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PACKAGE INTEGRITY MEASUREMENT TECHNOLOGY AND QUALITY ASSURANCE

Raytheon Company

Aaron DerMarderosian and Vincent Gionet

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SUMMARY

This study was initiated to improve the present methods found in MIL-STD-883D test, Method 1014.9 (Seal) and Method 1018.2 (Internal Water Vapor Content). The scope of the concern is to reduce the incidence of gaseous ambient induced failures by improving the present Mil-Standards.

The study focuses on reviewing present practices, exploring new ones and suggesting recommendations for revisions. The aim of the study was to try and gather as much useful information, i.e., data, comments, recommendations, ideas and new leak tests from the micro-electronic industry at large, and use this information to make improvements to the Mil-Standard.

The response to an industry wide survey of testing practices, comments and recommendations in the form of a questionnaire was minimal. Of the one-hundred-one (101) persons surveyed, only thirty-two (32) replied. For the most part, little information of value to this study was obtained with the exception of a few respondees who elaborated more with their replies and indicated a genuine concern for change. The inputs from all respondees were channeled into making the recommendations that would benefit everyone.

The study was initiated with a search and review of new technology and procedures which would demonstrate potential for inclusion in Method 1014. These included studying laser optical techniques and the use of a 37% He tracer gas. A study was also performed to evaluate the use of a pre mass spectrometer bake at 125°C to remove helium gas from package surfaces caused from the bombing process.

We have studied the behavior of so called one-way leakers. This was accomplished by varying the test pressure and temperature. Special fixturing was designed and fabricated for these tasks. The results of these experiments show that most parts leak bidirectionally and behave according to molecular flow. There were some examples, however, of directional flow behavior as well as those whose leak rates were severely affected by temperature. Because of the unpredictable nature of these parts (the directionality is not always predictable as to effect and direction), we cannot recommend a particular test method which can detect them consistently. We do feel, however, that the tighter limits ($< 1 \times 10^{-8}$ ATM cc/sec) coupled with package integrity design guidelines will go a long way towards their elimination.

The survey test data generated, along with a review of the existing procedures in MIL-STD-883D, Method 1014 for fine and gross leak testing, led us to the following major conclusions and recommendations: (The complete revision of Method 1014 is shown in Appendix A).

- o The present failure criteria for helium and Krypton 85 fine leak testing (Test Condition A and B) is too lenient. We recommend a maximum allowable air leak rate of 1×10^{-8} ATM cc/sec for all tests and packages regardless of package internal volume.
- o The helium fine leak fixed method (A_1) is a compromise and should be eliminated.
- o A post bomb bake prior to fine leak test at 100-125°C for 10 to 15 minutes should be allowed in order to rid the package of absorbed tracer gas. This will reduce background noise levels and allow for reliable multiple part tests as well as increase the sensitivity of the test.
- o The Krypton 85 Test (Condition B) should be rewritten for molecular flow (in place of viscous flow at present) and account for the loss of gas after depressurization, i.e., same principle as the flexible helium leak test method (Howl and Mann Equation).
- o Replace the fixed method with an alternative helium backfill method at seal. This would simplify testing and assure detection of leaks in larger packages down to 1×10^{-8} ATM cc/sec.
- o The gross leak bubble test should limit the number of parts tested at one time, to a maximum of four (4).
- o Simplify the Howl and Mann expression as described in 1014; A_2 .

The results of the 1018 correlation study revealed that many of the R.G.A. test facilities had "drifted" somewhat out of calibration and indicated problems with both ends of the volume range tested (.01 cc and 5.5 cc). The testing was performed in two trials. The first trial indicated a calibration problem with 2 of the 3 RGA houses while the second trial indicated a potential problem with the small volume correlation samples, since three (3) of the four (4) facilities were in reasonably close agreement with each other. The effects of the larger volume package, however, were still evident as shown in the first trial.

As a result of these findings we recommend that:

- A. Qualified RGA facilities should have several hundred correlation samples to test over a 3-6 month period in order to establish a meaningful statistical basis for their calibration, measurement approach, and procedure.

- B. Rome Laboratory should evaluate their data and procedures and establish a firm set of procedures which can be audited on an ongoing basis.
- C. Evaluate the use of a rolled gold interior for the correlation samples to eliminate any variabilities in oxide thickness levels within the package cavity.

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The authors would like to acknowledge the efforts of those who participated in the hermeticity survey. The responses from AMD and NASA were particularly thorough and helpful in our preparation during the rewriting of Method 1014. We would also like to thank Messrs. L. Bergquist and T. Greene of Martin Marietta for their efforts in examining their "single leak test" method for part of this study and Mr. J. Tyson of Laser Technology for his testing and method for gross leak detection based on laser interferometry. The latter has shown promise as a new method for inclusion into Method 1014 and joins the Kr85 and weight test methods for their ability to detect certain types of one-way leakers.

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION.	1
OUTLINE	
A. Test Method 1014 (Seal)	1
B. Test Method 1018 (Internal Water Vapor Content)	2
SECTION I MIL-STD-883D - TEST METHOD 1014 (SEAL)	3-6
ONE-WAY LEAKER STUDY.	6-8
TEST PROCEDURE WITH ONE-WAY LEAKER FIXTURE.	8-10
Room Temperature Tests	11
Normal Devices	11
Pressure Sensitive Devices	11-13
CONCLUSIONS	13
SECTION II MIL-STD-883D, TEST METHOD 1018.2.	24-30
RESIDUAL GAS ANALYSIS (RGA) CORRELATION STUDIES	
Manufacture and Sealing of Moisture Correlation Samples	30-35
Moisture Analysis	35-36
CONCLUSIONS	37
RECOMMENDATIONS	38
REFERENCES.	39
BIBLIOGRAPHY.	40
APPENDIX: A MIL-STD-883D Test Method 1014.10 Seal (Proposed Revision)	A1-A19
APPENDIX: B Questionnaire.	B1-B12
APPENDIX: C Questionnaire Summary.	C1- C-10

LIST OF FIGURES

Figures	Page
1. One-Way Leaker Test Fixture	7
2. 1/4" x 3/8" 16 Lead Flat Pak With Gold Ion Sputtered Hole Site	9
3. 1/4" x 3/8" Flat Pack With Soldered Copper Tubulation	9
4. Hybrid Device With Soldered Tubulation. to Test Plate	10
5. Cutaway View of One-Way Leaker Fixture. With Heater/Cooler Element	14
6. Graph of One-Way Leaker Experiments on. Device Serial No. 55 With Internal Pressure	15
7. Graph of One-Way Leaker Experiments on. Device Serial No. 55 With External Pressure	16
8. Graph of One-Way Leaker Experiments on. Serial No. 351 With External and Internal Pressure	17
9. Graph of One-Way Leaker Experiments on. Device Serial No. 216 With External and Internal Pressures	18
10. Graph of One-Way Leaker Experiments on. Device Serial No. 41 With External and Internal Pressures	19
11. Graph of One-Way Leaker Experiments on. Device Serial No. 214 With Internal Pressure	20
12. Graph of One- Way Leaker Experiment on. Device Serial No. 214 With External Pressure	21
13. Graph of One-Way Leaker Experiments on. Device Serial No. 038 External and Internal Pressures With Varying Temperatures (Runs 1, 2 and 3)	22
14. Graph of One-Way Leaker Experiments on. Device Serial No. 038 External and Internal Pressures With Varying Temperatures (Runs 4 and 5)	23

Figures

Page

15. Moisture Standard Correlation Samples	27
(Oblique View)	
16. Moisture Standard Correlation Samples	27
(Side View)	
17. Graph of Correlation Test Results Lot #1.	29
(Pilot Groups)	
18. Graph of Correlation Test Results Lot #2.	32

LIST OF TABLES

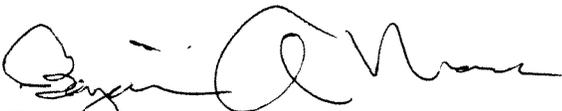
<u>Tables</u>	<u>Page</u>
1. Laser Optical Correlation Leak Study.	5
2. List of Moisture Standard Correlation Samples	25
3. Correlation Study Lot #1 R.G.A. Results	28
4. Correlation Study Lot #2 R.G.A. Results	31
5. Parts Description of Moisture Standard. Correlation Samples	33

EVALUATION

The objective of this effort was to assure the reliability of state of the art microelectronics used in Air Force systems by improving existing package integrity test methods found in MIL-STD-883D. The package in which a microelectronic device is contained not only prevents mechanical damage to the enclosed device but also should assure a benign gaseous atmosphere to prevent catastrophic failure mechanisms and/or electrical parameter drift to out of tolerance conditions. If the package is not hermetic or if the package contains potentially dangerous contaminants (i. e. water as vapor or adsorbed on internal surfaces), failure mechanisms, both short and long term, could be activated. MIL-STD-883D contains test methods to confirm the hermeticity (Test Method 1014) and limit the internal moisture content (Test Method 1018) of military microelectronics. However, packaging technology has become much more complex since the implementation of Test Method 1014. Also, new procedures for fine and gross leak testing have been developed. In addition, these larger, more complex packaging schemes, along with the inclusion of new materials within the package (glasses, die attaches, organics) have caused problems in correlating moisture measurements among certified laboratories.

Raytheon Company has accomplished the main objectives of the contract with respect to hermeticity testing. They surveyed industry for comments and suggestions for improvements to Test Method 1014. Raytheon has developed and tested a new procedure for fine leak testing that involves backfilling devices with known quantities of helium during the package sealing operation. This allows fine leak testing without pressure bombing and is especially appropriate for large surface area and "delicate" packages. The acceptable leak rate for this procedure is proposed to be 8×10^{-9} std cc/sec air. Raytheon also recommends removal of the fixed method for fine leak testing due to inconsistencies related to package volume ranges. In order to facilitate use of the alternate flexible fine leak testing method, the contractor has simplified the Howl-Mann equation used to determine test conditions. Raytheon also confirmed that the flow assumption (viscous rather than molecular) used to develop the radioactive krypton test procedure was in error. They have corrected the equations in this procedure to reflect molecular flow. Raytheon studied the "One Way Leaker" phenomena and discovered that, in most cases, that the fine leak criteria now in Test Method 1014 are much too liberal. Raytheon proposes for all package sizes for the existing procedures in Test Method 1014 an acceptable fine leak rate of 1×10^{-8} std cc/sec air.

Raytheon also manufactured moisture correlation samples and distributed them to commercial gas analysis facilities in order to determine the accuracy of analysis at each facility. Not all laboratories correlated. The presence of helium in correlation samples surfaced problems at labs that did not accurately calibrate for this gas. As a result, a second set of samples were produced without helium and distributed to the same laboratories. Again, not all labs agreed. Raytheon has sent the remaining samples to Rome Laboratory for continuation of the correlation study. This study emphasizes the need to conduct correlation studies with a matrix of samples more frequently than has been done previously.



BENJAMIN A. MOORE/PROGRAM MANAGER

INTRODUCTION

The rapid changes of the state-of-the-art technologies in the microelectronics industry has placed a major priority on manufacturing high reliability devices in the military industry. As a consequence of this, Rome Labs, in an effort to maintain this level of reliability consciousness, has undertaken a review of the current test methods found in MIL-STANDARD-883D, Methods 1014 (Seal Test) and Method 1018 (Internal Water-Vapor Content). The scope of their concern is to reduce the incidence of gaseous ambient induced failures by improving the present MIL-STANDARD Methods 1014 and 1018.

Raytheon Co., under contractual agreement with Rome Labs, has undertaken the task of providing a detailed study to investigate the current version of MIL-STD-883D, Method 1014 and explore and investigate new test methods for incorporation of a new revision to the present test methods. As part of this agreement, Raytheon was asked to provide correlation moisture standards for the purpose of surveying commercial RGA (Residual Gas Analysis) companies deemed certified by DESC to perform analysis for the military per MIL-STANDARD-883D, Method 1018.2. The present procedures and practices are to be closely scrutinized and recommendations made for improving the method for the purpose of achieving commonality with calibration and parity with test results.

The key elements of this study are contained in the following outline.

TEST METHOD 1014 (SEAL)

- o Study and Review Package Measurement Technology as it pertains to MIL-STD-883D, Method 1014
- o Survey the industry for recommendations to changes in Method 1014
- o Identify potential new test methods and techniques
- o Report findings
- o Review and study one-way leakers
- o Report findings
- o Make recommendations

TEST METHOD 1018 (INTERNAL VAPOR CONTENT)

- o Conduct a laboratory correlation study involving RGA tests of hermeticity sealed packages.
 1. Supply three-hundred-fifty (350) moisture standards at 5000 and 2000 ppmv.
 2. Distribute to suitable laboratories.
 3. Collect and analyze all data.
 4. Report findings.
 5. Make recommendations.

SECTION I
STUDY AND REVIEW
MIL-STD-883D, METHOD 1014 (SEAL)

To begin our study, we had to decide whether the existing procedures in MIL-STD-883D, Method 1014 were effective in screening out hermeticity failures in the fine and gross leak tests. In order to get an objective opinion of these leak tests, it was important to survey the rest of the industry and determine the likes and dislikes as well as any problems associated with the use of these test procedures. A questionnaire was prepared for this purpose as shown in Appendix B. The questionnaire was prepared in four (4) sections.

1. General questions about leak testing procedures, type of packages tested, thru-put, failures, likes, dislikes, recommendations, etc.
2. One-Way Leaker Phenomena - Knowledge of, experience with and data to share.
3. Equipment Manufacturers - Types of tests used, training of customers, changes in test specifications which would produce better equipment and recommendations.
4. Failure Analysis - Types and percentages of leakers, their leak sites and methods for finding their location.

A list of prospective questionees was drawn up from several sources to include names of persons supplied by Mr. B. Moore of Rome Labs, vendor lists, authors of pertinent papers and recommendations of other associates. Approximately three hundred (300) people were contacted via telephone, of this number, one-hundred-one (101) people expressed a willingness to answer a questionnaire if mailed to them. Out of the one-hundred-one (101) questionnaires mailed, we received thirty-two (32) replies, the replies were summarized and are enclosed in Appendix C. The replies from this survey seemed to express only a mild concern from most people, with the exception of less than ten (10) people whose replies were more in-depth with a greater concern to share and express their knowledge, experience, data and recommendations on the subject.

In the interim, we conducted a literature search through our Library Technical Search Service for the purpose of gathering for review all new as well as old hermetic seal testing information which might be made available. We were also interested in trying to obtain any relevant data pertinent to the one-way leaker phenomenon. The material searched included the following:

- o ASTM and MIL-STD tests.

- o IEEE papers on hermetic seal tests.
- o Manufacturer's test equipment data and specs.
- o All other papers concerning seal testing.

The list of papers which surfaced from this literature search are listed in the bibliography of this report.

One of the latest developments in leak testing technology to surface is a combined fine and gross leak helium leak test utilizing a modified cryopump which reportedly achieves a greater range of test sensitivity. According to the developers, Bergquist and Shertz, quoting⁽¹⁾ their findings and conclusions, "either the helium that has escaped from the component is measured or the rate in which it escapes is measured". Also "if the leak is gross, the helium will quickly escape to the level in the atmosphere which is 5 ppm in air. The differences between a gross and fine leak are easily detected because in the gross leak all the helium escapes into the manifold". Unfortunately we were unable to perform any correlation studies with this equipment during the contract period.

Another recent leak test is an optical method developed by LTI, Laser Technology, Inc. of Norristown, PA. which utilizes a laser illumination and video interferometry system and can accommodate singular components in a tray or complete circuit boards. The equipment measures the deformation of the device cover with an applied pressure or vacuum. Reducing the ambient pressure will cause the lid to bulge and if a leak is present the lid deformation will change as it "leaks down" thus relating to a leak rate. Knowing the geometry and the stiffness of the lid it can be factored into a leak rate equation to determine the actual leak rate. This system of detection and measurement works well for large electronic packages e.g., hybrids and devices with large covers but may prove ineffective with small and stiffer lidded devices.

This test method appears to have potential for study and for possible inclusion with Method 1014. We received a group of 20, 40 and 48 lead metal covered integrated circuits from Laser Technology, Inc. which were tested by them utilizing the laser optical method. Kr85 and helium leak tests were also performed at two other companies. We in turn performed our own leak study on these parts to determine if there was correlation between the optical and the helium leak test. Our test results shown in Table 1 indicate close correlation with that of Laser Optical Leak Rates. Based on these results, we feel that this technique shows promise.

(1) Lyle E. Bergquist, Stephen R. Shertz, Helium Leak Test for Small Components, Martin Marietta, Denver Aerospace, Denver, Colorado, USA.

TABLE I. LASER OPTICAL CORRELATION LEAK STUDY RESULTS

LASER OPTICAL CORRELATION LEAK STUDY					
DEVICE SERIAL NUMBER	LASER OPTICAL LEAK RATE	TEXAS INSTRUMENTS (KRYPTON) 1.5 YRS. AGO	HUGHES (KRYPTON) 8.0 MOS. AGO	RAYTHEON HELIUM LEAK TEST RESULTS	96 HR. BAKE WEIGHT LOSS MILLIGRAMS
A10	2.10E-05	6.70E-05	1.20E-04	2.60E-06	0.40
A2	NONE DETECTED	NONE DETECTED	NONE DETECTED	<1E-10	0.40
B3	>1E-4	4.40E-06	1.00E-05	>1E-4	42.40
B5	>1E-4	2.80E-06	7.00E-06	>1E-4	32.70
C7	2.40E-06	5.60E-06	7.50E-07	7.00E-07	0.20
C8	2.90E-06	5.50E-06	1.20E-06	9.00E-07	1.10
C10	1.30E-06	1.20E-05	1.50E-07	5.00E-07	0.40
D4	>1E-4	1.00E-06	3.00E-05	>1E-4	0.90
D5	1.80E-06	3.20E-06	5.00E-07	5.00E-07	0.00
D9	3.60E-07	4.40E-07	8.00E-08	3.0E-7 *	0.00

* SOMEWHAT PRESSURE SENSITIVE

The library search for information regarding one-way leakers turned up nothing significant on the subject. A technical article was found through a questionnaire response pertaining to one-way leakers ⁽²⁾ but did not provide any new information or methods for identifying one-way leakers. It rather focuses on RGA analyses of a large group of various devices from 1.2 to 17.8 cc volumes and attempts to correlate moisture ingress with package sizes as they relate to bombing pressures. The questionnaire didn't provide anymore revealing information from respondees about this phenomenon. Of the thirty-two (32) questionnaires returned, sixteen (16) responded that they were aware of this phenomenon and nine (9) responded with methods for detecting one-way leakers, they were: RGA, dye penetrant, Krypton 85 and the weight gain test (See Appendix C).

ONE WAY LEAKER STUDY

In preparation for our one-way leaker experiments we planned on enlisting the aid of other sources from the respondees of our questionnaire to help supply us with potential one-way leaker candidates. There were no positive responses. We, therefore, had to rely on our own inventory of parts, leakers and non-leakers to perform our experiments. It is important to note that all of the leakers that we used for this study were detected by the flexible method (A₂) utilizing a failure criteria of 1×10^{-8} ATM cc/sec; air. It is also important to note that we typically pressure bomb devices at 60 to 100 psig for periods of time in excess of sixteen (16) hours and as much as 100 hours prior to testing. This method increases the signal in the mass spectrometer and increases the internal pressure of the device. The increased pressure also helps to assure detection since some devices are pressure sensitive leakers. This pressure sensitivity will be shown in some of the devices we had tested.

A dual chambered test fixture was designed to perform these experiments. This fixture allowed for helium leak testing of a component in two directions; inwardly and outwardly so that a differential pressure could be applied either internally or externally to the device under test. The test fixture shown in Figure (1) has a dividing stainless steel test plate/tube assembly separating the two halves of the fixture. A test device is soldered onto the brass tube and plate assembly. The device/plate was then either placed upright or inverted in the fixture and clamped together depending on the direction of test. The total assembly was then attached to the inlet port of a helium leak detector.

(2) Dan Epstein, How to Test for One Way Leakers, ICL Data Device Corp., Bohemia, N.Y., USA,

ONE - WAY LEAKER FIXTURE

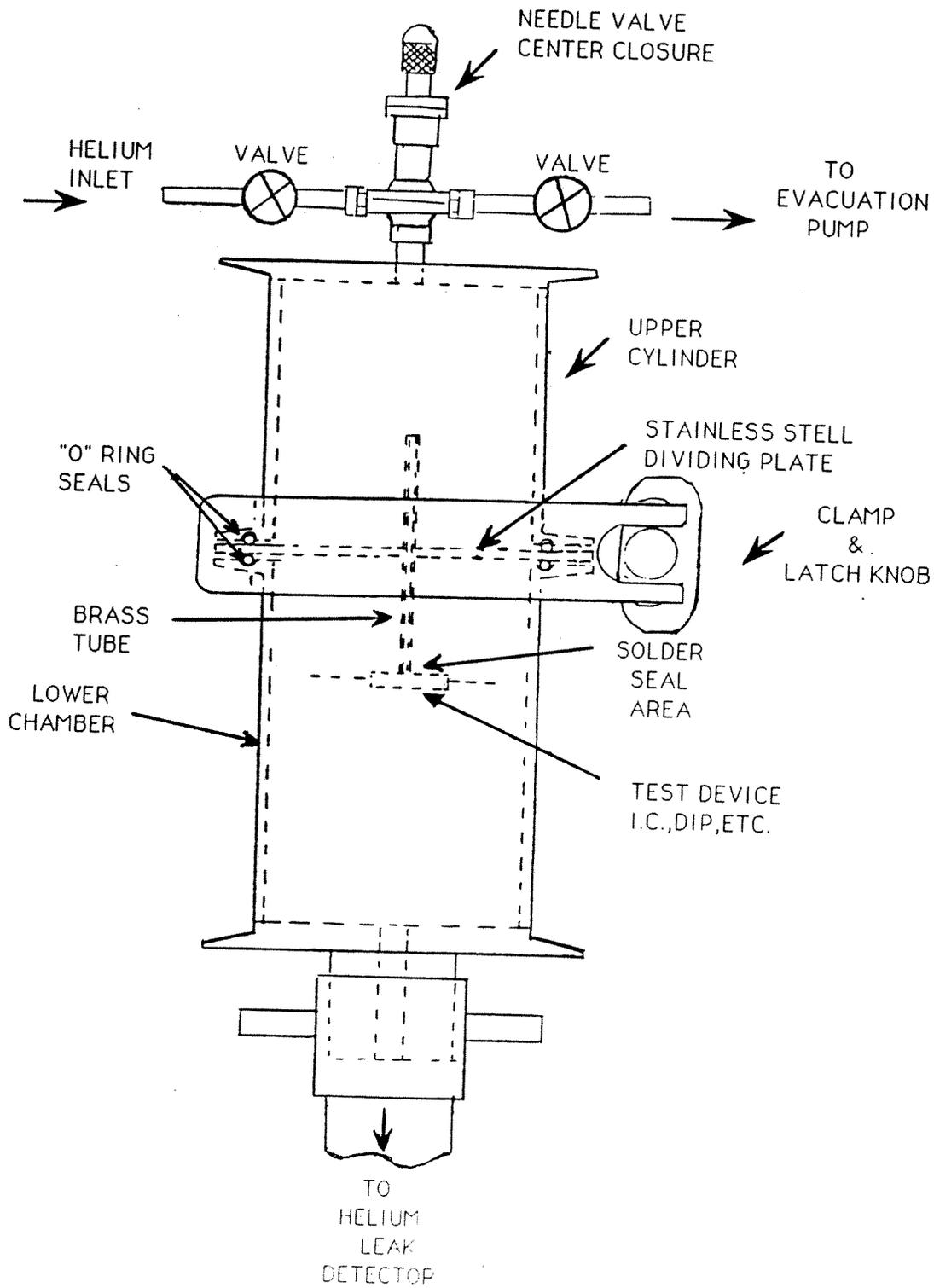


Figure 1

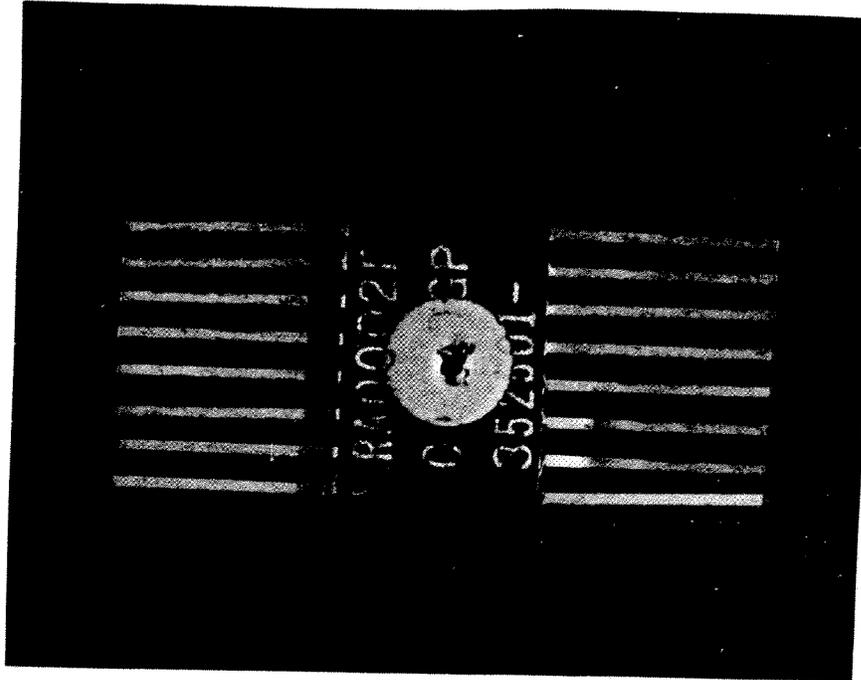
There were some problems associated with attempting to fasten a test device to the brass tubes on the plate. First of all, the interconnect had to be of a material which was impervious to helium. This ruled out the use of rubber, plastics and nylon etc. After some trial experiments it was decided that the best method was to attach a copper or brass tube directly to the test device which had a drilled or sand blasted hole to the package interior. Again this attachment also had to be impervious to helium. This was accomplished by soft soldering the tube directly to the device. Ceramic lidded devices had to be prepared by ion sputtering around the hole site with 100 to 200Å of chrome, 25,000Å nickel and 5,000Å of gold metallization (See Figures 2 and 3). Considerable care had to be exercised with the soldering because of the possibility of flux vapors plugging leak sites and solder plugging the inlet hole.

Once the device was attached to the tube/plate assembly, the internal pressure of the device was increased while it was submerged in fluorocarbon fluid. In this way, we could determine the leak pressure and leak site of the part as well as the quality of the solder connections. Figure (4) illustrates the attachment of a hybrid device to our tube/plate assembly.

TEST PROCEDURE WITH ONE-WAY LEAKER FIXTURE

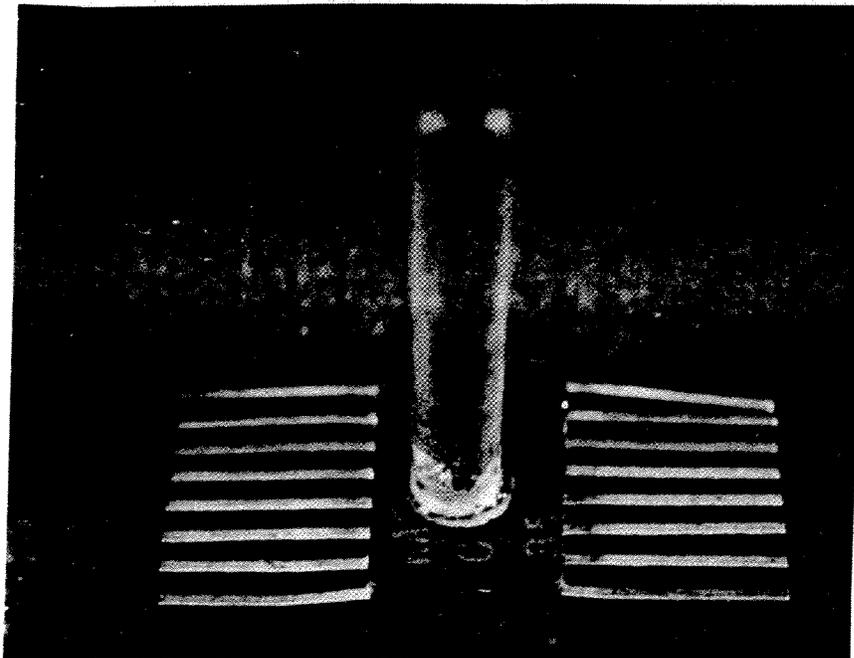
The test device plate was clamped into the test fixture and placed on the helium leak detector port as shown in Figure (1). The upper chamber was blanked off by three valves leading to a vacuum pump from a tee on one side and a helium tank and regulator on the other and a center closure needle valve. The upper chamber was then evacuated by opening the valves to the vacuum pump providing a zero "0" psi differential pressure by removing all the ambient air in the system. After a period of approximately 10 to 15 minutes, a zero or background leak detector reading was recorded. The vacuum line was then blanked off and helium pressure was slowly released into the upper chamber monitored by a vacuum/pressure gage graduated in 1 psi increments. Depending on the response of the helium leak detector, the device was incrementally pressurized and helium readings recorded. At 15 psi of 100% helium, the leak rate of the device can be simply converted to the standard air leak rate by dividing the value by 2.7. By incrementally increasing the pressure and observing the behavior of the leak readings it can be observed if the device is a pressure sensitive leaker. For example, if a small increase in pressure causes a large change in leak rate (up or down), then the device would be considered to be pressure sensitive. This effect can be seen clearly in figures 9-12. Subsequent testing of the device in the opposite direction will determine if the device is a one-way leaker and/or pressure sensitive.

We performed over fifty (50) experiments, often times repeating the same experiment on the same device several times to determine repeatability.



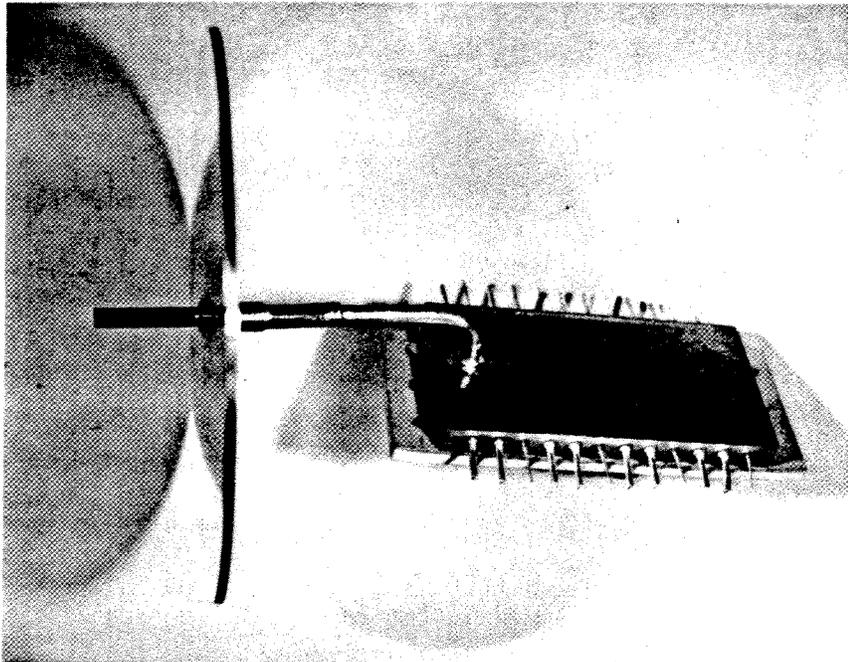
GOLD SPUTTERED I.C. 1/4 x 3/8

Figure 2



I.C. WITH SOLDERED CU TUBULATION

Figure 3



TUBULATED HYBRID DEVICE

Figure 4

ROOM TEMPERATURE TESTS:

There were a total of forty-five (45) devices tested. Fifteen (15) exhibited leak rates much greater than 1×10^{-6} ATM cc/sec and could not be used. Fifteen (15) were non-leakers and were used essentially as controls to assure that the results were not affected by "false" signals. Two (2) devices were damaged and hence not used. Nine (9) devices were equal leakers in both directions (molecular flow) and four (4) were found to leak greater in one direction than the other and were pressure sensitive as well.

"NORMAL" DEVICES:

The "molecular flow" devices were characterized by both (a) equal leak rates at all pressures in each direction and (b) followed the classic molecular flow equation prediction which describes the leak rate as one which is directly proportional to the pressure difference (i.e., doubling of the pressure, doubles the leak rate). See Figures 6-8 for the details of this type of leaker (Serial #55 and 351). As stated before, there were a total of nine (9) devices which behaved similar to these two (2). None of the devices tested in any of these experiments indicated a leak rate behavior which would be predictable by either viscous or transitional flow equations. We have concluded from these tests as well as others we have observed over several years, that the molecular flow assumptions of the flexible method of fine leak testing (A_2 of Method 1014) are correct and that the viscous flow assumptions of the Kr85 radioactive fine leak test are not valid and hence must be corrected in order to obtain reasonable correlation between these two (2) test methods.

PRESSURE SENSITIVE DEVICES:

Four (4) of the devices (16 lead flat packs) examined were clearly pressure and direction sensitive leakers. The leak behavior of these parts were somewhat predictable and at times erratic. These characteristics suggest that they were probably contaminated (flux, fluorocarbon etc.) In spite of this, it was felt that they represented some of the general population of non-hermetic devices and may help to shed some light on "confusing" residual gas analysis results. In examining Figures 9-12, some interesting behavior can be seen. As an example, Serial #216 (Figure 9) shows that little to no tracer gas could get into the device (external pressure) until about 100 psia and if it had leaked in, the internal pressure would have to exceed 75 psia to be "rejected" by using current Test Method 1018 criteria. It is clear that this part could easily escape detection at this time and would probably fail the requirements of Method 1018 residual gas analysis. Since this device had previously been detected as a leaker using the "flexible method" (A_2), we feel that it had somehow become

contaminated and is the root cause of this "new" behavior. Any number of environments could have provided the contamination for the part (i.e., soldering fluxes, thermal shock fluids, cleaning solvents, etc.). In any case, it is clear that the part, at present, could be classified as being a pressure sensitive leaker.

In examining the behavior of Serial #41 (Figure 10) another category of pressure sensitivity emerges. This part shows a clear direction sensitivity i.e., helium flows easily into the device following the molecular flow predictions yet does not flow out of the part until the pressure reaches about 60 psia and then rather dramatically increases its leak rate by nearly three (3) orders of magnitude at 75 psia! We suspect that this device is truly a pressure sensitive leaker and not afflicted with contamination. Since this part was originally rejected using the flexible method, which uses 90 psia as a bombing pressure for periods of time up to 60 plus hours, we would/could expect to detect this part as a leaker. In this case the longer bomb times can be advantageous in culling leakers.

In examining the behavior of Serial #214 (Figures 11 and 12) it is evident that the device is a pressure sensitive leaker in both directions. At approximately 75 to 90 psia the device changes its leak rate from $< 1 \times 10^{-9}$ ATM cc/sec He to $> 1 \times 10^{-6}$ ATM cc/sec He! As with the previous part (Serial #41), we feel that our practice of long pressurization periods helped to detect this device in the original leak tests. A standard "fixed" bomb time of just a few hours probably would have not detected this unusual behavior.

TEMPERATURE SENSITIVITY TESTING:

A test fixture was fabricated for the purpose of performing experiments at hot and cold temperatures. This fixture shown in Figure (5) incorporates a thermoelectric element for the purposes of heating and cooling the device under test (DUT). This fixture worked sufficiently well for heating a device but had its limitations when trying to cool a device below 0°C. Several experiments were performed with this test fixture and it worked sufficiently well. The results of our temperature tests indicated a net effect of slightly decreasing the leak rate when there was an elevated temperature of 100°C by a factor of 0.6 to 0.7 and had a reverse effect of slightly increasing the leak rate with an approximate 15°C drop in temperature from room ambient.

There was an exception in experiments #47 and #48 when the tests were repeated on device Serial #038 of varying temperature; see Figures (13) and (14). The results during these tests indicated that, by heating the device and holding the pressure constant, the leak rate was lowered and the leak was effectively closed. Cooling the device produced only a slight increase in the leak rate.

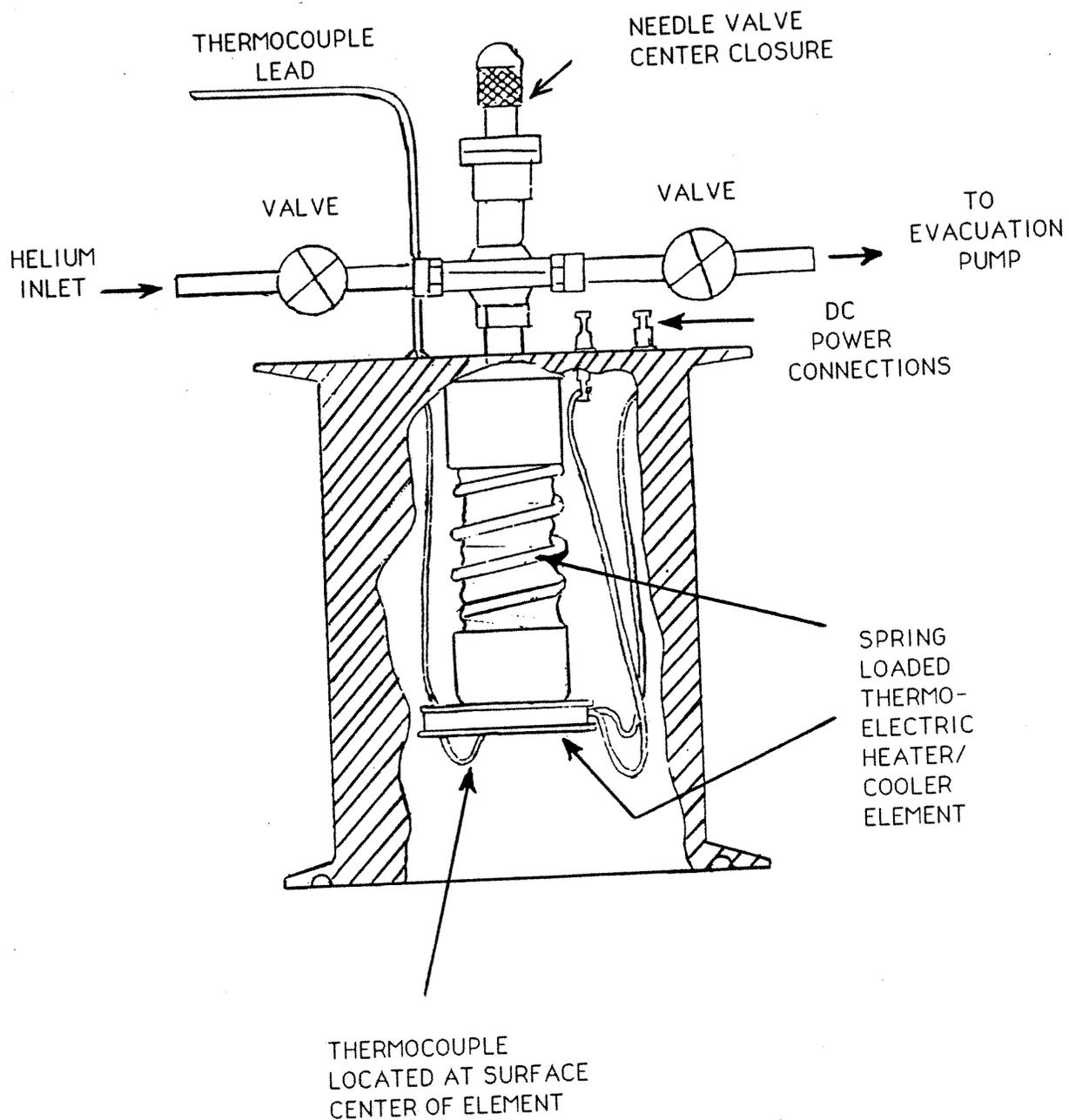
The results of the temperature sensitivity test for this one device indicates a dramatic effect from increasing temperature which is not clearly understood at this time. Although this device was found originally as a leaker that can be easily confirmed utilizing typical test procedures, it does create some concern in attempting to predict its behavior in future tests. Previous studies by others also noted a temperature sensitivity to some leakers but concluded that "temperature bombing" of parts would add little value to hermeticity testing. We also conclude the same based on our results.

CONCLUSIONS:

The results of these tests, although limited in nature, indicate that:

- A. One-way leakers clearly exist and that their presence can cause confusing RGA results.
- B. Molecular flow is the predominant regime for fine leakers.
- C. Pressure bombing at the higher pressures for longer periods of time (i.e., > 60 psia for > 12 hours on devices with cavity volumes less than ~ 0.1 to 0.2 cc) appear to increase one-way leaker capture rates. More work would be needed to obtain a clear statistical basis for this finding.
- D. The temperature test results support previous findings which have concluded that its use would be of little to no real value.

ONE-WAY LEAKER FIXTURE



CUTAWAY VIEW OF ONE-WAY LEAKER FIXTURE
WITH HEATER / COOLER ELEMENT

FIGURE 5.

ONE-WAY LEAKER STUDY
EXPERIMENT #15

INTERNAL PRESSURE

PART TYPE: 16 LEAD FLAT PAK
PART SERIAL# 55
LOT #: QUAL. LOT TR787-2002
TEST DATE: 10-2-90

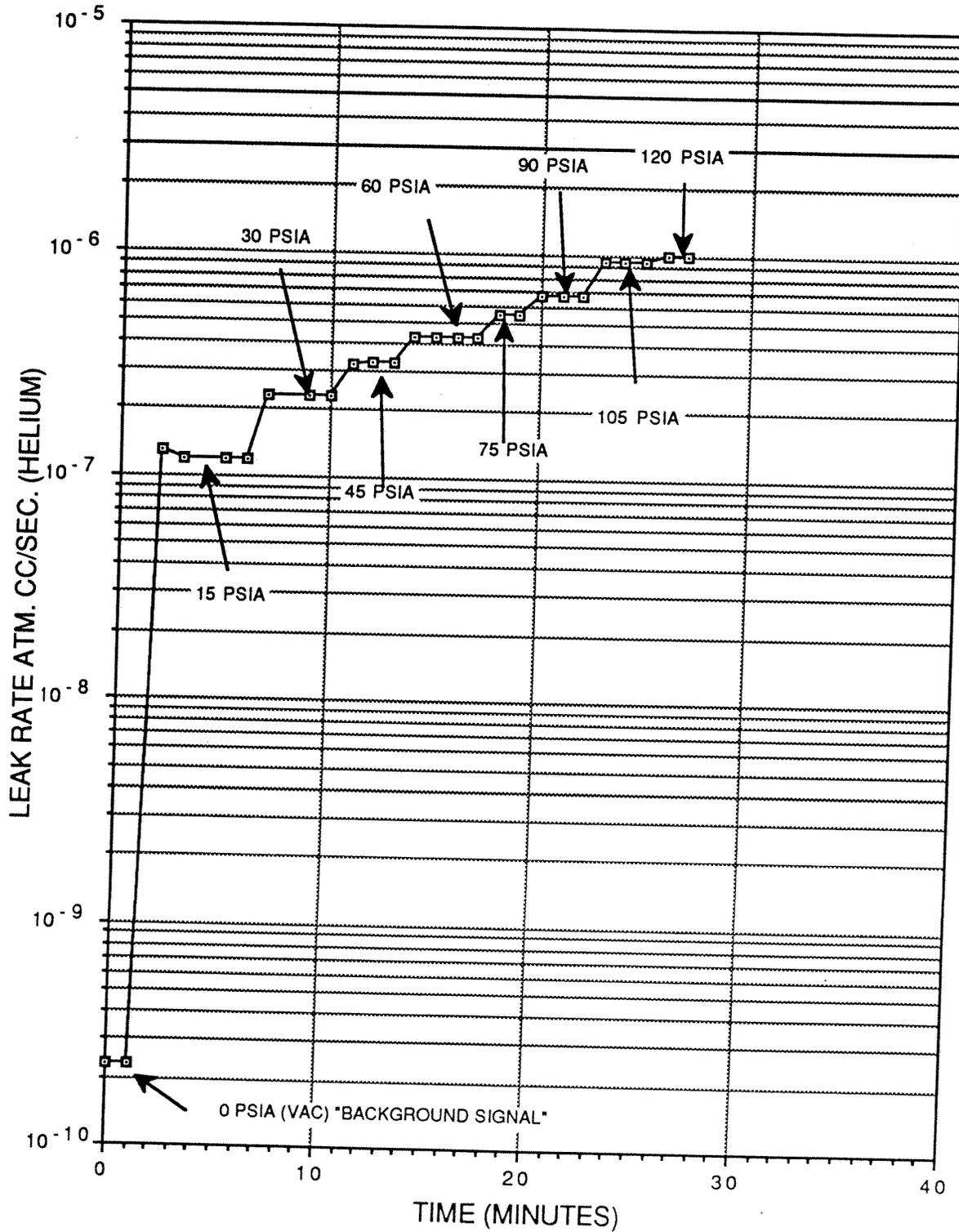


FIGURE 6.

ONE-WAY LEAKER STUDY
EXPERIMENT # 15

PART TYPE : 16 LEAD FLAT PAK
PART SERIAL# 55
LOT # : QUAL. LOT TR787-2002
TEST DATE: 10-2-90

EXTERNAL PRESSURE

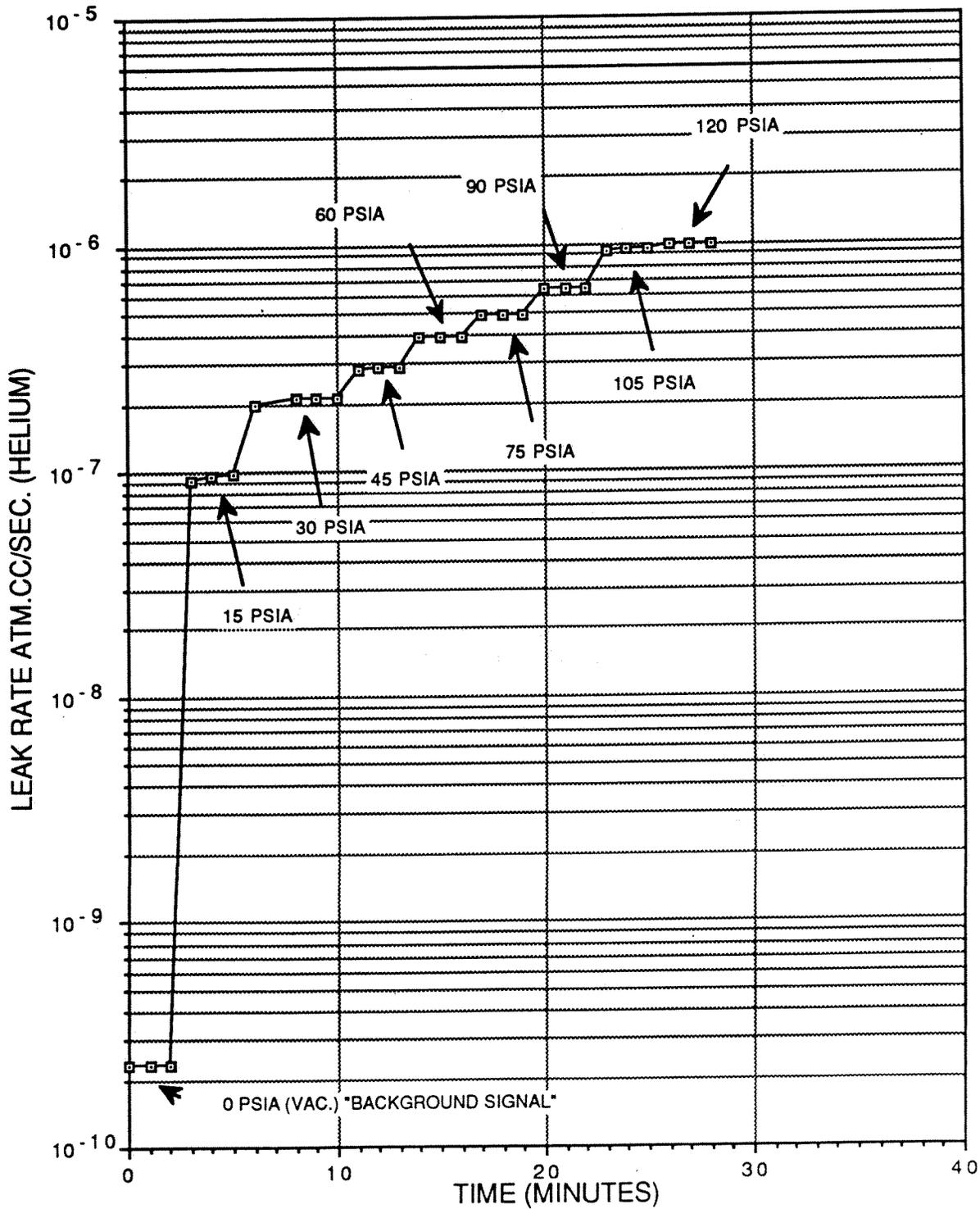


FIGURE 7.

ONE-WAY LEAKER STUDY
EXPERIMENT #42

PART TYPE: 16 LEAD FLAT PAK
PART SERIAL# 351
LOT # : V89-017
TEST DATE: 11-14-90

INTERNAL & EXTERNAL PRESSURE

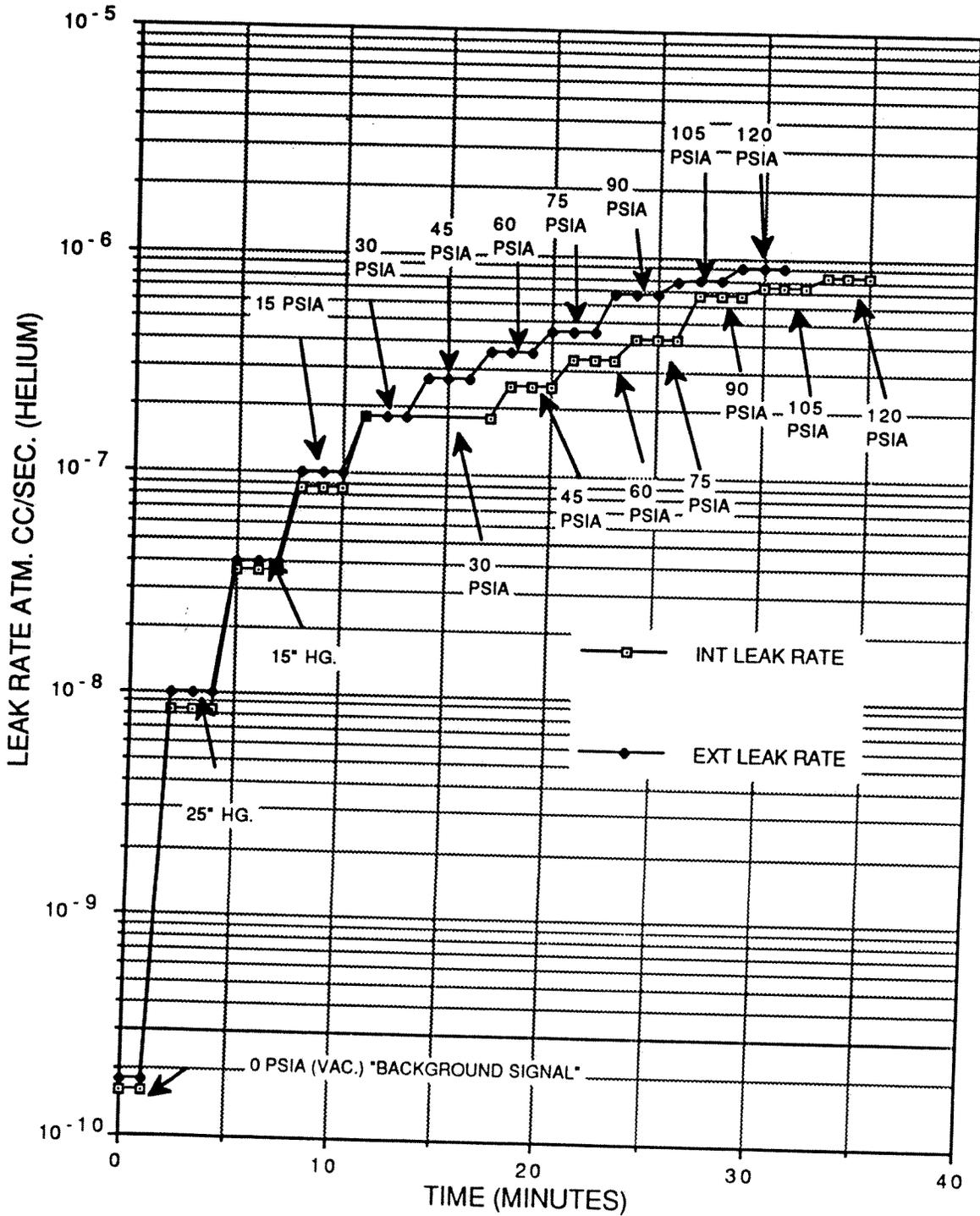


FIGURE 8.

ONE-WAY LEAKER STUDY
EXPERIMENTS # 1 & 2

PART TYPE: 16 LEAD FLAT PAK
PART SERIAL # 216
LOT # V89-017
TEST DATE: 9-19-90

INTERNAL PRESSURE & EXTERNAL PRESSURE

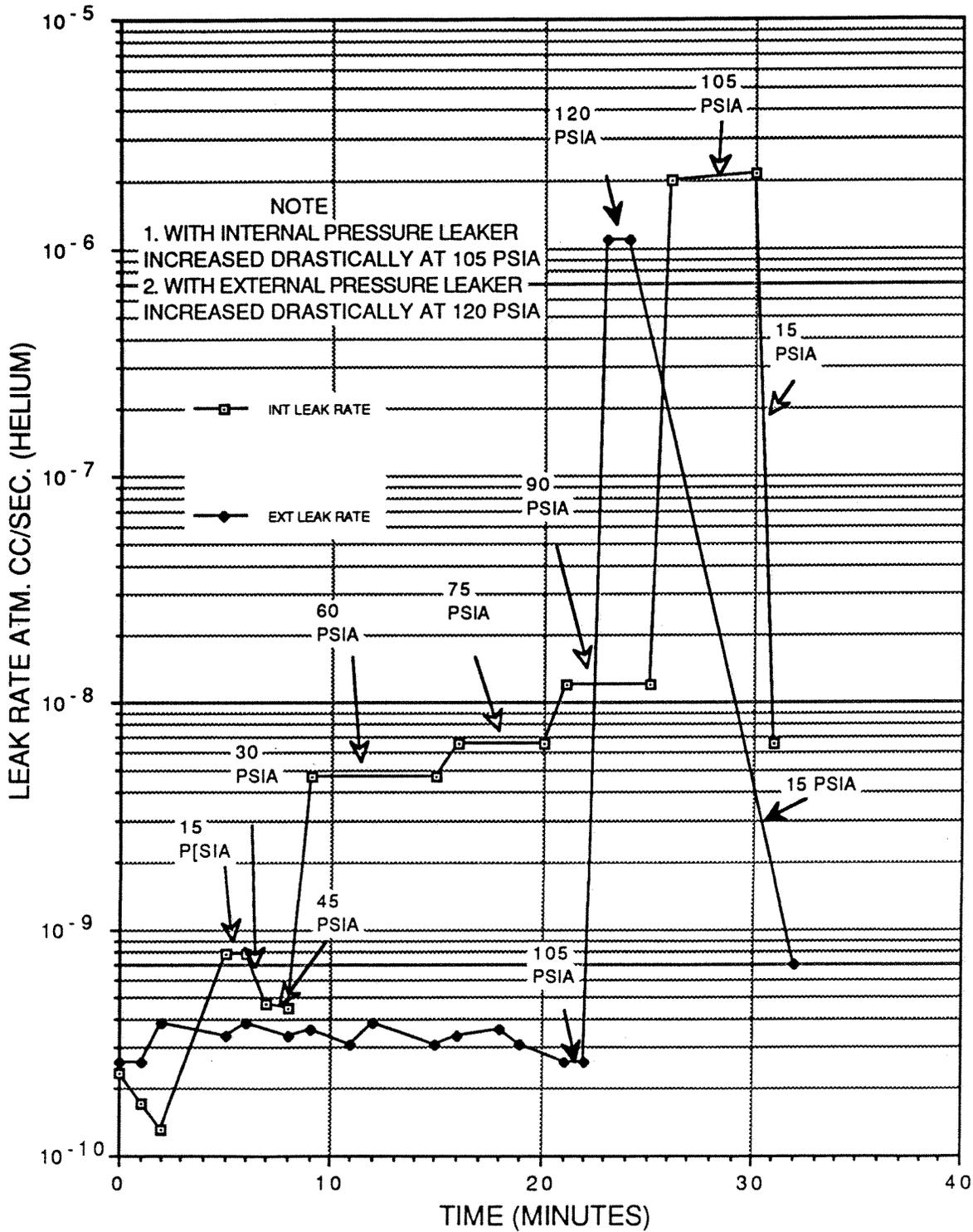


FIGURE 9.

ONE-WAY LEAKER STUDY
EXPERIMENT #16

PART TYPE: 16 LEAD FLAT PAK
PART SERIAL #41
LOT # 10-2
TEST DATE: 10-2-90

INTERNAL & EXTERNAL PRESSURE

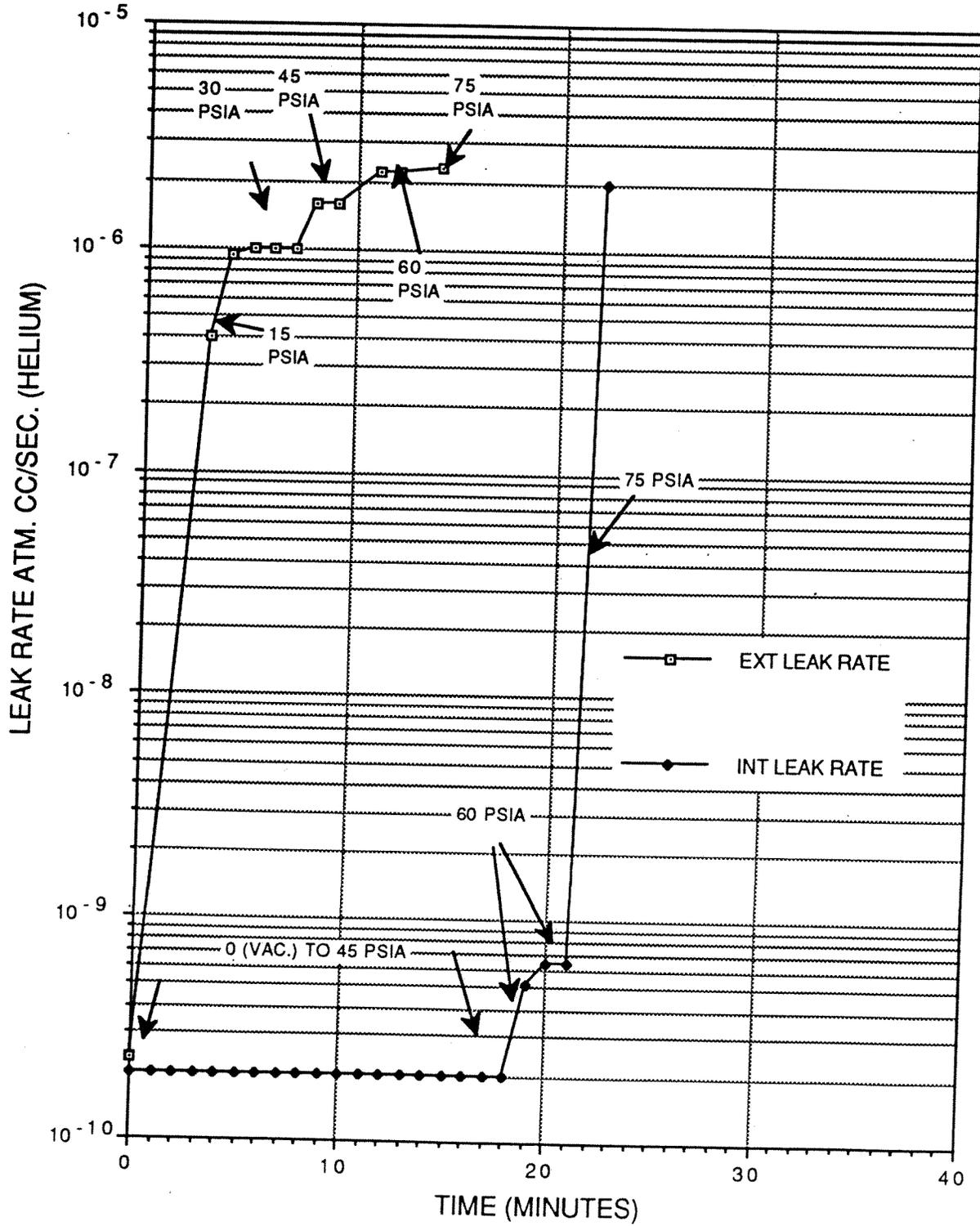


FIGURE 10.

ONE-WAY LEAKER STUDY
EXPERIMENT #11

PART TYPE: 16 LEAD FLAT PAK
PART SERIAL #214
LOT # : V89-017
TEST DATE : 9-27-90

INTERNAL PRESSURE

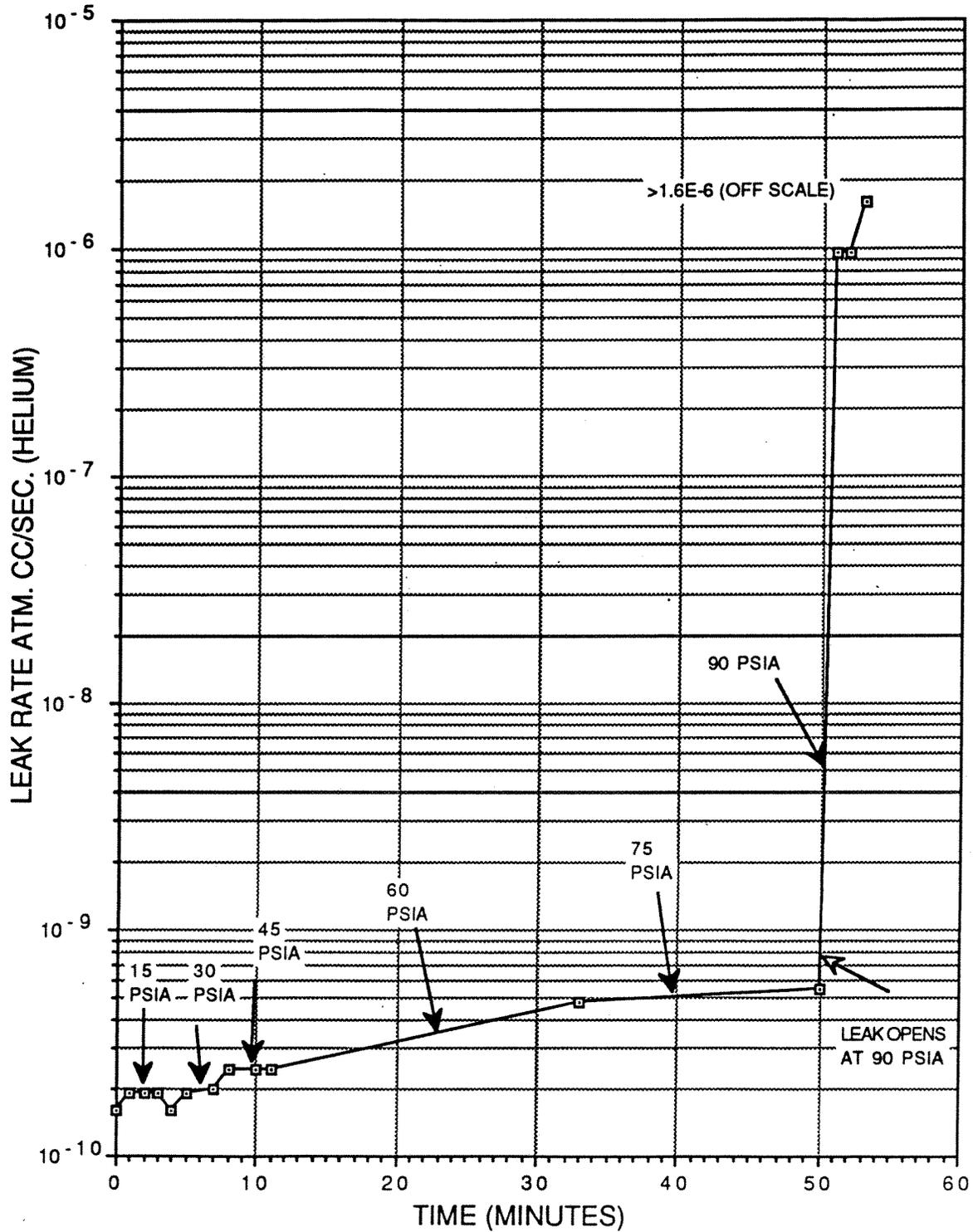


FIGURE 11.

ONE-WAY LEAKER STUDY
EXPERIMENT #11

PART TYPE: 16 LEAD FLAT PAK
PART SERIAL #214
LOT # :V89-017
TEST DATE : 9-28-90

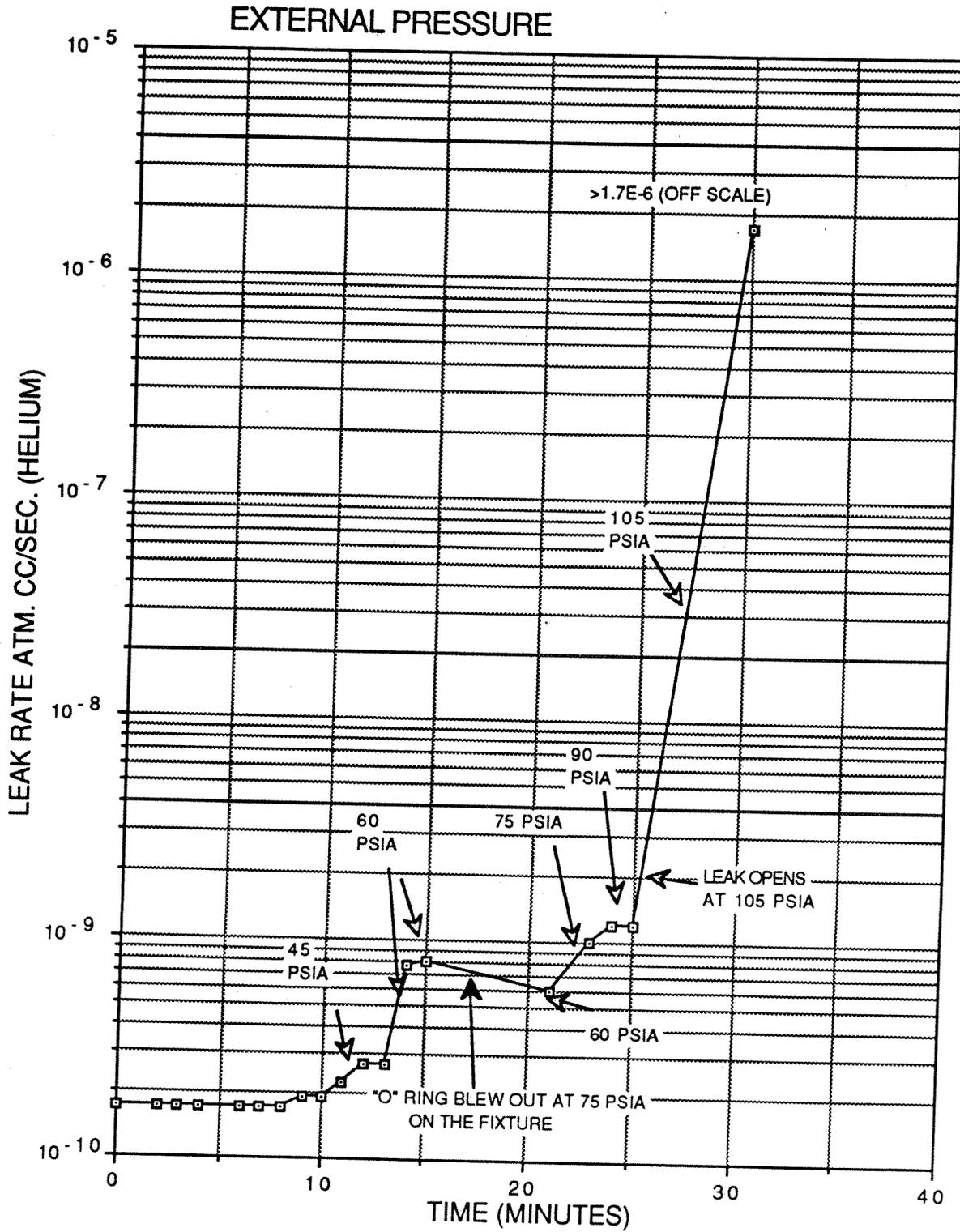


FIGURE 12.

ONE-WAY LEAKER STUDY

EXPERIMENT #47

RUN #1 INTERNAL PRESSURE

RUN #2 EXTERNAL PRESSURE

RUN #3 EXTERNAL PRESSURE & TEMPERATURE

PART TYPE: 16 LEAD FLAT PAK

PART SERIAL# 038

LOT # : V89-017

TEST DATE: 8-22-91

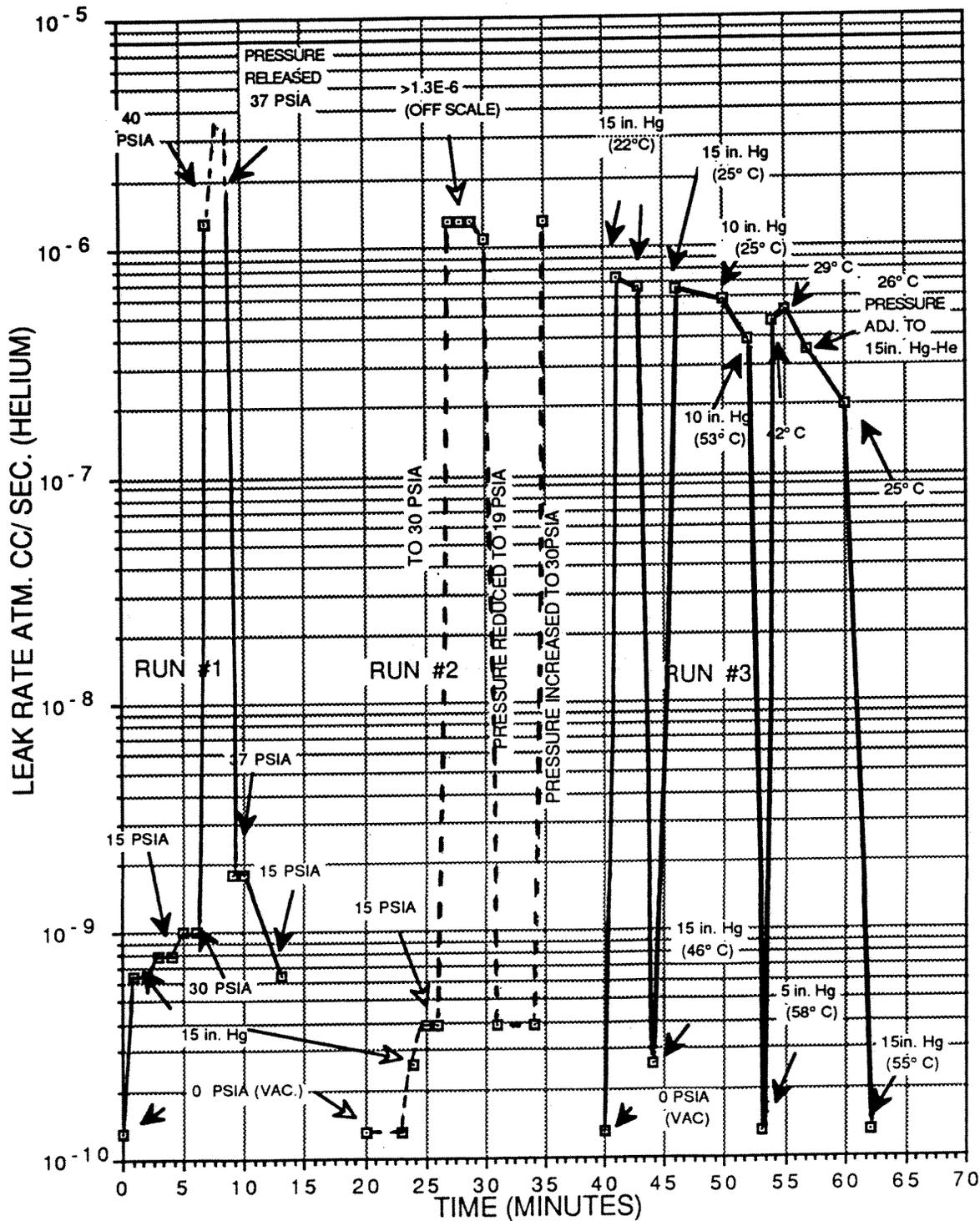


FIGURE 13.

ONE-WAY LEAKER STUDY
EXPERIMENT #48

PART TYPE: 16 LEAD FLAT PAK
PART SERIAL# 038
LOT # : V89-017
TEST DATE: 8-27-91

EXTERNAL PRESSURE
RUN #4 ROOM AMBIENT TEMPERATURE
RUN #5 COLD & HOT TEMPERATURE

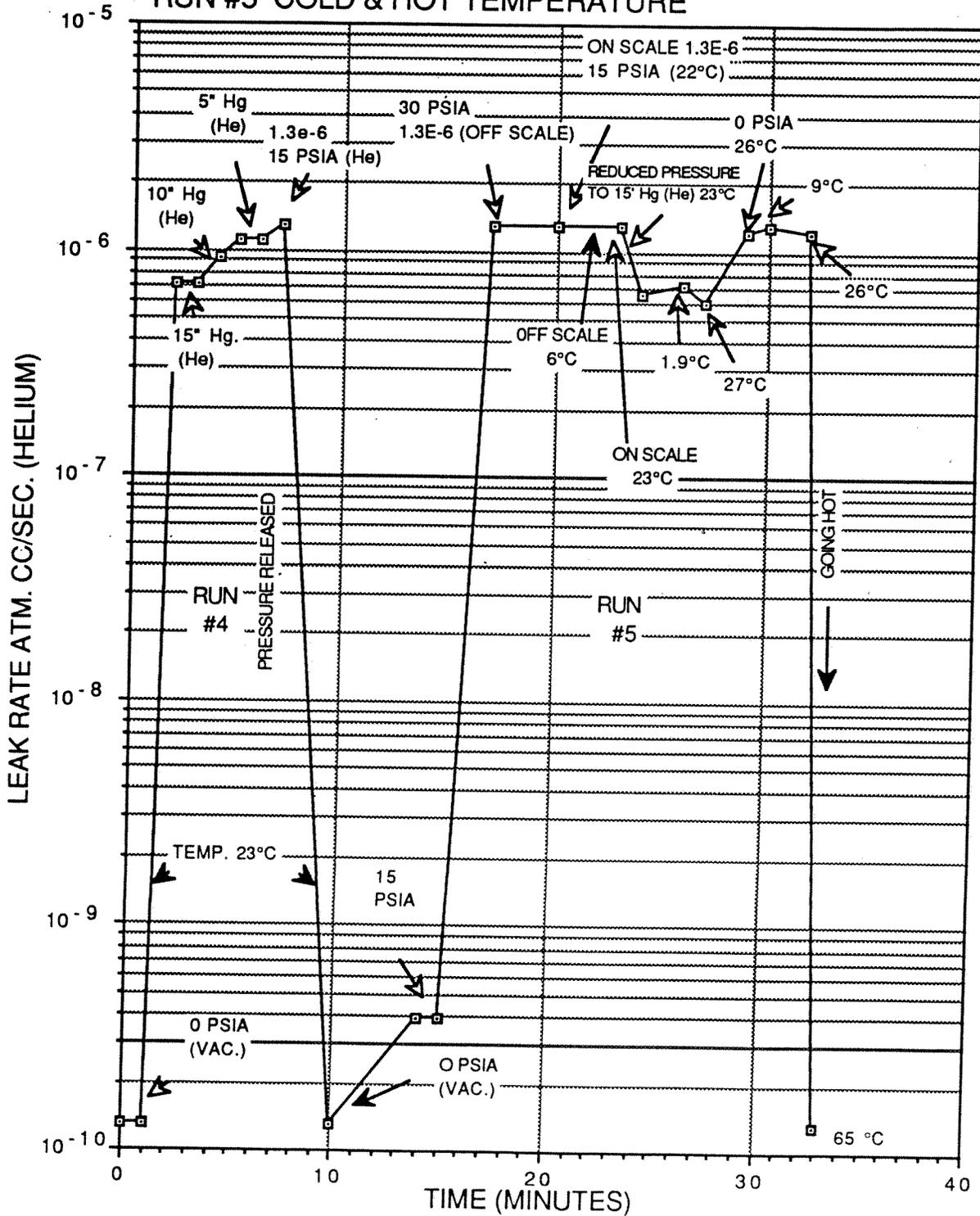


FIGURE 14

SECTION II
MIL-STD-883D, METHOD 1018.2
RESIDUAL GAS ANALYSIS (RGA) CORRELATION STUDIES

As outlined in the Statement of Work we were requested to conduct a laboratory correlation study. The purpose of this study was to evaluate the accuracy and precision of mass spectrometric gas analysis facilities that are presently suitable, or are candidates to be deemed suitable by the Defense Electronics Supply Center (DESC), to perform Method 1018 (Internal Water Vapor Content), Procedure 1 of MIL-STD-883C, dated 4 November 1986. Note: This study was not for the purpose of determining technical certification or suitability.

The government supplied a list of five (5) commercial RGA facilities for the purpose of performing analyses for this study. They are listed as follows:

COMMERCIAL LABORATORIES

Atlantic Analytical Laboratory
Whitehouse, New Jersey

AT&T Microelectronic Analytical Services
Allentown, Pennsylvania

IT International Technology Corp.
Cerritos, California

Oneida Research Services, Inc.
Whitesboro, New York

Pernicka Corporation
Fort Collins, Colorado

We were requested to provide three hundred fifty (350) correlation samples to be equally divided and distributed between commercial and non-commercial analytical laboratories, the latter half being directly distributed to non-commercial laboratories by the government (Rome Labs). The samples were fabricated from various all nickel T.O. series transistor packages, caps and bases in assorted combinations to approximate five (5) different volumes. We were instructed to seal with known quantities of moisture as shown in Table (2). Included among these were packages sealed with a military qualified organic "epoxy" properly cured (per manufacturer's instructions), die or substrate attach equal to that normally employed in microelectronics processing for die or substrate attach in 1.0 cc volume packages. The following is a list of the moisture standard samples provided:

TABLE 2. MOISTURE STANDARD CORRELATION SAMPLES

INTERNAL VOLUME IDEAL (Requested)	(CC) ACTUAL	MOISTURE CONTENTS AND QUANTITIES		
		2000 ppmv	5000 ppmv	5000 ppmv + Organic
.01	.016	0	50	0
.02	.028	50	50	0
0.10	.094	0	50	0
1.00	.89	0	50	50
10.0	5.60	0	50	0

TOTAL 350 Pieces

During the course of this study we fabricated a total of 700+ samples for this effort. The fabrication of these samples took place at two different time intervals and in two groups of 350 pieces. They are referred to as Lot #1 (pilot devices) and Lot #2 RGA correlation specimens. The first group of devices Lot #1 (pilot devices) were used to confirm our design values at DESC suitable commercial laboratories. Lot #2 became the group we considered as the standard for our correlation studies. The study proceeded as outlined in the contractor's Statement of Work (SOW).

~ .02 CC Vol. With 2,000 and 5,000 PPM Moisture:

To fabricate this particular 0.02 volume package we welded a tall profile 0.175" high TO-18 header to a TO-18 base sealed in our dry box at 2000 ppmv and 5000 ppmv respectively. The moisture level in the dry box was measured with a General Eastern Hygro-M1, Dewpoint monitor.

.01, 1.0 and 5.6 CC Vol. with 5,000 PPMV Moisture:

The 0.01 cc specimens were fabricated from low profile 0.135" high TO-18 headers and bases. The 0.1 cc volumes were fabricated from two 0.135" high TO-18 caps welded together. The 1.0 cc volume specimens were fabricated by welding two (2) TO-8 caps together. We were unable to obtain suitable packages that could be handled by our welding apparatus for obtaining a 10.0 cc volume package and settled for a smaller, 5.6 cc volume. These devices were fabricated by welding two 0.750" high TO-8 caps together. All

these samples were sealed in our dry box at 5000 ppmv. The completed devices are shown in Figure (15) and (16).

1.0 CC Vol. with 5,000 PPM Moisture and Organic Die Attach:

In fifty (50) of the 1.0 cc volume packages, a 0.250 x 0.250 inch silicon die was mounted with Ablestik 570K, insulating preform epoxy and attached per the manufacturer's instructions. This manufacturer was deemed qualified by DESC and chosen from the document list of MIL-STD-883C, Method 5011, qualified epoxies and their manufacturers.

The names of four suppliers were given to us by DESC, they were: Ablestik, Epotech, Amicon and A-I Technology. According to DESC these were the only ones at the time of selection to conform to MIL-STD-5011. We chose to go with Ablestik because of some prior experience with the product at our hybrid facility.

We submitted the proposed use of Ablestik 570K insulating preform epoxy along with manufacturing data and specifications to Rome laboratory as specified in CDRL, A006. Included was an independent test report prepared by ³. Mr. James McGrath, Raytheon Co., Quincy, MA. ⁽³⁾

The test design samples from Lot #1 (pilot devices) were sent out to three (3) commercial RGA laboratories. Twenty-one devices, three (3) of each type were sent to each laboratory. The results of these analyses are tabulated in Table (3) and the graph as shown in Figure (17), entitled RGA Correlation Test Results Lot #1 (Pilot Groups). The results show very good design correlation with Lab I results whereas the other two laboratories data are somewhat scattered. The data in the Table 3 does not include the results of other analyses performed on additional devices at Rome Laboratory and Lab F, those devices were submitted to Rome Laboratories for their own analysis and distribution. Based on these results, we prepared Lot #2 devices to be used as the formal 350 piece sample for the lab correlation study. Due to the depletion of the inventory of devices in Lot #1 for use as pilot devices to confirm our design values, it was necessary to seal another lot of devices for use as our formal correlation standards. Therefore, another group of three hundred fifty (350) devices were sealed and are referred to as Lot #2.

Lot #2 devices were distributed to four (4) commercial laboratories. The fifth laboratory was unable to perform any analysis due to equipment failure.

⁽³⁾ James McGrath, "New Deigns" with Attachment of MIL-STD-883C, Method 5011, Adhesive Evaluation Summary, Raytheon Co., Quincy, MA.

CORRELATION MOISTURE STANDARDS

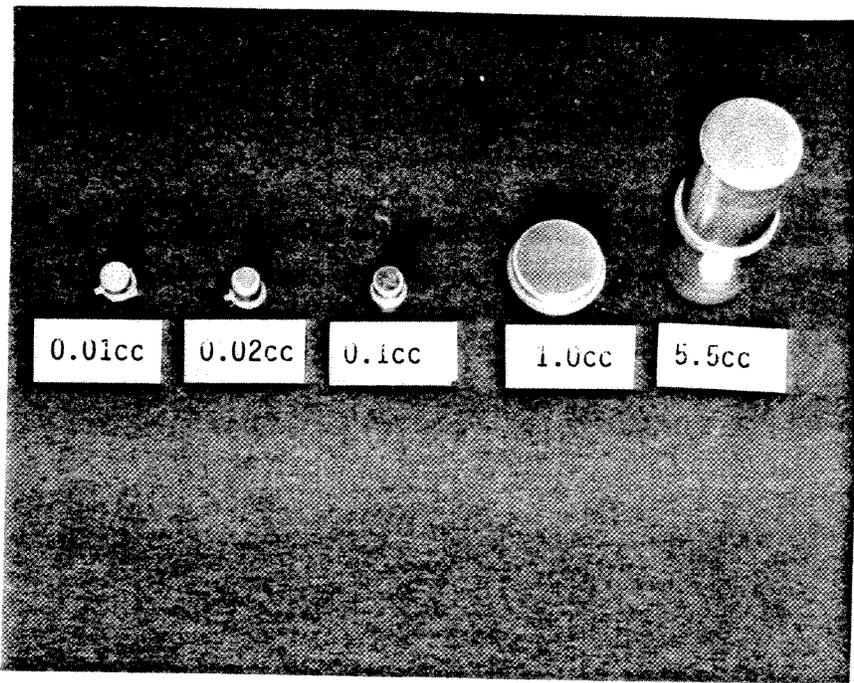


Figure 15

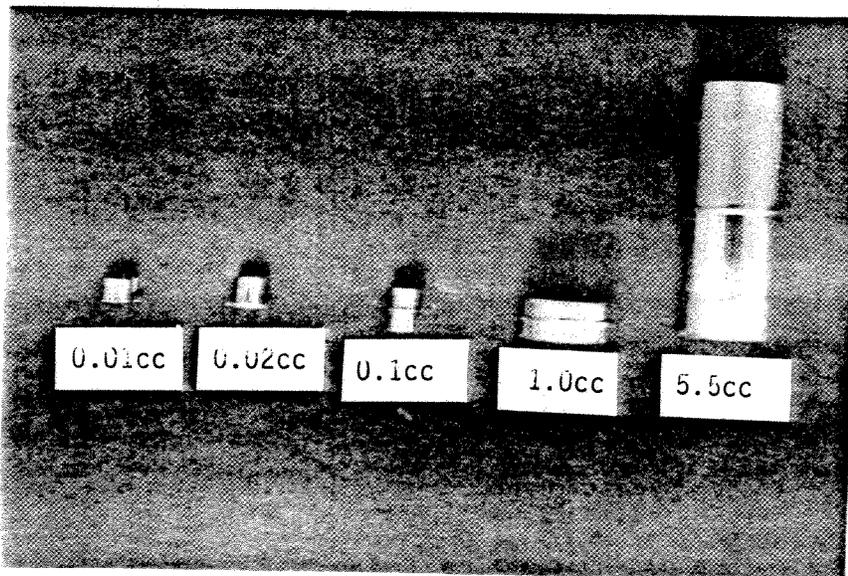


Figure 16

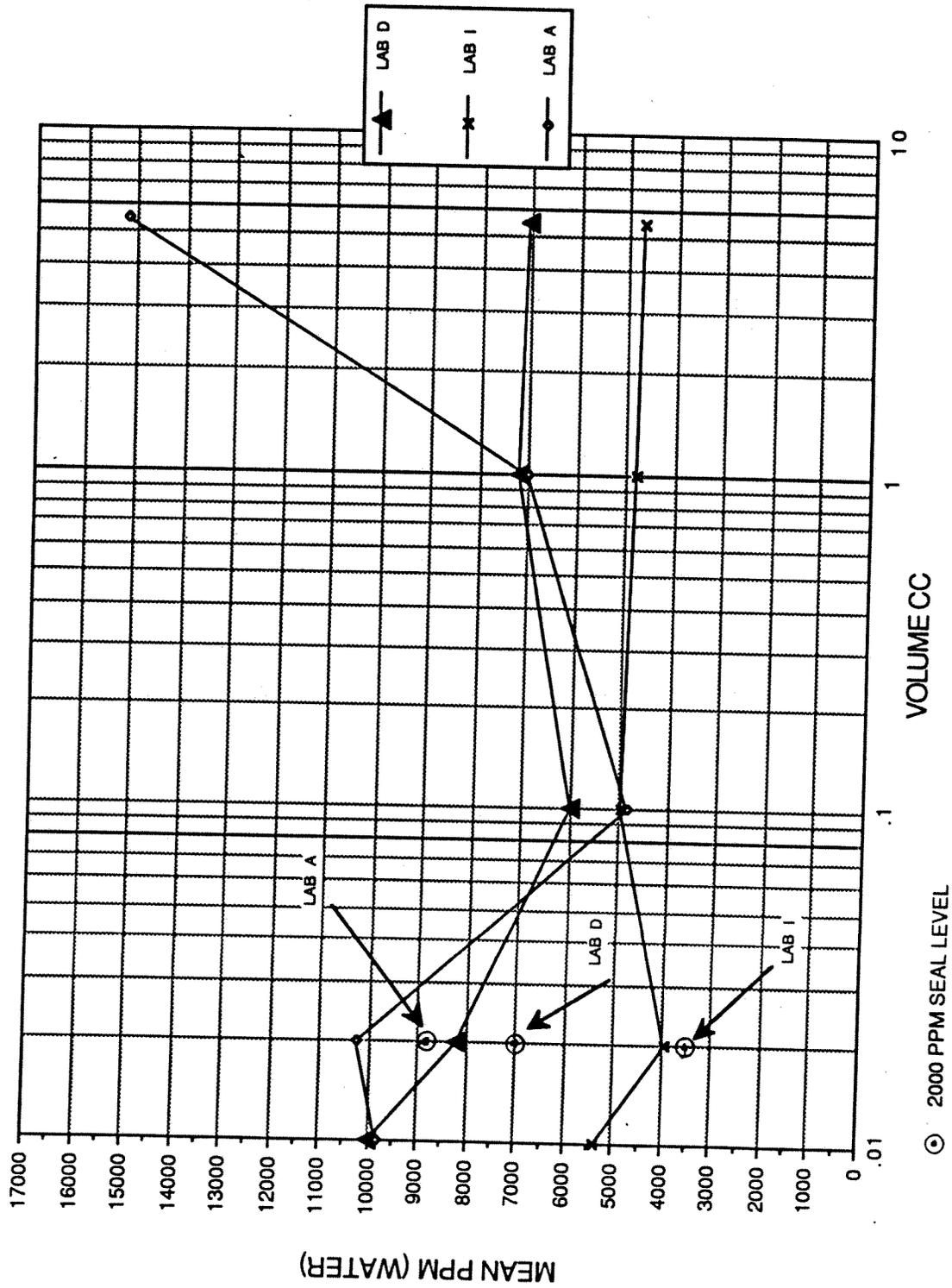
MIL-STD 883D METHOD 1018.2 CORRELATION STUDY LOT#1 RGA RESULTS

SEAL PARAMETERS			LAB I					LAB D					LAB A				
VOLUME CC	SEAL PPM/WATER	SEAL HELIUM%	SERIAL NUMBER	RGA HELIUM%	RGA PPM/WATER	MEAN PPM/WATER	STD. DEV.	SERIAL NUMBER	RGA HELIUM%	RGA PPM/WATER	MEAN PPM/WATER	STD. DEV.	SERIAL NUMBER	RGA HELIUM%	RGA PPM/WATER	MEAN PPM/WATER	STD. DEV.
0.01	5000	~ 10	102	11.9	5600	5367	169.9	101	13.2	11800	9967	1371.9	137	13.3	14050	9803	3213.1
0.01	5000	~ 10	114	11.9	5300			155	13.2	9600			145	14.6	6280		
0.01	5000	~ 10	171	11.8	5200			106	13	8500			152	14	9080		
0.02	5000	~ 10	231	12.3	4000			307	13.8	7500			240	13.2	14050		
0.02	5000	~ 10	278	12.3	3900	3933	47.1	315	14.2	7500	8200	989.9	267	13.4	11650	10236	3823.5
0.02	5000	~ 10	302	11.9	3900			320	13.7	9600			396	13.6	5010		
0.02	2000	~ 10	200	11.7	3500			204	13.1	7000			191	12.3	8000		
0.02	2000	~ 10	226	11.7	3300	3400	81.65	209	13.3	6900	7000	81.6	246	12.6	9540	8937	671.4
0.02	2000	~ 10	256	11.2	3400			283	13	7100			275	12.9	9270		
0.1	5000	~ 10	44	14.8	4900			10	14.8	5759			18	17.3	6230		
0.1	5000	~ 10	59	14.3	4800	4967	169.9	37	14.1	6359	5994	261.8	65	16.5	4000	4840	989.9
0.1	5000	~ 10	73	14.5	5200			90	1.8	5863			72	15.8	4290		
1	5000	~ 10	# 386	10.1	30000	30000	0	# 362	6.9	21500	21500	0	# 379	11.5	21370	21370	0
1	5000	1	351	1.5	4700			373	1.1	7200			352	2	7080		
1	5000	1	466	1.5	4900	4800	100	463	1.1	7200	7200	0	457	2	6980	7030	50
1	5000	1	422	1.4	12300			404	1	10300			415	2	8840		
1	5000	1	423	1.4	9600	13867	4269.5	410	1.1	8600	8967	974.1	441	1.8	7110	8690	1233.4
1	5000	1	427	1.4	19700			571	1.1	8000			450	2	10120		
5.5	5000	1	502	1.5	4500			505	0.99	7120			499	1.8	19930		
5.5	5000	1	536	1.5	4900	4700	163.3	521	1	7287	7046	233.4	530	1.5	6080	15196	6448
5.5	5000	1	544	1.5	4700			542	1	6760			533	1.8	19580		

SEALED IN AIR WITH AN ORGANIC

NOTE: THIS TABLE DOES NOT INCLUDE THE RESULTS OF THE RGA ANALYTICAL TESTS PERFORMED AT HARRIS. THOSE DEVICES WERE SUBMITTED BY ROME LABORATORY.

RGA CORRELATION TEST RESULTS LOT #1 (PILOT GROUPS)



⊙ 2000 PPM SEAL LEVEL
 *NOTE: ORGANIC TEST RESULTS NOT INCLUDED ON THIS GRAPH (SEE TABLE)

FIGURE 17.

We instructed all the analytical laboratories to analyze sixty percent (21) of the devices of the total (35) sent for MIL-STD-883C, Method 1018.2, Procedure I and report on these devices before proceeding with the remaining devices. We also requested that the devices to be tested per Paragraph 3 of Method 1018.2 of MIL-STD-883C with a prebake of 24 hours and that bake time and temperatures shall be reported in the analysis report for all devices.

After careful scrutiny of all of the reported analytical data from sixty percent (60%) of the devices tested at four (4) laboratories, Rome Labs decided to end further testing and recalled the remaining devices. The recalled devices were later shipped to Rome Labs at their request.

The analytical data from Lots #1 and #2 devices was tabulated in Tables (3) and (4) and graphical representations are shown in Figures (17) and (18).

Upon receipt of the analytical results from each testing laboratory the data was statistically analyzed to determine the mean and standard deviation. These results are tabulated along side our mean averages.

A plus (+) or minus (-) twenty (20) percent criteria allows for levels between 4000 and 6000 ppmv respectively for 5000 ppmv sealed levels and 1600 and 2400 ppmv for 2000 ppmv sealed devices.

It is interesting to note that the only analytical service to report within these boundaries was Lab I, in the Lot #1 group of analyses. The Lot #2 analytical results indicated levels far beyond the $\pm 20\%$ criteria with the exception of two labs who tested within specifications in the .1 to 1.0 cc volume ranges. Refer to Lot #2 data (Lab I and Lab D) test results in Figure 18.

In accordance with CLIN 001, Statement of Work Paragraph 4.1.3.3 the remaining one-hundred seventy-five (175) devices were shipped to Rome Laboratory for their inspection and acceptance.

MANUFACTURE AND SEALING OF MOISTURE CORRELATION SAMPLES

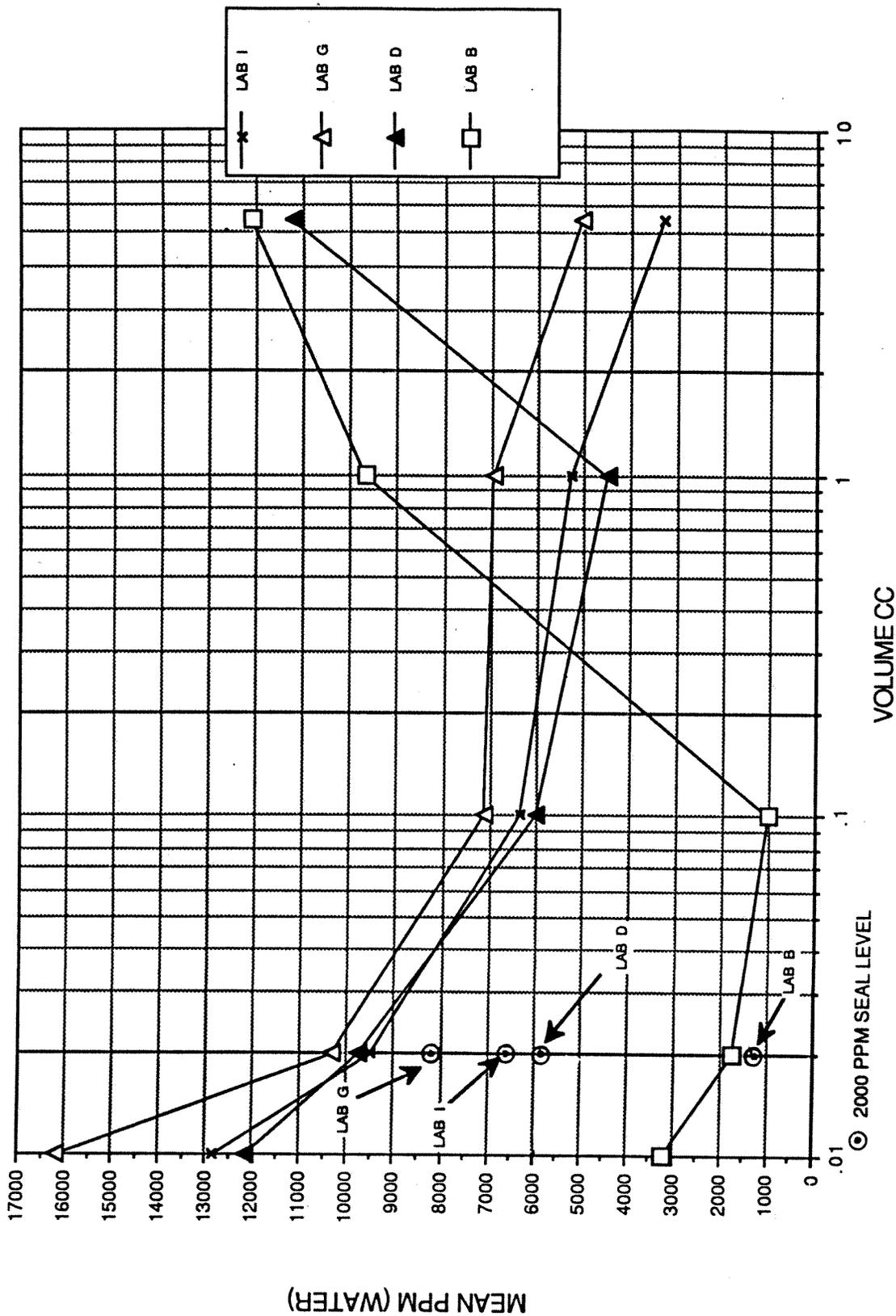
The samples were fabricated from various all nickel (Ni) plated T.O. series transistor packages as shown in Figures (15) and (16). The following table (Table 5) provides the dimensional data on those parts used for fabricating the correlation samples.

TABLE 4. CORRELATION . JDY LOT #2 RGA RESULTS

MIL-STD 883D METHOD 1018.2 CORRELATION STUDY										LOT#2 RGA RESULTS														
SEAL PARAMETERS					LAB I					LAB G					LAB D					LAB B				
VOLUME	SEAL	NITROGEN	SERIAL	RGA	RGA	MEAN	STD.	SERIAL	RGA	RGA	MEAN	STD.	SERIAL	RGA	RGA	MEAN	STD.	SERIAL	RGA	RGA	MEAN	STD.		
CC	PPM WATER	HELIUM %	NUMBER	NS / NS %	NS / NS %	PPM WATER	DEV.	NUMBER	NS / NS %	NS / NS %	PPM WATER	DEV.	NUMBER	NS / NS %	NS / NS %	PPM WATER	DEV.	NUMBER	NS / NS %	NS / NS %	PPM WATER	DEV.		
0.01	5000	100 N2	A01	98% / N.D.	12600	12600		A16	<0.05/BAL	16500	16500		A06	N.D./98.6	12500	12500		A21	0 / 99.53	3323	3323			
0.01	5000	100 N2	A02	98% / N.D.	13400	12833	402.77	A17	<0.05/BAL	15000	16166.7	1040.8	A07	N.D./98.8	10300	12133	1371.9	A22	0 / 99.6	2924	2924	3205	199.3	
0.01	5000	100 N2	A03	98% / N.D.	12500			A18	<0.05/BAL	17000			A08	N.D./98.5	13800			A23	0 / 99.57	3367				
0.02	5000	100 N2	A81	98% / N.D.	9750			A96	<0.05/BAL	10200			A86	N.D./98.9	10300			A101	0 / 99.8	1278				
0.02	5000	100 N2	A82	98% / N.D.	9370	9600	176.82	A97	<0.05/BAL	10800	10333	416.33	A97	N.D./98.8	9600	9787	385.9	A102	0 / 99.69	1942	1724	315.6		
0.02	5000	100 N2	A83	98% / N.D.	9380			A98	<0.05/BAL	10000			A88	N.D./98.8	9400			A103	0 / 99.73	1953				
0.02	2000	100 N2	A161	99% / N.D.	6600			A176	<0.05/BAL	8500			A166	N.D./99.2	5639			A186	0 / 99.81	1045				
0.02	2000	100 N2	A162	99% / N.D.	6630	6527	125.52	A177	<0.05/BAL	8200	8233	251.66	A187	N.D./99.4	5544	5855	375.1	A187	0 / 99.78	1528	1342	212.4		
0.02	2000	100 N2	A163	99% / N.D.	6350			A178	<0.05/BAL	8000			A168	N.D./99.3	6383			A188	0 / 99.78	1454				
0.1	5000	100 N2	A241	99% / N.D.	6290			A256	<0.05/BAL	8800			A246	NO DATA	COMPUTER ERROR			A261	0 / 99.79	1063				
0.1	5000	100 N2	A242	99% / N.D.	6160	6340	171.1	A258	<0.05/BAL	7100	7100	244.9	A247	N.D./99.4	5743	5968	225	A262	0 / 99.79	988	1015	33.8		
0.1	5000	100 N2	A243	99% / N.D.	6570			A259	<0.05/BAL	7400			A248	N.D./99.3	6193			A263	0 / 99.8	995				
1	5000	100 N2	A321	99% / N.D.	5350			A336	<0.01/BAL	7000			A326	NO DATA	IMPROPER PUNCTURE			A341	0 / 99.85	9890				
1	5000	100 N2	A322	99% / N.D.	5440	5227	240.88	A337	<0.01/BAL	6900	6933	47.1	A327	N.D./99.5	4373	4487	114	A342	0 / 99.87	9824	9681	121.9		
1	5000	100 N2	A323	99% / N.D.	4880			A338	<0.01/BAL	6900			A328	N.D./99.5	4801			A344	0 / 99.86	9585				
1	5000	99 N2-1 He	A391	97% / 1.41	9820			A412	1.35/BAL	10600			A308	1.49/97.5	9117			A411	2.05/98.26	15787				
1	5000	99 N2-1 He	A497	97% / 1.41	10600	10773	1018.9	A498	1.36/BAL	11200	10867	249.4	A339	1.46/97.5	9358	8516	1026.6	A424	1.98/98.18	17321	18198	647.9		
1	5000	99 N2-1 He	A522	97% / 1.41	12100			A431	134/BAL	10800			A48	1.5/97.5	7072			A425	1.98/98.36	15845				
5.5	5000	100 N2	A401	99% / N.D.	3230			A427	<0.01/BAL	5100			A410	N.D./98.3	11200			A435	0 / 99.52	12189				
5.5	5000	100 N2	A402	99% / N.D.	3340	3285	55	A428	<0.01/BAL	5100	5050	70.7	A413	N.D./98.5	11300	11233	47.1	A436	0 / 98.52	12154	12081	128.3		
5.5	5000	100 N2	A404	DAMAGED AT LAB I	4950			A429	<0.01/BAL	4950			A415	N.D./98.6	11200			A437	0 / 98.81	11901				

WITH AN ORGANIC

RGAs CORRELATION TEST RESULTS LOT #2



*NOTE: THE ORGANIC TEST RESULTS ARE NOT INCLUDED ON THIS GRAPH. (SEE TABLE)

FIGURE 18.

TABLE 5. MOISTURE CORRELATION SAMPLES

INTERNAL VOLUME CC		PART DESCRIPTION AND SIZE						MOISTURE CONTENTS AND QUANTITIES				
IDEAL	ACTUAL	COMPONENT	HEIGHT/DIA. INCHES	COMPONENT	NO. 2 INCHES	HEIGHT/DIA. INCHES	2000	5000	5000	PPMV	PPMV	with ORGANIC
0.01	0.16	T.O.-18 CAP W.R.	.135 X .175 ID	T.O.-18 BASE	.100 X .175 OD		0	50		50	0	
0.02	0.28	T.O.-18 CAP W.R.	.175 X .175 ID	T.O.-18 BASE	.100 X .175 OD		50	50		50	0	
0.1	0.94	T.O.-18 CAP W.R.	.135 X .175 ID	T.O.-18 CAP	.135 X .175 ID		0	50		50	0	
1	0.89	T.O.-8 CAP W.R.	.125 X .06 ID	T.O.-8 CAP	.125 X 0.6 ID		0	50		50	50	
10	5.6	T.O.-8 CAP W.R.	.75 X .06 ID	T.O.-8 CAP	.75 X 0.6 ID		0	50		50	0	

NOTE: W.R. = WITH WELD RING

TOTAL =350 PIECES

LOT #1 PRE-CONDITIONING

Prior to sealing the Lot #1 components were cleaned with several cleaning solutions then baked for 16 hours at 125°C (overnight). The sealing chamber (dry box) containing the welding apparatus was pre-conditioned overnight (purged with 90% dry N₂) and (10%) He. The R.H. in the dry box was controlled by bubbling dry nitrogen through a cylinder containing water. The flow was adjusted to provide the required dew point in the dry box. A fan was included in the dry box to circulate the N₂ and He and H₂O atmosphere. The dew point was sampled periodically utilizing a General Eastern Co. (HYGRO-M1-PACER). The measuring instrument samples the gas and measures its dew point automatically on a mirrored surface. The dew points were monitored periodically during pre-conditioning and during sealing. In addition to these samples, we sealed some devices at ambient room condition at dew points approaching room temperature. These samples were included in the analysis to provide us with a method of "verifying" the testing of each RGA vendor. The serial number of the device, time of day and dew point were recorded for each device during sealing.

SEALING OF LOT #1 DEVICES

The parts were removed from the pre-conditioning bake in sealed containers and transferred to a remote sealing site. The parts were placed in the dry box temperature/vacuum ante chamber where upon the devices were given an additional thermal/vacuum bake for approximately one (1) hour then transferred to the sealing dry box which was pre-conditioned overnight to a dew point of -2.5°C (5000 ppmv). All the 5000 ppmv parts were sealed first then the dry box was re-conditioned by dropping the dew point to -13°C or (2000 ppmv H₂O + N₂ + He atmosphere for sealing the 0.02 cc volume, 2000 ppmv devices.

After sealing, all the devices were subjected to a helium tracer gas fine leak test and a fluorocarbon FC-77 weight gain gross leak test. Only those devices with a leak rate < 1 x 10⁻⁸ ATM cc/sec air were considered acceptable.

LOT #2 PRECONDITIONING

The Lot #2 group of parts were preconditioned similar to Lot #1, with the exception that the overnight bake was at 100°C rather than 125°C. The devices saw an additional bake at the sealing facility similar to the procedures of Lot #1 device conditioning except that we were instructed by Rome Labs to omit helium gas in our sealing

procedure. The reason for this omission was based on problems that surfaced during analysis of Lot #1 devices at two laboratories. These problems were traced to inaccurate calibration for helium. It was not known why the presence of helium caused the problems. If any gas in the ambient matrix is not assayed properly, the results for all other gases in the package ambient matrix will be skewed. In order to direct emphasis to moisture measurement correlation, Rome Laboratory requested that helium be omitted from Lot 2 samples. Rome Laboratory, upon completion of the laboratory survey, will recommend procedures to assure analytical accuracy for moisture in all normally encountered microelectronic device ambients. It was not known why the presence of helium caused the problems. This time we chose to seal all the 2000 ppmv devices first since conditioning the dry box from a low dew point to a higher dew point would hopefully solve the problem with the higher ppm levels that we experienced with the 0.02 cc "2000 ppmv" devices in the Lot #1 analyses. Again, the serial number, time of seal and dew point were recorded for each device.

Moisture Analysis (Figures and Tables)

The lot #1 RGA data clearly shows that Lab I provided mean values on all volume devices which were within the target values chosen (5,000 ppm). The standard deviation is also shown to be small and indicates that the parts and the test are reasonably consistent.

The lot #1 RGA data from Lab D shows a trend of higher readings for the smaller volumes (.01 and .02 cc) and a fairly even response for the .01, 1, and 5.5 cc. The standard deviation indicates more spread in the data than Lab I thus raising an issue of consistency.

The lot #1 RGA data from Lab A shows mean values similar to Lab D for the volume range of .01 to 1 cc but shows a significant departure at 5.5 cc (variation on the high side by a factor of 2 to 3 as compared to Lab I and Lab D). There is also a significant difference in the standard deviation (much more spread in data) than the others. It would appear that they have "volume effects" as well as test consistency problems.

There were three (3) devices in lot #1 (Serial #3's 362, 379 and 386) which were intentionally sealed in a dramatically different ambient air to assure that the test houses were able to detect outliers in a population of devices. These parts were sealed in a room air ambient with a dewpoint of 15.4°C. This dewpoint converts to ~ 17,200 ppm. As shown in the data, each of the R.G.A. facilities (lot #1) showed high values of moisture ranging from 21,000 to 30,000 ppmv. Although there were significant differences between the test houses in the moisture values for these parts, they clearly were able to identify the devices as outliers.

The 2,000 ppmv values obtained from all three vendors were considerably higher than the target values. It was felt that this could have been attributed to the order of seal (i.e., 5,000 ppmv groups were sealed first followed by 2,000 ppmv. The 2,000 ppmv parts probably had not equilibrated). Another thought was the possibility of a minimum quantity of moisture adsorbed onto the internal surfaces of the devices in an ambient of 2,000 ppmv. As an example, if we assume that one (1) monolayer were adsorbed on the interior surface, this could amount to approximately 2,000 ppmv for the .016 cc volume (surface roughness factor of unity). Combining this value with the water entrapped in the cavity volume would result in a total moisture content of ~ 4,000 ppmv. For the 0.028 cc volume in an ambient of 2,000 ppmv this single monolayer would amount to a total moisture content of approximately 3,000 ppmv. In order to confirm this hypothesis a series of follow-on tests should be performed. This work is critical for small volume, low moisture level standards.

The preparation of the correlation samples has evolved over several years to a procedure which we feel is rigorous in execution and as consistent as practical. The solid nickel headers and caps are initially inspected at 10-30X magnification. Any visual anomalies is cause for rejection i.e., specks, dents, etc. This is followed by a thorough cleaning step designed to remove any residual greases, finger prints and loose particles. The parts are then rinsed, blown dry and baked for 24 hours. They are then stored in a desiccator and finally sealed in a dry box which has been stabilized at the appropriate moisture level and ambient gas content. The moisture level is monitored with a dew point instrument (General Eastern) throughout the entire seal process. All appropriate parameters are recorded (time, seal schedule, gas mix, moisture level, serial number, etc.). We have conformed to this procedure for the past 8-10 years and have found it to be effective and a sound method. This has been evidenced by the several round robin trials as well.

In spite of the divergent results reported by the laboratories in this recent correlation study, we feel that the correlation samples are consistent and are properly filled with each of the stated target values. This conclusion is based on the fact that each of the RGA test facilities were reasonably consistent within their own readings. In previous trials we had noted a great degree of scatter in the intra laboratory data whenever our correlation samples were not properly prepared.

In summary we feel that, in spite of the results of these trials, the correlation samples are sufficiently consistent in moisture content to have highlighted the problems noted with some of the RGA facilities.

CONCLUSIONS

The data obtained from the first trial seen at the three (3) laboratories strongly suggests the following:

1. RGA testing can be consistent and accurate when performed carefully and when calibrations are performed frequently.
2. The correlation samples were themselves accurate and consistent within each lot.
3. The high helium content placed in the samples for leak testing purposes in general, did not adversely affect the moisture measurements.
4. Parts sealed with an approved organic die attach material consistently indicated higher moisture levels than sister packages that did not contain them. The moisture levels of those containing the die attach material varied from 20 to 400% greater than those without it. We suspect that this difference can be attributed to the prebake period and/or the method of moisture sampling (integration vs instantaneous burst). In any event, this area needs further exploration in order to shed more light on this important issue.

The data obtained from the second trial run was somewhat mixed. The following are our conclusions to date:

1. Three (3) laboratories (Lab I, Lab G, and Lab D) had similar results for moisture content in the volume range from .01 to 1.0 cc. Lab I and Lab G followed each other out to the 5.6 cc volume, while Lab D diverged considerably (> a factor of 2 higher) similar to the results of Lab B. Lab B's data for the volumes ranging from .01 to 0.1 cc were much lower than the others but exceeded all others above that. These results all suggest that Lab I, Lab D and Lab G are consistent in volumes less than 1-2 cc and have significant variations above that. The Lab B data suggests calibration and/or test methodology problems exist in their technique.
2. At this time we do not know why the smaller volume devices (.01 to .02 cc) appear to have moisture values significantly higher than the target values. There is an ongoing investigation which is attempting to address this issue. Until a clear answer is found, conclusions which fault either the correlation samples or the RGA houses can only be based on conjecture.

RECOMMENDATIONS

- A) The procedures should be consistent among the RGA facilities. In order to accomplish this, we feel it would be necessary to provide each of the facilities with hundreds of correlation samples each to be evaluated over a several month period. At the conclusion of these tests, the participants, under the auspices of Rome Laboratory, should generate a detailed step by step method and procedure for RGA tests.

- B) In order to accomplish the above recommendation, it is necessary to produce several thousand correlation samples for distribution. At present and in the past, the only accepted mechanism was through Rome Laboratory. It would probably be more efficient if they could be fabricated directly for the RGA facilities under the guidance of Rome Laboratory or their designee.

- C) Finally, there are still some unresolved issues regarding the correlation samples themselves. Although they have been reasonably consistent for the last several trials, the following area remains and should be addressed:

The absolute accuracy needs to be worked out with an independent method. We have basically relied on the dewpoint measurements in the dry box for our guide in combination with agreement from RGA facilities. This method is particularly delicate for the small volume devices (0.01 to 0.02 cc) which are vulnerable to the effects of surface to volume ratios (i.e., a single monolayer of water could have a major affect on the readings as well as thick or thin oxides on the nickel surface. It may be prudent to fabricate the samples from a rolled gold composite to eliminate any effects due to oxidation layers. In addition, heating of the devices during the sealing process may be useful in minimizing or eliminating adsorbed moisture.

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ASTM STANDARDS

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Designation F730-81
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Designation F979-86
Standard Test Method for Hermeticity of Hybrid Microcircuit Packages Prior to Lidding.