Implication of Multiple Leak Tests and Impact of Rest Time on Avionic Hybrids

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Abstract

Since 2007 Northrop Grumman's Baltimore facility has leak tested Hybrid packages primarily through the Optical Leak method. The Optical Leak systems allow for individual part readings performed in parallel and they eliminate the need for separate fine and gross leak tests. As with most leak test operations, there are occasionally parts that need to be retested. One of the benefits of Optical Leak Test is that there is no exposure to liquids, greases, or other contaminates that may plug fine leaks. However, there is concern about the aggregate impact of re-leak testing, and interest in any time effects or "charging" that may occur from repeated test exposure. To investigate the impact of repeated test exposure and determine the effect on test results of retesting parts, NGES Baltimore performed testing on a dozen parts (both leakers and good seals) to measure the amount of distortion repeated testing generates. This paper describes the parts tested and the results from a series of tests spaced approximately 24 hours apart as well as tests performed immediately in conjunction – exposing the parts to repeated pressure cycling without a rest period for recovery. The results show that rapid, repeated testing will yield a slight worsening of the leak measurements (i.e. the test may falsely fail a good part), although the overall magnitude of the shift was not great. Allowing a rest time of 4x the test time worked as a rule of thumb for eliminating the "pressure-charging" effect of prior tests, and that testing performed on different days yielded very consistent results. The current method 1014 leak test MIL-STD-883 has specific guidance against retesting parts. At Northrop Grumman we believe there are instances in which retesting parts is useful, and have shown that with appropriate handling, retest will yield consistent results.

Key words

Hermeticity, MIL-STD-883, Optical Leak, Pressure-charging, Retest

I. Introduction

MIL-STD-883 establishes uniform methods, controls, and procedures for testing microelectronic devices suitable for use within Military and Aerospace electronic systems to ensure a uniform level of quality and reliability appropriate for the intended application of those devices [1]. Method 1014.14 is the test method used to determine the effectiveness (hermeticity) of the seal of microelectronic devices with designed internal cavities [1]. Method 1014.14 establishes the following requirements for retesting devices:

> *"1.3.1 Retest. Devices which fail gross leak 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 shall not be retested for acceptance unless specifically permitted by the applicable acquisition document. The applicable acquisition document must also state that a failed device that passes retest needs not be counted as a failure in the sample size accept number calculations, otherwise if will count. 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."* [1]

For the purposes of this paper, retest refers only to devices which have been leak tested through helium bomb and test (test conditions A1 and A2) or optical leak test (test conditions C4 and C5) and have not been gross leak tested or exposed to liquids, greases, or other contaminates that may plug fine leaks.

Although per MIL-STD-883 retest is only allowable if specifically permitted per the applicable acquisition document, this paper reviews leak test data which argues that retest using test condition C4 or C5 is acceptable in any case. This paper investigates only optical leak (test conditions C4 and C5) retest data, but it is believed that retesting using helium bomb and test (test conditions A1 and A2) is acceptable as well, given appropriate rest times between retest.

II. Purpose of Retest

During traditional fine Helium leak testing, test conditions A1 and A2, retesting is frequently used if it is suspected that an external geometry or contaminant is holding sufficient Helium to fail the test or if the background noise is suspected to be too high [2]. Retesting using test conditions A1 and A2 involves a full re-bomb and a new fine leak detection.

During optical leak test, test conditions C4 and C5, retesting is typically used if there is a question about the placement of a part or the camera's access to the window of interest, if an error is generated because enough data could not be unwrapped, if the lid stiffness is outside limits, if the leakage value is offset too far to the negative, if the percentage of pixels is below the limit [3], or if it is necessary to go to a longer, more precise test. Retesting using conditions C4 and C5 involves a new pressurization cycle and lid deflection measurement.

III. Optical Leak Test

Optical leak tests hermetically sealed devices by holding them under a controlled pressure and measuring their sub-micron lid deflection over time using holography [3]. The test chamber can be pressurized with helium, nitrogen, or clean dry air (CDA) up to 75psig. Fig. 1 shows the lid deflection for hermetically sealed devices, gross leakers, and fine leakers. A hermetic device has initial lid deflection after chamber pressurization prior to the start of the test, and no lid movement throughout the test. A gross leaking device has no lid deflection after chamber pressurization because the leak is so large that test gas rushes into the device to equalize it with the chamber, and no lid movement during test. A fine leaker shows initial lid deflection after the chamber is pressurized, but as the device leaks, its internal pressure becomes closer to the pressure of the surrounding environment, causing the lid to relax and move upward. The change in lid position from start to end of the test is the lid deflection used to calculate leak rate [4].

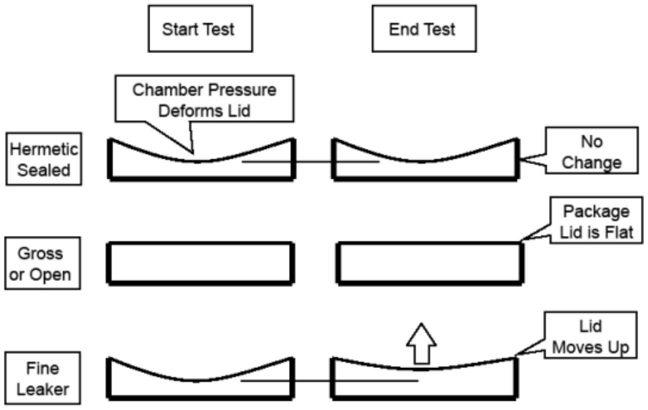

Fig. 1: Lid deflection of various seals throughout optical leak test

Optical leak test cuts down on the test time required to determine device leak rate, performs fine and gross leak simultaneously, does not introduce any fluids or other contaminants to the devices, and can be done while devices remain in their manufacturing fixtures.

III. Concerns with Retest

Any leak test method must provide the operator with accurate test results. The primary concern of retesting devices is that this could change the accuracy of test results, leading to miscategorization of a device. There are two primary types of miscategorization: escapes and false alarms.

An escape is a leaking device that is tested as passing. It is possible that a leaking device could be tested as passing if the leak path is plugged from cleaning fluids, finger oils, test fluids, etc. An escape typically leads to delivering a "bad" device.

A false alarm is a passing device that is tested as leaking. It is possible that a passing device could be tested as leaking if the leak threshold is overly conservative or if an error occurs during test. A false alarm typically leads to scrapping a "good" device.

Each retest introduces an opportunity for an erroneous result. In our testing, we were interested in looking for physical changes that occur as a result of retesting a device, such as "pressure-charging", that would render test results inaccurate.

III. Test Method

Only one style of part was used for this testing. This device has outer dimensions 1.193" x 0.915" with Ni/Au plated kovar lid, 0.005" thick. The lid is mounted on a shallow Ni/Au plated kovar ringframe brazed to a multilayer ceramic base. The material configuration is typical of devices usually tested, and the internal volume is in the middle of the family of devices tested.

Although both the fine leak method using helium tracer gas (test conditions A1 and A2) and the optical leak method (test conditions C4 and C5) are discussed in this paper, only the physical impact of retest using optical leak was studied for this analysis. All devices were optical leak tested using helium as the pressurization gas and all leak rates reported are equivalent leak rates (L) in atm-cc/sec helium, unless otherwise specified.

The impact of optical leak retest was studied using 12 identical devices with an internal volume of 1.3cc. 8 of the 12 devices were hermetic, 2 were fine leakers on the 6-scale, 1 was a gross leaker on the 5-scale, and 1 was a gross leaker with a hole so big the test could not quantify leak rate and reported as "Gross". The test used a window size of 64 x 142, test pressure of 60psig, test time of 5 minutes, and critical leak rate of 2.6e-06. 11 tests, immediately in conjunction, were performed on the devices. The leak rates of the 12 devices after repeated testing are shown in Fig. 2. The green line indicates the passing leak threshold of 2.6e-06. Leak results of "Gross" are reported as 1.0e-04 for plotting purposes. We will look at these data points in three groups: gross leakers, fine leakers, and hermetic devices.

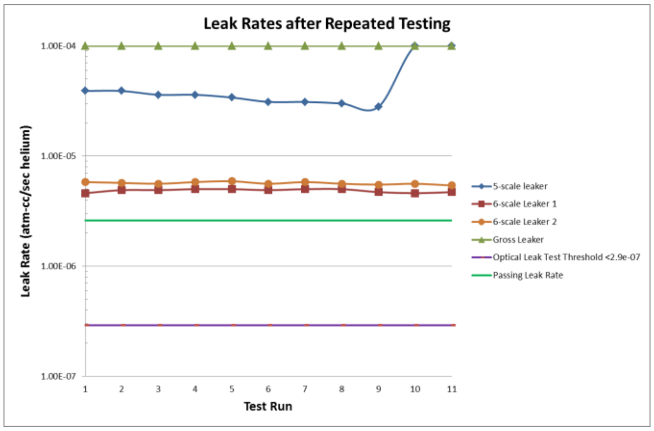

Fig. 2: Impact of repeated test exposure on three groups of devices: gross leakers, fine leakers, hermetic devices (all hermetic devices passed the <2.9e-07 optical leak test threshold)

IV. Test Results

Gross Leakers

Equivalent leak rates greater than 1.0e-05 atm-cc/sec air are considered gross leak rates [2]. This converts to 2.6e-05 atm-cc/sec helium. The impact of repeated test exposure was observed on two gross leaking devices. One with a leak rate so gross the optical leak system could not quantify a leak rate and reported the failure as "Gross", and one with a leak rate of ~3.6e-05 (Fig. 3). The "Gross" leaker was not affected by repeated testing, as shown in Fig. 2. The 5-scale gross leaker saw initial improvement in leak rate, until the test results eventually classify the part as "Gross" and display a stiffness error. The red bars in Fig. 3 show the day-to-day variation expected (determined by daily SPC data). The results show that a 5-scale gross leaker can hold pressure, impacting subsequent tests, but eventually the device fails due to a stiffness error. Because the critical leak rate is 2.6e-06, a gross leaker on the 5-scale would fail with an error before it improves enough to pass the leak threshold.

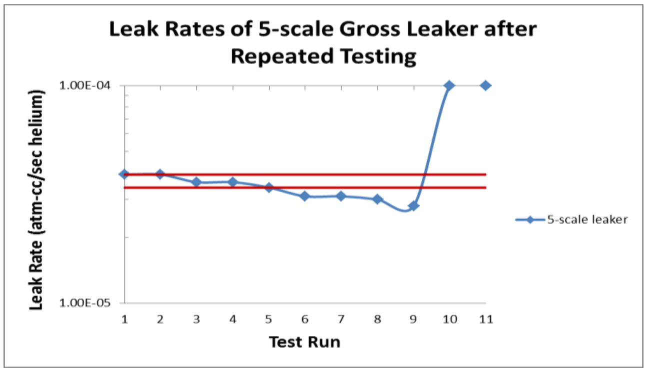

Fig. 3: Leak Rates of 5-scale gross leaker after repeated test exposure

Fine Leakers

Equivalent leak rates less than 1.0e-05 atm-cc/sec air and greater than 1.0e-06 atm-cc/sec air are considered fine leak rates. This converts to 2.6e-05 atm-cc/sec helium > fine leak rate > 2.6e-06 atm-cc/sec helium. The impact of repeated test exposure was observed on two fine leaking devices (Fig. 4). The 6-scale fine leakers varied slightly for each test, but the variation is within the expected window (determined by daily SPC testing), shown by the red bars in Fig. 4. This testing shows that optical leak test does not pressurize 6-scale fine leakers enough to impact subsequent leak rate.

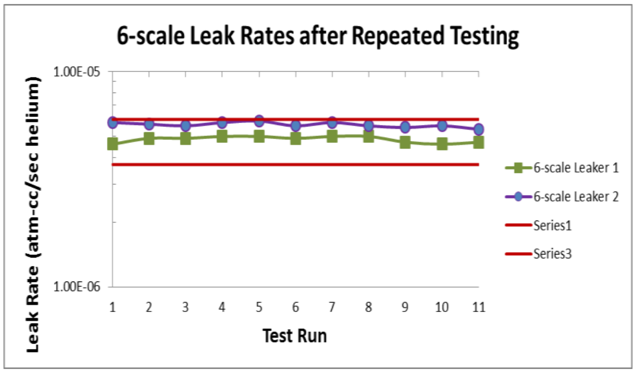

Fig. 4: Leak rates of 6-scale fine leakers after repeated test exposure

Hermetic Devices

All hermetic devices observed for this testing had lower leak rates than the optical leak test threshold of 2.9e-07 (indicated by the purple line in Fig. 2). No hermetic devices were impacted by retest, even when performed immediately in conjunction.

To determine if the standard rest time of 4x test time is an appropriate rest time between optical leak tests, the devices were left at ambient for 48 hours to allow any "pressure-charging" effects to dissipate. They were then tested once and retested after a 4x test time (20 minutes) rest. The results are shown in Fig. 5. Only the 5-scale and 6-scale leakers are plotted as the hermetic devices and "Gross" leaker showed no change in leak rate. All leak rates show a slight increase after retest, but generally remain level.

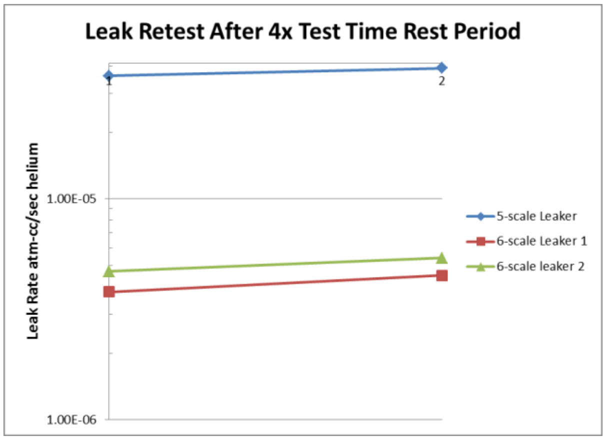

Fig. 5: Impact of retest after 4x test time rest period

To ensure the leak rates of the devices reported from optical were accurate, each part was fine bombed using the flexible method (test condition A2). The parts were pressurized at 45psi for 8 hours. All parts had some epoxy on them, which can hold helium, so reported leak rates are likely higher than the actual cavity leak rate. All hermetic parts passed the 3.0e-08 atm-cc/sec measured leak rate (R) threshold. The gross leaker also passed the 3.0e-08 threshold. The 5 scale fine leaker failed on the 4-scale. One 6-scale fine leaker failed on the 6-scale. The second 6-scale fine leaker failed on the 5-scale, but this part had an additional plastic piece on it which introduced another source of helium. No parts were gross bombed to avoid introducing them to liquid or other contaminates which could plug fine leaking holes.

V. PRESSURE-CHARGING

Based on test results generated from repeated test exposure, it appears there are only "pressure-charging" effects for gross leakers on the 5-scale; the "pressure-charging" effects eventually cause the part to fail as "Gross". Given that the passing leak threshold is at the lower end of the 6-scale (2.6e-06 atm-cc/sec in helium), there is low risk associated "pressure-charging" effects on the 5-scale.

Hermetic devices, fine leakers, and "Gross" leakers are not impacted by retest.

VI. Conclusion

The optical leak test method gives reliable, repeatable leak measurement results, even after repeated test exposure. Fine leakers (6-scale leakers) and hermetic devices are not impacted by retest. Gross leakers on the 5-scale are impacted by repeated pressure exposure, but fail as "Gross" before they would falsely pass. The 4x test time rest at ambient before retest serves as a general rule of thumb to allow parts to return to their actual leak rate.

This testing was conducted only on one device configuration and test time, but it is expected that results will repeat with devices with larger internal volumes and longer test times.

Acknowledgment

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References

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