

Fine Leak Testing
MIL-STD-883
Application of the Flexible Method to a Sealed Package

Executive Summary:

Per MIL-STD-883, sealed microcircuit packages are considered hermetic if the leak rate of AIR is less than the standard outlined in Table 1, below:

Table 1

Max leak of Air		Volume
5.00×10^{-8}	Small	Is .01 cc or less, small
1.00×10^{-7}	Medium	Is greater than .01 cc but equal or less than .4 cc, medium
1.00×10^{-6}	Large	Is greater than .4cc, large

If the molded ceramic packages listed in Table 2 are pressurized in a helium (He) bomb under the conditions shown in the table, and if the measured leak rates of He are less than the allowed maximum, then the package is hermetic per MIL-STD-883.

Table 2

Part Number	volume cc ³	Small, Med, or Large	Max Air Leak, L	Pressure PSIG *	dwel time hours	test time hours	Max Allowed He leak
G1010M-2	0.00265	Small	5.00×10^{-8}	15	5	1	1.37×10^{-7}
G1010M-9	0.00235	Small	5.00×10^{-8}	15	5	1	1.44×10^{-7}
G1616M-1	0.00851	Small	5.00×10^{-8}	15	5	1	6.40×10^{-8}
G2121M-1	0.01202	Med.	1.00×10^{-7}	15	5	1	1.68×10^{-7}
GW2121M-3	0.01269	Med.	1.00×10^{-7}	15	5	1	1.62×10^{-7}
G2121M-8	0.01202	Med.	1.00×10^{-7}	15	5	1	1.68×10^{-7}
GW2525M-1	0.0201	Med.	1.00×10^{-7}	15	5	1	1.12×10^{-7}
G3333M-1S	0.05357	Med.	1.00×10^{-7}	15	5	1	4.66×10^{-8}
G3333M-2	0.05151	Med.	1.00×10^{-7}	15	5	1	4.84×10^{-8}
G3838M-1	0.10177	Med.	1.00×10^{-7}	15	5	1	2.53×10^{-8}
G3838M-8	0.0859	Med.	1.00×10^{-7}	15	5	1	2.98×10^{-8}
G4040M-5	0.11007	Med.	1.00×10^{-7}	15	5	1	2.34×10^{-8}
G5050M-1	0.16268	Med.	1.00×10^{-7}	15	5	1	1.60×10^{-8}
G6237M-2	0.25643	Med.	1.00×10^{-7}	15	6	1	1.23×10^{-8}
G6237C-1	0.15158	Med.	1.00×10^{-7}	15	5	1	1.72×10^{-8}
GW6262CT-2	0.24332	Med.	1.00×10^{-7}	15	5	1	1.08×10^{-8}

***NOTE! 15 psig which is 30 psia is the MAXIMUM recommended test pressure.**

If pressure is 30 psia (15 psig) for five hours and packages are tested within one hour or less, and the measured leak rate is a maximum as indicated on the right column, then the packages are hermetic per MIL-STD-883. Note that at approximately 0.25 cc package volume, it is necessary to pressurize for six hours to assure sufficient test sensitivity.

The following is an explanation of the derivation for the above summary.

MIL-STD-883H, Method 1014.13 addresses several methods to test hermeticity of electronic devices. Following the required military format, Method 1014.13 first presents an overview of all the methods, then

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the equipment and procedure for all the methods, and finally the criteria for all the methods. To make things easier to follow, the key parts of essentially ONE method (Flexible method) that use He gas for leak detection is transcribed here along with some annotation to aid in understanding the MIL-STD requirement. Two other methods, open face leak testing and fixed testing are also addressed briefly to illustrate the contrast.

Open (unsealed, or packages with no cap or lid) packages are typically tested by measuring the rate at which He gas will leak through the structure. He is used because it is very penetrating, and it is relatively inexpensive to make a small, accurate mass spectrometer that is very sensitive to the small amount or flow rates of gas present. Indeed, most packages are so gas tight that the amount of He that will pass through them is below the detection limit for conventional production He leak check equipment.

The following is taken directly from MIL-STD-883H, METHOD 1014.13

3.1 Test condition A1, A2, or A4 tracer gas (He) fine leak. Test condition A1 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 (R1). Test condition A2 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 (R1). Test condition A4 is a method that will detect the required measured leak rate (R1) of an unsealed package.

Method 1014.13 groups the methods that employ He as the tracer gas as "Condition A". The first one usually encountered is A4 for unsealed packages. The requirement is as follows:

3.1.2.1 Failure criteria. Unless otherwise specified, devices shall be rejected if the measured leak rate (R1) exceeds 1×10^{-8} atm cc/s He.

This is commonly called "Open Face Leak Testing." It is used by the package manufacturer and by package users to ensure that only hermetic packages enter production process. Once a lid or a cap has been sealed to the package, it is necessary to check that the seal is hermetic, and that the initial hermeticity of the package has not been compromised by the fabrication processes. Sealed packages are tested as below:

3.1.1 Test conditions A1 and A2, 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 ± 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 (R1). (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 A1 or within the chosen value of dwell time t_2 for test condition A2.)

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

3.1.1.1 Test condition A1, fixed method. The device(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.

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Note that pounds per square inch absolute means the pressure gauge reads absolute pressure above zero, or relative to a vacuum. Most common gauges are calibrated psig (pounds per square inch, gauge). These gauges measure the pressure above the ambient air pressure. Ambient pressure is approximately 14.7 psia (or 15 psia at 2 significant figures). If one has a gauge reading psig, set the pressure to 15 psig. Most gauges indicate psia or psig on the gauge dial. **Checking this can avoid a common error of exposing the parts to excessive bomb pressure.**

Once again, the following is taken directly from MIL-STD-883H, METHOD 1014.13

3.1.1.2 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 (R1) 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 (R1) 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:

R1 = 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.

PE = The pressure of exposure in atmospheres absolute.

PO = The atmospheric pressure in atmospheres absolute. (1)

MA = The molecular weight of air in grams. (28.7)

M = The molecular weight of the tracer gas (Helium) in grams. (4)

t1 = The time of exposure to PE in seconds.

t2 = 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 ejected 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.

From a procurement standpoint, it is convenient to specify thresholds based on the He leak rate. The common requirement is 1×10^{-8} standard cubic centimeter of He per second. However, when sealed packages are in service, the concern is not how much He will leak through, but how much air will leak through. MIL-STD-883 discusses leak rates of both He and of air. One must take care to note the unit of measure of leak rate. Note that the fixed method indicates R1, which is expressed in units of **He**. The variable method actually addresses leak rates for **air**.

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In Table 2, on page 1, the calculated, nominal internal volume of several popular StratEdge Corporation molded ceramic packages is listed.

In column 4 of Table 2 the allowable, equivalent standard leak rate (L) is also listed. Given this for each package, one can apply the equation in 3.1.1.2 Test Condition A2 and find the maximum allowable He leak rate for each sealed package. The equation above yields the measured leak rate in He, with input of package volume, test pressure conditions, and the appropriate failure criteria in air.

The objective is to keep the test pressure as low as possible, but the minimum allowed by the specification is 2 atmospheres, ergo the bomb pressure for He will be 2 atmospheres, absolute pressure.

Recommended test conditions are:

R1 = 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. (1×10^{-7} cc/s, air) – for many in the table

PE = The pressure of exposure in atmospheres absolute. (2)

PO = The atmospheric pressure in atmospheres absolute. (1)

MA = The molecular weight of air in grams. (28.7)

M = The molecular weight of the tracer gas (Helium) in grams. (4)

t1 = The time of exposure to PE in seconds. (5 hrs x 60 x 60 = 18000 sec.)

t2 = The dwell time between release of pressure and leak detection, in seconds. (1 hr x 60 x 60 = 3600 sec or less)

V = The internal volume of the device package cavity in cubic centimeters – as listed in the table

We have a spreadsheet established for these calculations. It contains the conversions to put time in more convenient units of hours. The equations in paragraph 3.1.1.2 are a set of coupled first order decay equations. They yield the calculated “R1”.

Consider package G4040M-5, for example. Table 2 tells us that tested under the conditions in Table 2, if the measure leak rate is less than 2.28×10^{-8} of He, then the package leak rate is less than 10^{-7} of air, and the package is hermetic to MIL-STD-883. The bomb conditions or 30 psia or 2 atmospheres will guarantee that packages meet the hermeticity requirement of MIL-STD-883.