R-4206

A TECHNOLOGICAL LOOK
at
"MIL-STDs CALLOUTS
for
HERMETIC SEAL TESTING"

This is a summary of the technology that was presented by IsoVac Engineering at the JEDEC meeting May 21-24, 2007, in Myrtle Beach, SC. It is a scientific analysis of the application of the Seal-Testing procedures that are being used and have been used for years. Those methods involving the use of Helium Mass Spectrometry, (HMS), have been falling far short of the assumed leak testing sensitivities, and are resulting in many non-hermetic escapes going into the field. The failures that have been occurring in the field are most commonly misinterpreted as "electrical failures", when good failure analysis is confirming that many, (if not most), of them are associated with defective seals, (non-hermetic devices).

BACKGROUND: IsoVac engineering has been involved in the hermetic seal test industry for 38 years, both Radioisotope and Helium. At the request of DSCC, (Alan Barone) last year, IsoVac did a technological review of two subjects: (1) The predictable life of a part with a known internal volume and various leak rates; and (2) Review of the history and technical facts associated with the HMS leak testing methods in the 1071 specification.
(1) The evaluation of predictable life produced a series of tables that were presented at the January 2006 JEDEC meeting. Those tables showed the entry of Oxygen and moisture would be unacceptably high with the leak rate requirements in the current specifications. It was obvious that the devices should not be considered viable for the 5, 10, 15, or 20 year life they were expected to survive. That data confirmed the need for DSCC to tighten the leak rate specification in the standard.
(2) The review of the HMS procedures clearly showed that the method was not being applied properly, and that it was not well understood by the industry using the procedure. DSCC concern was stimulated by the industry reaction to the tightening of the sensitivity requirements in the new 1071.8 specification. This concern was also stimulated by those of us in industry that have been showing confirmed leakers that are not detectable on production HMS machines, and in many cases are directly connected to confusing RGA data, performed on devices indicated to be hermetic by the previous HMS testing procedures in the specifications. Most of those non-hermetic devices have leak rates below the actual measurements called for in the Standards, but within a range of detection that was assumed to have been met.

The HMS test method was originally deferred to MIL-STD 202, in the 1968 version of 1071. MIL-STD 202 called for 1 x 10-8 atm cc/sec. In 1974 883, T/M 1014 included the HMS method with the option of using either the "Fixed-Table", or the "Flexible-Method". The 1071 spec followed that same philosophy shortly thereafter. The Fixed-table was originally derived from "Equation-3" included in the Flexible-method, (The Howl & Mann Equation). Its purpose was to provide a simple "read-and-run' method for the user to see what bomb time and pressure to use for his volume part, and satisfy the spec requirement. That was misinterpreted as being the simple way to run the HMS test, and it has led to a complete misunderstanding of the actual 'leak rate sensitivity' that is being measured. To further deteriorate the results, both specifications have allowed changes that have lost some of the original specificity of the test. The following will hopefully clarify the misunderstandings and show the true shortfall in the leak rate sensitivities that are being measured by these HMS test methods.

THE TECHNOLOGY REVIEW:

A – The 1071 "Terms and Definitions"

The specification, (1071), provides a very simple and very specific "Definition" for the seal test results and reporting. There are three specific definitions provided there:

2.1 **Standard leak rate.** "…Standard leak rate shall be expressed in units of atmospheric cubic centimeters per second (atm cm^3/s air)

2.2 **Measured leak rate**. Measured leak rate **(R_1)** is defined as the ***measurement*** of a given package "…..expressed in atmospheric cubic centimeters per second (atm cm^3/s of the gas medium used for the test)….the measured leak rates must be converted to the equivalent standard leak rates, (converted to air equivalents)."

2.3 **Equivalent standard leak rate.** The equivalent standard leak rate **(L)** with a **measured leak rate (R_1),** …The equivalent standard leak rate shall be expressed in units of atmospheric cubic centimeters per second (atm cm^3/s) **(air).**

B – The Helium Table: "1071-V" Fixed conditions for test condition H_1

TABLE 1071-V. Fixed conditions for test condition H_1.

Volume of package (cm^3)	Bomb condition			R_1 reject limit (atm cm^3/s)
	kPa ±15 (psia) ±2	Minimum Exposure time in hours (t_1) (+1.0 - 0.0)	Maximum dwell time (hour)	
< 0.01	517 (75)	2	1	5×10^{-9}
> 0.01 ≤ 0.05	517 (75)	3	1	1×10^{-8}
> 0.05 ≤ 0.5	517 (75)	4	1	1×10^{-8}
> 0.5 ≤ 1.0	517 (75)	2	1	1×10^{-8}
> 1.0 ≤ 10.0	413 (60)	5	1	5×10^{-8}
> 10.0 ≤ 20.0	310 (45)	10	1	5×10^{-8}

Figure 1

The table in MIL-STD-750E, Test Method 1071.8 that is grossly misinterpreted is the Fixed table in para. 10.2.1.1 . (shown above) That table is commonly used to test devices with the Helium Mass Spectrometer, (HMS). It allows the user to see the volume of his package, the bombing pressure, the bombing time, and the resultant reading on the HMS. The serious error that has occurred is the assumption that the reading on the HMS, (R_1), is the leak rate sensitivity of the test. **IT IS NOT**. That reading is only the result of the amount of helium that has entered the part if it had a leak rate "L", (as listed in para. 10.2.2 "Failure Criteria"). With "Back-Pressurized" testing we have only been testing parts to the "L" values in the spec.

This is a complex issue and must be very carefully reviewed to understand exactly what this actually means:

1. The Fixed Table was created using "Equation 3" in 10.2.1.2, (The "Flexible Equation")
2. The "Failure Criteria" in the standard is the "L" value in equation 3. It is the "Equivalent Standard Leak Rate" of the device, in atmosphere cm^3/s (*air*). It is not the reading you see on the HMS. The "L" value for each package volume is stated in the Failure Criteria, and that is the leak rate your part must pass to be acceptable.

3. Until DSCC tightened the leak rate sensitivities, the "Failure Criteria" was 1 x 10^{-7} (air), for packages < 0.4 cm^3; and 1 x 10^{-6} (air) for packages > 0.4 cm^3. (For reference: the (He) leak rate is ~ 2.69 x the (air) leak rate. That means we have only been testing to "L" values of: 2.69 x 10^{-7} (He) for < 0.4 cm^3; and 2.69 x 10^{-6} (He) for > 0.4 cm^3.
4. The "R_1" values in the table above are also incorrect, and have been for many years. (They are however being corrected in the newest draft of 1071). They will be based on the newly established "L" values. Those are the tighter leak rate values that DSCC has established as required for the devices covered by this spec.

The "Fixed Table" in MIL-STD-883, TM 1014, was first released in 1974. It showed both the "R_1" and the "L" values in the table. This was good because it tied the Fixed method to the Flexible equation. It also brought attention to the relationship of air and helium.

MIL-STD-883A
15 November 1974

TABLE I. Helium leak test conditions for various volumes and pressures.

V Package volume cc	P_E Bomb pressure atm	t_1 Bomb time 1/ Min	Constants P_o=1 M=4 M_A=28.7 t_2=30 min
0.1 0.1 0.1	3 4 5	45 30 30	R_1=5x10^{-8} atm cc/sec L=5x10^{-7} atm cc/sec
0.1-10.0 0.1-10.0 0.1-10.0	3 4 5	160 120 60	R_1=5x10^{-7} atm cc/sec L=5x10^{-6} atm cc/sec
>10-20.0 >10-20.0 >10-20.0	5 4 5	320 240 190	
>20	Use formula (see 3.1.1.2)		

1/ t_1 values shown are to the nearest 5 minutes with a minimum of 30 minutes. Calculations were made using the largest volume in range shown.

Figure 2

Unfortunately most of the detail was dropped over the years and the use of the equation was lost. It is important to note that the "L" values, ("Failure Criteria") was only 5 x 10^{-7}(air), and 5 x 10^{-6} (air). Those were later changed to 5 x 10^{-8}(air), 1.4 x 10^{-7} (He) for < 0.01cm^3; 1 x 10^{-7}(air, 2.69 x 10^{-7}(He) for 0.01 to 0.4 cm^3; and 1 x 10^{-6}(air), 2.69 x 10^{-6}(He). >0.4 cm^3. Those values are in effect today, and thus we are not testing to a very high sensitivity in either 883 or 750 if we are using the 'back-pressurization methods.

The 1071.8 Table 1071-V, (shown in Figure 1 above), is shown below with the R_1 readings seen on the HMS. Those are not the leak rate readings of the part. The equivalent "L" value, (or actual leak sensitivity being achieved for the part), is shown in **red**, which obviously is not what was being assumed, and not what is required in the new specification.

TABLE 1071-V. Fixed conditions for test condition H_1.*

Volume of package (cm^3)	Bomb condition kPa ±15 (psia) ±2	Minimum Exposure time in hours (t_1) (+1 - 0)	Maximum dwell time (hour) (t_2)	R_1 reject limit ($atm\ cm^3/s$) (He)	These R1 'readings' ** equate To the following 'air' equivalents ($atm\ cm^3/s$) (air)
0.01	517 (75)	2	1	5×10^{-9}	1.4 x 10-8
0.01 ≤ 0.05	517 (75)	3	1	1×10^{-8}	1.6 x 10-8 - 3.6 x 10-8
0.05 ≤ 0.5	517 (75)	4	1	1×10^{-8}	3.2 x 10-8 - 1.0 x 10-7
0.5 < 1.0	517 (75)	2	1	1×10^{-8}	1.4 x 10-7 - 2.0 x 10-7
1.0 ≤ 10.0	413 (60)	5	1	5×10^{-8}	3.1 x 10-7 - 9.9 x 10-7
10.0 < 20.0	310 (45)	10	1	5×10^{-8}	8.0 x 10-7 - 1.1 x 10-6

*Note: This table is derived from Equation 3
** Note: The 'air' equivalents shown here are not the "L" values in 10.2.2

Figure 3

C - Equation 3

This equation has had an error in the format for many years: It did not include an "equal sign" between R_1 and the equation.

10.2.1.2 Test condition H_2 and CH2 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 DUTs (if defective) will be greater than the minimum detectable leak rate capability of a mass spectrometer. The devices shall be subjected to a minimum of 29 psi (203 kPa) of helium atmosphere. The chosen values of pressurization and time of pressurization, 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 specified in 10.2.2, shall be used to calculate the measured leak rate (R_1) limit using the following formula:

Equation (3): "=“

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

Where: R_1 = The resultant measured leak rate of tracer gas (H_e) through the leak in atm cm^3/s.
L = The equivalent standard leak rate in atm cm^3/s. **(Air)**
P_e = The pressure of exposure in atmospheres absolute.
P_o = 1 standard atmosphere.
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.

It is also very important to note: "…will be greater than the minimum detectable leak rate capability of the mass spectrometer…"

The terms used in Equation 3 need to be clearly understood.

Where: **R_1 = The indicated leak rate of tracer gas (H_e) as measured on the mass spectrometer in atm cm^3/s (He). This value is not the actual "leak rate of the device". See para.2.2 & 2.3**
L = The equivalent standard leak rate in atm cm^3/s (air). This is your "specified leak rate limit" for the device, in atm cm^3/s (air). (see para.2.3)
P_e = The pressure of the exposure in atmospheres absolute.
P_0 = 1 standard atmosphere.
t_1 = The time of exposure 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.

D – The Options for Compliance with the 1071.8 requirements:

- There are two basic types of high volume production leak detection equipment available to satisfy the Military Standards: Helium Mass Spectrometry or Radioisotope leak testing with Krypton85 gas.
- The production HMS equipment in use today for fine leak testing to the Standards is at the state-of-the-art for fast cycling production equipment, and is seen to have a nominal background in the 3 to 5 x 10^{-9} atm cm^3/s (He). That means that you will not see leakage in a part that does not have sufficient helium in the part to give a reading that is greater than that background, (> 5 x 10^{-9})
- To detect leaks to the 10.2.2 "Failure Criteria" using HMS will require either "pre-filling" parts with at least 10% He, or advancing the state-of-the-art of HMS to be able to measure parts to sensitivities in the 10^{-10} to 10^{-11} atm cc/sec range in production quantities. The only other option is to bomb devices in Helium for extremely long intervals of time, (days to even weeks).
- The alternate test method in 1071.8 is the radioisotope test method. It allows a test for either gross, fine, or a gross/fine combination test to the required sensitivities, with relatively short bomb times. Those fine leak sensitivity requirements can be met with bomb times of 0.2 to ~ 1.5 hours, (depending on the package volumes).

E – Examples of the "Fixed Table" conditions based on the "Failure Criteria" 10.2.2:

- The table in Figure 4 below shows a comparison of the R_1 readings for the "L" values called out in the Failure Criteria.
- There are three values included to show a comparison of the callouts in 10.2.2 at three different times: 3 years ago; 1 year ago; and the new spec callouts.
- The values shown in **'blue'** for 3 years ago, only included two volume sizes and only 2 "L" values. Note that the resultant R_1 readings are in a range that was easily seen on a production HMS.
- The values shown in '**black'** are based on the "L" values called out in 10.2.2 one year ago. Note that those R_1 readings are within the range of detectability of the production HMS.
- The values shown in **'red'** are based on the current "L" values in 10.2.2, (1071.8) dated November 2006. The "R_1" values shown are the readings based on Equation 3. They are the readings that are the result of the bomb times and pressure listed in the Fixed Table. It is quickly seen that with the new "L" values, the resultant R_1 readings are well below the detectability of the common HMS.

"L" values (atm cm3/s) (Air)	Volume of Pkg. (cm3) (min) (max)	Bomb Press (psia)	Bomb Time (hrs)	R1 HMS "Measured" leak rate atm cm3/s (He): R_1 Fixed Table Value	Calculated R_1 Values* (min Vol)	Calculated R_1 Values* (max Vol)
1 x 10-7	< 0.01	(75)	2	5 x 10-9	2 x 10-7	
1 x 10-9					3 x 10-11	
1 x 10-7	< 0.05	(75)	2	5 x 10-8	5 x 10-8	
1 x 10-7	> 0.01 < 0.05	(75)	3	1 x 10-8	3 x 10-7	7.5 x 10-8
5 x 10-9					1.0 x 10-9	2 x 10-10
1 x 10-6	> 0.05 < 0.5	(75)	4	1 x 10-8	6 x 10-6	1 x 10-6
5 x 10-9					3 x 10-10	3 x 10-11
1 x 10-6	> 0.5 < 1.0	(75)	2	1 x 10-8	5 x 10-7	2.6 x 10-7
1 x 10-8					5 x 10-11	2.6 x 10-11
1 x 10-6	> 0.5 <1.0	(45)	2	1 X 10-7	3 X 10-7	1.5 X 10-7
1 x 10-6	> 1.0 < 10.0	(60)	5	5 x 10-8	5 x 10-7	5 x 10-8
5 x 10-8					1 x 10-9	1 x 10-10
1 x 10-6	> 1.0 < 10	(45)	5	5 X 10-8	4 X 10-7	4 X 10-8
1 x 10-6	> 10 < 20	(45)	10	5 x 10-8	8 x 10-8	4 x 10-8
5 x 10-8					2 x 10-10	1 x 10-10

BLUE: Spec "L" values 3 years ago.
BLACK: "L" values 0ne year ago
RED: Current Spec "L" values

* "Calculated" using "Equation 3"

Figure 4

F – The Optional bombing pressures and times to achieve 'measurability' on the HMS are shown in Figure 5 below:

- Recognizing that the production HMS can only reliably detect readings greater than 3 to 5 x 10-9 atm cc/s (He), this table used 5 x 10^{-9} as the "R_1" 'minimum-reading', and calculated the bomb times and pressures required to assure that reading for various volume packages and their corresponding required "L" values per 10.2.2.
- Equation 3 was used to calculate the various test parameters for the HMS to provide a view of the possibilities for meeting the new spec using the HMS.
- It can be quickly seen that with the specification tightening of the required "L" leak test values, it becomes difficult and very time consuming to satisfy the spec with the HMS.

"L" (Air)	"L" (He)	Volume (cc)	Press. (atm)	Time (hrs)	"R1" atm cc/s (He)	
1 x 10-8	2.69 x 10-8	0.01	6	3.3	*5 x 10-9*	
5 x 10-9	1.35 x 10-8	0.01	6	15	***5 x 10-9***	<-----
1.9 x 10-9	5 x 10-9	0.01	6	100	***5 x 10-9***	
1 x 10-9	2.69 x 10-9	0.01	6	384	***5 x 10-9***	
Conditions required for a 0.01 cc package to read 5 x 10-9 atm cc/s (He) on HMS as R1						
1 x 10-8	2.69 x 10-8	0.05	6	17	***5 x 10-9***	<------
5 x 10-9	1.35 x 10-8	0.05	6	60	***5 x 10-9***	
1.9 x 10-9	5 x 10-9	0.05	6	485	***5 x 10-9***	
1 x 10-9	2.69 x 10-9	0.05	6	1920	***5 x 10-9***	
Conditiona required for a 0.05 cc package to read 5 x 10-9 atm cc/s (He) on HMS as R1						
5 x 10-8	1.35 x 10-7	0.1	5	1.6	***5 x 10-9***	
1 x 10-8	2.69 x 10-8	0.1	6	33	***5 x 10-9***	<------
5 x 10-9	1.35 x 10-8	0.1	6	132	***5 x 10-9***	
Conditions required for a 0.1 cc package to read 5 x 10-9 atm cc/s (He) on HMS as R1						
5 x 10-8	1.35 x 10-7	0.5	5	8	***5 x 10-9***	<------
1 x 10-8	2.69 x 10-8	0.5	5	198	***5 x 10-9***	
1 x 10-8	2.69 x 10-8	0.5	6	163	***5 x 10-9***	
5 x 10-9	1.35 x 10-8	0.5	5	798	***5 x 10-9***	
5 x 10-9	1.35 x 10-8	0.5	6	660	***5 x 10-9***	
Conditions required for a 0.5 cc package to read 5 x 10-9 atm cc/s (He) on HMS as R1						
5 x 10-8	1.35 x 107	1	6	13	***5 x 10-9***	<------
1 x 10-8	2.69 x 10-8	1	6	325	***5 x 10-9***	
Conditions required for a 1.0 cc package to read 5 x 10-9 atm cc/s (He) on HMS as R1						
1 x 10-7	2.69 x 10-7	1.3	5	5	***5 x 10-9***	
5 x 10-8	1.35 x 107	1.3	5	20	***5 x 10-9***	<------
1 x 10-8	2.69 x 10-8	1.3	5	509	***5 x 10-9***	
Conditions required for a 1.3 cc package to read 5 x 10-9 atm cc/s (He) on HMS as R1						
1 x 10-7	2.69 x 107	5	5	20	***5 x 10-9***	<------
5 x 10-8	1.35 x 10-7	5	5	77	***5 x 10-9***	
1 x 10-8	2.69 x 10-8	5	5	1960	***5 x 10-9***	
Conditions required for a 5 cc package to read 5 x 10-9 atm cc/s (He) on HMS as R1						
5 x 10-7	1.35 x 10-6	10	5	1.6	***5 x 10-9***	
1 x 10-7	2.69 x 10-7	10	5	39	***5 x 10-9***	<------
5 x 10-8	1.35 x 10-7	10	5	154	***5 x 10-9***	
1 x 10-8	2.60 x 10-8	10	5	3915	***5 x 10-9***	
Conditions required for a 10 cc package to read 5 x 10-9 atm cc/s (He) on HMS as R1						

Per 1071.8 para 10.2.2 "Failure Criteria", the "L" value is the "actual leak rate of the part" (in atm cc/s (air)). The R1 reading is the "measured leak rate", or the reading on the HMS. This table was put together based on the realization that the R1 reading on the HMS must always be "above" the normal background of the HMS, and that background is found to be ~ 5 x 10-9 as a minimum. This table shows the bombing conditions required to introduce sufficient helium into a leaking part to assure a detectable reading at or above that background.

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Figure 5

G – The other optional method for satisfying the new spec requirements:

Radioisotope leak detection:

- The radioisotope gross leak and fine leak procedures using Krypton85 tracer gas have been in 1071 since 1968, and over 50 billion hermetics have been leak tested with this method.
- The sensitivities of the fine test have always been tighter than the HMS "L" value callouts. Those Kr85 leak rate callouts in 1071-IV are shown in Figure 6.
- The test parameters are very reasonable as compared to HMS.

9.5.1 Failure criteria. Unless otherwise specified, devices that exhibit a leak rate equal to or greater than the test limits of table 1071-IV shall be considered as failures.

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

Volume of package (cc)	Q_S
<0.05	5×10^{-9}
>0.05 < 0.5	1×10^{-8}
>0.5 <10.0	5×10^{-8}
> 10.0 < 20.0	5×10^{-8}

Figure 6

- The 1071-IV table with (air) & (He) equivalents is shown in Figure 7

Volume of package (cm^3)	Q_s Kr^{85}	Equivalent leak rates (atm cm^3/s)	
		(air)	**(He)**
< 0.05	5×10^{-9}	8.6×10^{-9}	2.3×10^{-8}
> 0.05 < 0.5	1×10^{-8}	1.7×10^{-8}	4.7×10^{-8}
> 0.5 < 10.0	5×10^{-8}	8.6×10^{-8}	2.3×10^{-7}
> 10. > 20.0	5×10^{-8}	8.6×10^{-8}	2.3×10^{-7}

Figure 7

- The pressurization times required to satisfy the Q_s sensitivities typically range from 0.2 to 1.5 hours.

H – SUMMARY:

The technological review of the field failures and hermeticity shortcomings has justified the tightening of the leak rate requirements in the specification. The requirements may still be short of what needs to be required, but it is a major step in the right direction. One consequence of the tightening of the specification is that it has instantly opened the door to the "Hermeticity Hoax", brought the hermeticity issue out in the open, caused both manufacturers and users to scrutinize the products in manufacture and in use today. Perhaps the greatest benefit will be that the parts thought to be high rel quality, will now be proven to be at least better than they may have been in the past.

This revision will impose some care and cost impositions on at least the manufacturers, and in many cases the users who re-verify the hermeticity of what they are buying. Those costs and impositions are very small in comparison to the cost of failures in the field. Most of which appear to have been miss-diagnosed, and thus have not raised hermeticity challenges.