* METHOD 1014.12

SEAL

1. PURPOSE. The purpose of this test is to determine the effectiveness (hermeticity) of the seal of microelectronic and semiconductor devices with designed internal cavities

1.1 Definitions.

a. Standard leak rate. Standard leak rate is defined as that 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 (760 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 (atm cc/s).

b. Measured leak rate. Measured leak rate (R_1) is defined as the leak rate of a given package as measured under specified conditions and employing a specified test medium. Measured leak rate shall be expressed in units of atmosphere cubic centimeters per second (atm cc/s). For the purpose of comparison with rates determined by other methods of testing, the measured leak rates must be converted to equivalent standard leak rates.

c. Equivalent standard leak rate. The equivalent standard leak (L) of a given package, with a measured leak rate (R_1), is defined as the leak rate of the same package with the same leak geometry that would exist under the standard conditions of 1.1a. The formula (does not apply to test condition B) in 3.1.1.2 represents the L/R ratio and gives the equivalent standard leak rate (L) of the package with a measured leak rate (R_1) where the package volume and leak test conditioning parameters influence the measured value of (R_1). The equivalent standard leak rate shall be expressed in units of atmosphere cubic centimeters per second (atm cc/s).

2. APPARATUS. The apparatus required for the seal test shall be as follows for the applicable test condition:

2.1 Test conditions A_1, A_2, and A_4, 1/ tracer gas helium (He) fine leak. Apparatus required shall consist of suitable pressure and vacuum chambers and a mass spectrometer-type leak detector preset and properly calibrated for a helium leak rate sensitivity sufficient to read measured helium leak rates of 10^{-9} atm cc/s and greater. The volume of the chamber used for leak rate measurement should be held to the minimum practical, since this chamber volume has an adverse effect on sensitivity limits. The leak detector indicator shall be calibrated using a diffusion-type calibrated standard leak at least once during every working shift. In addition for test condition A_4, the following apparatus is required:

a. Fixture and fittings to mate the package to be tested to the leak detector.

b. Surgical rubber gasket.

c. Apeizon grease (type M or N), perfluorocarbon fluid 2/, or equivalent, if required to obtain seal.

1/ A_3 was intentionally omitted.
2/ Perfluorocarbons contain no chlorine or hydrogen.

* 2.2 Test condition B_1, radioisotope fine leak. Apparatus for this test shall consist of:

* a. Radioactive tracer gas pressurization console.

b. Counting equipment consisting of a scintillation crystal, photomultiplier tube, preamplifier, ratemeter, and krypton-85 reference standards. The counting station shall be of sufficient sensitivity to determine through the device wall the radiation level of any krypton-85 tracer gas present within the device. The counting station shall * have a minimum sensitivity of 10,000 counts per minute per micro-curie of krypton-85 and shall be calibrated at least once every working shift using krypton-85 reference standards and following the equipment manufacturer's instruction.

* c. A tracer gas that consists of a mixture of krypton-85 and dry nitrogen. The concentration of the krypton-85 in dry nitrogen shall be no less than 100 micro-curies per atmospheric cubic centimeter. This value shall be determined at least once each 30 days and recorded in accordance with the calibration requirements of this standard (see 4.5.1 of MIL-STD-883).

2.3 Test condition C, perfluorocarbon gross leak. Apparatus for this test shall consist of:

a. A vacuum/pressure chamber for the evacuation and subsequent pressure bombing of devices up to 105 psia up to 23.5 hours.

b. A suitable observation container with provisions to maintain the indicator fluid at a temperature of 125°C and a filtration system capable of removing particles greater than 1 micrometer in size from the fluid (condition C1 only).

c. A magnifier with a magnification in the range between 1.5X to 30X for observation of bubbles emanating from devices when immersed in the indicator fluid (condition C1 only).

d. Sources of type I detector fluids, and type II indicator fluids as specified in table I.

e. A lighting source capable of producing at least 15 thousand foot candles in air at a distance equal to that which the most distant device in the bath will be from the source. The lighting source shall not require calibration but the light level at the point of observation (i.e., where the device under test is located during observation for bubbles), shall be verified (condition C1 only).

f. Suitable calibrated instruments to indicate that test temperatures, pressures, and times are as specified.

g. Suitable fixtures to hold the device(s) in the indicator fluid (condition C1 only).

h. A perfluorocarbon vapor detection system capable of detecting vapor quantities equivalent to 0.167 or 1/6 microliter of type I fluid (condition C3 only).

i. The vapor detector used for condition C3 shall be calibrated at least once each working shift using a type I fluid calibration source, and following the manufacturer's instructions.

2.4 Test condition D, penetrant dye gross leak. The following apparatus shall be used for this test:

a. Ultraviolet light source with peak radiation at approximately the frequency causing maximum reflection of the dye (3650 Å for Zyglo; 4935 Å for Fluorescein; 5560 Å for Rhodamine B, etc.).

b. Pressure chamber capable of maintaining 105 psia.

c. Solution of fluorescent dye (such as Rhodamine B, Fluorescein, Dye-check, Zyglo, FL-50, or equivalent) mixed in accordance with the manufacturer's specification.

d. A magnifier with a magnification in the range between 1.5X to 30X for dye observation.

2.5 Test condition E, weight gain gross leak. Apparatus for this test shall consist of:

a. A vacuum/pressure chamber for the evacuation and subsequent pressure bombing of devices up to 90 psia up to 10 hours.

b. An analytical balance capable of weighing the devices accurately to 0.1 milligram.

c. A source of type III detector fluid as specified in table I.

d. A filtration system capable of removing particles greater than 1 micrometer in size from the perfluorocarbon fluid.

e. Suitable calibrated instruments to measure test pressures and times.

TABLE I. Physical property requirements of perfluorocarbon fluids. 1/

Property	Type I	Type II	Type III	ASTM test method
Boiling point (°C)	50-95	140-200	50-110	D-1120
Surface tension (Dynes/cm) at 25°C		< 20		D-971 D-1331
Density at 25°C (gm/ml)	> 1.6	> 1.6	> 1.6	D-941
Density at 125°C (gm/ml)		> 1.5		D-941
Dielectric strength (volts/mil)	> 300	> 300	> 300	877
Residue (:gm/gm)	< 50	< 50	< 50	D-2109
Appearance	Clear colorless			NA

1/ Perfluorocarbons contain no chlorine or hydrogen.

2.6 Test conditions C_4 and C_5 - optical gross/fine leak. This test condition applies to individual devices and devices mounted on printed circuit boards or higher level assemblies. Apparatus required shall consist of suitable pressure or vacuum/pressure chamber with an integral interferometry leak detector. The optical leak detector shall be preset and properly calibrated for an equivalent standard leak rate sensitivity sufficient to read measured Helium leak rates of 10^{-5} atm-cc/sec and greater for gross leak detection (C_4), and 5 X 10^{-9} atm-cc/sec and greater for fine leak detection (C_5).

Note: Prior to performing optical gross/fine leak testing, the test designer will need to know what limits the DUT has. Extreme pressure/vacuum may cause damage to some devices. The test designer will need to design the test conditions around such limitations.

2.6.1 Apparatus initial setup. The optical gross/fine leak test equipment requires system parameter normalization as determined uniquely for each particular device under test. To accomplish this an initial device package set up and calibration shall be performed using two or more package specimens with a known hermeticity of <5X10^{-8} cc-atm/sec and a known internal free volume. These device packages shall be of the same type and geometry as the packages to be tested. These known good packages are tested in the system to calibrate the device stiffness values used in determining the device leak sensitivity (see 3.6.2).

2.6.2 Process monitoring. A group of “system check devices” with a known hermeticity of <5X10^{-8} cc-atm/sec, maintained by the test facility, shall be used for system operation verification at the beginning and end of each work shift. This check of the system’s operation shall be completed using a minimum of two package specimens from the “system check devices”.

* 2.7 Test condition B_2 – radioisotope gross leak. This test shall be used to leak test with an internal free-volume greater than 0.02 cc; (or smaller, only if it can be demonstrated that the following requirements are met:)

* a. A 5 mil diameter hole shall be made in a representative sample 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 indication 1000 cpm or greater is considered a reject. The device must remain a reject for a minimum of ten minutes after removal from the pressurization tank. If the device does not fail, this test condition shall not be used.

* 2.8 Test condition B_1 and B_2 – radioisotope gross/fine combination leak. The apparatus for this test is the apparatus as in paragraph 2.2. This test may be applied as combination of conditions B_1/B_2 and is used in accordance with the requirements of those conditions.

* 3. PROCEDURE. Fine and gross leak tests shall be conducted in accordance with the requirements and procedures of the specified test condition. Testing order shall be fine leak (condition A or B_1 or C_5) followed by gross leak (condition B_2, C_1, C_3, C_4, D, or E) except when C_4 or B_2 is used together with A, B_1, or C_5. When specified (see 4), measurements after test shall be conducted following the leak test procedures. Where bomb pressure specified exceeds the microcircuit package capability, alternate pressure, exposure time, and dwell time conditions may be used provided they satisfy the leak rate, pressure, time relationships which apply, and provided a minimum of 30 psia (2 atmospheres absolute) bomb pressure is applied in any case or for condition C_4, a minimum of 10 psi differential test pressure is applied in any case. When test condition A_4 is used, gross leak testing is not required. However A_4 shall not be used in lieu of the required seal testing of lidded packages. When batch testing (more than one device in the leak detector at one time) is used in performing test condition A or B and a reject condition occurs it shall be noted as a batch failure. Each device may then be tested individually one time for acceptance if all devices in the batch are retested within one hour after removal from the tracer gas pressurization chamber. For condition B_1, B_2 only, devices may be batch tested and/or individually remeasured for acceptance providing all measuring is completed within one-half hour for B_1 and within 10 minutes for B_2 or combination B_1/B_2, after removal from the tracer gas pressurization chamber. For condition C_3 only, devices that are batch tested, and indicate a reject condition, may be retested individually one time using the procedure of 3.3.3.1 herein, except that re-pressurization 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 conditions C_4 and C_5 only, the package must meet lid stiffness requirements defined in 3.6.1. This includes devices that are conformal coated such as circuit board assemblies.

3.1 Test condition A_1, A_2, or A_4 tracer gas (He) fine leak. Test condition A_1 is a "fixed" method with specified conditions in accordance with table II that will ensure the test sensitivity necessary to detect the required measured leak rate (R_1) . Test condition A_2 is a "flexible" method that allows the variance of test conditions in accordance with the formula of 3.1.1.2 to detect the specified equivalent standard leak rate (L) at a predetermined leak rate (R_1). Test condition A_4 is a method that will detect the required measured leak rate (R_1) of an unsealed package.

3.1.1 Test conditions A_1 and A_2, procedure applicable to "fixed" and "flexible" methods. The completed device(s), shall be placed in a sealed chamber which is then pressurized with a tracer gas of 100 +0, -5 percent helium for the required time and pressure. The pressure shall then be relieved and each specimen transferred to another chamber or chambers which are connected to the evacuating system and a mass-spectrometer-type leak detector. When the chamber(s) is evacuated, any tracer gas which was previously forced into the specimen will thus be drawn out and indicated by the leak detector as a measured leak rate (R_1). (The number of devices removed from pressurization for leak testing shall be limited such that the test of the last device can be completed within 60 minutes for test condition A_1 or within the chosen value of dwell time t_2 for test condition A_2.)

Note: Flexible Method shall be used unless otherwise specified in the acquisition document, purchase order, or contract.

3.1.1.1 Test condition A_1, fixed method. The devices(s) shall be tested using the appropriate conditions specified in table II for the internal cavity volume of the package under test. The time t_1 is the time under pressure and time t_2 is the maximum time allowed after release of pressure before the device shall be read. The fixed method shall not be used if the maximum equivalent standard leak rate limit given in the acquisition document is less than the limits specified herein for the flexible method.

TABLE II. Fixed conditions for test condition A_1.

Volume of package (V) in cm^3	Bomb condition			R_1 Reject limit (atm cc/s He)
	Psia ±2	Minimum exposure time hours (t_1)	Maximum dwell hours (t_2)	
<0.05	75	2	1	5×10^{-8}
$\geq$0.05 - <0.5	75	4	1	5×10^{-8}
$\geq$0.5 - <1.0	45	2	1	1×10^{-7}
$\geq$1.0 - <10.0	45	5	1	5×10^{-8}
$\geq$10.0 - <20.0	45	10	1	5×10^{-8}

3.1.1.2 Test condition A_2, flexible method. Values for bomb pressure exposure time, and dwell time shall be chosen such that actual measured tracer gas leak rate (R_1) readings obtained for the devices under test (if defective) will be greater than the minimum detection sensitivity capability of the mass spectrometer. The devices shall be subjected to a minimum of 2 atmospheres absolute of helium atmosphere. The chosen values, in conjunction with the value of the internal volume of the device package to be tested and the maximum equivalent standard leak rate (L) limit (as shown below or as specified in the applicable acquisition document), shall be used to calculate the measured leak rate (R_1) limit using the following formula:

*

$$R_1 = \frac{LP_E}{P_O}\left(\frac{M_A}{M}\right)^{\frac{1}{2}} \left\{ 1 - e^{-\left[\frac{Lt_1}{VP_0}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\right]} \right\} e^{-\left[\frac{Lt_2}{VP_0}\left(\frac{M_A}{M}\right)^{\frac{1}{2}}\right]}$$

Where:

R_1 = The measured leak rate of tracer gas (He) through the leak in atm cc/s He.
L = The equivalent standard leak rate in atm cc/s air.
P_E = The pressure of exposure in atmospheres absolute.
P_O = The atmospheric pressure in atmospheres absolute. (1)
M_A = The molecular weight of air in grams. (28.7)
M = The molecular weight of the tracer gas (Helium) in grams. (4)
t_1 = The time of exposure to P_E in seconds.
t_2 = The dwell time between release of pressure and leak detection, in seconds.
V = The internal volume of the device package cavity in cubic centimeters.

3.1.1.2.1 Failure criteria. Unless otherwise specified, devices with an internal cavity volume of 0.01 cc or less shall be rejected if the equivalent standard leak rate (L) exceeds 5×10^{-8} atm cc/s air. Devices with an internal cavity volume greater than 0.01 cc and equal to or less than 0.4 cc shall be rejected if the equivalent standard leak rate (L) exceeds 1×10^{-7} atm cc/s air. Devices with an internal cavity volume greater than 0.4 cc shall be rejected if the equivalent standard leak rate (L) exceeds 1×10^{-6} atm cc/s air.

3.1.2 Test condition A_4, procedure applicable to the unsealed package method. The fixture and fittings of 2.1a. shall be mounted to the evacuation port of the leak detector. Proof of fixturing integrity shall be verified by sealing a flat surfaced metal plate utilizing the gasket of 2.1 (and grease or fluid of 2.1 if required to obtain seal) and measuring the response of the leak test system. Testing shall be performed by sealing the package(s) to the evacuation port and the package cavity evacuated to 0.1 torr or less. Care shall be taken to prevent contact of grease with package (seal ring not included) to avoid masking leaks. The external portion of the package shall be flooded with Helium gas either by the use of an envelope or a spray gun, at a pressure of 10 psig.

3.1.2.1 Failure criteria. Unless otherwise specified, devices shall be rejected if the measured leak rate (R_1) exceeds 1 x 10^{-8} atm cc/s He.

* 3.2 Test condition B_1, radioisotope fine or B_1/B_2 Combination gross/fine leak test.

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

$$Q_S = \frac{R}{skTPt} \qquad (1)$$

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

Q_S = The maximum leak rate allowable, in atm cc/s Kr, for the devices to be tested.

* 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 background reading of the microcircuit, if it has been through prior radioactive leak tests.

* s = The specific activity, in micro-curies per atmosphere cubic centimeter, of the krypton-85 tracer gas in the pressurization system.

* k = The counting efficiency of the specific scintillation crystal used in the testing to measure krypton-85 within the internal cavity of the specific component being evaluated. This k-factor must be determined in accordance with 3.2.2 for each device geometric configuration in combination with the specific scintillation crystal in which it will be measured.

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

* $\overline{P}$ = $P_e^2 - P_i^2$, where P_e is the bombing pressure in atmospheres absolute and P_i is the original internal pressure of the devices in atmospheres absolute. The activation pressure (P_e) may be established by specification or if a convenient soak time (T) has been established, the activation 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.

* 3.2.2 Determination of counting efficiency (k). The counting efficiency (k), or k-factor is the efficiency of measurement of radioactive krypton-85 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 (see 3.2.2.1, 3.2.2.2, 3.2.2.3). 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 3.2.2.1, 3.2.2.2, and 3.2.2.3.

* 3.2.2.1 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 counting efficiency (k). This representative sample shall have an accurately known micro-curie content of krypton-85 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.

* 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 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.

* 3.2.2.2 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 counting efficiency (k). This representative sample shall have an accurately known micro-curie content of krypton-85 placed within its internal void.

* 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 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.

* 3.2.2.3 Dynamic 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 counting efficiency (k). This representative sample shall have an accurately known micro-curie content of krypton-85 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.

* 3.2.2.4 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, (3.2.2.1, 3.2.2.2, or 3.2.2.3).

* 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 counts per minute from the emission from one micro-curie of krypton-85 contained within the cavity of a device. Those values are limited by the total radiation emitted from krypton-85; 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 c/m/μCi.

* The counting efficiency (k-factor) for most device configurations and crystal combinations can sometimes be obtained from the equipment manufacturer by providing the equipment manufacturer with representative samples of the same geometric configuration as the device to be tested.

* 3.2.3 Evaluation of surface sorption. All device encapsulations consisting of glass, metal, and ceramic or combinations thereof, that also include external coatings and external sealants or labels, shall be evaluated for surface sorption of krypton-85 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 3.2.1. 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 time" specified in 3.2.4.

* 3.2.4 Test Procedure B_1, Fine Leak; B_2, Gross Leak; or B_1/B_2 Gross/Fine combination test. The devices shall be placed in a radioactive tracer gas pressurization chamber. The pressurization chamber may be partially filled with inert material (aluminum filler blocks), to reduce the cycle time and increase the efficiency of the system. It is the equipment manufacturer's recommendation that all 'small-cavity' devices be measured within 10 minutes after removal from the pressurization tank.

* a. B_1 – Fine Leak: The tank shall be evacuated to 0.5 torr. The devices shall be subjected to a minimum of 2 atmospheres absolute pressure of kypton-85/air mixture. Actual pressure and soak time for B_1 shall be determined in accordance with 3.2.1. When the 'soak time' is completed, the krypton-85/air mixture shall be transferred to storage until 0.5 torr pressure exits in the pressurization chamber. The storage cycle shall be completed in 3 minutes maximum as measured from the end of the pressurization cycle or from the time the tank pressure reaches 60 psia if a higher bombing pressure was used. The tank shall then immediately be backfilled with air and the devices removed from the tank and measured within 30 minutes after removal using a scintillation crystal equipped counting station as in 3.2.2.1, 3.2.2.2, or 3.2.2.3. Device encapsulations that come under the requirements of 3.2.3 shall be exposed to ambient air for a time not less than the 'wait time' determined by 3.2.3. Device encapsulations that do not come under the requirements of 3.2.3 may be tested without a 'wait time'. The R value shall not be less than 500 counts per minute above background. (It is recommended practice that the number of devices pressurized for leak testing is limited such that the test of the last device can be completed within 30 minutes).

* b. B_2 – Gross Leak: The tank shall be evacuated to 0.5 torr. The devices shall be subjected to a minimum of 2 atmospheres absolute pressure of krypton-85/air mixture and the bomb time no less than 2 minutes. When the soak time is completed the krypton-85/air mixture shall be transferred to storage until 2.0 torr pressure exists in the pressurization tank. The storage cycle shall be completed in 3 minutes maximum as measured from the end of the pressurization cycle. The

* tank shall then immediately be backfilled with air. The devices shall be removed from the tank and measured within 10 minutes after removal using a scintillation crystal equipped counting station as in 3.2.2.1, 3.2.2.2, or 3.2.2.3. (It is recommended practice that the number of devices pressurized for the gross leak test is limited such that the test of the last device can be completed within 10 minutes).

* c. B_1/B_2 Gross/fine combination: The tank shall be evacuated to 0.5 torr. The devices shall then be subjected to a minimum of 2 atmospheres absolute pressure of krypton-85/air mixture. The actual bomb time and pressure shall be in accordance with 3.2.1 for B_1. When the soak time is completed the krypton-85/air mixture shall be transferred to storage until 2.0 torr pressure exists in the pressurization tank. The storage cycle shall be completed in 3 minutes maximum as measured from the end of the pressurization cycle, or from the time the tank pressure reaches 60 psia if a higher bombing pressure was used. The tank shall then immediately be backfilled with air. The devices shall be removed from the tank and measured within 10 minutes after removal using a scintillation crystal equipped counting station as in 3.2.2.1, 3.2.2.2, or 3.2.2.3. (It is recommended practice that the number of devices pressurized for the gross leak test is limited such that the test of the last device can be completed within 10 minutes). Devices requiring a ‘wait time’ per 3.2.3 must be subjected to B_1 and/or B_2 separately. Device encapsulations that do not come under the requirements of 3.2.3 may be tested without a ‘wait time’.

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

$$Q = \frac{\text{(ACTUAL READOUT IN NET COUNTS PER MINUTE) X } Q_S}{R}$$

Where Q = Actual leak rate in atm cc/s, and Q_S and R are defined in 3.2.1.

*

3.2.5 Failure criteria. Unless otherwise specified, devices that exhibit a leak rate equal or greater than the test limits of table III shall be considered as failures.

*

TABLE III. Test limits for radioisotope fine leak method.

Volume of package cc	Q_S
< 0.01	1 x 10^{-8}
> 0.01, $\leq$ 0.4	5 x 10^{-8}
> 0.4	5 x 10^{-7}

*

3.3 Test condition C_1 or C_3, perfluorocarbon gross leak. Test condition C_1 is a fixed method with specified conditions that will ensure the test sensitivity necessary. Test condition C_2 has been replaced by C_1. Test condition C3 is a fixed method that uses a vapor detection system instead of an indicator bath.

3.3.1 Procedure applicable to fixed (C_1) method. The devices shall be placed in a vacuum/pressure chamber and the pressure reduced to 5 torr or less and maintained for 30 minutes minimum. The vacuum cycle may be omitted for packages with an internal volume $\geq$ 0.1 cm^3. A sufficient amount of type I detector fluid shall be admitted to cover the devices. When the vacuum cycle is performed, the fluid will be admitted after the minimum 30 minute period but before breaking the vacuum. The devices shall then be pressurized in accordance with table IV. When the pressurization period is complete the pressure shall be released and the devices removed from the chamber without being removed from a bath of detector fluid for greater than 20 seconds. A holding bath may be another vessel or storage tank. When the devices are removed from the bath they shall be dried for 2 ±1 minutes in air prior to immersion in type II indicator fluid, which shall be maintained at 125°C ±5°C. The devices shall be immersed with the uppermost portion at a minimum depth of 2 inches below the surface of the indicator fluid, one at a time or in such a configuration that a single bubble from a single device out of a group under observation may be clearly observed as to its occurrence and source. The device shall be observed against a dull, nonreflective black background though the magnifier, while illuminated by the lighting source, from the instant of immersion until, expiration of a 30-second minimum observation period, unless rejected earlier.

For packages greater than 5 grams, the effects of package thermal mass shall be determined by evaluating each package family with known leakers and measuring the time for bubbles to be observed. If the evaluation time exceeds the 30 seconds required for the observation time, then the observation time shall be extended to take into account the package thermal mass effect. Alternate methods may be used to meet this intent provided the method is documented and made available to the preparing or acquiring activity upon request.

3.3.1.1 Test condition C_1, fixed method. Allowable fixed method conditions shall be as shown in table IV, herein.

TABLE IV. Condition C pressurization conditions.

Pressure psia (min)	Minimum pressurization time (hour)	
	C_1	C_3
30	23.5	12
45	8	4
60	4	2
75	2	1
90	1	0.5
105	0.5	N/A

3.3.2 Failure criteria. A definite stream of bubbles or two or more large bubbles originating from the same point shall be cause for rejection.

CAUTION: When the leak is large, the operator may notice a stream of liquid exiting the package without the release of bubbles. This condition shall result in the package being rejected.

3.3.3 Test condition C_3, perfluorocarbon vapor detection.

3.3.3.1 Procedure. The devices shall be placed in a vacuum/pressure chamber and the pressure reduced to 5 torr and maintained for 30 minutes minimum. A sufficient amount of type I detector fluid shall be admitted to the pressure chamber to cover the devices. The fluid shall be admitted after the 30 minute minimum vacuum period but before breaking the vacuum. The devices shall then be pressurized in accordance with table IV. The pressure shall be maintained for a period of 30 minutes minimum. Upon completion of the pressurization period, the pressure shall be released, the devices removed from the pressure chamber without being removed from a bath of detector fluid for more than 20 seconds and then retained in a bath of perfluorocarbon fluid. When the devices are removed from the fluid they shall be air dried for a minimum of 20 seconds and a maximum of 5 minutes prior to the test cycle. If the type I detector fluid has a boiling point of less than 80°C, the maximum drying time shall be 3 minutes.

The devices shall then be tested with a perfluorocarbon vapor detector that is calibrated in accordance with 2.3h and 2.3i. "Purge" time shall be in accordance with table V. Test time shall be a minimum of 3.5 seconds (unless the device is rejected earlier) with the perfluorocarbon vapor detector purge and test chambers at a temperature of 125 ±5°C, or 2.5 seconds minimum with the purge and test chambers at a temperature of 150 ±5°C.

NOTE: Air dry, purge and test limits for each device shall be complied with in all cases, including stick to stick handling.

NOTE: Test temperature shall be measured at the chamber surface that is in contact with the device(s) being tested. Device orientation within the test cell should maximize heat transfer from the heated chamber surface to the cavity of the device within the capability of the equipment.

3.3.3.2 Failure criteria. A device shall be rejected if the detector instrumentation indicates more than the equivalent of 0.167 or 1/6 microliter of type I detector fluid in accordance with table I.

TABLE V. Purge time for condition C_3.

Package with internal free volume (CM^3)	Purge time (seconds)
$\leq$0.01	$\leq$ 5
>0.01 $\leq$0.10	$\leq$ 9
>0.10	$\leq$ 13

NOTE: Maximum purge time can be determined by cycling a device with a 0.02 to 0.05 inch hole and measuring the maximum purge time that can be used without permitting the device to escape detection during the test cycle.

3.3.4 Precautions. The following precautions shall be observed in conducting the perfluorocarbon gross leak test:

a. Perfluorocarbon fluids shall be filtered through a filter system capable of removing particles greater than 1 micrometer prior to use. Bulk filtering and storage is permissible. Liquid which has accumulated observable quantities of particulate matter during use shall be discarded or reclaimed by filtration for re-use. Precaution should be taken to prevent contamination.

b. Observation container shall be filled to assure coverage of the device to a minimum of 2 inches.

c. Devices to be tested should be free from foreign materials on the surface, including conformal coatings and any markings which may contribute to erroneous test results.

d. A lighting source capable of producing at least 15 thousand foot candles in air at a distance equal to that which the most distant device in the bath will be from the source. The lighting source shall not require calibration but the light level at the point of observation (i.e., where the device under test is located during observation for bubbles) shall be verified.

e. Precaution should be taken to prevent operator injury due to package rupture or violent evolution of bomb fluid when testing large packages.

3.4 Test condition D, penetrant dye gross leak. This test shall be permitted only for destructive verification of devices (see 3.7). The pressure chamber shall be filled with the dye solution to a depth sufficient to completely cover all the devices. The devices shall be placed in the solution and the chamber pressurized at 105 psia minimum for 3 hours minimum. For device packages which will not withstand 105 psia, 60 psia minimum for 10 hours may be used. The devices shall then be removed and carefully washed, using a suitable solvent for the dye used, followed by an air-jet dry. The devices shall then be immediately examined under the magnifier using an ultraviolet light source of appropriate frequency.

3.4.1 Failure criteria. Any evidence of dye penetration into the device cavity shall constitute a failure.

3.5 Test condition E, weight gain gross leak.

3.5.1 Procedure. The devices shall be placed in an oven at 125°C for 1 hour minimum, after which they shall be allowed to cool to room ambient temperature. Each device shall be weighed and the initial weight recorded or the devices may be categorized into cells as follows. Devices having a volume of <0.01 cc shall be categorized in cells of 0.5 milligram increments and devices with volume ≥0.01 cc shall be categorized in cells of 1.0 milligram increments. The devices shall be placed in a vacuum/pressure chamber and the pressure reduced to 5 torr and maintained for 1 hour except that for devices with an internal cavity volume ≥0.1 cc, this vacuum cycle may be omitted. A sufficient amount of type III detector fluid shall be admitted to the pressure chamber to cover the devices. When the vacuum cycle is performed, the fluid shall be admitted after the 1-hour period but before breaking the vacuum. The devices shall then be pressurized to 75 psia minimum except that 90 minimum psia shall be used when the vacuum cycle has been omitted. The pressure shall be maintained for 2 hours minimum. If the devices will not withstand the 75 psia test pressure, the pressure may be lowered to 45 psia minimum with the vacuum cycle and the pressure maintained for 10 hours minimum.

Upon completion of the pressurization period, the pressure shall be released and the devices removed from the pressure chamber and retained in a bath of the perfluorocarbon fluid. When the devices are removed from the fluid they shall be air dried for 2 ±1 minutes prior to weighing. Transfer the devices singly to the balance and determine the weight or weight category of each device. All devices shall be tested within 4 minutes following removal from the fluid. The delta weight shall be calculated from the record of the initial weight and the post weight of the device. Devices which were categorized shall be separated into two groups, one group which shall be devices which shifted one cell or less and the other group which shall be devices which shifted more than one cell.

3.5.2 Failure criteria. A device shall be rejected if it gains 1.0 milligram or more and has an internal volume of ≤ 0.01 cm^3 and 2.0 milligrams or more if the volume is > 0.01 cm^3. If the devices are categorized, any device which gains enough weight to cause it to shift by more than one cell shall be considered a reject. A device which loses weight of an amount which if gained would cause the device to be rejected may be retested after it is baked at 125°C for a period of 8 hours.

3.6 Test condition C_4 or C_5 - optical gross/fine leak.

3.6.1 Lid Stiffness. Test condition C_4 and C_5 are valid for packages with relatively thin metallic or ceramic lids or other materials that meet the lid stiffness requirements stated below. The test sensitivity is related to the extent of measurable deformation of the lid. The measurable deformation is increased by increasing the specific pressure differential and the test time used. For a specific lid material and size the following formula indicates the minimum measurable deformation:

For condition C_4:

$$R^4/ET^3 > 1.0 \times 10^{-4}$$

For condition C_5:

$$R^4/ET^3 > 3.0 \times 10^{-4}$$

Where:

R = The minimum width of free lid (inside braze or cavity dimension in inches).

E = The modulus of elasticity of the lid material.

For Example: $E = 10 \times 10^6$ lbs/in^2 for Aluminum,
$E = 20 \times 10^6$ lbs/in^2 for Kovar,
and $E = 60 \times 10^6$ lbs/in^2 for Ceramic.

T = The thickness of the lid (inches).

Note: As test time (t) and pressure (P_0) are increased, C_5 will become smaller approaching C_4.

3.6.2 Leak sensitivity. The optical leak test shall be performed with a test pressure (P_0) and time (t), which will provide the leak rate sensitivity required. The leak rate sensitivity is provided by the following equation:

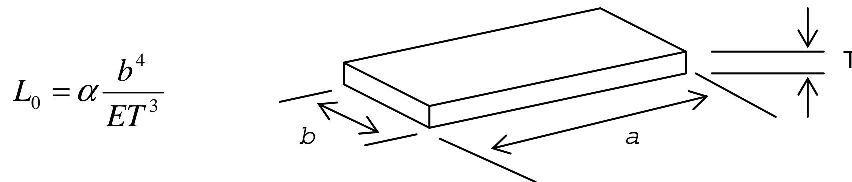
* $L = (-V_0 / k_2\, t)\ X\ \ln (1 - {}_{\circ}D_{yt}/P_0L_0)$

Where:

L = The leak rate sensitivity of the test (atm-cc/sec).
V_0 = The volume of the package cavity (in^3).
K_2 = The leak test gas constant (air = 1.0, He = 2.67)
t = The test duration time (seconds).
D_{Yt} = The measured deformation of the package lid (inches).
P_0 = The chamber pressure during the test (psig).
L_0 = The lid stiffness constant calculated from the package dimensions (inch/psi).

Note: L_0 is calculated using the Roark formula for stress and strain on a flat plate having a uniform load over the entire area. The formula for a rectangular lid is:

$$L_0 = \alpha \frac{b^4}{ET^3}$$



Where:

α = Aspect Ratio Constant determined by measurements *a and b* (See table VI, below.)
a = Lid length – measure of the longer side (inches).
b = Lid width – measure of the shorter side (inches).
E = Modulus of Elasticity for the lid material used.
T = Lid thickness (inches).

The Aspect Ratio Constant (α) can be selected from a table based on the dimensions of the package lid and a determination of which package model best describes the structure of the package. These models are respectively based on “pin” or “fixed” boundary conditions.

Condition 1 (pin boundary): Flexible Wall Package (e.g. thin walled packages or stamped packages)

Condition 2 (fixed boundary): Rigid fixed wall package (e.g. thick walled or ceramic packages)

TableVI: Aspect Ratio Constant (α)

Aspect Ratio	$\frac{a}{b}$	1	1.2	1.4	1.6	1.8	2	3	4	5	∞
Flexible Package	α - pin	0.0444	0.0616	0.0770	0.0906	0.1017	0.1110	0.1335	0.1400	0.1417	0.1421
Rigid Package	α - fixed	0.0138	0.0188	0.0226	0.0251	0.0267	0.0277				0.0284

These two package models represent the limits of the lid stiffness calculations. The stiffness of virtually all package lids will lie within the limits set by the pin and fixed boundary conditions.

3.6.2.1 Controlling sensitivity by controlling test time and pressure. As stated above, for a specific package lid thickness (T), and volume (V_0), the leak rate sensitivity (L) is improved by increasing the test time (t) and chamber pressure (P_0).

3.6.3 Test condition C_4 - optical gross leak. (This test may be performed in conjunction with optical fine leak C_5.) The completed device(s) shall be placed in the sealed test chamber. The optical interferometer shall be set to observe the package lid(s). The chamber shall then be pressurized or evacuated while the deformation of the lid(s) is being observed with the optical interferometer. The deformation of the lid(s) with the pressure change, and the lack of continued deformation of the lid(s) with the pressure (P_0) held for time t (or equivalent procedure), will be observed for each package in the field of view simultaneously.

3.6.3.1 Failure criteria. A device shall be rejected for any of the following criteria:

a. If the optical interferometer did not detect deformation of the lid as the chamber pressure was changed.

b. If the interferometer detects the lid deforming as the chamber pressure is held constant (or equivalent procedure.

3.6.4 Test condition C_5 – optical fine leak . (This test may be performed in conjunction with optical gross leak C_4.) The completed device(s) shall be placed in the sealed test chamber. An optical interferometer is set to observe the package lid(s). The sealed test chamber is then pressurized with Helium gas to no more than the maximum design pressure as determined by the package manufacturer or the design limit of the chamber, which ever is less. The chamber is then pressurized or evacuated while the deformation of the lid(s) is being measured with the optical interferometer. The deformation of the lid(s) with the pressure change for time t (or equivalent procedure) will be measured for each package in the field of view simultaneously.

The sealed test chamber is then pressurized with Helium gas to 30 psig. The lack of deflection of the lid(s) is then observed with an optical interferometer for time t_2 (or equivalent procedure).

3.6.4.1 Failure criteria. A device shall be rejected for any of the three following criteria:

a. If the interferometer did not detect proportional deformation of the lid as the chamber pressure was charged.

b. If the interferometer detects the lid deforming from the package leaking in the pressurized Helium gas during time t as the pressure is held constant (or equivalent procedure).

3.7 Retest. Devices which fail gross leak (test conditions C or E) may be retested destructively. If the retest shows a device to pass, that was originally thought to be a failure, then the device need not be counted as a failure in the accept number of sample size number calculations. Devices which fail fine leak (test conditions A_1, A_2, A_4, or B) shall not be retested for acceptance unless specifically permitted by the applicable acquisition document. Where fine leak retest is permitted, the entire leak test procedure for the specified test condition shall be repeated. That is, retest consisting of a second observation on leak detection without a re-exposure to the tracer fluid or gas under the specified test condition shall not be permissible under any circumstances. Preliminary measurement to detect residual tracer gas is advisable before any retest.

4. SUMMARY. The following details shall be specified in the applicable acquisition document:

a. Test condition letter when a specific test is to be applied (see 3).

b. Accept or reject leak rate for test condition A or B or C_5 when other than the accept or reject leak rate specified herein applies (see 3.1.1.1, 3.1.1.2, 3.1.2, 3.2.5, and 3.6.4.1).

c. Where applicable, measurements after test (see 3).

d. Retest acceptability for test conditions A and B (see 3.7).

e. Order of performance of fine and gross if other than fine followed by gross except when using C_4/C_5 (see 3).

f. Where applicable, the device package pressure rating shall be specified if that rating is less than 75 psia.

g. Leak testing with conditions C_4 and C_5 also includes package testing on completed assemblies (PC boards), packages with external absorbing materials (connectors), or other special conditions.