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

HERMETICITY 101

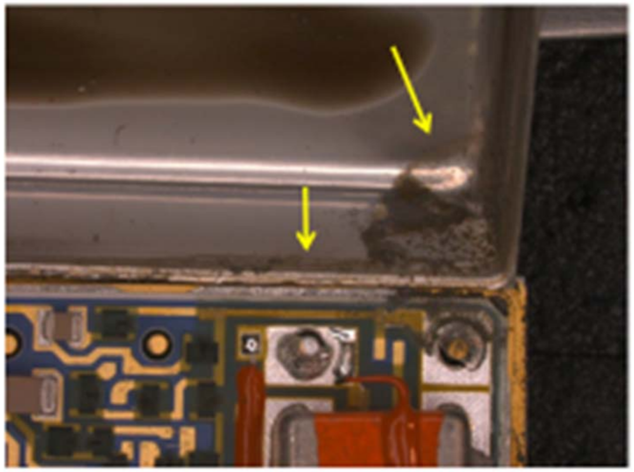
High reliability design applications typically require the use of hermetically sealed microelectronics to insure device longevity and ruggedness in an attempt to mitigate risk to mission critical electronic systems.

- 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 MEMS
  - Arc discharge in the presence of Argon

HERMETICITY 101

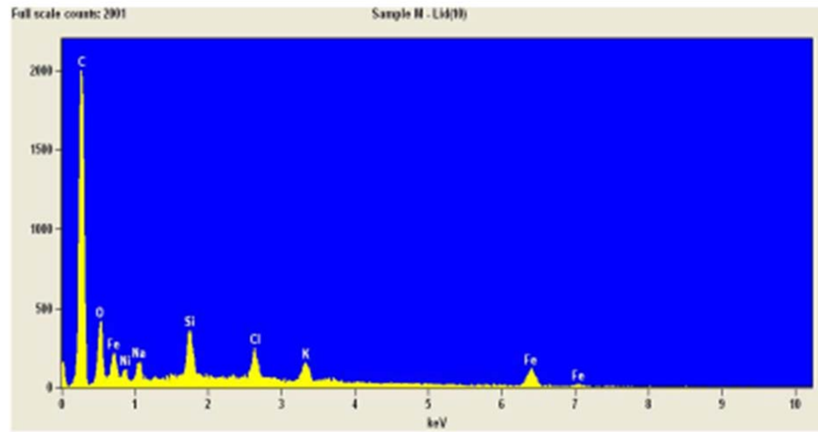
- **Hermetic Failures**

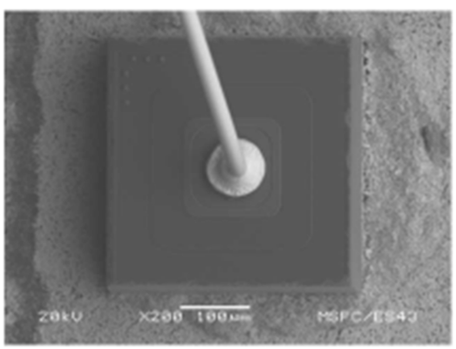
Evidence of corrosion with reduced electrical stability



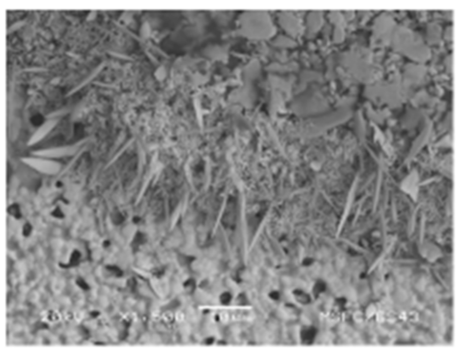
Examination of a representative Ag_2S corrosion area

Elemental analysis provides evidence of ionic contamination and corrosion

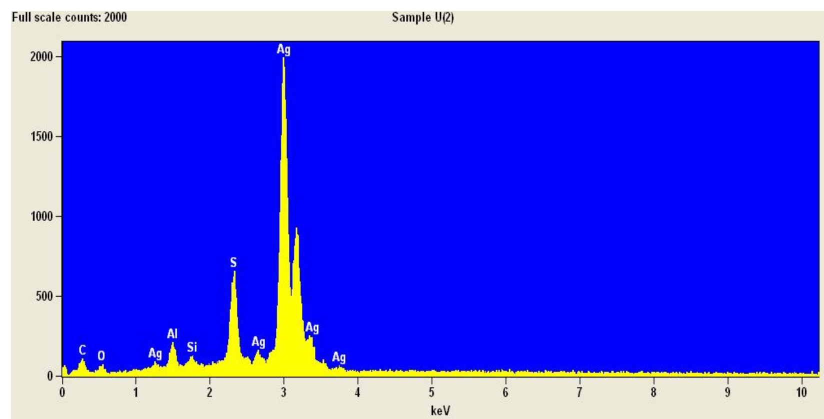




Die and bond area at low magnification



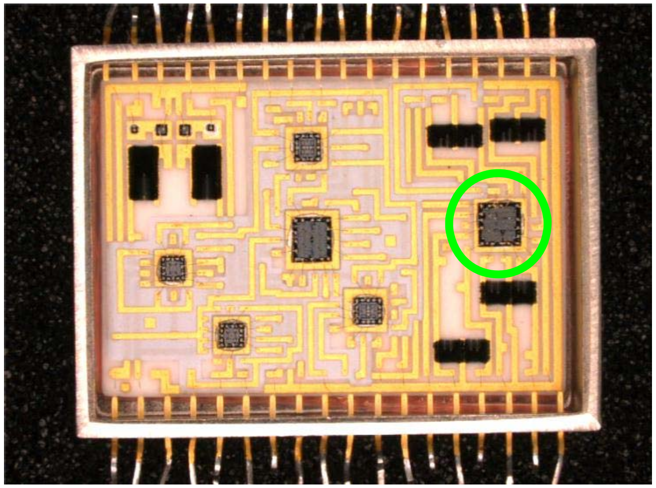
Evidence of heavy growth of Ag_2S along Ag die attach edge and bond pad

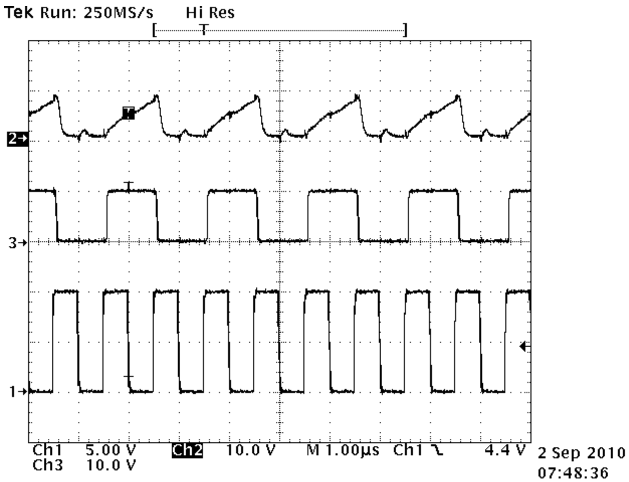


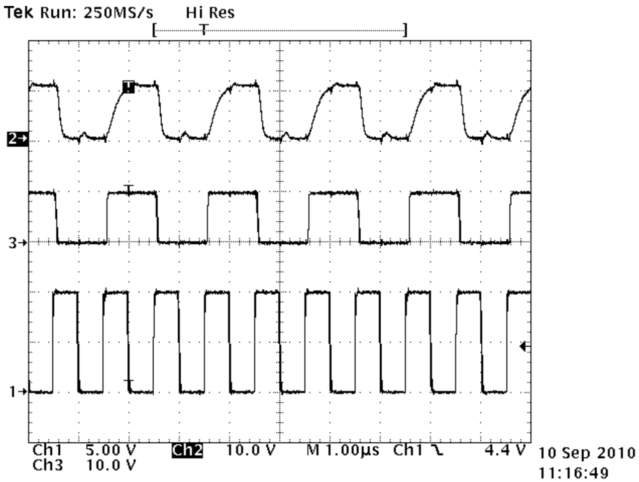
- **Surface Electrical Leakage**

  Electrical instability in the presence of ionic contamination and moisture

- Failure: MDM Module in an IEA (2009)
- Isolated: 8-bit CMOS Shift Reg. Die (LDC 8222)
- Electrical Testing
  - As Received
  - 24 hr Bake Out @ 125°C

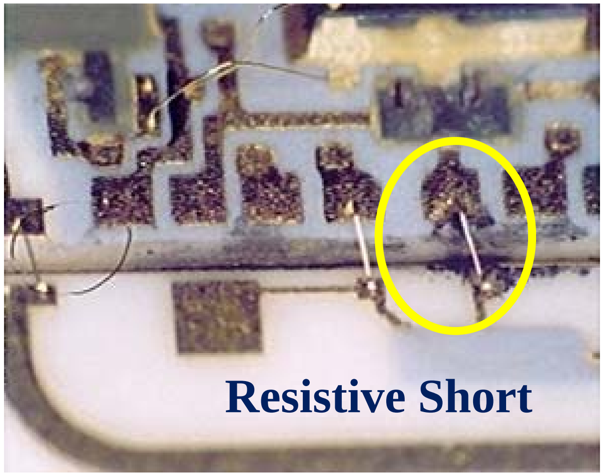






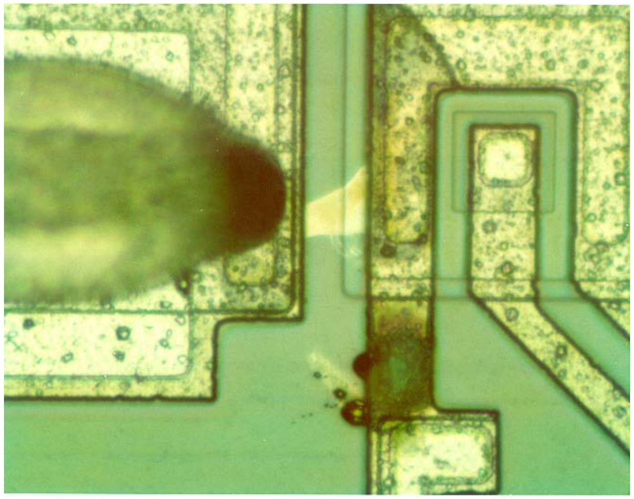
- **Dendritic Growth**

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



- **Surface Arcs**

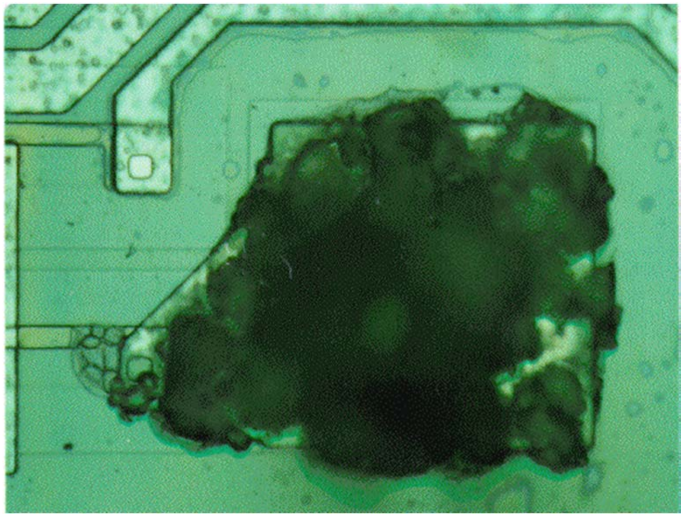
Usually occur over a 300V transient but are dependent on surface glassivation and moisture

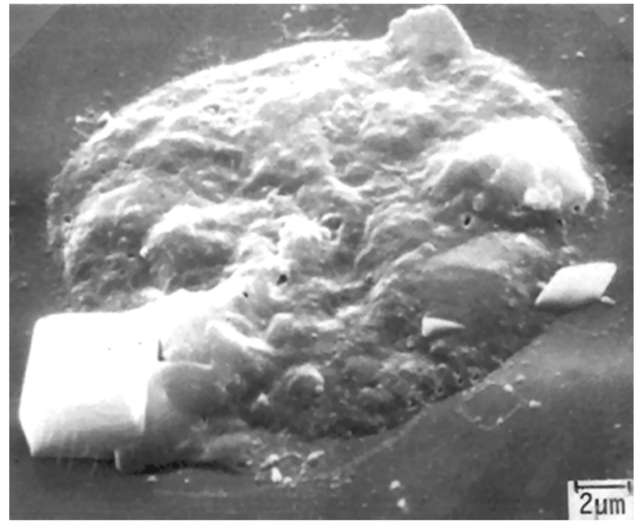


HERMETICITY 101

- **Corrosion**

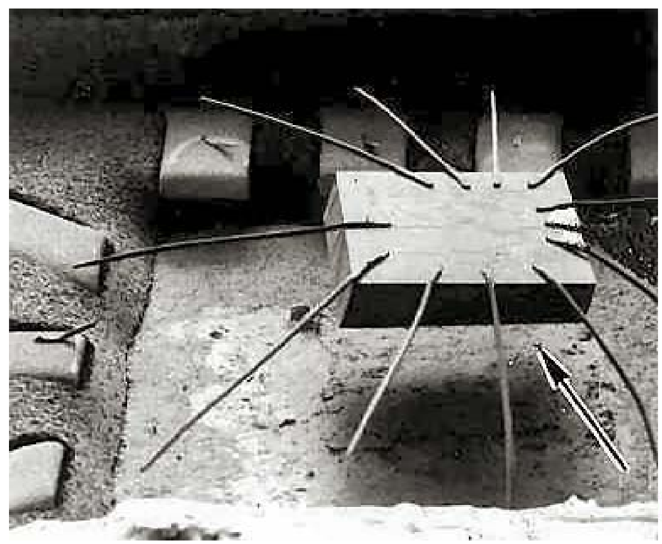
  Aluminum bond pad corrosion in the presence of ionic contamination and moisture



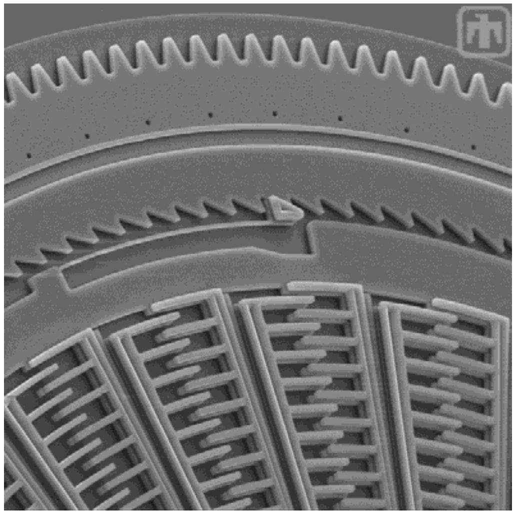


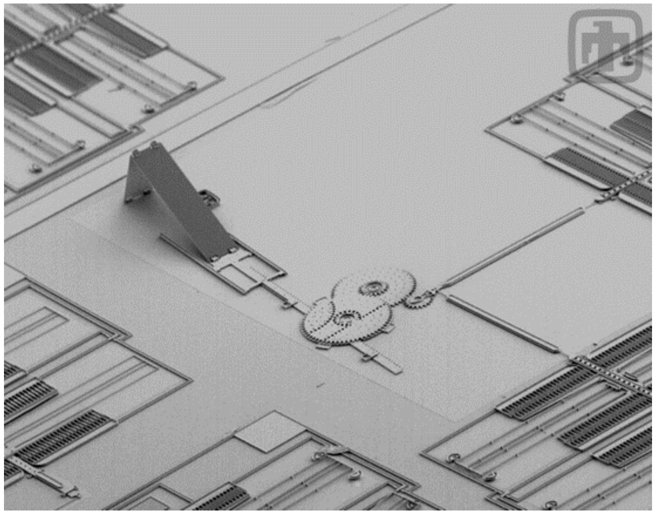
- **Die Lifting**

  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.

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 10-5 as being GROSS and smaller than 10-6 as being FINE.
- Three systems are used to non-destructively test: CHLD, KR-85, OLT
  - *CHLD, 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 and MIL-STD-750 for 1071 for discrete semiconductor devices

TASK OBJECTIVES

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

- Determine CHLD test equipment capability between NASA centers as well as correlation of test results with other equipment used for hermeticity testing (OLT, Krypton-85, IGA)
- 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)

Krypton-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, 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 GLT to detect gross leaks

Step 3

Test Parts Using CHLD, OLT, and Kr85 Equipment

- Order of testing was CHLD-MSFC, CHLD-GSFC, OLT - NorCom, Kr85–IsoVac, Kr85–MSFC, Kr85 Red Dye-IsoVac (if applicable)
- Exception: Set 1 T0-18 gross leakers were tested by CHLD-MSFC after OLT-NorCom

Step 4:

Test Parts With IGA 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

Kr85

- 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.

IGA

- ORS, Inc. tested in accordance with MIL-STD-750 TM1018
- TO-5, TO-18 IGA 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

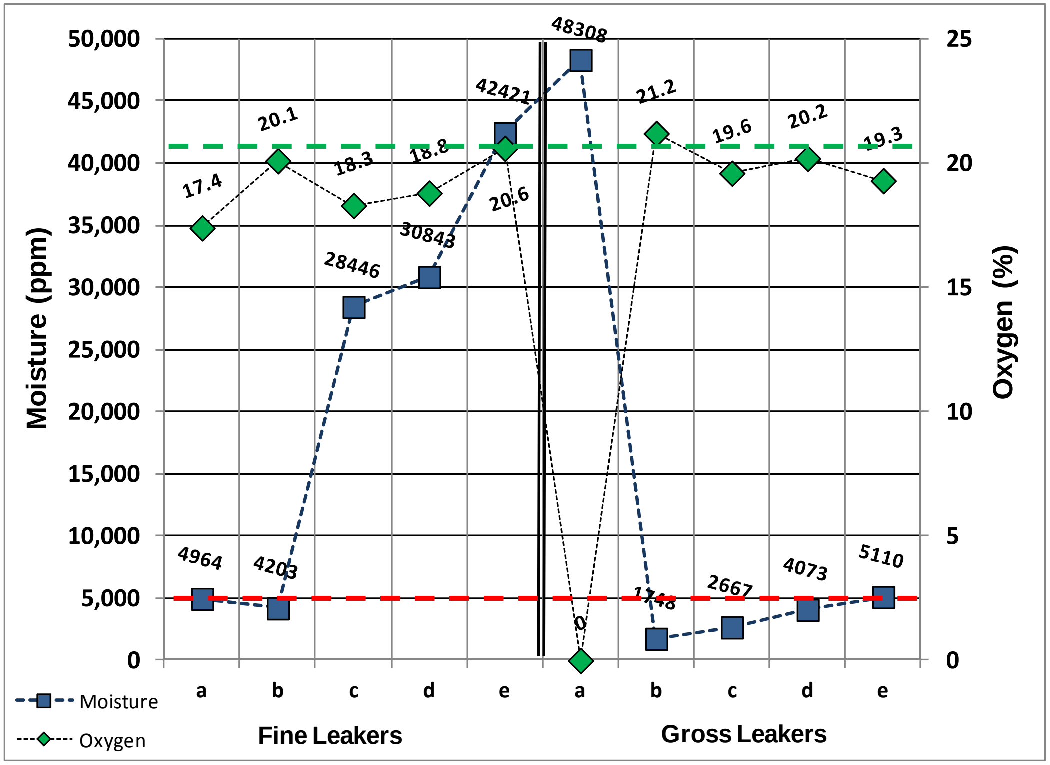
Legend for Correlation Data Tables

(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 grey)	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 (grey)	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 1×10^{-9} atm-cc/sec air



Test Result Summary

Gross:

- All instruments but OLT identified gross leakers per Mil-STD-750 TM's
- 5/10 RGA moisture under ppm failure criteria but indicated atmospheric exchange (Note: 883 would have passed these 4)
- 100% correlation between Kr85, CHLD, IGA.

Fine:

- Parts are plugged. Initially Kr85 was able to detect leakers subsequent CHLD, OLT, Kr85 testing could not.

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.

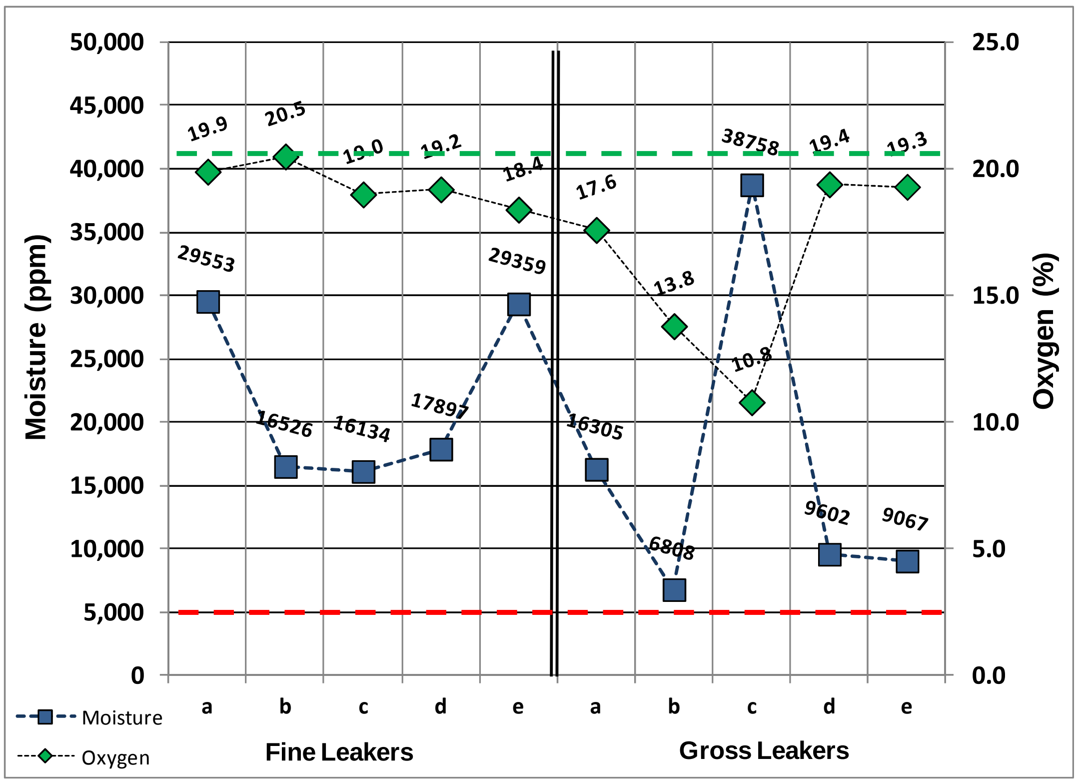
Storage

- 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

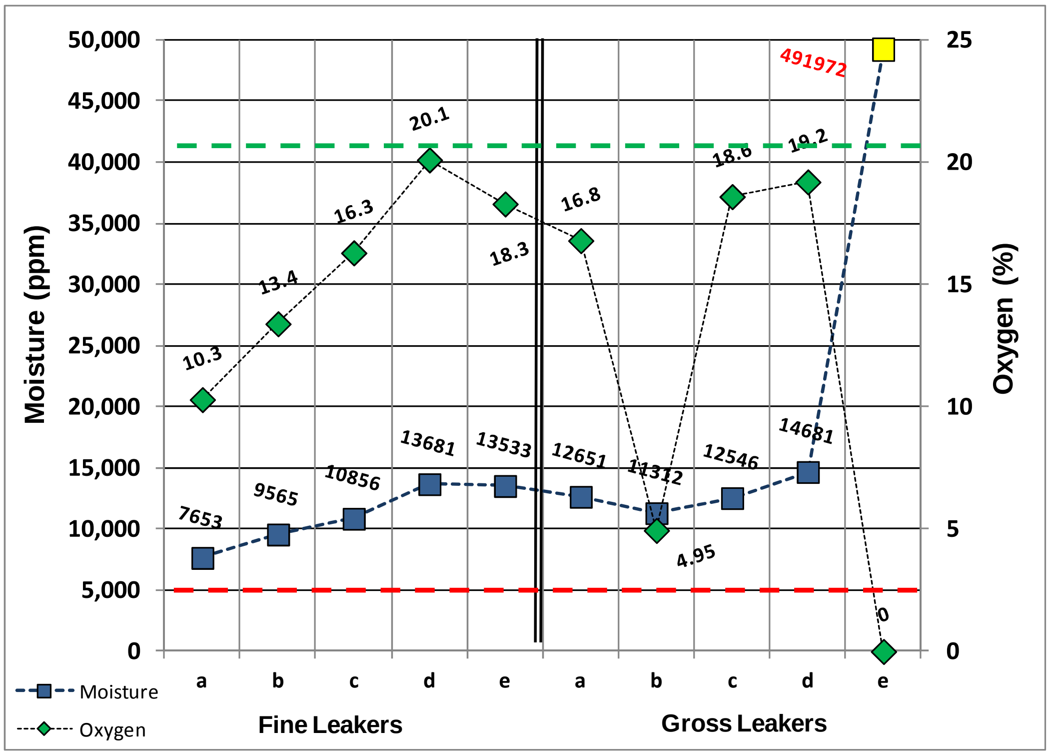
Fine:

- 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						Order of Testing	Gross					
		a	b	c	d	e	Results		a	b	c	d	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
	IsoVac	P	P	P	P	P	*0/5*	IsoVac	P	P	P	P	P	*0/5*
Kr85	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 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 Kr85.
- 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/Kr85 data for TO-18 packages and one gross TO-5 package.
- If OLT data was omitted, the results in this study correlate in regards to segregating failed devices and plugging.
- OLT could not 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 IGA 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 and/or completely plug at anytime.
- The mechanism of plugging requires more study to determine root cause.

IGA

- 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.

IGA

- 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

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.

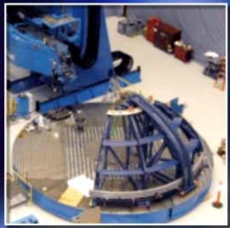
Status

- 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 Kr85 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 specification for gross leak qualification is invalid as written and evaluate smaller diameter holes to determine optimum size.
- Evaluating the Kr85 red dye gettering efficiency which is used to test small volume packages that fail the 5mil hole criteria in the test methods 5, 4, and 3 mil size sample holes will be drilled in-house for testing.

NEPP Program Task 14-294: Joint Hermeticity Correlation Study

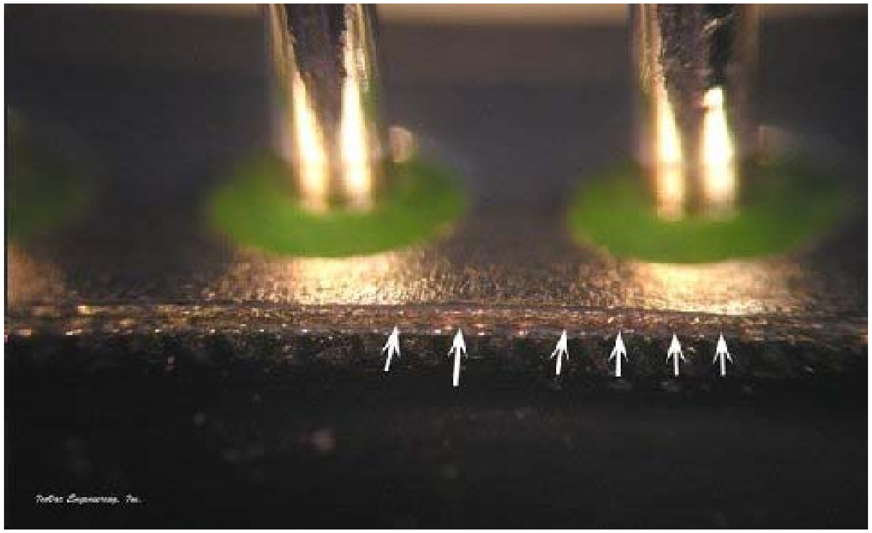
Questions?

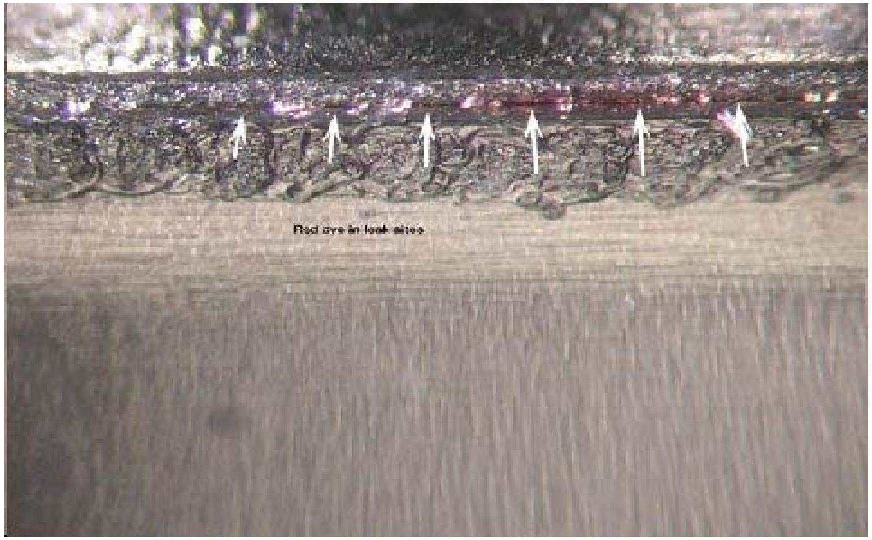


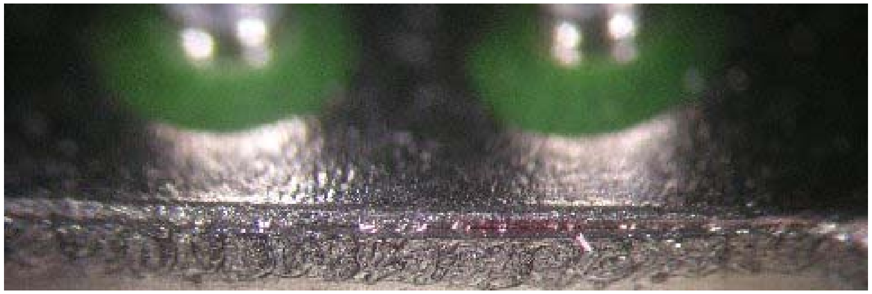



Plugging Mechanism

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.

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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

<table>
<tr><th rowspan="2">Mark V
System Parameters</th><th rowspan="2">Leak Test</th><th colspan="3">Bomb Conditions</th></tr>
<tr><th>TO-18</th><th>T0-5</th><th>UB</th></tr>
<tr><td rowspan="2">SA = 230 µCi/atm-cc
K = 14,444 CPM/µCi
R = 500 CPM</td><td>Gross</td><td colspan="3">75 psia @ 0.03 hours</td></tr>
<tr><td>Fine</td><td>Q_s = 2.9 X 10^{-9} atm-cc/sec Kr
P = 75 psia
T = 0.57 hrs</td><td colspan="2">Q_s = 5.8 X 10^{-10} atm-cc/sec Kr
P = 75 psia
T = 2.87 hrs</td></tr>
</table>

Raw Data: Kr85

			Kr 85							
		Sample #	IsoVac			IsoVac Red Dye		MSFC		
			atm-cc/sec Kr	atm-cc/sec Air				atm-cc/sec Kr	atm-cc/sec Air	Judgement
Set 1	Fine	a	PASS	PASS	P	PASS	PASS	PASS	PASS	P
TO-18		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:*
    - ❑ $\leq$ 0.002 cc: 5 X 10^{-10}
    - ❑ > 0.002 and $\leq$ 0.02 cc: 1 X 10^{-9}
    - ❑ > 0.02 and $\leq$ 0.5 cc: 5 X 10^{-9}
    - ❑ > 0.5 cc: 1 X 10^{-8}
- **MIL-STD-883J, Test Method 1014.14 “Seal”**
  - *Equivalent standard leak rates (atm cc/s air) for volumes:*
    - ❑ $\leq$ 0.05 cc: 5 X 10^{-8} except 1 X 10^{-9} for Hybrid Classes S and K
    - ❑ > 0.05 and $\leq$ 0.4 cc: 1 X 10^{-7} except 5 X 10^{-9} for Hybrid Classes S and K
    - ❑ > 0.4 cc: 1 X 10^{-6} except 1 X 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.

MIL-STD-883 TM 1014 Leak Rate Limits

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 = 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.

MIL-STD-883 TM 1014 Leak Rate Limits (yellow)

MIL-STD-750 TM 1071 Leak Rate Limits (green)