The Cumulative Helium Leak Detector

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I. Introduction

The Cumulative Helium Leak Detector (CHLD) was developed by John Pernicka at the Pernicka Corporation in 1988 in response to EPA's broad requirement to stop the worldwide use of Fluorocarbons in order to protect the Ozone layer. Leak testing semiconductor devices has traditionally been a two step process requiring a gross leak test utilizing Fluorocarbons and a fine leak test using Helium. The Mil-Std 883, Method 1014 spells out various optional ways to accomplish the leak test in order to insure hermeticity in military devices. Method 1014 is also specified as a requirement in NASA, Military, High-Rel, and Communication applications as well as commercial applications which have a Hermeticity Specification.

Renewed interest in this old, "new" method of leak testing was prompted by the advent of smaller and smaller semiconductor packages and the difficulty in leak testing them using conventional test methods. Recent data suggests that in order to control moisture ingress in small packages, tighter leak specifications are required which exceed the detection limits of most Helium leak detectors.

The CHLD method meets all the requirements of Method 1014 and is currently being proposed as an alternate method which covers both the fine and gross leak test range with one test which does not use Fluorocarbons. In addition, the fine leak test requirements for small military packages (MIL-STD 750, Method 1071, Procedures CH1 and CH2) are being revised to include levels which are below the detection limits for most conventional Helium Leak Testers. The CHLD can measure leaks from 1.0 std-cc/sec down to 3.0E-13 std-cc/sec which is well beyond the limits of most Helium leak detectors (1.0E-06 to 5E-10 atm-cc/sec).

Transitioning to the CHLD is simplified since all the sample handling, dwell time and bombing requirements are the same as the Method 1014 Helium Leak test which is currently in use.

The following discussion compares the CHLD method with the conventional Helium leak test, provides an example of data covering the entire leak range, and presents the preliminary results of a number of correlation experiments.

II. Test Method Description

Reviewing the historic Helium Leak Tester (Fig. xx), it consists of:

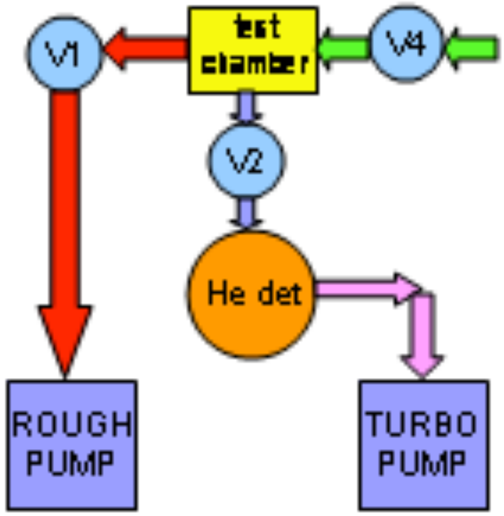
a. A test chamber
b. Roughing pump

c. High vacuum pump
d. Helium detector (mass analyzer tuned to 4 AMU)
e. Intra connecting valves

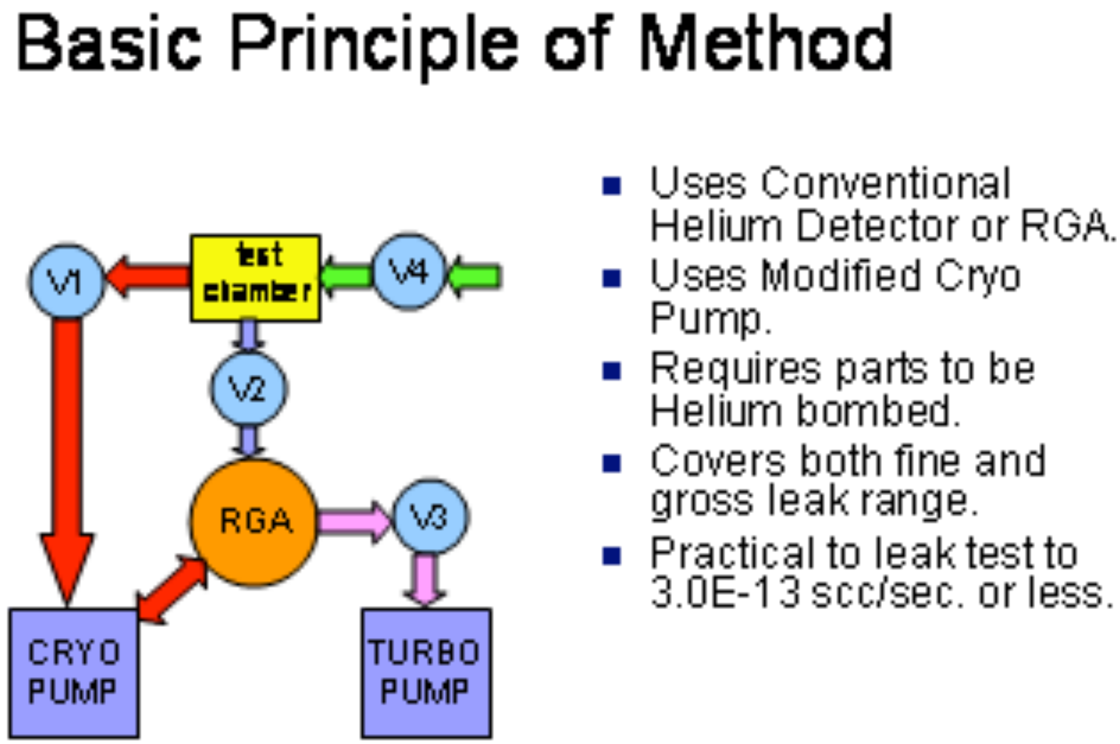
A sample to be tested is placed in the test chamber, roughed down to a vacuum, and then analyzed by the detector while the vacuum pump is removing Helium continuously from the chamber. A leak rate is determined by measuring a Helium amplitude which is compared to the amplitude of a Helium leak standard. Gross leaks can not be measured since all the Helium is pumped out during the roughing stage of the test procedure.

The CHLD system (Fig. xy), consists of the same elements as a conventional Helium Leak Tester, however, a specially prepared Cryo-pump is used to rough down the test chamber and pump on the sample during analysis. This modified Cryo-pump does not pump Helium. A gross leak is detected by simply noting a large jump in Helium signal, where as, a leak rate is simply measured by calculating the ratio of the slope of the signal to the slope of a Helium Leak Standard (Fig. xz). The high vacuum pump is used to remove Helium from the system in preparation for the next sample.

Basic He Leak Test Method

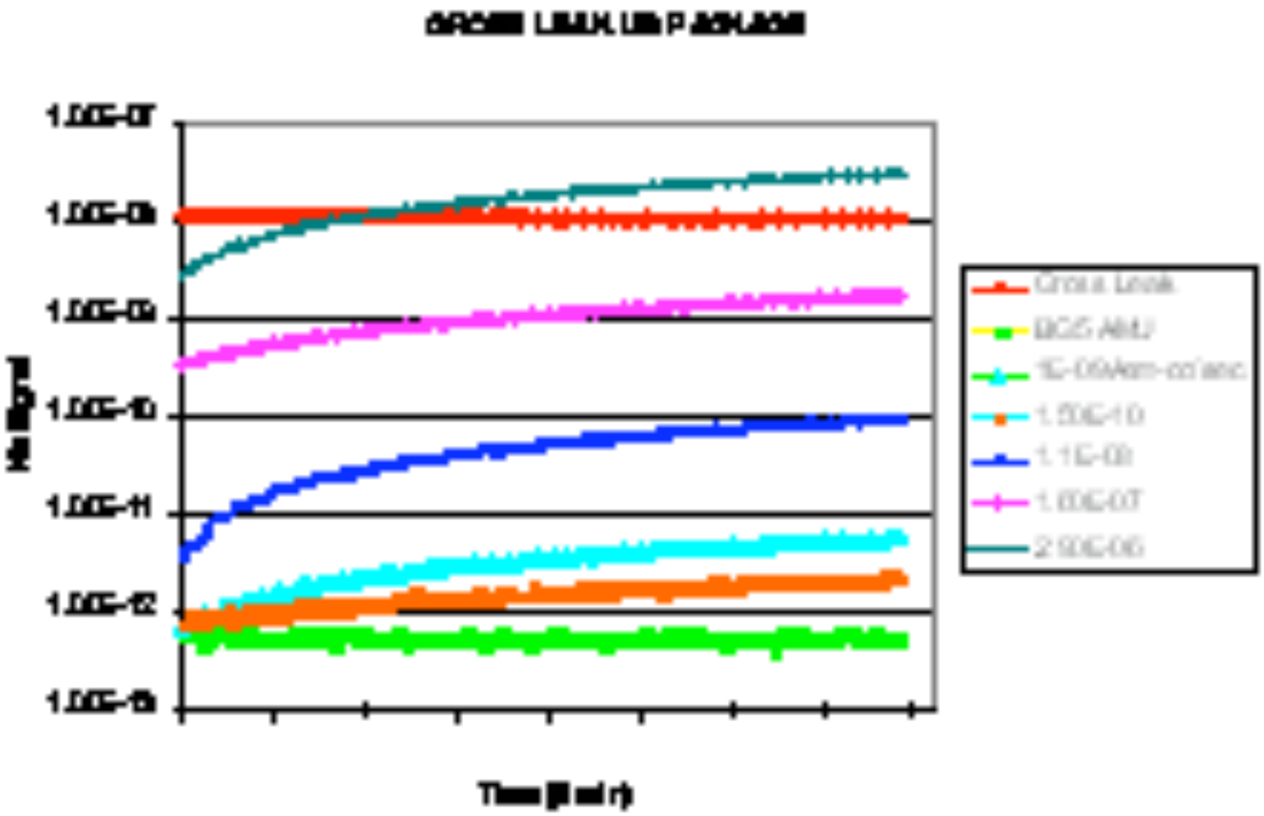


- Test Chamber is pumped down through (V1).
- Resulting Helium from fine leak is transferred to Detector through (V2).
- Helium is continuously pumped through detector by Turbo Pump.
- Practical detection limit is 1.0E-09 scc/sec.
- Gross leak undetected.



III. Sample Data

Figure xz illustrates on a log scale the various slopes measured as a function of leak rate for UB packages which have an internal volume of 0.002 cc.


Cross Leak
1.00E-07
1.00E-08
1.00E-09
1.00E-10
1.00E-11
1.00E-12
1.00E-13

IV. Correlation Experiments

27 serialize UB packages were fine and gross leak tested and then sent to Pernicka for Cumulative Helium Leak Testing. After the tests, the parts were returned for another round of fine and gross leak tests. The data is presented below:

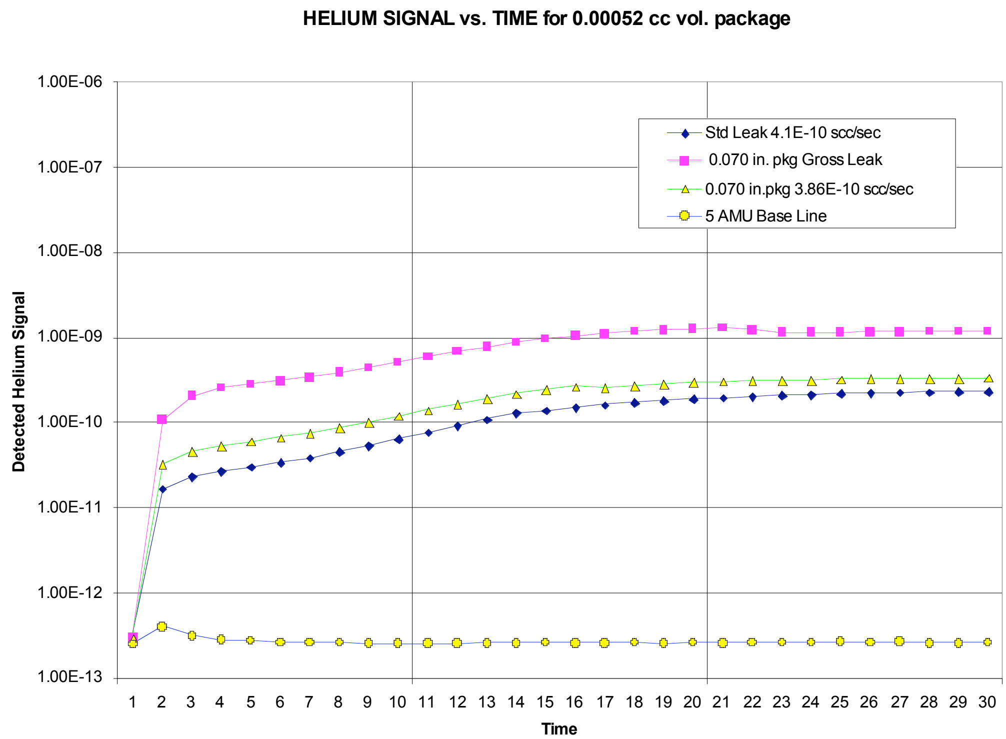
FINE AND GROSS LEAK CORRELATION EXPERIMENT

	5/6/2004	5/6/2004	5/6/2004	9/15/2005	9/15/2005	9/15/2005	**Cumulative Helium Detection 9/01/05**			**Time**
Serial No.	**Fine Leak (Pass or Fail)**	**Gross Leak (Pass or Fail)**	**(Leak rate)**	**Fine Leak (Pass or Fail)**	**Gross Leak (Pass or Fail)**	**(Leak rate)**	**(Leak rate)**	**Fine Leak**	**Gross Leak**	**after bomb**
1987	Pass	Pass	0.2 x E-8	Not Returned			Not Received			
0282	Pass	Pass	0.3 x E-8	Pass	Pass	0.5 x E-8	2.7 x E-9	Pass		1:16
0480	Pass	Pass	0.3 x E-8	Pass	Pass	0.5 x E-8	8.1 x E-10	Pass		3:17
0431	Pass	Pass	0.2 x E-8	Pass	Pass	0.5 x E-8	5.5 x E-10	Pass		:26
0669	Pass	Pass	0.5 x E-8	Pass	Pass	0.5 x E-8	1.4 x E-9	Pass		3:25
0459	Pass	Pass	0.4 x E-8	Pass	Pass	0.5 x E-8	8.1 x E-9	Pass		1:43
0306	Pass	Pass	0.4 x E-8	Pass	Pass	0.5 x E-8	1.1 x E-8	Pass		2:13
0707	Pass	Pass	0.1 x E-8	Pass	Pass	0.5 x E-8	1.9 x E-9	Pass	**Fail**	3:09
0450	Pass	Pass	0.2 x E-8	Not Returned			Not Received			
0978	Pass	Pass	0.6 x E-8	Pass	Pass	0.5 x E-8	5.5 x E-9	Pass		2:08
0717	Pass	Pass	0.2 x E-8	Pass	Pass	0.5 x E-8	3.4 x E-9	Pass		1:25
0307	Pass	Pass	0.2 x E-8	Pass	Pass	0.5 x E-8	9.0 x E-9	Pass		2:25
1040	Pass	Pass	0.2 x E-8	Pass	Pass	0.5 x E-8	3.2 x E-9	Pass		1:00
0987	Pass	Pass	0.2 x E-8	Pass	Pass	0.5 x E-8	5.9 x E-9	Pass		3:41
0401	Pass	Pass	0.8 x E-8	Pass	Pass	0.5 x E-8	3.4 x E-9	Pass		3:50
0961	Pass	Pass	0.3 x E-8	Pass	Pass	0.5 x E-8	4.8 x E-9	Pass		3:33
0420	Pass	Pass	0.2 x E-8	Not Returned			Not Received			
2554	Pass	Pass	0.3 x E-8	Pass	Pass	0.5 x E-8	1.0 x E-8	Pass		2:16
0014	Pass	Pass	0.9 x E-8	**Fail**	n/a	**5.0 x E-6**	1.1 x E-8	Pass		2:41
0013	Pass	**Fail**	0.2 x E-8	Pass	Pass	0.5 x E-8	9.7 x E-11	Pass		3:58
0012	**Fail**	n/a	**> 1 E-7**	**Fail**	n/a	**3.0 x E-6**	**6.1 x E-7**	**Fail**		:43
0011	Pass	**Fail**	0.2 x E-8	Pass	**Fail**	0.5 x E-8	8.5 x E-9	Pass		1:43
0010	Pass	**Fail**	0.2 x E-8	Fail	n/a	**10.0 x E-6**	4.3 x E-9	Pass		2:59
0009	Pass	Pass	0.1 x E-8	Not Returned			Not Received			

0008	**Fail**	n/a	**> 1 E-7**	Fail	n/a	**7.0 x E-6**	4.0 x E-8	Pass	**Fail**	:52
0007	**Fail**	n/a	**> 1 E-7**	Fail	n/a	**2.0 x E-7**	**1.6 x E-7**	**Fail**		2:00
0006	Pass	**Fail**	0.2 x E-8	Fail	n/a	**2.0 x E-6**	1.5 x E-10	Pass		1:34
0005	Pass	Pass	1.0 x E-8	Fail	n/a	**3.0 x E-6**	1.2 x E-8	Pass	**Fail**	:35
0004	**Fail**	n/a	**> 1 E-7**	Pass	**Fail**	0.5 x E-8			**Fail**	:16
0003	**Fail**	n/a	**> 1 E-7**	Fail	n/a	**5.0 x E-6**	**2.4 x E-6**	**Fail**		1:08
0002	Pass	**Fail**	0.1 x E-8	Fail	n/a	**3.0 x E-6**	**6.7 x E-8**	**Fail**		1:51
0001	Pass	Pass	0.4 x E-8	Not Returned			Not Received			

After the parts had been leak tested three times, they were returned to Pernicka for destructive RGA testing to analyze the gas contents of each package. The packages which did not correlate are highlighted in yellow. The majority of these were leak tested outside the one hour time limit from the removal of the Helium Bomb. Also, some of the packages were passed by the conventional fine and gross leak test and were failed by the CHLD and these failures were verified by the RGA test.

Additional correlation tests were conducted on some 0.00052 cc packages that failed the gross leak test ether once or twice. The parts were tested with the CHLD system and then destructively RGA tested. The results below indicate that some of the gross leakers were plugged by the fluorocarbons during the first gross leak test, and as a result, passed the second time they were tested. This would not have happened if the parts had only been tested with CHLD system.


HELIUM SIGNAL vs. TIME for 0.00052 cc vol. package
Std Leak 4.1E-10 scc/sec
0.070 in. pkg Gross Leak
0.070 in.pkg 3.86E-10 scc/sec
5 AMU Base Line
Detected Helium Signal
1.00E-06
1.00E-07
1.00E-08
1.00E-09
1.00E-10
1.00E-11
1.00E-12
1.00E-13
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Time

Leak Test Summary

Pkg	Volume	He measured	F	Comments
Std L	n/a	4.10E-10 scc/sec	N	Calibration Std
0.100" 1039	0.000766 cc	5.3E-10 scc/sec	N	Failed g/l first time Passed fine leak
0.070" 47	0.00052 cc	6.86E-10 scc/sec	N	Failed g/l first time Passed fine leak
0.070" 70	0.00052 cc	3.86E-10 scc/sec	N	Failed g/l first time Passed fine leak
0.070" 97-214	0.00052 cc	Gross Leak	N	Failed g/l twice Passed fine leak

The RGA test results indicate high Fluorocarbons for the four packages which passed the gross leak test the second time and the RGA confirmed the gross leaker which failed twice with the fluorocarbon test and once with the CHLD system. Leakage can also be confirmed by observing the Oxygen levels in the RGA data. Since we know pure Nitrogen was used in the sealing process, the presents of Oxygen indicated that the parts had a leak. Also, Helium was found in the parts from the bombing during the fine leak test. These tests have provided irrefutable evidence that Fluorocarbons used in the gross leak test can plug the leak path, and from that point forward, make the package appear to be hermetic. Note the CHLD system measured leaks in the -10 range which under the current specification in the MIL-STD would indicate these packages were acceptable. Had the CHLD system been used during the very first leak test, these parts would have been rejected as gross leakers each successive time they were tested.

RGA Summary

Gasses	1039	47	70	97-214
H2	04.7947	01.2216	16.5932	09.2864
He	00.0011	00.0001	00.0217	00.0096
H2O	03.3299	05.4832	26.7999	43.6246
N2	90.8515	91.0918	41.7146	30.3237
O2	00.5611	01.2733	07.3846	10.2704
Ar	00.0182	00.0524	00.1742	00.1659
CO2	00.3561	00.7665	05.4068	04.9098
HC+Org	00.0320	00.0366	00.4213	00.3282
Flurocbs	00.0117	00.0049	00.1536	00.0561

V. Conclusion

The CHLD system compares favorably with the conventional fine and gross leak test and has the additional benefit of being able to conduct repeated leak tests on the same part without the risk of plugging the leak path. It has also identified gross leaks in small packages which were missed by the Fluorocarbon bubble test. Since the system has a broad dynamic range, actual leak rates can be reported instead of just a pass or fail. Many of the low fine leak values reported for the conventional Helium leak test in the correlation study were limited by either background or sensitivity of the conventional instrument and do not reflect the actual leak rate of the package being tested. The CHLD system was able to measure all of the leaks, even the very small ones, since its detection limit was 3.0E-13 atms-cc/sec. The RGA test is a powerful tool to determine if a leak exists, however, since it is a destructive test procedure, product yields tend to suffer.

VI. Appendix

Appendix The following papers or presentations provide additional background information which will assist the reader in understanding the technology and evolution of the test method.

1. UB Package Leak Rates Determined by the Cumulative Helium Leak Test, by John C. Pernicka, JEDEC Hermetic Small Package Testing Task Group, 19 September 2005.
2. Moisture in UB Packages as a Function of Measured Leak Rate, by John C. Pernicka, RGA task group, JEDEC, 19 September 2005.
3. Cumulative Helium Leak Detector, by John C. Pernicka, Space Parts Working Group, 13-14 April 2004.
4. Leak Testing Small Packages, by John C. Pernicka, JEDEC JC13.1 General Session, January 2004.
5. The Value of RGA in Manufacturing Semiconductors, by John C. Pernicka, JEDEC RGA task group, 8 September 2003.
6. Interpretation of Mass Spectrometry Data, by John C. Pernicka, JEDEC RGA task group, 12 January 2003.