NASA Electronic Parts and Packaging

NEPP Program Task 14-294: Joint Hermeticity Correlation Study

NASA MSFC/GSFC

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AGENDA

I. **Hermeticity 101**

II. **Task Objectives**

III. **Task Update**

   A. Instrument Correlation Study

   B. Gross Leak Standard Development

   C. Test Method Optimization

Acronyms

Ag_2S:	Silver Sulfide
Ar:	Argon
CMOS:	Complementary Metal Oxide Semiconductor
CHLD:	Cumulative Helium Leak Detection
DLA:	Defense Logistics Agency
EEE:	Electrical, Electronic, and Electromechanical
FIB:	Focused Ion Beam
GLT:	Gross Leak Threshold
GSFC:	Goddard Space Flight Center
HMS:	Helium Mass Spectrometry
IEA:	Integrated Electronics Assembly
IGA:	Internal Gas Analysis
Kr-85:	Krypton-85
LDC:	Lot Date Code
MDM:	Multiplexor Demultiplexor
MEMS:	Micro-Electro-Mechanical Systems
MIL-STD:	Military Standard
MSFC:	Marshall Space Flight Center
Ni:	Nickel
NEPP:	NASA Electronics Parts and Packaging
OLT:	Optical Leak Test
ORS:	Oneida Research Services, Inc.
RGA:	Residual Gas Analysis (IGA and RGA can be used interchangeably)
TM:	Test Method
V:	Volt

HERMETICITY 101

High reliability design applications typically require the use of hermetically sealed microelectronics. Hermetic seals ensure device longevity and ruggedness, which mitigate risk to mission critical electronic systems.

- Damaged or defective seals and feedthroughs can allow ambient air/water vapor to enter the internal cavity of a device, which over time and under the right conditions, can lead to device failure.
- Examples of failure modes due to moisture/air ingress:
  - Chemical corrosion of device metallization
  - Die lifts due to oxidation of solder die attach
  - Surface electrical leakage
  - Electrical shorts due to dendritic growth
  - Stiction in Micro-Electro-Mechanical Systems (MEMS)
  - Arc discharge in the presence of Argon (Ar)

HERMETICITY 101

Fine and gross leak testing are used to determine the effectiveness of package seals in microelectronic packages.

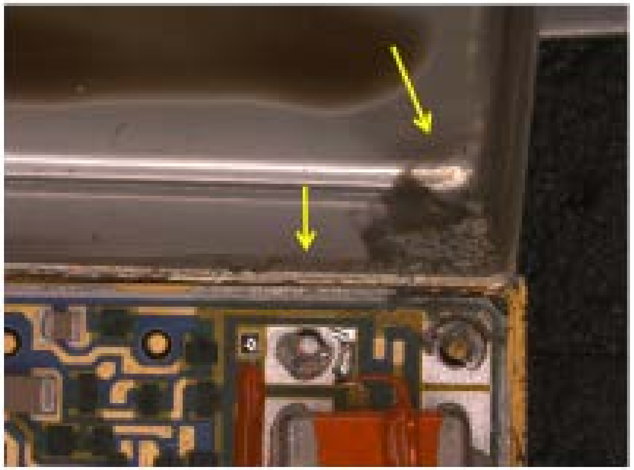
- Most specifications for hermeticity testing define leak rates larger than 10E-5 as being GROSS and smaller than 10E-6 as being FINE.

- Three types of systems are commonly used to non-destructively test hermeticity of sealed packages: Helium Mass Spectrometry (HMS), including Cumulative Helium Leak Detection (CHLD); Krypton-85 (Kr-85); and Optical Leak Test (OLT).
  - *HMS and Kr-85 systems use back pressurization of a tracer gas to enter existing leak paths. A detector is used to determine the presence of gas.*
  - *OLT uses an interferometer to measure package lid deflection in the response to changes in ambient pressure. The amount or absence of lid deflection is directly correlated to a helium leak rate.*

- Testing is performed in accordance with MIL-STD-883 Test Method 1014 for hybrids/microcircuits, MIL-STD-750 Test Method 1071 for discrete semiconductor devices, and MIL-STD-202 Test 112 or manufacturer specification for other EEE parts commodities.

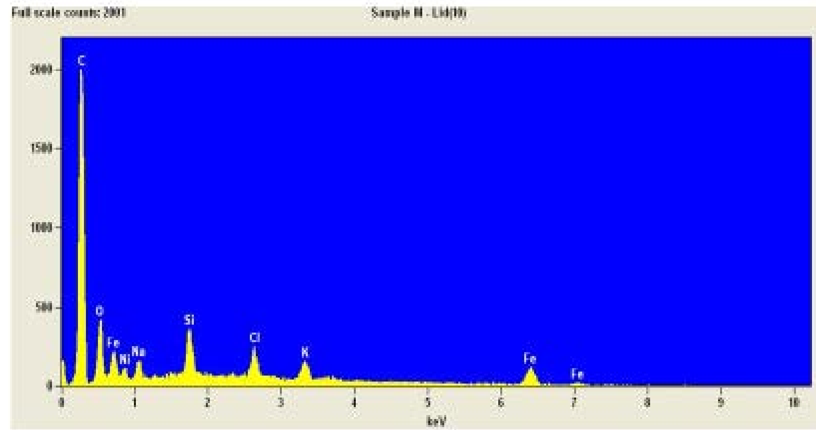
- **Hermetic Failure Examples**

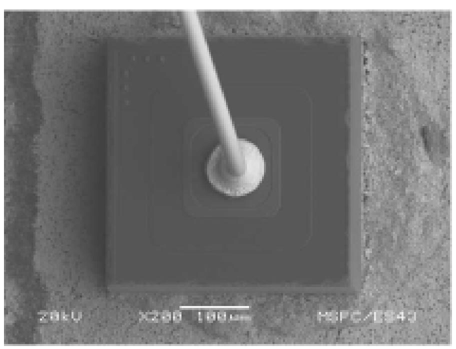
Evidence of corrosion with reduced electrical stability



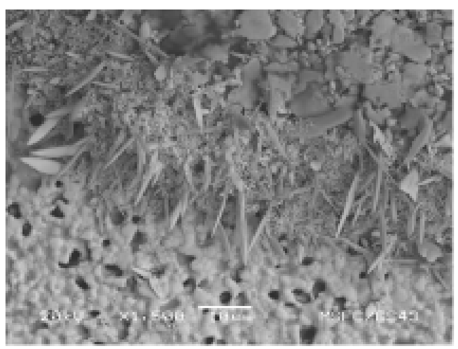
Examination of a representative Ag_2S corrosion area

Elemental analysis provided evidence of corrosion

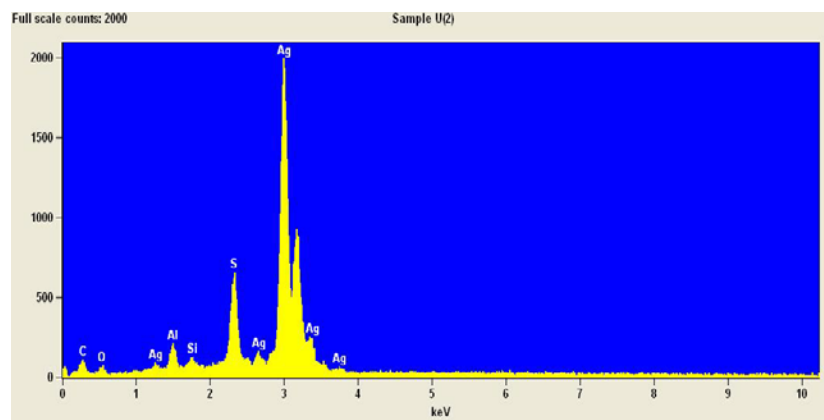




Die and bond area at low magnification



Evidence of heavy growth of Ag_2S along Ag die attach edge and bond pad

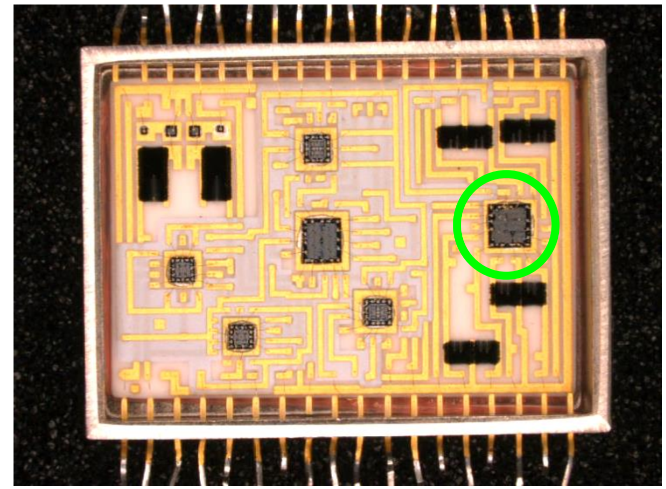


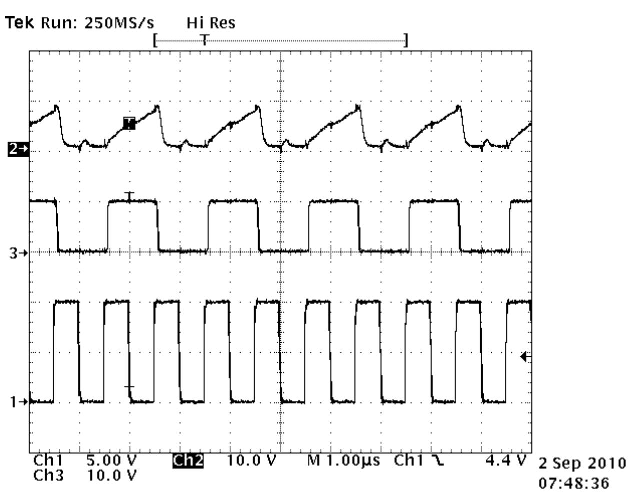
HERMETICITY 101

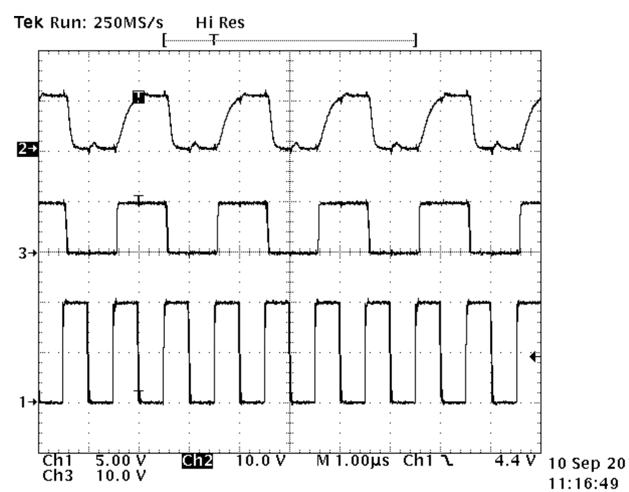
- **Surface Electrical Leakage**

Electrical instability in the presence of positive ionic contamination and moisture

- Failure: MDM Module in an IEA (2009)
  - Flew 7 missions between 10/1990 and 8/2007
- Isolated: 8-bit CMOS Shift Reg. Die (LDC 8222)
- Air leak rate ≈ 4E-7 atm-cc/sec
  - Passes 883: L = 1E-6 atm-cc/sec Air
  - Fails 750: L = 1E-8 atm-cc/sec Air
- Electrical Testing
  - As Received
  - 24 hr Vacuum Bake Out @ 125°C



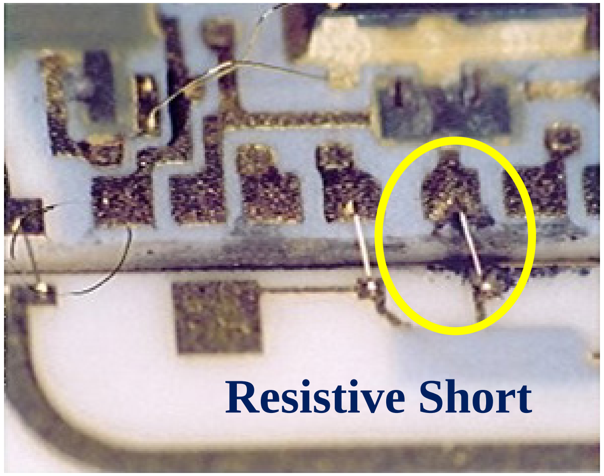




HERMETICITY 101

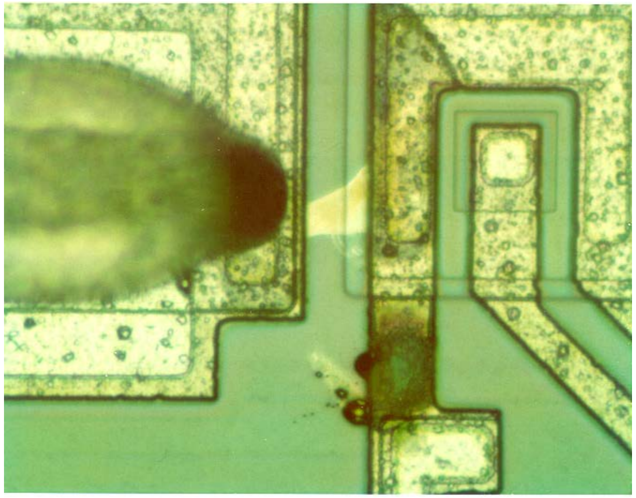
- **Dendritic Growth**

Growth is caused by a combination of electrical bias, contamination, and moisture



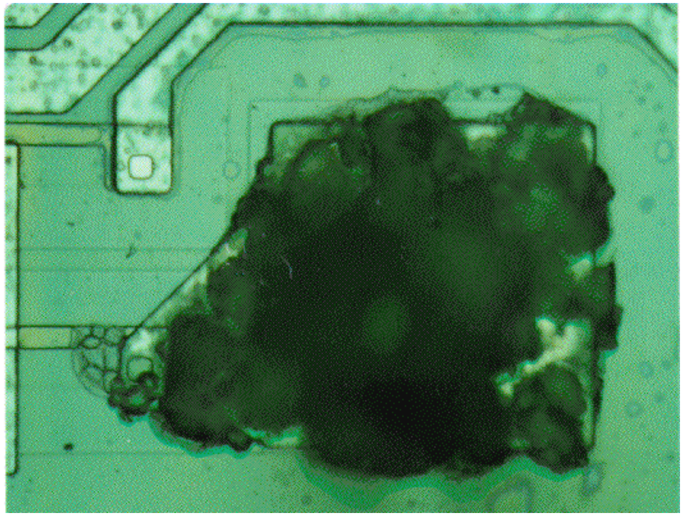
- **Surface Arcs**

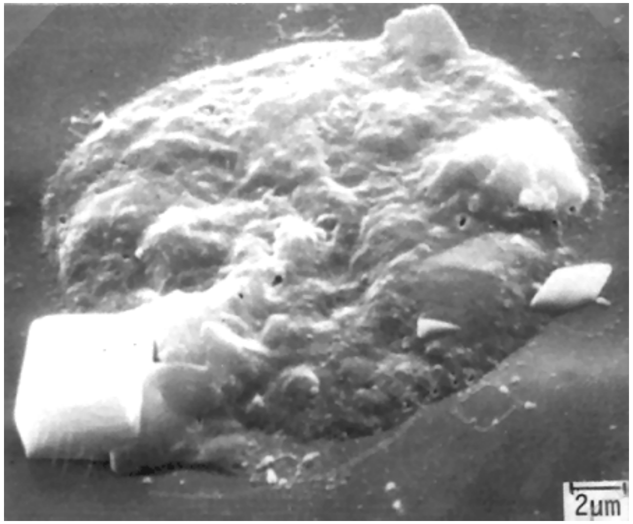
Usually occur over a 300V transient but are dependent on surface glassivation and moisture



- **Corrosion**

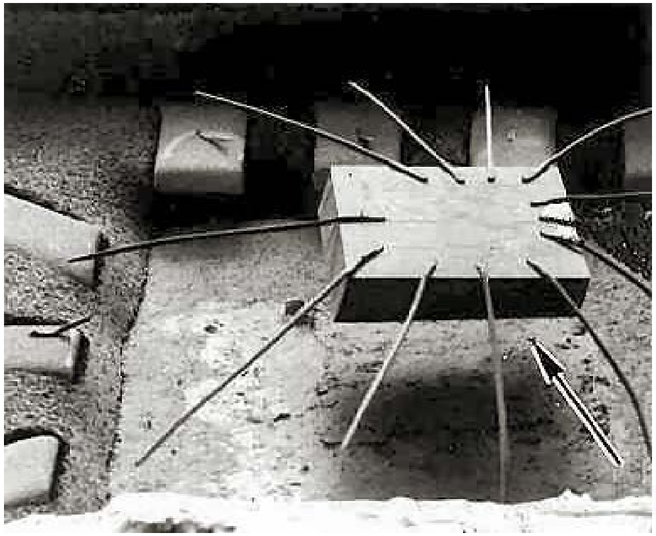
Aluminum bond pad corrosion in the presence of ionic contamination and moisture



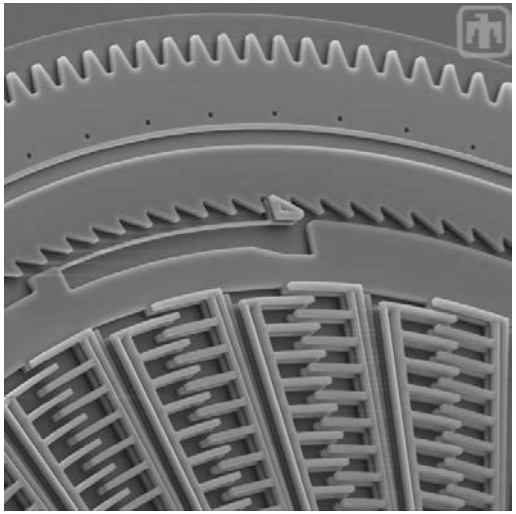


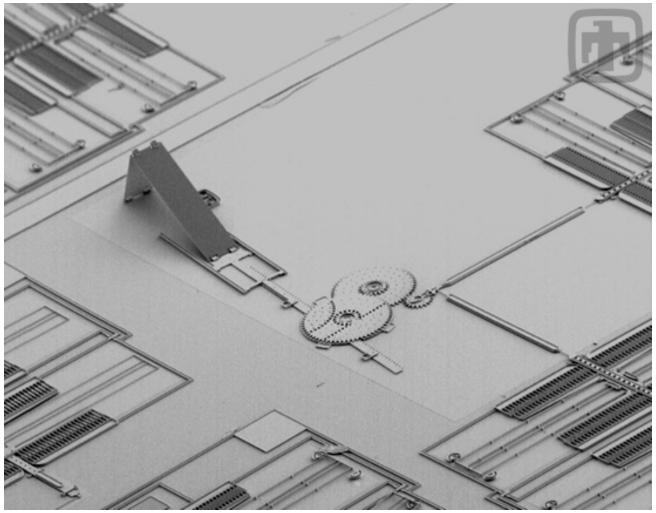
- **Die Lifting**

Oxidation of solder die attach



- **MEMS Failure Modes**





Stiction:

Internal MEMS structures are so small that surface forces (capillary condensation, van der Waals molecular forces, and chemical and hydrogen bonds between the surfaces) cause microscopic structures to stick together when their surfaces come into contact.

Humidity:

Surface micromachined devices are extremely hydrophilic for reasons related to processing. In the presence of humidity, water will condense into small cracks and pores on the surface of these structures (i.e. gears) and effect operability.

TASK OBJECTIVES

NEPP Hermeticity task is a collaborative effort between GSFC/MSFC to address the following:

- Determine CHLD test equipment capability between NASA centers
- Correlate CHLD test results with other equipment used for hermeticity testing (OLT, Kr-85) and verify hermeticity test results using Residual Gas Analysis (RGA)
- Design, fabricate, and test gross leak hermeticity standards
- Provide input to DLA Land & Maritime to optimize hermeticity specifications based on the knowledge gained during correlation studies, part testing, and research efforts

What was the purpose of this study?

Conduct a round robin study of non-hermetic parts to evaluate hermetic test equipments capability to positively identify fine and gross leaking devices.

CHLD
(Pernicka 700H System)

Kr-85
(IsoVac Mark V Bomb Station)

OLT System
(NorCom 2020 Optical Leak Test System)

Test Plan

Step 1

Secure Non-Hermetic Parts

- Obtained 3 sets, 10 parts each, of MIL-STD-750 gross/fine leakers from IsoVac Engineering, Inc. which were go/no go tested (Pre-requisites: Nitrogen sealed, no fluorocarbon/red dye testing)
- 3 package styles were used: TO-18, TO-5, and UB

Step 2

Confirm GSFC/MSFC CHLD Performance

- Used 2 calibrated helium leak standards to verify high/low leak range accuracy
- Verified empty chamber values to confirm analyzer sensitivity to detect fine leaks and set the gross leak threshold (GLT) to detect gross leaks

Step 3

Test Parts Using CHLD, OLT, and Kr-85 Equipment

- Order of testing was CHLD-MSFC, CHLD-GSFC, OLT - NorCom, Kr-85–IsoVac, Kr-85–MSFC, Kr-85 Red Dye-IsoVac (if applicable)
- Exception: Set 1 TO-18 gross leakers were tested by CHLD-MSFC after OLT-NorCom

Step 4:

Test Parts With RGA to Confirm Parts Selected Were Non-Hermetic

- Testing was done for final confirmation of part hermeticity and to ensure fluorocarbons were not present ,which could skew test results

Test Specifics

CHLD

- MSFC/GSFC tested in accordance with MIL-STD-750 TM1071 Test Condition CH_2
- Both used identical bombing conditions, equipment setup, and comparable wait times prior to testing each sample
- CHLD test conditions and system setup are summarized in a backup chart

OLT

- NorCom, Inc. tested in accordance with MIL-STD-750 TM1071 Test Condition L_2
- OLT test and bombing conditions were determined by NorCom
- Testing was observed by GSFC
- OLT test conditions and system setup are summarized in a backup chart

Kr-85

- MSFC/IsoVac Eng., Inc. tested in accordance with MIL-STD-750 TM1071
- Gross leak was performed using Test Condition B
- Fine leak was performed using Test Condition G-1
- Red dye testing was performed by IsoVac Eng., Inc. in accordance with Test Condition A
- Test conditions and system setup are summarized in a backup chart.

RGA

- ORS, Inc. tested in accordance with MIL-STD-750 TM1018
- TO-5, TO-18 RGA was performed using a quadrupole mass spectrometer. TO-18 required special mounting (<0.7cm diameter)
- UB High Resolution HR-IGA was performed using a time of flight (TOF) mass spectrometer. (volume <0.01)
- All samples were prebaked 16-24hrs @100°C and tested at 100°C

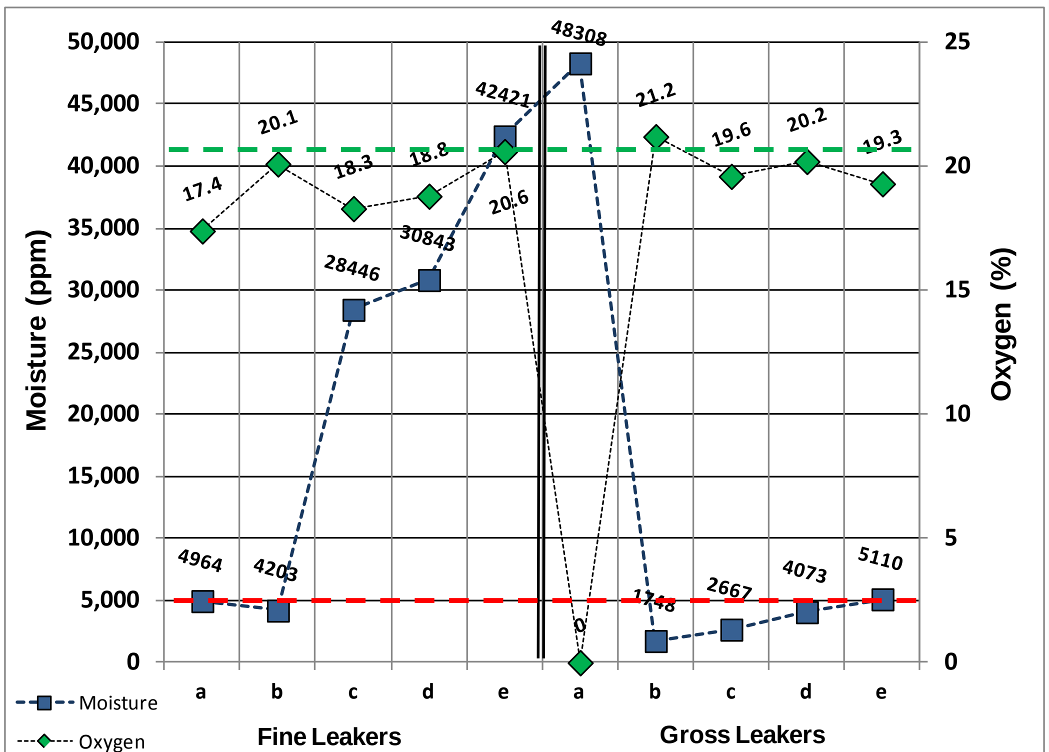
Legend for Correlation Data Tables

(green)	Failed (correlates with baseline Kr85 and RGA)
F (red)	Failed fine when initially Kr85 failed as gross
G (red)	Failed gross when initially Kr85 failed as fine
P (hatched)	Plugged resulting in passing a failed part
P (orange)	OLT passed device when other instruments failed the device
P (yellow)	OLT fails device when CHLD/Kr85 data indicates its plugged
(black)	Instrument not capable to test part
N/A (gray)	Not Applicable

Data & Results: Set 3 UB

System	Order of Testing	Fine						Gross					
		a	b	c	d	e	Results	a	b	c	d	e	Results
Kr85	IsoVac (Pass/Fail)						5/5						5/5
CHLD	MSFC	P	P	P	P	P	0/5						5/5
	GSFC	P	P	P	P	P	0/5						5/5
OLT	Norcom	Package Type Cannot Be Tested With OLT											
Kr85	IsoVac	P	P	P	P	P	0/5						5/5
	MSFC	P	P	P	P	P	0/5						5/5
	IsoVac (Red Dye)	P	P	P	P	P	0/5	N/A					
RGA	ORS						5/5						5/5

Lot Date Code is unknown; Fine leak limit is 1 X 10^{-9} atm-cc/sec air



Test Result Summary

Gross:

- All instruments but OLT identified gross leakers per Mil-STD-750 TMs
- 5/10 RGA moisture under ppm failure criteria but could be the result of atmospheric exchange or moisture sealed in pkg during manufacturing (Note: 883 would have passed these 4)
- 100% correlation between Kr85, CHLD, RGA.

Fine:

- Parts may be plugged. Initially Kr85 failed these devices as leakers. The devices passed the second round of CHLD and Kr85 testing.

Plugging

Handling & Testing

- When non-hermetic parts are handled/tested outside of a clean room environment, atmospheric particle counts are higher and can plug existing leak paths.
- Test conditions during screening by mfg/user can expose device to ambient conditions and thermal/pressurized environments, which can result in conditions conducive to plugging.

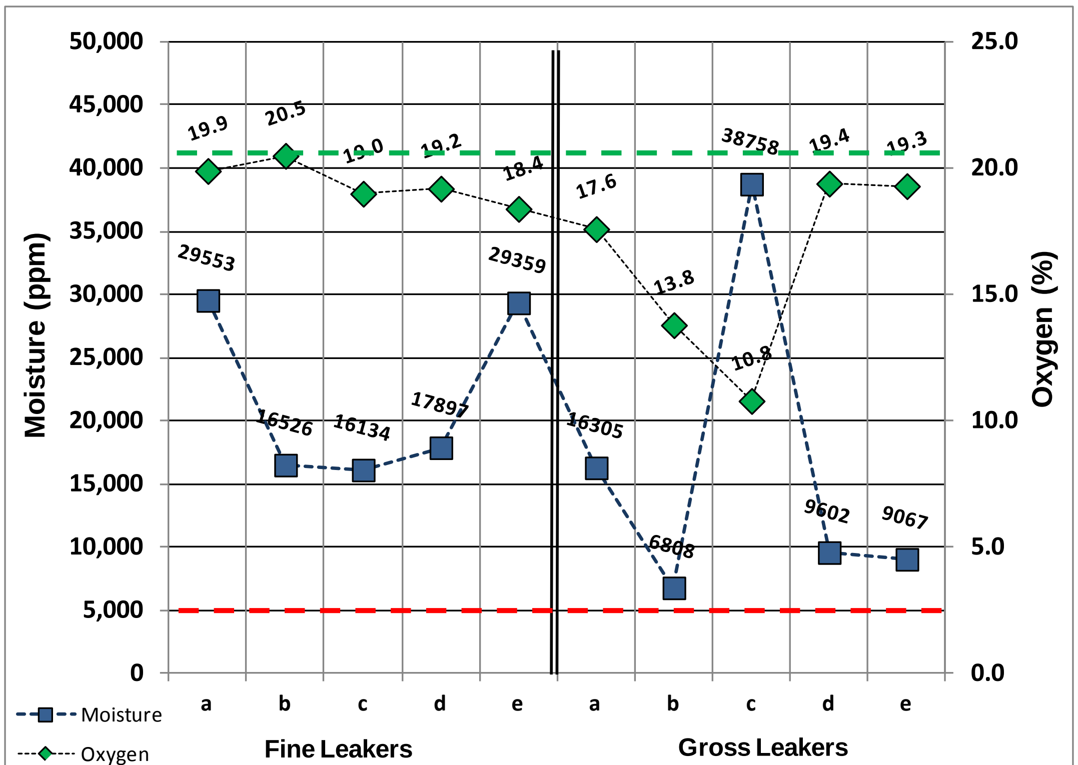
Storage

- Parts stored in ambient conditions provides a suitable environment for oxidation. Metal compounds used in the sealing process and device construction can rust and plug existing leak paths.
- Storage conditions that allow moisture ingress or internal moisture to form inside the device cavity can cause one way leakers.

Data & Results: Set 2 TO-5

Order of Testing	Fine						Gross					
	a	b	c	d	e	Results	a	b	c	d	e	Results
IsoVac (Pass/Fail)						5/5						5/5
MSFC	2.5E-08	G	G	G	1.6E-08	5/5				1.2E-08	1.2E-08	5/5
GSFC	2.5E-08	G	3.4E-08	2.5E-08	1.8E-08	5/5	3.7E-08	3.8E-08		1.5E-08	1.6E-08	5/5
Norcom	P	2.9E-08	P	8.3E-09	P	2/5	P	P		P	P	1/5
MSFC	P	1.6E-08	P	4.1E-08	P	2/5	1.7E-08	P		P	P	2/5
IsoVac (Final)	P	2.4E-08	P	3.9E-08	P	2/5	1.7E-08	P		P	P	2/5
ORS						5/5						5/5

Lot Date Code 1009; Fine leak limit is 5 X 10^{-9} atm-cc/sec air



Test Result Summary

Gross:

- MSFC/GSFC CHLD failed all 5 parts
- 3 parts plugged after CHLD testing
- Of 2 remaining parts, OLT passed 1 failed part and failed 1 part.
- Kr85 failed 2 parts which correlates with CHLD and conflicts with OLT
- RGA data confirms that all 5 parts were leakers

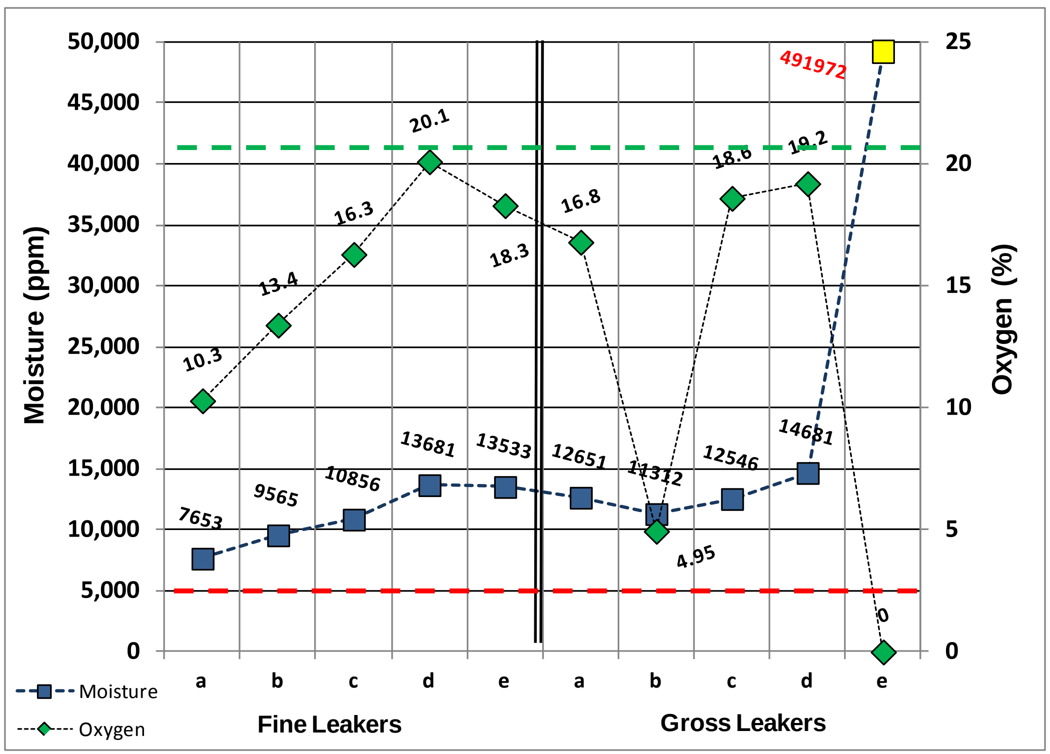
Fine:

- CHLD failed all 5 parts
- 3 parts plugged after CHLD GSFC testing, allowing Kr85 to only fail 2 parts
- RGA data confirms that all 5 parts were leakers

Data & Results: Set 1 TO-18

System	Order of Testing	Fine a	Fine b	Fine c	Fine d	Fine e	Results	Order of Testing	Gross a	Gross b	Gross c	Gross d	Gross e	Results
Kr85	IsoVac (Pass/Fail)						5/5	IsoVac (Pass/Fail)						5/5
CHLD/OLT	CHLD:MSFC	P	P	G	P	G	2/5	CHLD: GSFC	P		P		P	2/5
	CHLD: GSFC	P	P	P	P	P	0/5	OLT: Norcom			9.2E-08	1.3E-08	P	3/5
	OLT: Norcom	G	1.2E-08	1.9E-08	P	G	4/5	CHLD: MSFC	P		P	P	P	1/5
Kr85	IsoVac	P	P	P	P	P	*0/5*	IsoVac	P	P	P	P	P	*0/5*
	MSFC	P	P	P	P	P	*0/5*	MSFC	P	P	P	P	P	*0/5*
	IsoVac (Red Dye)	P	P	P	P	P	*0/5*	IsoVac (Red Dye)	N/A	P	N/A	N/A	P	*0/2*
RGA	ORS						5/5	ORS						5/5

Lot Date Code is 0937; Fine leak limit is 5 X 10^{-9} atm-cc/sec air



Test Result Summary

Gross:

- **All samples exhibited plugging**
- **CHLD GSFC passed one failed part that NorCom identified as a fine leak.**
- **One part shifted during OLT testing and would require retesting (?? Wait time and 5 hr rebomb)**

Fine:

- **All samples exhibited plugging**
- **GSFC identified all parts as passed. MSFC indicated 2 parts failed. OLT indicated 4 parts failed. Several scenarios possible; unable to make a conclusion due to lack of correlation.**

Correlation Without OLT

Part	System	Order of Testing	Fine a	Fine b	Fine c	Fine d	Fine e	Fine Results	Order of Testing	Gross a	Gross b	Gross c	Gross d	Gross e	Gross Results
Set 1	Kr85	IsoVac (Pass/Fail)						5/5	IsoVac (Pass/Fail)						5/5
(TO-18)	CHLD	CHLD:MSFC	P	P	G	P	G	2/5	CHLD: GSFC	P		P		P	2/5
0.0345 cc		CHLD: GSFC	P	P	P	P	P	0/5	CHLD: MSFC	P		P	P	P	1/5
	Kr85	IsoVac	P	P	P	P	P	0/5	IsoVac	P	P	P	P	P	0/5
		MSFC	P	P	P	P	P	0/5	MSFC	P	P	P	P	P	0/5
		IsoVac (Red Dye)	P	P	P	P	P	0/5	IsoVac (Red Dye)	N/A	P	N/A	N/A	P	0/2
	RGA	ORS						5/5	ORS						5/5

Part	System	Order of Testing	Fine a	Fine b	Fine c	Fine d	Fine e	Fine Results	Gross a	Gross b	Gross c	Gross d	Gross e	Gross Results
Set 2	Kr85	IsoVac (Pass/Fail)						5/5						5/5
(TO-5)	CHLD	MSFC	2.5E-08	G	G	G	1.6E-08	5/5				1.2E-08	1.2E-08	5/5
0.2244 cc		GSFC	2.5E-08	G	3.4E-08	2.5E-08	1.8E-08	5/5	3.7E-08	3.8E-08		1.5E-08	1.6E-08	5/5
	Kr85	MSFC	P	1.6E-08	P	4.1E-08	P	2/5	1.7E-08	P		P	P	2/5
		IsoVac (Final)	P	2.4E-08	P	3.9E-08	P	2/5	1.7E-08	P		P	P	2/5
	RGA	ORS						5/5						5/5

Part	System	Order of Testing	Fine a	Fine b	Fine c	Fine d	Fine e	Fine Results	Gross a	Gross b	Gross c	Gross d	Gross e	Gross Results
	Kr85	IsoVac (Pass/Fail)						5/5						5/5
	CHLD	MSFC	P	P	P	P	P	0/5						5/5
Set 3		GSFC	P	P	P	P	P	0/5						5/5
(ceramic)	Kr85	IsoVac	P	P	P	P	P	0/5						5/5
0.0026 cc		MSFC	P	P	P	P	P	0/5						5/5
		IsoVac (Red Dye)	P	P	P	P	P	0/5	N/A					
	RGA	ORS						5/5						5/5

Summary

Correlation CHLD

- GSFC and MSFC were able to fail the same devices when plugging did not occur.
- If plugging is considered, CHLD correlates with Kr-85.
- When GSFC and MSFC both identified a fine leak, the leak rates correlated within < 1/4 magnitude.

Correlation OLT

- There is a lack of correlation between OLT and CHLD/Kr-85 data for TO-18 packages and one gross TO-5 package.
- If OLT data is omitted, the results in this study correlate to segregating failed devices and plugging.
- NorCom could not use OLT to test ceramic/metal lid UB parts.

Correlation Kr85

- MSFC and IsoVac correlate 100%.
- All gross leaks and plugged devices were identified, and fine leak rates were within <1/4 magnitude.
- IsoVac initial testing and ORS RGA correlate 100%, proving these devices were all leakers at one time.

Lessons Learned

Plugging

- The **most reliable leak test** is the one performed during initial lot screening by the manufacturer.
- Leaky parts can gradually or completely plug at anytime.
- The mechanism of plugging requires more study to determine root cause.

RGA

- All constituent gases should be considered in the pass/fail criteria of MIL-STD-883 TM 1018.

OLT

- OLT should undergo additional qualification testing prior to its inclusion into the seal test methods.
- A list of devices that can not be tested with this instrument should be identified in the test methods.

Follow-up Work

Plugging	• Resealed RGA holes and performed a bake out test on 8 gross leakers to study the one way leak phenomena. 3 devices recovered prior to bake out (1 gross/2 fine). Isolated the leak to the seal area of the gross leaker using Kr-85 "sniffing" technique. The oven experienced thermal runaway during testing which jeopardized further leak testing.
RGA	• Submitted essential comments to add constituent gases to the pass/fail criteria of MIL-STD-883 TM 1018.
Testing	• Supporting a second instrument correlation study of MIL-STD-883 devices.

Gross Leak Standard Development Plan

Phase 1: Design

- Adsorption Free Construction Materials
- Fabricated Using Typical Manufacturing Processes
- Micron Sized Holes (? - ? µm)

Phase 2: Validation

- Round Robin Measurements with Hermetic Test Equipment
- Identification of Strengths & Weaknessses
- Design Review: Go/No Go Decision

Phase 3: Implementation

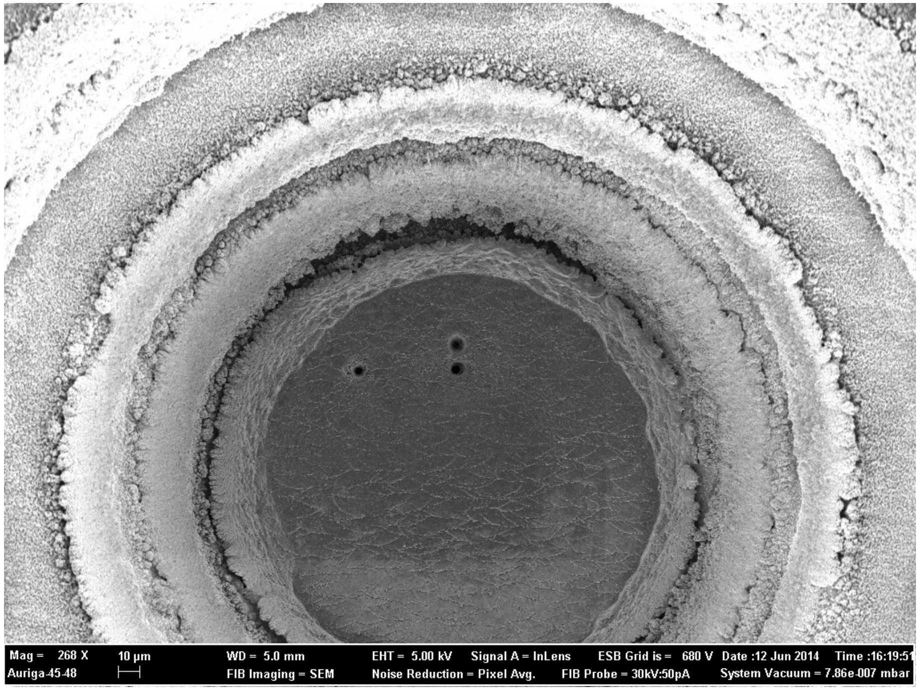
- MIL-STD Optimization Based on Validation
- NIST and/or ANSI Standardization

• Status – Phase 1 Design

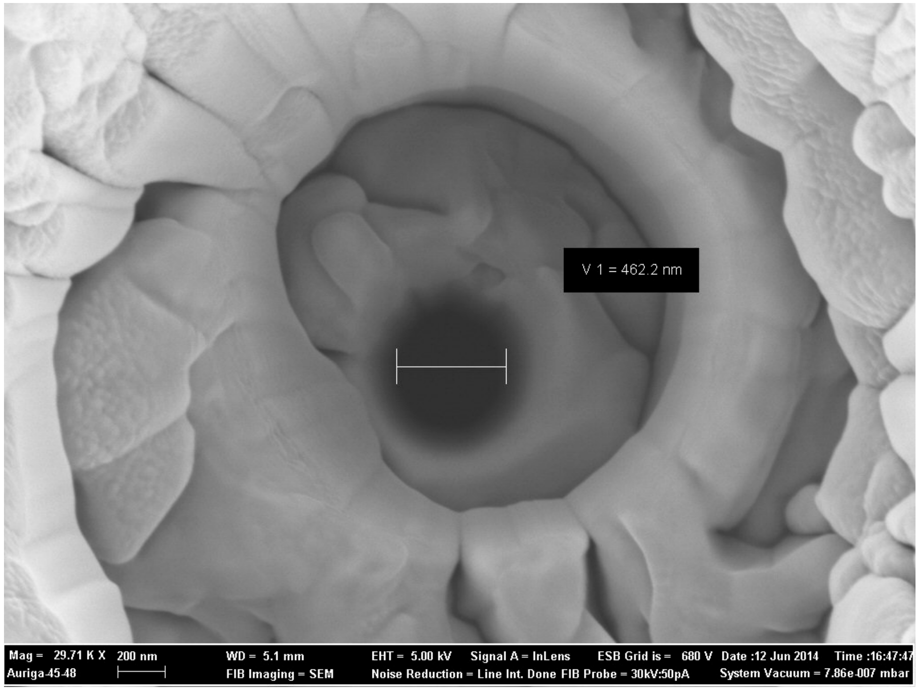
- Fabricated 3 package types: TO-5, TO-18, and TO-46
  - *Construction: Ni (Nickel) can sealed to a Kovar header (N_2 filled)*
  - *Manufactured by Micropac, Inc.*
- MSFC pre-drilled 1 of each package type to thin the 10 mil thick Ni can to approximately 5 mils
- Submitted samples to Zeiss for machining submicron holes
  - *Provided Ni cans to optimize procedure*
  - *Provided 3 standards (one sample of each package type)*
  - *Received FIB/SEM images of practice samples and of the TO-5 standard*
    - *Auriga Laser was used to perform a tapered laser cut*
    - *Focused Ion Beam (FIB) was used to mill micron holes and obtain images*

Leak Standard Development

- **Images of Ni can practice run**
  - *After laser cutting, Zeiss was able to mill a 0.5 micron hole*



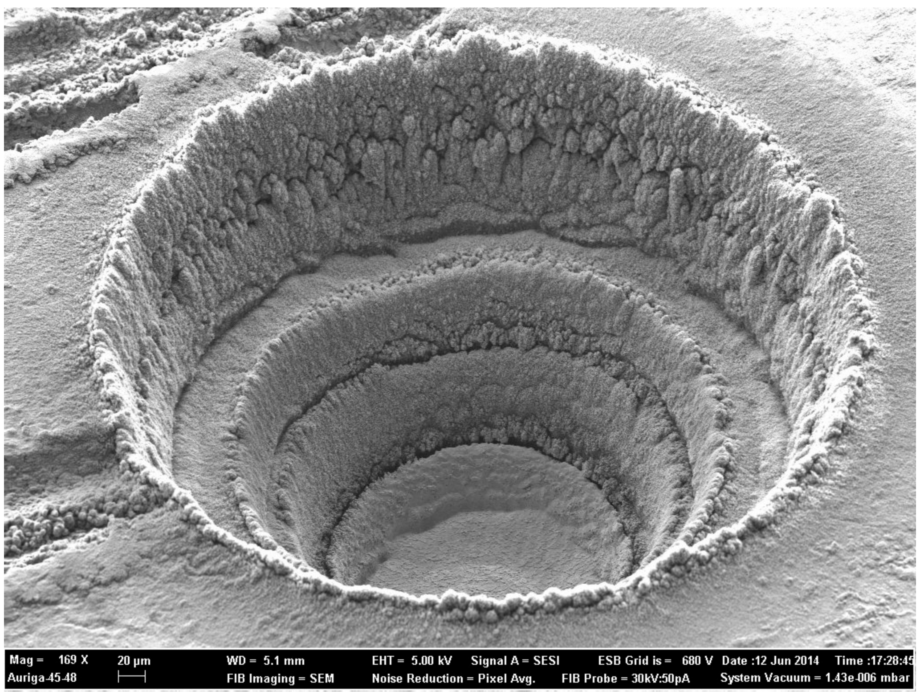
Laser Cut



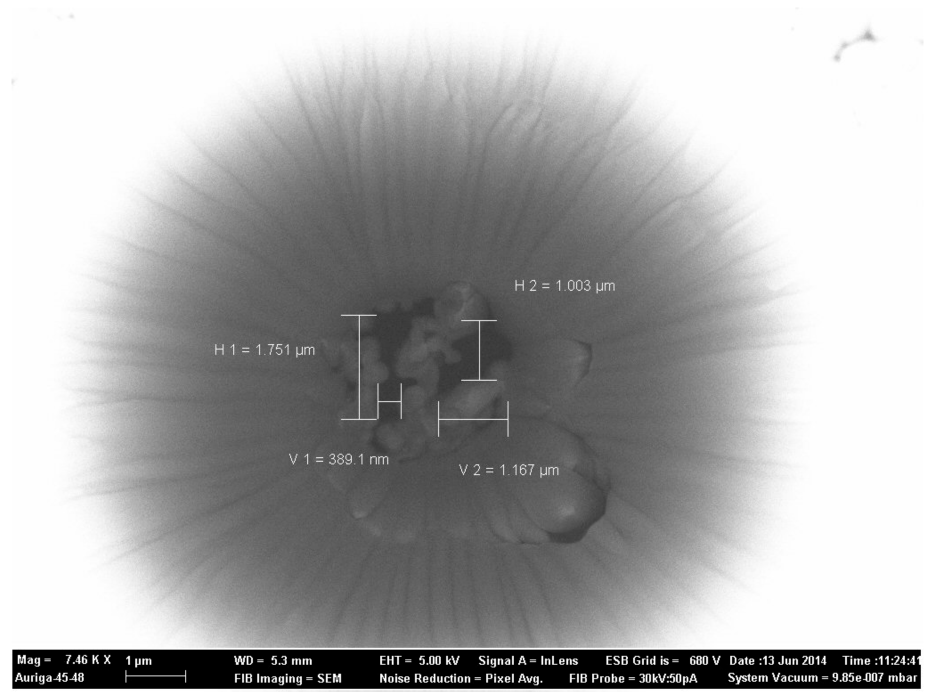
FIB Milled Hole

Leak Standard Development

- **Images of TO-5 Standard**
  - *Hole is not a uniform circle when compared to the test can*
  - *Zeiss feels that they can achieve the same results as the test can and possibly mill the hole even smaller*



Laser Cut



FIB Milled

Test Method Optimization

Objective

- Provide input to DLA Land & Maritime to optimize hermeticity specifications based on the knowledge gained during correlation study, part testing, and research efforts.

Status

- Calculated and submitted a CHLD fixed rate table to support the tightening MIL-STD-883 leak rate limits for class K devices.
- Currently working with Minco Technologies to correlate Kr-85 gross leak test data of various small volume package samples which have 5, 4, 3, 2, and 1 mil holes. The data will be used to determine if the current 5-mil hole specification for gross leak qualification is valid as written. Smaller diameter holes will be evaluated to determine optimum size required for qualification procedure.
- Evaluating Kr-85 red dye gettering efficiency. A red dye test is performed on small volume packages that fail the 5-mil hole criteria of the test methods. Five, 4, and 3 mil sample holes will be drilled in-house for testing.

References

Greenhouse, H., Hermeticity of Electronic Packages, 2nd Edition, 2012

DerMarderosian, A. and Gionet, V., Raytheon, *Package Integrity Measurement Technology and Quality Assurance*, RL-TR-93-159, Rome Laboratories, August 1993

ORS White Paper, *Interpretation of RGA Data*, 1994

Epstein, D., ILC Data Device Corporation, *How to Test for One Way Leakers*, Hybrid Circuit Technology (March 1988)

Clark, R. A., Teledyne and DerMarderosian, A., Raytheon, *Variable Leak Rate Phenomena in Glass to Metal Seals*, International Symposium on Microelectronics (1998)

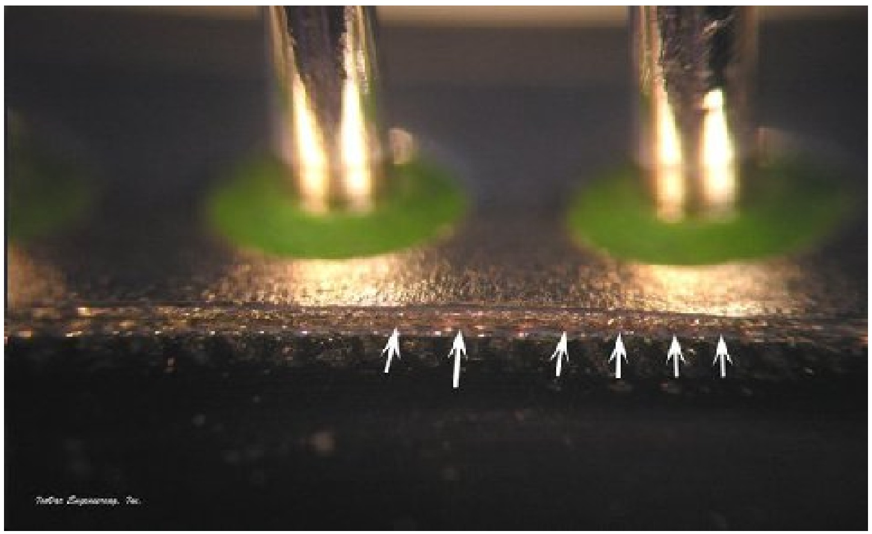
Devaney, J. Hi-Rel and Dicken, H. DM Data, *Failure Mechanisms and Picture Dictionary*, IEEE Parts Technology Seminar Powerpoint Presentations @ MSFC (Sept. 2007)

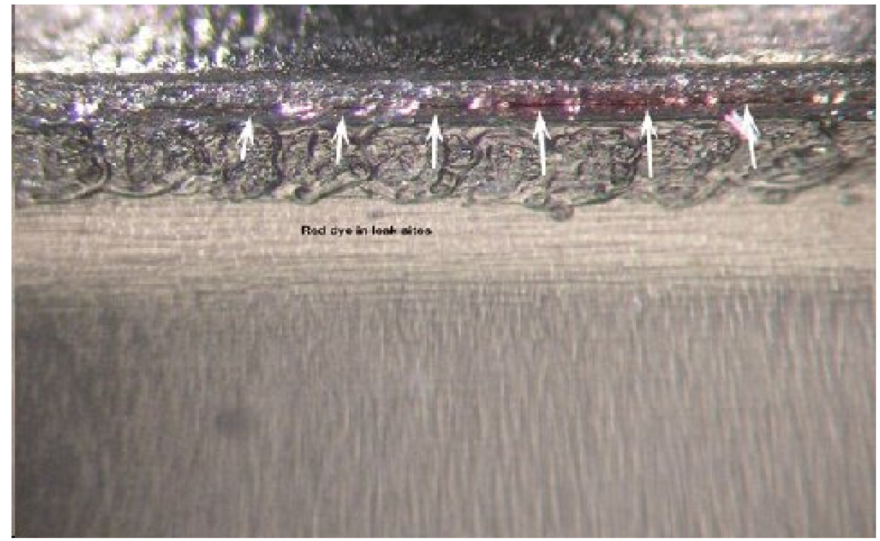
NEPP Program Task 14-294: Joint Hermeticity Correlation Study

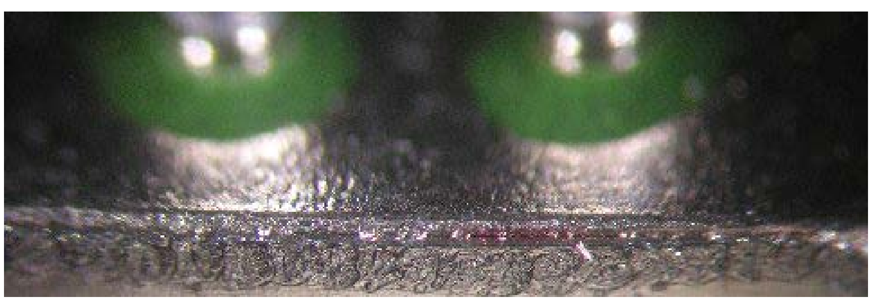
Questions?

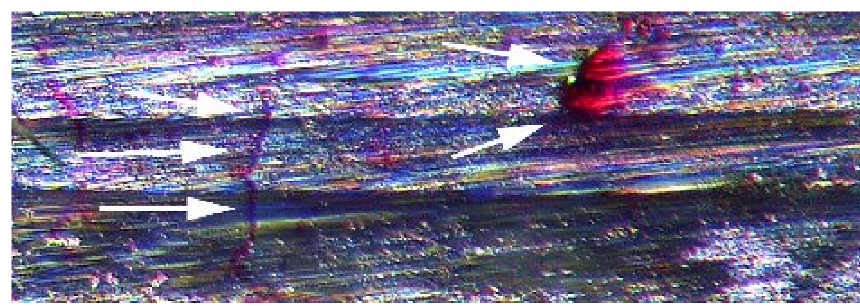
Plugging Mechanism

These images show leaks in the weld material of TO-257 parts. The metal is "steel", which will start to rust right away in humid environments. Rust can potentially “plug holes.” Gross leakers are shown below. Note that fine leaks may seal quicker.









Courtesy of IsoVac Engineering, Inc.

Test Specifics: CHLD

Group	Desc.	LDC	Volume (cc)	L (air) (atm-cc/sec)	Item	SN's	He Bombing Pressure (psig)	He Bombing Time (hr)	He Bombing R1 (He) (atm-cc/sec)	CHLD Set Values Chamber	CHLD Set Values Insert (mm)	CHLD Set Values GLT	CHLD Set Values Method	Testing Dwell (min)	Testing Test Order
Set 1	2N2907A	0937*	0.0345	5.00E-09	Fine	1-5	60	90	8.03E-09	Small	7/11	1.00E-09	20/3/30/30/3	20/24	SN
(T0-18)					Gross	B07, B19, B27, B37, B42	60	90	8.03E-09	Small	7/7	5.00E-10	10/3/10/10/3	40/45	SN
Set 2	2N2219A	1009	0.2244	5.00E-09	Fine	6-10	60	4	5.96E-11	Small	13/7	1.00E-09	10/3/10/10/3	10/14	SN
(T0-5)					Gross	1-5	60	2	2.98E-11	Sm/Med	13/11	1.00E-09	20/3/50/50/5	12/14	SN
Set 3	4 Leaded		0.0026	1.00E-09	Fine	6-10	60	2	1.00E-10	Small	7/7	1.00E-09	10/3/10/10/3	11/6	SN
(ceramic)	Lug				Gross	1-5	60	2	1.00E-10	Small	7/7	1.00E-09	10/3/10/10/3	10/9	SN

Raw Data: CHLD

		Sample #	CHLD					
			GSFC			MSFC		
			atm-cc/sec He	atm-cc/sec Air	Jud	atm-cc/sec He	atm-cc/sec Air	Jud
Set 1 TO-18	Fine	a	3.96E-09	Pass	P	3.25E-09	Pass	P
		b	3.09E-09	Pass	P	2.50E-09	Pass	P
		c	2.62E-09	Pass	P	Gross	Gross	G
		d	2.32E-09	Pass	P	1.82E-09	Pass	P
		e	2.53E-09	Pass	P	Gross	Gross	G
	Gross	a	1.79E-09	Pass	P	2.25E-09	Pass	P
		b	Gross	Gross	G	Gross	Gross	G
		c	1.73E-09	Pass	P	2.12E-09	Pass	P
		d	Gross	Gross	G	2.01E-09	Pass	P
		e	1.46E-09	Pass	P	1.90E-09	Pass	P
TO-5	Fine	a	1.41E-09	2.46E-08	F	1.42E-09	2.47E-08	F
		b	Gross	Gross	G	Gross	Gross	G
		c	2.70E-09	3.40E-08	F	Gross	Gross	G
		d	1.49E-09	2.53E-08	F	Gross	Gross	G
		e	7.78E-10	1.83E-08	F	5.82E-10	1.58E-08	F
	Gross	a	1.59E-09	3.70E-08	F	Gross	Gross	G
		b	1.68E-09	3.80E-08	F	Gross	Gross	G
		c	Gross	Gross	G	Gross	Gross	G
		d	2.81E-10	1.55E-08	F	1.80E-10	1.24E-08	F
		e	3.03E-10	1.61E-08	F	1.73E-10	1.22E-08	F
UB	Fine	a	6.63E-11	Pass	P	5.37E-11	Pass	P
		b	4.12E-11	Pass	P	4.99E-11	Pass	P
		c	5.91E-11	Pass	P	4.38E-11	Pass	P
		d	4.30E-11	Pass	P	4.19E-11	Pass	P
		e	4.36E-11	Pass	P	3.98E-11	Pass	P
	Gross	a	Gross	Gross	G	Gross	Gross	G
		b	Gross	Gross	G	Gross	Gross	G
		c	Gross	Gross	G	Gross	Gross	G
		d	Gross	Gross	G	Gross	Gross	G
		e	Gross	Gross	G	Gross	Gross	G

Test Specifics: OLT

- OLT was performed by NorCom Systems Inc (located in Norristown PA) using NorCom 2020
  - NorCom 2020 resolution: 15nm
  - Pressurization gas: Helium

Parameters	TO-5	TO-18*	UB package
Package Cavity [cc]	0.2244	0.0345	0.0026
Test Time	10 hours	5 hours	Could not be tested in OLT
Helium pressure +/- modulation [psi]	57.3psi +/- 2	57.3psi +/- 2	
Fine Leak Limit (L_2) [atm cc/sec He]	1.37e-08	1.37e-08	
Test Sensitivity of NorCom 2020 for this part[†]	6.0e-9	3.7e-09	
Fine Leak Limit (L) [atm cc/sec air] per MIL-STD-750	5e-09	5e-09	
Number of parts tested	10	10	

(*) TO-18 lid stiffness and package size are right at the edge of NorCom 2020 detection capability

(†) Conversion L= L_2/2.69 results in L values that are tighter than stated in MIL-STD-750

Raw Data: OLT

		Sample #	OLT NorCom		
			atm-cc/sec He	atm-cc/sec Air	Judge
Set 1 TO-18	Fine	a	Gross	Gross	G
		b	3.31E-08	1.23E-08	F
		c	4.97E-08	1.85E-08	F
		d	Pass	Pass	P
		e	Gross	5.00E-06	G
	Gross	a	No Data	No Data	ND
		b	Gross	5.00E-06	G
		c	2.48E-07	9.22E-08	F
		d	3.38E-08	1.26E-08	F
		e	Pass	Pass	P
TO-5	Fine	a	Pass	Pass	P
		b	7.85E-08	2.92E-08	F
		c	Pass	Pass	P
		d	2.24E-08	8.33E-09	F
		e	Pass	Pass	P
	Gross	a	Pass	Pass	P
		b	Pass	Pass	P
		c	Gross	Gross	G
		d	Pass	Pass	P
		e	Pass	Pass	P
UB	Fine	a	No Data	No Data	ND
		b	No Data	No Data	ND
		c	No Data	No Data	ND
		d	No Data	No Data	ND
		e	No Data	No Data	ND
	Gross	a	No Data	No Data	ND
		b	No Data	No Data	ND
		c	No Data	No Data	ND
		d	No Data	No Data	ND
		e	No Data	No Data	ND

Test Specifics: MSFC Kr85

Mark V System Parameters	Leak Test	Bomb Conditions		
		TO-18	T0-5	UB
SA = 230 μCi/atm-cc K = 14,444 CPM/μCi R = 500 CPM	Gross	75 psia @ 0.03 hours		
	Fine	Q_s = 2.9 X 10^{-9} atm-cc/sec Kr P = 75 psia T = 0.57 hrs	Q_s = 5.8 X 10^{-10} atm-cc/sec Kr P = 75 psia T = 2.87 hrs	

Raw Data: Kr85

		Sample #	Kr 85							
			IsoVac			IsoVac Red Dye		MSFC		
			atm-cc/sec Kr	atm-cc/sec Air				atm-cc/sec Kr	atm-cc/sec Air	Judgement
Set 1 TO-18	Fine	a	PASS	PASS	P	PASS	PASS	PASS	PASS	P
		b	PASS	PASS	P	PASS	PASS	PASS	PASS	P
		c	PASS	PASS	P	PASS	PASS	PASS	PASS	P
		d	PASS	PASS	P	PASS	PASS	PASS	PASS	P
		e	PASS	PASS	P	PASS	PASS	PASS	PASS	P
	Gross	a	2.00E-08	3.42E-08	F			4.46E-07	7.63E-07	F
		b	Gross	Gross	G			Gross	Gross	G
		c	PASS	PASS	P	PASS	PASS	PASS	PASS	P
		d	1.80E-08	3.08E-08	F			PASS	PASS	P
		e	PASS	PASS	P	PASS	PASS	PASS	PASS	P
TO-5	Fine	a	PASS	PASS	P			PASS	0.00E+00	P
		b	1.40E-08	2.39E-08	F			9.3E-09	1.59E-08	F
		c	2.75E-09	4.70E-09	P			1.2E-09	2.05E-09	P
		d	2.30E-08	3.93E-08	F			2.40E-08	4.10E-08	F
		e	PASS	PASS	P			PASS	PASS	P
	Gross	a	1.00E-08	1.71E-08	F			1.00E-08	1.71E-08	F
		b	PASS	PASS	P			PASS	PASS	P
		c	Gross	Gross	G			Gross	Gross	G
		d	PASS	PASS	P			PASS	PASS	P
		e	PASS	PASS	P			PASS	PASS	P
UB	Fine	a	PASS	PASS	P	PASS	PASS	PASS	PASS	P
		b	PASS	PASS	P	PASS	PASS	PASS	PASS	P
		c	PASS	PASS	P	PASS	PASS	PASS	PASS	P
		d	PASS	PASS	P	PASS	PASS	PASS	PASS	P
		e	PASS	PASS	P	PASS	PASS	PASS	PASS	P
	Gross	a	Gross	Gross	G			Gross	Gross	G
		b	Gross	Gross	G			Gross	Gross	G
		c	Gross	Gross	G			Gross	Gross	G
		d	Gross	Gross	G			Gross	Gross	G
		e	Gross	Gross	G			Gross	Gross	G

Leak Rate Limits

What are the leak rate limits?

- **MIL-STD-750F, Test Method 1071.11 “Hermetic Seal”**
  - *Equivalent standard leak rates (atm cc/s air) for volumes:*
    - ❑ ≤ 0.002 cc: 5×10^{-10}
    - ❑ > 0.002 and ≤ 0.02 cc: 1×10^{-9}
    - ❑ > 0.02 and ≤ 0.5 cc: 5×10^{-9}
    - ❑ > 0.5 cc: 1×10^{-8}

- **MIL-STD-883J, Test Method 1014.14 “Seal”**
  - *Equivalent standard leak rates (atm cc/s air) for volumes:*
    - ❑ ≤ 0.05 cc: 5×10^{-8} except 1×10^{-9} for Hybrid Classes S and K
    - ❑ > 0.05 and ≤ 0.4 cc: 1×10^{-7} except 5×10^{-9} for Hybrid Classes S and K
    - ❑ > 0.4 cc: 1×10^{-6} except 1×10^{-8} for Hybrid Classes S and K

Atmospheric Exchange

How do we determine optimum leak rate requirements?

Leak Rates : Vol cc : Time to Exchange 50% atmoshphere

Volume	1.00E-06	5.00E-07	1.00E-07	5.00E-08	1.00E-08	5.00E-09	1.00E-09	5.00E-10
0.002 cc	0.4 Hrs	0.8 Hrs	3.9 Hrs	7.7 Hrs	1.6 Days	3.2 Days	16.0 Days	32 Days
0.01 cc	1.9 Hrs	3.9 Hrs	1 Days	2 Days	8.0 Days	16 Days	80 Days	160.5 Days
0.1 cc	19 Hrs	2 Days	8 Days	16 Days	80.2 Days	160 Days	2.2 Years	4.4 Years
0.4 cc	3 Days	6 Days	32 Days	64 Days	321 Years	2 Years	8.8 Years	17.6 Years
0.75 cc	6 Days	12 Days	60 Days	120.3 Days	2 Years	3 Years	16 Years	33.0 Years
1 cc	8 Days	16 Days	80 Days	160.5 Days	2 Years	4 Years	22 Years	44 Years
3 cc	24 Days	48 Days	240.7 Years	1.3 Years	7 Years	13 Years	66 Years	132 Years
5 cc	40 Days	80 Days	1.1 Years	2.2 Years	11 Years	22 Years	110 Years	220 Years
8 cc	64 Days	128.4 Days	1.8 Years	3.5 Years	18 Years	35 Years	176 Years	352 Years
10 cc	80 Days	160.5 Days	2.2 Years	4.4 Years	22 Years	44 Years	220 Years	440 Years
12 cc	96 Days	192.5 Days	2.6 Years	5.3 Years	26 Years	53 Years	264 Years	528 Years
15 cc	120.3 Days	240.7 Days	3.3 Years	6.6 Years	33 Years	66 Years	330 Years	659 Years

Volume	1.00E-10
0.002 cc	4.4 Years

Volume	5.00E-11
0.002 cc	320.9 Days

Volume	1.00E-11
0.01 cc	2.2 Years

$$P_t = P_0 e^{-(kt)}$$

$$k = \frac{\text{leak rate}}{\text{vol cc}}$$

t = time (sec)

This "Exchange Table" shows the number of 'hours,' 'days,' or 'years' required for a device to ingest 50% of the atmoshphere to which it is exposed, based on the volume of the part, (cc), and the leak rate of the part.

These exchange values have been studied and confirmed using Kr85 measured leak rates and IGA evaluation.

Yellow: MIL-STD-883 TM 1014 Leak Rate Limits

Green: MIL-STD-750 TM 1071 Leak Rate Limits

Atmospheric Exchange

How do we determine optimum leak rate requirements?

Leak Rates : Vol cc : Time to Exchange 90% atmoshphere

Volume	1.00E-06	5.00E-07	1.00E-07	5.00E-08	1.00E-08	5.00E-09	1.00E-09	5.00E-10
0.002 cc	1.3 *Hrs*	2.6 *Hrs*	12.8 *Hrs*	1.1 *Days*	5.3 *Days*	10.7 *Days*	53.3 *Days*	107 *Days*
0.01 cc	6.4 *Hrs*	12.8 *Hrs*	3 *Days*	5 *Days*	26.7 *Days*	53 *Days*	267 *Days*	1.5 *Years*
0.1 cc	3 *Days*	5 *Days*	27 *Days*	53 *Days*	266.5 *Days*	1 *Years*	7.3 *Years*	14.6 *Years*
0.4 cc	11 *Days*	21 *Days*	107 *Days*	213 *Days*	3 *Years*	6 *Years*	29.2 *Years*	58.4 *Years*
0.75 cc	20 *Days*	40 *Days*	200 *Days*	1.1 *Years*	5 *Years*	11 *Years*	55 *Years*	109.5 *Years*
1 cc	27 *Days*	53 *Days*	267 *Days*	1.5 *Years*	7 *Years*	15 *Years*	73 *Years*	146 *Years*
3 cc	80 *Days*	160 *Days*	2.2 *Years*	4.4 *Years*	22 *Years*	44 *Years*	219 *Years*	438 *Years*
5 cc	133 *Days*	267 *Days*	3.7 *Years*	7.3 *Years*	37 *Years*	73 *Years*	365 *Years*	730 *Years*
8 cc	213 *Days*	1.2 *Years*	5.8 *Years*	11.7 *Years*	58 *Years*	117 *Years*	584 *Years*	1,168 *Years*
10 cc	267 *Days*	1.5 *Years*	7.3 *Years*	14.6 *Years*	73 *Years*	146 *Years*	730 *Years*	1,460 *Years*
12 cc	320 *Days*	1.8 *Years*	8.8 *Years*	17.5 *Years*	88 *Years*	175 *Years*	876 *Years*	1,752 *Years*
15 cc	1.1 *Years*	2.2 *Years*	10.95 *Years*	21.9 *Years*	109.5 *Years*	219 *Years*	1,095 *Years*	2,190 *Years*

Volume	1.00E-10
0.01 cc	7.3 *Years*

Volume	5.00E-11
0.002 cc	2.9 *Years*

Volume	1.00E-11
0.002 cc	14.6 *Years*

$$P_t = P_0 e^{-(kt)}$$

$$k = \frac{\text{leak rate}}{\text{vol cc}}$$

$$t = \text{time (sec)}$$

This "Exchange Table" shows the number of 'hours,' 'days,' or 'years' required for a device to ingest 90% of the atmoshphere to which it is exposed, based on the volume of the part, (cc), and the leak rate of the part.

These exchange values have been studied and confirmed using Kr85 measured leak rates and IGA evaluation.

Yellow: MIL-STD-883 TM 1014 Leak Rate Limits

Green: MIL-STD-750 TM 1071 Leak Rate Limits

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