HERMETICITY TEST METHOD

ESCC Basic Specification No. 21100

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1 PURPOSE

This specification defines test methods, conditions, procedures and requirements to be applied to determine the hermeticity of components with designed internal cavities.

The test methods, conditions, procedures and requirements specified herein are closely based on the following hermetic seal tests specified in MIL-STD-750 and MIL-STD-883:

- MIL-STD-750, Method 1071.8 (for discrete semiconductor components)
- MIL-STD-883, Method 1014.13 (for integrated circuit components, and other families as specified)

2 SCOPE

This specification includes various fine and gross leak test conditions to be applied during evaluation, qualification, maintenance of qualification, or procurement of components for space applications.

Fine and gross leak seal testing shall be performed in accordance with the requirements and procedures of the applicable test conditions specified herein as called up in the applicable test requirement specification.

Unless otherwise specified, fine leak shall be performed before gross leak.

Unless otherwise specified, the test conditions that shall apply, for particular component families, shall be selected from the following:

(a) For discrete semiconductors components:
- Fine leak:
  - Test Condition H1, Tracer gas (He) fixed method (see Para. 5.2)
  - Test Condition H2, Tracer gas (He) flexible method (see Para. 5.2)
- Gross leak:
  - Test Condition C, Fixed method that uses a Perfluorocarbon liquid bath (see Para. 5.3)
  - Test Condition K, Fixed method that uses a Perfluorocarbon vapour detection system (see Para. 5.3)
  - Test Condition E, Penetrant dye method (see Para. 5.4)

(b) For integrated circuit components, and other families as specified:
- Fine leak:
  - Test Condition A1, Tracer gas (He) fixed method (see Para. 6.2)
  - Test Condition A2, Tracer gas (He) flexible method (see Para. 6.2)
  - Test Condition B1, Radioisotope tracer gas (Krypton 85) method (see Para. 6.3)
- Gross leak:
  - Test Condition C1, Fixed method that uses a Perfluorocarbon liquid bath (see Para. 6.4)
  - Test Condition C3, Fixed method that uses a Perfluorocarbon vapour detection system (see Para. 6.4)
  - Test Condition D, Penetrant dye method (see Para. 6.5)

3 RELATED DOCUMENTS

3.1 APPLICABLE DOCUMENTS

The following documents form part of this specification. The relevant issue shall be that in effect on the date of placing the Purchase Order.

- ESCC Basic Specification No. 21300, Terms, Definitions, Abbreviations, Symbols and Units.
- ESCC Basic Specification No. 21500, Calibration System Requirements.

3.2 REFERENCE DOCUMENTS

- MIL-STD-750, Test Methods for Semiconductor Devices.
- MIL-STD-883, Test Methods and Procedures for Micro-electronics.

4 TERMS, DEFINITIONS, ABBREVIATIONS, SYMBOLS AND UNITS

The terms, definitions, abbreviations, symbols and units as specified in ESCC Basic Specification No. 21300 shall apply. In addition the following definitions shall apply:

- Standard Leak Rate:
  The quantity of dry air at +25°C in atm.cm^3/s flowing through a leak or multiple leak paths when the high pressure side is at 101kPa (absolute) (1atma) and the low pressure side is at near total vacuum, $\leq$ 133Pa (absolute) (0.001atma). Standard leak rate shall be expressed in atm.cm^3/s of air.

- Measured Leak Rate:
  The leak rate that is measured on the detector for a given package, using the specified test conditions and employing a specified test medium (tracer gas. i.e. Helium, Krypton 85) specific to that detector. Measured leak rate is expressed in atm.cm^3/s for the medium used.

  NOTE: R1 is the maximum allowed measured leak rate, as measured on a mass spectrometer, for the test medium used (i.e. Helium).

  NOTE: Q_S is the maximum allowed measured leak rate, as measured on a radioisotope detector, for the test medium used (i.e. Krypton 85).

- Equivalent Standard Leak Rate:
  The leak rate that a given package would have under the same standard conditions as given for Standard Leak Rate (see above). The equivalent standard leak rate of a package, can be calculated by converting the measured leak rate of the component under test to the standard leak rate using appropriate calculations (i.e. converted to air equivalents). The equivalent standard leak rate shall always be expressed in atm.cm^3/s of air.

  NOTE: L is the specified maximum allowed equivalent standard leak rate for a package.

5 REQUIREMENTS FOR DISCRETE SEMICONDUCTOR COMPONENTS (CONDITIONS H1, H2, C, K, E)

NOTE:

For all test conditions H1, H2, C, K, E, where the specified bomb pressure exceeds the component package capability, alternate pressure, exposure time, and dwell time conditions may be used provided they satisfy the specified leak rate, pressure, and time relationships and provided no less than 207kPa (absolute) (2atma) bomb pressure is applied.

5.1 BATCH TESTING

For test condition H1, H2, when batch testing is used (more than one component in the leak detector at one time), and a reject condition occurs, it shall be noted as a batch failure.

For test condition H1, H2, components with a cavity > $0.5cm^3$ that are batch tested and indicate a reject condition may then be tested individually one time for acceptance if all components in the batch are retested within 1 hour after removal from the tracer gas pressurization chamber; components with cavity ≤ $0.5cm^3$ shall be measured within ten minutes or repressurised and then re-measured.

For test condition K only, components that are batch tested, and indicate a reject condition, may be retested individually one time for acceptance, except that repressurisation is not required if the components are immersed in type I detector fluid within 20s after completion of the first test, and they remain in the bath until retest.

5.2 TEST CONDITIONS H1, H2 (TRACER GAS (HE) FINE LEAK)

Test condition H1 is a fixed method with specified test conditions in accordance with Para. 5.2.2.1.1. Test condition H2 is a flexible method that allow the variance of test conditions in accordance with the equation 1 given in Para. 5.2.2.1.2.

Unless otherwise specified in the applicable test requirement specification, test condition H2 shall be used.

5.2.1 Apparatus

Apparatus for this test shall consist of the following:

(a) 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 1×10^{-9} $atm.cm^3/s$ 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.

(b) The leak detector indicator shall be calibrated using a diffusion-type calibrated standard leak at least once during every working shift.

5.2.2 Test Procedure: Test Conditions H1, H2

The completed components(s) shall be placed in a sealed chamber which is then pressurized with a tracer gas of 100 (+0, -5)% Helium for the required time and pressure. The pressure shall then be relieved (an optional air nitrogen wash may be applied) 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.

The number of components removed from pressurization for leak testing shall be limited such that the test of the last component can be completed within 60 minutes for test condition H1, or within the chosen value of dwell time t_2 for test condition H2.

5.2.2.1 Evaluation of Surface Sorption (Test Conditions H1, H2)

When considered necessary, all component encapsulations consisting of glass, metal, and ceramic, or combinations thereof, including coatings and external sealants, shall be evaluated for surface sorption of Helium before establishing the leak test parameters.

Representative specimens of the questionable components should be opened and all parts of each component as a unit shall be subjected to the predetermined pressure and time conditions established for the component configuration as specified in Paras. 5.2.2.1.1 and 5.2.2.1.2. The measured leak rate for each component shall be monitored and the lapsed time shall be determined for the indicated leak rate to fall to $\leq 0.5 \times R1$ as specified in Table 1 for test condition H1 or as predetermined for test condition H2. The average of the lapsed time following the release of pressure will determine the minimum usable dwell time.

Note that the sensitivity of measurement increases as this background indicated leak rate decreases relative to the R1 reject level.

Alternatively, whole (unopened) specimens of the questionable components shall be subjected to the same process; then, the shortest value of lapsed time so obtained will determine the minimum dwell time.

The fixed method (test condition H1) shall not be used if the consequent dwell time exceeds the maximum value specified in Table 1.

It is noted that sorption may vary with pressure and time of exposure so that some trial may be required before satisfactory exposure values are obtained.

5.2.2.1.1 Test Condition H1 (Fixed Method)

The fixed method shall not be used if the maximum standard leak rate limit given in the applicable test requirement specification is less than the limits specified herein for the flexible method.

The component(s) shall be tested using the appropriate fixed bomb conditions specified in Table 1 for the internal cavity volume of the package under test.

TABLE 1 – TEST CONDITIONS AND FAILURE CRITERIA FOR TEST CONDITION H1

Internal Volume of Package	Fixed Bomb Conditions			Failure Criteria
V (cm^3)	Pressure Pe (1)	Minimum Exposure Time t_1 (2) (hour)	Maximum Dwell Time t_2 (3) (hour)	Mass-Spec. Measured Leak Rate Maximum Limit (He) R1 ($atm.cm^3/s$)
≤ 0.01	517 ±15kPa (absolute) [5atma]	2	1	5 x10^{-9}
> 0.01 ≤ 0.05	517 ±15kPa (absolute) [5atma]	3	1	1 x10^{-8}
> 0.05 ≤ 0.5	517 ±15kPa (absolute) [5atma]	4	1	1 x10^{-8}
> 0.5 ≤ 1	517 ±15kPa (absolute) [5atma]	2	1	1 x10^{-8}
> 1 ≤ 10	413 ±15kPa (absolute) [4atma]	5	1	5 x10^{-8}
≥ 10 ≤ 20	310 ±15kPa (absolute) [3atma]	10	1	5 x10^{-8}

NOTES:

1. Equivalent pressure values in atma are given for information purposes only.
2. t_1 is the time under bomb pressure.
3. t_2 is the maximum time allowed after the release of bomb pressure before the measurement.

5.2.2.1.2 Test Condition H2 (Flexible Method)

Values for bomb pressure, exposure time, and dwell time shall be chosen such that actual measured tracer gas leak rate readings obtained for the component(s) under test (if defective) will be greater than the minimum detectable leak rate capability of the mass spectrometer. The components shall be subjected to a minimum of 203kPa (absolute) (2atma) of Helium atmosphere. The chosen values of bomb pressure and exposure time, in conjunction with the value of the internal volume of the component package to be tested, and the maximum equivalent standard leak rate (L) limit as specified in Para. 5.2.3(b), shall be used to calculate the measured leak rate limit (R1) using the following formula (equation 1):

$$R_1 = \frac{2.69\,L\,P_e}{P_o}\left[1 - \exp - \left(\frac{2.69\,L}{P_o\,V} \bullet t_1\right)\right] \exp - \left(\frac{2.69\,L}{P_o\,V} \bullet t_2\right)$$

Where:

- R1 = the calculated limit for the measured leak rate of tracer gas (He) through the leak in $atm.cm^3/s$.
- L = the specified equivalent standard leak rate limit in $atm.cm^3/s$ (air) for the component (see Para. 5.2.3(b))
- Pe = bomb pressure in atmospheres absolute.
- Po = 1 standard atmosphere.
- t_1 = time of exposure to Pe in seconds.
- t_2 = dwell time between release of pressure and leak measurement, in seconds.
- V = internal volume of the component package cavity in cm^3.

5.2.3 Failure Criteria – Test Conditions H1, H2

(a) Test Conditions H1: Unless otherwise specified, components shall not be accepted if the measured leak rate limit, R1, given in Table 1 is exceeded.

(b) Test Condition H2: Unless otherwise specified, components shall not be accepted if the equivalent standard leak rate limit, L, given in Table 2 is exceeded.

TABLE 2 – FAILURE CRITERIA FOR TEST CONDITION H2

Internal Volume of Package V (cm^3)	Failure Criteria
	Equivalent Standard Leak Rate Maximum Limit (air) L ($atm.cm^3/s$)
≤ 0.01	1 x10^{-9}
> 0.01 ≤ 0.5	5 x10^{-9}
> 0.5	1 x10^{-8}

5.3 TEST CONDITIONS C, K (PERFLUOROCARBON GROSS LEAK)

Test condition C is a fixed method that uses perfluorocarbon liquid in an indicator bath. Test condition K is a fixed method that uses a perfluorocarbon vapour detection system.

5.3.1 Apparatus

Apparatus for this test shall consist of the following:

(a) A vacuum/pressure chamber for the evacuation and subsequent pressure bombing of components up to 724kPa (absolute) (7atma) for up to 23.5 hours.

(b) A suitable observation container with provisions to maintain the type II indicator fluid at a temperature of +125 ±5°C and a filtration system capable of removing particles greater than 1µm in size from the fluid (test condition C only).

(c) A magnifier capable of magnifying an object 1.5 to 30 times its normal size for observation of bubbles emanating from components when immersed in the indicator fluid (test condition C only).

(d) Sources of type I detector fluids and type II indicator fluids with the following physical properties:

Property (Note 1)	Type I Detector Fluid	Type II Indicator Fluid
Boiling point (°C)	50-95	140-200
Surface tension (dyn/m) at +25°C	-	< 200
Density at +25°C (kg/l)	> 1.6	> 1.6
Density at +125°C (kg/l)	-	> 1.5
Dielectric strength (MV/m)	> 11.8	> 11.8
Residue (µg/g)	< 50	< 50
Appearance	Clear colourless	Clear colourless

NOTE:
1. Perfluorocarbons contain no chlorine or hydrogen.

(e) A lighting source capable of producing a collimated beam of at least 161klx in air at a distance equal to that which the most distant component in the bath will be from the source (test condition C only).
The lighting source shall not require calibration but the light level at the point of observation (i.e. where the component under test is located during observation for bubbles) shall be verified. The lighting source shall be placed for best detection of bubbles, without excessive incident or reflective glare being directed toward observer.

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

(g) Suitable fixtures to hold the component(s) in the type II indicator fluid (test condition C only).

(h) A perfluorocarbon vapour detection system capable of detecting vapour quantities equivalent to 280µg of type I detector fluid (test condition K only).

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

5.3.1.2 *Precautions*

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

(a) Perfluorocarbons fluids shall be filtered through a filter system capable of removing particles greater than 1µm 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 component to a minimum of 50.80mm.

(c) Components to be tested shall be free of foreign materials on the surface, including conformal coatings, and any markings which may contribute to erroneous test results.

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

(e) Packages with less than 0.01cm^3 internal volume shall be tested, with extremely careful observation.

5.3.2 Test Procedure: Test Condition C

The components shall be placed in a vacuum/pressure chamber and the pressure reduced to 670Pa (absolute) (0.007atma) or less and maintained for 30 minutes minimum. This vacuum cycle may be omitted for components with an internal volume $\geq$ 0.1cm^3. A sufficient amount of type I detector fluid shall be admitted to cover the components. When the vacuum cycle is performed, the fluid shall be admitted after the minimum 30 minute period but before breaking the vacuum. The components shall then be pressurized in accordance with Table 3.

When the pressurization period is complete, the pressure shall be released and the components removed from the chamber without being removed from the bath of type I detector fluid for greater than 20s. A holding bath may be another vessel or storage tank. When the components 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 ±5°C.

TABLE 3 - PRESSURIZATION CONDITIONS (TEST CONDITIONS C, K)

Pressure (minimum) (Note 1) kPa (absolute) (atma)	Minimum Pressurization Time (hour)	
	Test Condition C	Test Condition K
207 (2)	23.5	12
310 (3)	8	4
413 (4)	4	2
517 (5)	2	1
621 (6)	1	0.5
724 (7)	0.5	N/A

NOTE:
1. Do not exceed the capability or degrade the integrity of the component.

The components shall be immersed with the uppermost portion at a minimum depth of 50.8mm below the surface of the type II indicator fluid, one at a time or in such a configuration that a single bubble from a single component out of a group under observation may be clearly observed as to its occurrence and source. Unless rejected earlier, the component shall be observed against a dull, non-reflective black background through the magnifier, while illuminated by the lighting source, from the instant of immersion until expiration of a 30s minimum observation period.

For packages greater than 5g, 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 30s 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 appropriate authority upon request.

5.3.3 Test Procedure: Test Condition K

The components shall be placed in a vacuum/pressure chamber and the pressure reduced to 667Pa (absolute) (0.007atma) or less and maintained for 30 minutes minimum. A sufficient amount of type I detector fluid shall be admitted to the pressure chamber to cover the components. The fluid shall be admitted after the 30 minute minimum vacuum period but before breaking the vacuum. The components shall then be pressurized in accordance with Table 3.

Upon completion of the pressurization period, the pressure shall be released, the components removed from the pressure chamber without being removed from a bath of type I detector fluid for more than 20s and then retained in a bath of perfluorocarbon fluid. When the components are removed from the fluid they shall be air dried for a minimum of 20s 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 components shall then be tested with a calibrated perfluorocarbon vapour detector; see Para. 5.3.1(h) and (i). Purge time shall be in accordance with Table 4. Test time shall be a minimum of 3.5s (unless the component is rejected earlier) with the perfluorocarbon vapour detector purge and test chambers at a temperature of +125 ±5°C, or 2.5s minimum with the purge and test chambers at a temperature of +150 ±5°C.

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

TABLE 4 – PURGE TIME (TEST CONDITION K)

Internal Volume of Package (cm^3)	Purge time (s)
≤ 0.01	≤ 5
> 0.01 ≤ 0.1	≤ 9
> 0.1	≤ 13

NOTE:
1. Purge time shall be defined as the total time the component is heated prior to entering the test mode.
2. Maximum purge time can be determined by cycling a component with a 0.51mm to 1.27mm hole and measuring the maximum purge time that can be used without permitting the component to escape detection during the test cycle.

5.3.4 Failure Criteria – Test Conditions C, K

(a) Test Condition C: A definite stream of bubbles, or two or more 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.

(b) Test Condition K: A component shall be rejected if the detector instrumentation indicates more than the equivalent of 280µg of type I detector fluid in accordance with Para. 5.3.1(d).

5.4 TEST CONDITION E (PENETRANT DYE GROSS LEAK)

Unless otherwise specified, this test only applies to transparent glass encapsulated discrete semiconductors or for destructive verification of opaque components.

5.4.1 Apparatus

Apparatus for this test shall consist of the following:

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

(b) Pressure chamber capable of maintaining 719kPa (absolute) (7atma).

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

(d) A magnifier capable of magnifying an object 1.5 to 30 times its nominal size.

5.4.2 Test Procedure: Test Condition E

The pressure chamber shall be filled with the dye solution to a depth sufficient to completely cover all the components. The components shall be placed in the solution and the chamber pressurized at 719kPa (absolute) (7atma) minimum for 3 hours minimum. For component packages which will not withstand 724kPa, 414kPa (absolute) (4atma) minimum for 10 hours may be used. The components shall then be removed and carefully washed, using a suitable solvent for the dye used, followed by an air jet dry.

Transparent discrete semiconductor components may be examined under magnification capable of magnifying an object up to 1.5 times its normal size using ultraviolet light source of appropriate frequency for evidence of the dye penetration.

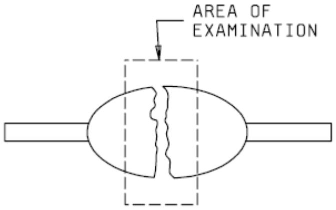
For the destructive examination of opaque discrete semiconductor components, the components shall be delidded and examined internally under the magnifier using an ultraviolet light source of appropriate frequency.

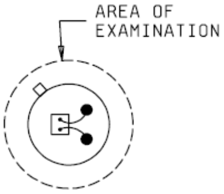
5.4.3 Failure Criteria – Test Condition E

Any evidence of dye penetration into the cavity of the component shall constitute a failure.

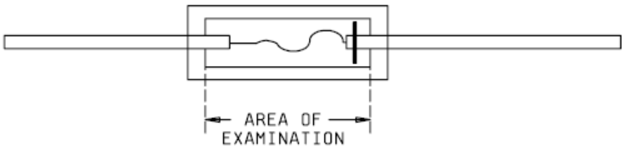
The following specific failure criteria shall also apply:

(a) Opaque components:
After de-lidding or separation of the component (as applicable), any evidence of dye penetration shall be cause for rejection. Area of examination shall be as follows:



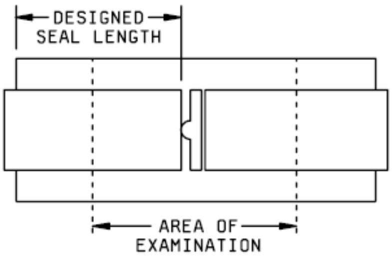


(b) Components made of transparent glass, with a large cavity:
Any evidence of dye penetration in the component cavity shall be cause for rejection. Area of examination shall be as follows:



(c) Components with transparent glass, double plug construction:

Any evidence of dye penetration in the die area shall be cause for rejection. In addition, evidence of dye penetration into a crack, fracture, void, which is closer to the die than 50% of the designed seal length shall be rejected. Area of examination shall be as follows:



6 REQUIREMENTS FOR INTEGRATED CIRCUIT COMPONENTS AND OTHER FAMILIES AS SPECIFIED (CONDITIONS A1, A2, B1, C1, C3, D)

NOTE:
For all test conditions, where the specified bomb pressure exceeds the component package capability, alternate pressure, exposure time, and dwell time conditions may be used provided they satisfy the specified leak rate, pressure, and time relationships and provided no less than 207kPa (absolute) (2atma) bomb pressure is applied.

6.1 BATCH TESTING

For test condition A1, A2, B1, when batch testing is used (more than one component in the leak detector at one time), and a reject condition occurs, it shall be noted as a batch failure.

For test condition A1, A2, components that are batch tested and indicate a reject condition may then be tested individually one time for acceptance if all components in the batch are retested within 1 hour after removal from the tracer gas pressurization chamber.

For test condition B1, components that are batch tested and indicate a reject condition may then be tested individually one time for acceptance if all components in the batch are retested within 30 minutes after removal from the tracer gas pressurization chamber

For test condition C3 only, components that are batch tested, and indicate a reject condition, may be retested individually one time for acceptance, except that repressurisation is not required if the components are immersed in type I detector fluid within 20s after completion of the first test, and they remain in the bath until retest.

6.2 TEST CONDITIONS A1, A2 (TRACER GAS (HE) FINE LEAK)

Test condition A1 is a fixed method with specified test conditions in accordance with Para. 6.2.2.1. Test condition A2 is a flexible method that allows the variance of test conditions in accordance with the equation 2 given in Para. 6.2.2.2.

Unless otherwise specified in the applicable test requirement specification, test condition A2 shall be used.

6.2.1 Apparatus

Apparatus for this test shall consist of the following:

(a) 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 1 x10^{-9} atm.cm^3/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.

(b) The leak detector indicator shall be calibrated using a diffusion-type calibrated standard leak at least once during every working shift.

6.2.2 Test Procedure: Test Conditions A1, A2

The completed components(s) shall be placed in a sealed chamber which is then pressurized with a tracer gas of 100 (+0, -5)% Helium for the required time and pressure. The pressure shall then be relieved (an optional air nitrogen wash may be applied) 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.

The number of components removed from pressurization for leak testing shall be limited such that the test of the last component can be completed within 60 minutes for test condition A1 or within the chosen value of dwell time t_2 for test conditions A2.

6.2.2.1 Test Condition A1 (Fixed Method)

The fixed method shall not be used if the maximum standard leak rate limit given in the applicable test requirement specification is less than the limits specified herein for the flexible method.

The component(s) shall be tested using the appropriate fixed bomb conditions specified in Table 5 for the internal cavity volume of the package under test.

TABLE 5 – TEST CONDITIONS AND FAILURE CRITERIA FOR TEST CONDITION A1

Internal Volume of Package	Fixed Bomb Conditions			Failure Criteria
V (cm^3)	Pressure Pe (1)	Minimum Exposure Time t_1 (2) (hour)	Maximum Dwell Time t_2 (3) (hour)	Mass-Spec. Measured Leak Rate Maximum Limit (He) R1 ($atm.cm^3/s$)
< 0.05	517 ±15kPa (absolute) [5atma]	2	1	5 x10^{-8}
≥ 0.05 < 0.5	517 ±15kPa (absolute) [5atma]	4	1	5 x10^{-8}
≥ 0.5 < 1	310 ±15kPa (absolute) [3atma]	2	1	1 x10^{-7}
≥ 1 < 10	310 ±15kPa (absolute) [3atma]	5	1	5 x10^{-8}
≥ 10 < 20	310 ±15kPa (absolute) [3atma]	10	1	5 x10^{-8}

NOTES:

1. Equivalent pressure values in atma are given for information purposes only.
2. t_1 is the time under bomb pressure.
3. t_2 is the maximum time allowed after the release of bomb pressure before the measurement.

6.2.2.2 Test Condition A2 (Flexible Method)

Values for bomb pressure, exposure time, and dwell time shall be chosen such that actual measured tracer gas leak rate readings obtained for the component(s) under test (if defective) will be greater than the minimum detectable leak rate capability of the mass spectrometer. The components shall be subjected to a minimum of 203kPa (absolute) (2atma) of Helium atmosphere. The chosen values of bomb pressure and exposure time, in conjunction with the value of the internal volume of the component package to be tested, and the maximum equivalent standard leak rate (L) limit as specified in Para. 6.2.3(b), shall be used to calculate the measured leak rate limit (R1) using the following formula (equation 2):

$$R_1 = \frac{2.69\,L\,P_e}{P_o}\left[1 - \exp - \left(\frac{2.69\,L}{P_o\,V} \bullet t_1\right)\right] \exp - \left(\frac{2.69\,L}{P_o\,V} \bullet t_2\right)$$

Where:

- R1 = the calculated limit for the measured leak rate of tracer gas (He) through the leak in atm.cm^3/s.
- L = the specified equivalent standard leak rate limit in atm.cm^3/s (air) for the component (see Para. 6.2.3(b))
- Pe = bomb pressure in atmospheres absolute.
- Po = 1 standard atmosphere.
- t_1 = time of exposure to Pe in seconds.
- t_2 = dwell time between release of pressure and leak measurement, in seconds.
- V = internal volume of the component package cavity in cm^3.

6.2.3 Failure Criteria – Test Conditions A1, A2

(a) Test Condition A1: Unless otherwise specified, components shall not be accepted if the measured leak rate limit, R1, given in Table 5 is exceeded.

(b) Test Condition A2: Unless otherwise specified, components shall not be accepted if the equivalent standard leak rate limit, L, given in Table 6 is exceeded.

TABLE 6 – FAILURE CRITERIA FOR TEST CONDITION A2

Internal Volume of Package V (cm3)	Failure Criteria
	Equivalent Standard Leak Rate Maximum Limit (air) L (atm.cm^3/s)
≤ 0.01	5 x10^{-8}
> 0.01 ≤ 0.4	1 x10^{-7}
> 0.4	1 x10^{-6}

6.3 TEST CONDITION B1 (RADIOISOTOPE TRACER GAS (KRYPTON 85) FINE LEAK)

6.3.1 Apparatus

Apparatus for this test shall consist of the following:

(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 component wall the radiation level of any Krypton 85 tracer gas present within the component. The counting station shall have a minimum sensitivity of 10000 counts/minute/µCi 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 air. The concentration of the Krypton 85 in the Krypton 85/dry air mixture shall be no less than 100µCi/atm.cm^3. This value shall be determined at least once each 30 days and recorded in accordance with the calibration requirements of ESCC Basic Specification No. 21500.

6.3.2 Test Procedure: Test Conditions B1

The components shall be placed in a radioactive tracer gas pressurization chamber. The pressurization chamber may be partially filled with inert material (aluminium 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’ components be measured within 10 minutes after removal from the pressurization tank.

The tank shall be evacuated to 67Pa (absolute) (0.0007atma). The components shall be subjected to a minimum of 203kPa (absolute) (2atma) of Krypton 85/air mixture. Actual pressure and soak time shall be determined in accordance with Para. 6.3.2.1.

When the ‘soak time’ is completed, the Krypton 85/air mixture shall be transferred to storage until 67Pa (absolute) (0.0007atma) 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 414kPa (absolute) (4atma) if a higher bombing pressure was used. The tank shall then immediately be backfilled with air and the components removed from the tank and measured within 30 minutes after removal using a scintillation crystal equipped counting station as described in Para. 6.3.2.2.

Component encapsulations that come under the requirements of Para. 6.3.2.3 shall be exposed to ambient air for a time not less than the ‘wait time’ determined by Para. 6.3.2.3. Component encapsulations that do not come under the requirements of Para. 6.3.2.3 may be tested without a ‘wait time’. The R value (see Para. 6.3.2.1) shall not be less than 500 counts per minute above background. (It is recommended practice that the number of components pressurized for leak testing is limited such that the test of the last component can be completed within 30 minutes).

6.3.2.1 *Testing Parameters*

The bombing pressure and soak time shall be determined in accordance with the following formula (equation 2):

$$Q_S = \frac{R}{skTPt}$$

Where:

- Q_S = the maximum leak rate allowable, in atm.cm^3/s Kr, for the components to be tested.
- R = counts per minute above the ambient background after pressurization if the component 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 component under test, if it has been through prior radioactive leak tests.
- s = the specific activity, in µCi/atm.cm^3 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 Para. 6.3.2.2 for each component geometric configuration in combination with the specific scintillation crystal in which it will be measured.
- T = soak time, in hours, that the components are to be pressurized.
- P = $Pe^2 - Pi^2$, where Pe is the bombing pressure in atmospheres absolute and Pi is the original internal pressure of the components in atmospheres absolute. The activation pressure (Pe) may be established by specification or if a convenient soak time (T) has been established, the activation pressure (Pe) can be adjusted to satisfy equation 2.
- t = conversion of hours to seconds and is equal to 3600s/hour.

6.3.2.2 *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 component 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 component to be tested (see (a), (b) and (c) below).

This is done using a component ‘sample’ of the same geometric configuration as the component to be tested. The geometric centre of the cavity, or its internal void, is the point called the “centre of mass” of the radioactive gas being measured. The location of the centre of mass is the point referred to for the k-factor of the component as it is positioned in each of the scintillation crystal detection systems described in (a), (b) and (c) as follows:

(a) Scintillation “Well-Crystal”
A representative sample, consisting of a component with the same geometric configuration as the test sample component(s), shall be used to determine the counting efficiency (k). This representative sample shall have an accurately known µCi content of Krypton 85 placed within its internal void.

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 component should be in the exact position as test components will be tested. If not, then the sample component shall be located at a height not to be exceeded by any component tested (see note below). From this measured value the counting efficiency, in counts/µCi, shall be calculated for that component/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 component is placed on top of other components such as in testing multiple components simultaneously, then the top component will have the least measured k-factor effect. Thus, the measured k-factor, determination using the sample component 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 component, including any one of the multiple components being simultaneously tested.

(b) Scintillation “Flat-Top Crystal”
A representative sample consisting of a component with the same geometric configuration as the test sample component(s) shall be used to determine the counting efficiency (k). This representative sample shall have an accurately known µCi content of Krypton 85 placed within its internal void.

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 components will be tested. The k-factor for the sample shall be measured with the sample placed flat in a position centred to the main body of the crystal. Some flat-top crystals are solid cylinders of approximately 7.6cm diameter, and the component sample is placed on the cylinder in the same manner, as mentioned. From this measured value, the counting efficiency, in counts/minute/µCi shall be calculated for that component/crystal system.

(c) Dynamic Measurement with a Scintillation-Crystal
A representative sample consisting of a component with the same geometric configuration as the test sample component(s) shall be used to determine the counting efficiency (k). This representative sample shall have an accurately known µCi content of Krypton 85 placed within its internal void.

A crystal, (or crystals), can be used for dynamic testing of components 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 component standing at the centre 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/minute/µCi shall be calculated. This k-factor determination is most commonly determined by the equipment manufacturer.

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 components, as long as the same test procedure and equipment is used, and the components are measured using the same measurement system, (a), (b) or (c) as above.

It should be noted that state-of-the-art scintillation crystals are only capable of detecting (measuring) a maximum reading of 16000 to 18000 counts per minute from the emission from 1µCi of Krypton 85 contained within the cavity of a component. 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 component to that crystal; and the materials of construction of the component.

The counting efficiency (k-factor) for most component 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 component to be tested.

6.3.2.3 *Evaluation of surface sorption*

All component 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 component configuration as specified by Para. 6.3.2.1. 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 Para. 6.3.2.

6.3.3 Failure Criteria – Test Condition B1

Unless otherwise specified, components shall not be accepted if the measured leak rate limit, Qs, given in Table 7, is exceeded.

TABLE 7 – FAILURE CRITERIA FOR TEST CONDITION B1

Internal Volume of Package	Failure Criteria
(cm^3)	Measured Leak Rate Maximum Limit (Kr85) Q_S (atm.cm^3/s)
≤ 0.01	1 x10^{-8}
> 0.01 ≤ 0.4	5 x10^{-8}
> 0.4	5 x10^{-7}

6.4 TEST CONDITIONS C1, C3 (PERFLUOROCARBON GROSS LEAK)

Test condition C1 is a fixed method that uses a perfluorocarbon liquid in an indicator bath. Test condition C3 is a fixed method that uses a perfluorocarbon vapour detection system.

6.4.1 Apparatus

Apparatus for this test shall consist of the following:

(a) A vacuum/pressure chamber for the evacuation and subsequent pressure bombing of components up to 724kPa (absolute) (7atma) for up to 23.5 hours.

(b) A suitable observation container with provisions to maintain the type II indicator fluid at a temperature of +125 ±5°C and a filtration system capable of removing particles greater than 1µm in size from the fluid (test condition C1 only).

(c) A magnifier capable of magnifying an object 1.5 to 30 times its normal size for observation of bubbles emanating from components when immersed in the indicator fluid (test condition C1 only).

(d) Sources of type I detector fluids and type II indicator fluids with the following physical properties:

Property (Note 1)	Type I Detector Fluid	Type II Indicator Fluid
Boiling point (°C)	50-95	140-200
Surface tension (dyn/m) at +25°C	-	< 200
Density at +25°C (kg/l)	> 1.6	> 1.6
Density at +125°C (kg/l)	-	> 1.5
Dielectric strength (MV/m)	> 11.8	> 11.8
Residue (µg/g)	< 50	< 50
Appearance	Clear colourless	Clear colourless

NOTE:

1. Perfluorocarbons contain no chlorine or hydrogen.

(e) A lighting source capable of producing a collimated beam of at least 161klx in air at a distance equal to that which the most distant component in the bath will be from the source (test condition C1 only).
The lighting source shall not require calibration but the light level at the point of observation (i.e. where the component under test is located during observation for bubbles) shall be verified. The lighting source shall be placed for best detection of bubbles, without excessive incident or reflective glare being directed toward observer.

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

(g) Suitable fixtures to hold the component(s) in the type II indicator fluid (test condition C1 only).

(h) A perfluorocarbon vapour detection system capable of detecting vapour quantities equivalent to 167nl of type I detector fluid (test condition C3 only).

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

6.4.1.2 Precautions

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

(a) Perfluorocarbons fluids shall be filtered through a filter system capable of removing particles greater than 1µm 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 component to a minimum of 50.80mm.

(c) Components to be tested shall be free of foreign materials on the surface, including conformal coatings, and any markings which may contribute to erroneous test results.

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

(e) Packages with less than 0.01cm^3 internal volume shall be tested, with extremely careful observation.

6.4.2 Test Procedure: Test Condition C1

The components shall be placed in a vacuum/pressure chamber and the pressure reduced to 667Pa (absolute) (0.007atma) or less and maintained for 30 minutes minimum. This vacuum cycle may be omitted for components with an internal volume ≥ 0.1cm^3. A sufficient amount of type I detector fluid shall be admitted to cover the components. When the vacuum cycle is performed, the fluid shall be admitted after the minimum 30 minute period but before breaking the vacuum. The components shall then be pressurized in accordance with Table 8.

TABLE 8 - PRESSURIZATION CONDITIONS (TEST CONDITIONS C1, C3)

Pressure (minimum) (Note 1) kPa (absolute) (atma)	Minimum Pressurization Time (hour)	
	Test Condition C1	Test Condition C3
207 (2)	23.5	12
310 (3)	8	4
413 (4)	4	2
517 (5)	2	1
621 (6)	1	0.5
724 (7)	0.5	N/A

NOTE:

1. Do not exceed the capability or degrade the integrity of the component.

When the pressurization period is complete, the pressure shall be released and the components removed from the chamber without being removed from the bath of type I detector fluid for greater than 20s. A holding bath may be another vessel or storage tank. When the components 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 ±5°C.

The components shall be immersed with the uppermost portion at a minimum depth of 50.8mm below the surface of the type II indicator fluid, one at a time or in such a configuration that a single bubble from a single component out of a group under observation may be clearly observed as to its occurrence and source. Unless rejected earlier, the component shall be observed against a dull, non-reflective black background through the magnifier, while illuminated by the lighting source, from the instant of immersion until expiration of a 30s minimum observation period.

For packages greater than 5g, 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 30s 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 appropriate authority upon request.

6.4.3 Test Procedure: Test Condition C3

The components shall be placed in a vacuum/pressure chamber and the pressure reduced to 667Pa (absolute) (0.007atma) or less and maintained for 30 minutes minimum. A sufficient amount of type I detector fluid shall be admitted to the pressure chamber to cover the components. The fluid shall be admitted after the 30 minute minimum vacuum period but before breaking the vacuum. The components shall then be pressurized in accordance with Table 8.

Upon completion of the pressurization period, the pressure shall be released, the components removed from the pressure chamber without being removed from a bath of type I detector fluid for more than 20s and then retained in a bath of perfluorocarbon fluid. When the components are removed from the fluid they shall be air dried for a minimum of 20s 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 components shall then be tested with a calibrated perfluorocarbon vapour detector; see Para. 6.4.1(h) and (i). Purge time shall be in accordance with Table 9. Test time shall be a minimum of 3.5s (unless the component is rejected earlier) with the perfluorocarbon vapour detector purge and test chambers at a temperature of +125 ±5°C, or 2.5s minimum with the purge and test chambers at a temperature of +150 ±5°C.

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

TABLE 9 – PURGE TIME (TEST CONDITION C3)

Internal Volume of Package (cm^3)	Purge time (s)
≤ 0.01	≤ 5
> 0.01 ≤ 0.1	≤ 9
> 0.1	≤ 13

NOTE:

1. Purge time shall be defined as the total time the component is heated prior to entering the test mode.
2. Maximum purge time can be determined by cycling a component with a 0.51mm to 1.27mm hole and measuring the maximum purge time that can be used without permitting the component to escape detection during the test cycle.

6.4.4 Failure Criteria – Test Conditions C1, C3

(a) Test Condition C1: A definite stream of bubbles, or two or more 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.

(b) Test Condition C3: A component shall be rejected if the detector instrumentation indicates more than the equivalent of 167nl of type I detector fluid in accordance with Para. 6.4.1(d).

6.5 TEST CONDITION D (PENETRANT DYE GROSS LEAK)

Unless otherwise specified, this test only applies for destructive verification of components.

6.5.1 Apparatus

Apparatus for this test shall consist of the following:

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

(b) Pressure chamber capable of maintaining 724kPa (absolute) (7atma).

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

(d) A magnifier capable of magnifying an object 1.5 to 30 times its nominal size.

6.5.2 Test Procedure: Test Condition D

The pressure chamber shall be filled with the dye solution to a depth sufficient to completely cover all the components. The components shall be placed in the solution and the chamber pressurized at 724kPa (absolute) (7atma) minimum for 3 hours minimum. For component packages which will not withstand 724kPa, 414kPa (absolute) (4atma) minimum for 10 hours may be used. The components 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.

6.5.3 Failure Criteria – Test Condition D

Any evidence of dye penetration into the cavity of the component shall constitute a failure.