chamber shall be evacuated to 66.7 Pa (0.5 torr). The devices shall be subjected to a minimum of 30 psia (207 kPa) of ^{85}Kr/air mixture for a minimum of 12 minutes. Actual pressure and soak time for G_2 shall be in accordance with 9.5. The R value in counts per minute shall not be less than 500 cpm above background. When the soak time is completed the ^{85}Kr/air mixture shall be transferred to storage until 266.6 Pa (2.0 torr) pressure exists in the pressurization chamber. The storage cycle shall be completed in 3 minutes as measured from the end of the pressurization cycle or from the time the tank pressure reaches 60 psia, (if a higher pressure was used). The tank shall then be backfilled with air. The devices shall immediately be removed from the tank and measured at the counting station within 10 minutes after removal from the tank. Devices that come under the conditions of 9.6.4 and require a "wait time", cannot be subjected to the gross/fine combination test. Those devices must be subjected to G_1 and a gross leak condition separately. The counting station calibration must be checked at least once every shift using a ^{85}Kr reference standard following equipment manufacturer's procedure, and a record of proper function shall be maintained.

NOTE 1: Devices rejected by this condition may be either gross or fine leakers. The actual leak rate can only be classified as a reject "greater than the test sensitivity of the test". If quantitative values are required another condition must be used.

13.4.1 Failure criteria. The failure criteria for optical fine leak method L_2 shall be in accordance with table 1071–VII.

TABLE 1071–VII. Failure criteria for optical fine leak method L_2.

Vol. of package cm^3	Failure criteria L atm-cc/sec (air)	Reject level "L_2" atm-cc/sec (He)
≤ 0.002	5×10^{-10}	1.37×10^{-9}
>0.002 ≤ 0.02	1×10^{-9}	2.74×10^{-9}
>0.02 ≤ 0.5	5×10^{-9}	1.37×10^{-8}
> 0.5	1×10^{-8}	2.75×10^{-8}

14. Test condition G_t – radioisotope thermal leak test. This test is for the evaluation of package hermetic integrity at elevated temperature. It is intended to verify that the package structural design will maintain hermetic integrity at elevated temperatures. Devices to be evaluated in this thermal leak test shall be packages that should not have not been subjected to any prior liquid immersion testing. The devices to be tested for thermal leakage shall first be subjected to test condition A, B, or G_2 to at least the sensitivity requirement for that package in the standard, and the hermeticity to that sensitivity, establishing the package is hermetic at ambient temperature.

14.1 Apparatus. The apparatus required for test condition G_t shall be as follows:

a. Radioactive tracer gas pressurization console containing ^{85}Kr/air mixture. A ^{85}Kr pressure/vacuum thermal test chamber capable of evacuation and pressurization at temperatures to 125ºC, and thermal cycling from ambient temperature to 125ºC while maintaining ^{85}Kr/air pressure.

b. Counting station with a minimum sensitivity of 5,000 cpm per µCi of ^{85}Kr tracer gas and a minimum detectable count rate of 500 cpm above background level. The counting station calibration shall be checked at least once every working shift using a ^{85}Kr reference standard following the equipment manufacturer's procedure, and a record of proper function shall be maintained.

c. A tracer gas consisting of a mixture of ^{85}Kr and air. The concentration of ^{85}Kr in air shall be no less than 100 µCi per atm-cc/sec. This value shall be determined at least once each 30 days, following manufacturer's procedure, and recorded in accordance with the calibration requirements of the general test method standard MIL–STD–750.

14.2 Testing parameters. Prior to performing this test condition, the devices shall be pre-tested to the sensitivity of the standard following the radioisotope procedure A and B, or G_2, radioisotope gross/fine test. The bombing pressure and soak time for the pre-test shall be established for the package following 9.2.

14.3 Determination of counting efficiency (K). The determination of K-factor shall be in accordance with 9.2.

14.4 Evaluation of surface sorption. The evaluation of surface sorption shall be in accordance with 9.4.

14.5 Procedure. The devices shall be placed in the radioactive tracer gas thermal-pressurization chamber. The tank shall be evacuated to 66.7 Pa (0.5 torr) . The devices shall be subjected to a pressure of ^{85}Kr/air mixture at a pressure of 60 psia (414 kPa) (typical), or a minimum of 30 psia (207 kPa) (dependent upon the structural compatibility of the package).

14.5.1 Thermal test. The devices are placed in the thermal/pressure chamber and pressurized with ^{85}Kr/air mixture to the pressure established in 14.5. The chamber is then heated to 100ºC ±10ºC minimum to 125ºC ±10ºC maximum, and maintained at the elevated temperature for 10 minutes minimum. The temperature is then returned to ambient, at which time the ^{85}Kr is returned to storage and the devices are removed from the thermal/pressure chamber and measured at the scintillation crystal detection station for any ^{85}Kr gas trapped within the devices. Device encapsulations that come under the requirements of 9.4 shall be exposed to ambient air for a time not less than the "wait time" determined by 9.4. In no case will the time between removal from the pressurization chamber and measurement exceed 60 minutes. Any device containing measurable ^{85}Kr gas is a thermal-reject. This test is frequently applied to devices that have little or no indicated leakage at ambient temperature in order to establish if they open to a larger leak rate at temperature.

14.6 Failure criteria. This test is a "go-no go" test to detect packages that ‘open-up’, or become non-hermetic at elevated temperature. The detection of a measurable amount of ^{85}Kr, (greater than 500 cpm above ambient background), within the part after exposure to ^{85}Kr pressure at temperature indicates a "thermal-reject", (hermetic failure at elevated temperature). A thermal reject may be placed in a vacuum oven and the temperature increased for 10 minutes minimum, at 10ºC intervals, and the device removed to measure the ^{85}Kr content after each 10ºC increase, until the temperature is reached at which the ^{85}Kr reading begins to decrease, indicating the temperature at which the device opened during pressurization. This will indicate the approximate temperature at which the device is leaking, (or increasing its leak rate).

15. Test conditions CH_1 and CH_2 – combined fine/gross leak. Test conditions CH_1 and CH_2 expand the range of helium fine leak to include the gross leak range and require the same test conditions using a specialized measurement apparatus Cumulative Helium Leak Detector (CHLD).

NOTE: The flexible method, H_2 or CH_2, shall be used unless otherwise specified in the acquisition document, purchase order, or contract.

15.1 Apparatus. The apparatus for this procedure shall be as in 10.1 except that the optimum calibration leak standard is 5×10^{-10} atm-cc/sec, and since the slope of the accumulated helium is a linear function, measurements beyond 10^{-12} are achievable if the analyzer has sufficient sensitivity. A 5×10^{-12} helium leak standard shall be used to validate the sensitivity and linearity of the lower leak rate range and a 1×10^{-8} helium leak standard used for the higher range. The volume of the test chamber used for leak rate measurement should be held to the minimum practical, since too large (>100) a ratio between the device internal volume and the chamber dead volume will reduce the sensitivity limits when detecting gross leaks. The leak detector indicator shall be calibrated using a diffusion-type calibrated standard leak at least once every working shift. In addition, the test apparatus for CH_1 and CH_2 shall utilize a specialized pumping system which enables the volume of helium released to be measured as well as the rate of change or "slope" of the helium such that the leak rate is determined from the slope measurement for fine leaks and the volume for gross leaks.

The maximum ratio of test chamber dead volume to device internal volume Vc/Vd shall be established for individual part testing and batch testing to insure a gross leak amplitude will be detected with a signal to background ratio of at least 3 to one. This ratio is a function of the helium content of the purge gas as well as the internal volume and number of devices to be batch tested.

15.2 Procedure. The procedure for CH_1 "fixed" and CH_2 "flexible" methods shall be as in paragraph 10.2.

15.2.1 Evaluation of surface sorption. The evaluation of surface sorption shall be in accordance with 10.2.1.

15.2.1.1 Test condition CH_1. Test condition CH_1 fixed method shall be shall be in accordance with 10.2.

15.2.1.2 Test condition CH_2. Test condition CH_2 flexible method shall be shall be in accordance with 10.2.

d. The radioisotope method G_1 may be used to re-screen devices that have been subjected to fluorocarbon fluids, but they shall be tested to a higher sensitivity to detect leakage. The true leak rate however is sometimes seen to be two orders of magnitude greater than the indicated leak rate. When fine leak rates are detected, a re-test will demonstrate a non-linear increase in ^{85}Kr reading if the device has previously been subjected to fluorocarbon fluid. A vacuum-decay test can confirm that the leak rate is either a fine-leak and the true leak rate of the part, or that it is a 'diffusion' or 'solubility' leak rate through a liquid medium. Surface sorption is not a problem with ^{85}Kr as surface fluorocarbon liquid is easily detected by measuring the Beta radiation from ^{85}Kr gas absorbed in surface fluorocarbon fluid residues, since the Beta radiation is only detectable on surfaces and will not penetrate from within the device, ^{85}Kr gas quickly desorbs from surface fluorocarbon fluids, reducing surface sorption problems. The gamma radiation readings will confirm the amount of ^{85}Kr that has actually penetrated into the device if it is non-hermetic, and that confirms the leakage into the device.

e. When retesting devices to test condition H_1 the history of device exposure to helium including dates, backfilling performed, tracer gas concentrations, pressure, and time exposed, should be known in order to ensure reliable results. Whenever parts were sealed in helium, or prior helium testing may have been performed on a device, the internal helium content is unknown and any subsequent helium test may be flawed. In that case any device detected as a marginal reject should be retested using a different dry gas medium as in A, B, or G_2. When retesting devices to conditions A, B, G_2, the history of the prior ^{85}Kr testing is not required. The devices are pre-read for residual ^{85}Kr gas just prior to retesting. Any prior ^{85}Kr reading is subtracted from the reading after retesting. The new “net” reading indicates the leak rate of the package.

NOTE: The following procedure is based on the assumption that a complete and accurate history of prior helium testing has been accurately recorded.

f. When retesting devices to test condition H_1, H_2 or CH, the history of device exposure to helium including dates, backfilling performed, tracer gas concentrations, pressure, and time exposed, should be known in order to ensure reliable results. The sum of the bombing times and the total dwell time from the first bombing interval to the expected subsequent leak test can be used in the Howl-Mann equation to compute a new R_1 value if no helium was sealed in the device.

g. If the history of the part indicates that it has been subjected to fluorocarbon fluid testing, or if there is no history evidencing that it has not been subjected to any fluorocarbon fluids, then it shall be assumed that the part could be fluorocarbon contaminated and the recommendations of 17.

NOTE: The requirements of 18.c and 18.d shall be followed.

h. Surface adsorption: This test method has reduced the maximum allowable leak rate historically allowed for hermetic devices by several orders of magnitude and as a result, the effects of surface adsorption of the tracer gas from surface contamination such as moisture, grease, or oils, or attached or printed labels, or surface porosity or materials which have a significant diffusion rate for the tracer gas shall be addressed and requires additional diligence to obtain useful data in a reasonable time period. When helium is used as the tracer gas, it is particularly important to keep the devices under test clean and free of surface contamination as well as the test chamber and any associated fixturing. Especially troublesome are the low vapor pressure organic binders that are found in cosmetic products. Never handle devices to be leak tested or inlet chambers or fixtures of the leak tester with bare hands. Always use finger cots or ESD gloves which are clean. If any solvent cleaning is performed prior to leak testing, make certain the solvent is fully dispersed prior to any leak testing procedure.