“Inadequacy of traditional test methods for detection of non-hermetic energetic components”
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The Authors Competency

- Many decades of experience in leak detection and failure analysis
- Manufacture of ordnance devices
- Fundamental research in ordnance device designs and performance
- Academic research in leak testing theory and application
- Preparation of Military Standards & Commercial Test Specifications
The Hermeticity Test Problem

- Poor understanding of leak test theory
- Misapplication of test methodologies
- Failure to understand device geometry
- Committing to traditional practices
- Ignoring MIL-STD limitations
- Lack of Field Feedback
- Inferior failure analysis
- Weak Statistical recordkeeping
The Hermeticity Callouts

Most Ordnance Devices have “Seal-Test” callouts of:

Visible to $5 \times 10^{-6}$ std cm$^3$/sec
(The “Gross-Leak Rate Range”)

Many Ordnance Devices have Small & Zero-Cavities that are:

$0.01$ cm$^3$ through $0.000001$ cm$^3$
Test Methodology Reviewed

Helium Mass Spectrometry

Radioisotope Test Method

Red Dye Penetrant Failure Analysis
Typical Leak-Rate Distribution

Over 98% of leakers
Test Methods

Helium ‘Mass-Spec’ leak test method, (HMS)

- Being misapplied for “Gross-Leak” testing
- Requires “Caution” with small ordnance devices
- MIL-STDs limit HMS to Fine leak testing only, and not allowed for Gross leak testing.
- Unreliable to detect “gross leaks” in “Small & Zero-Cavity” devices
Helium Mass Spectrometry

“Back-Pressurization”

- Various bomb times and pressures
- Parts measured Individually
- Parts are evacuated prior to measurement
- Helium is lost during evacuation

Tracer-Gas loss During Evacuation:

0.0001 cm$^3$ cavity with $10^{-4}$ std cc/s leak

- 99.99% of Helium tracer gas in 10 sec.
Helium Mass Spectrometry

A “Leakage passage” Usually has short length and a ‘passage’ volume: < 10^{-5} cm^3

Therefore: With a 10^{-4} cm^3/s leak rate:
“Helium is gone in Less than 1 second”. Then: Detectable helium is only from:
“Interparticulate” cavities or “He Dissolved in Binders”, very slowly released.
Result is an “Indicated-Leak” less than the spec, and an “escaped leaker”.
Radioisotope (Kr85) leak testing

- Called out in MIL-STDs for Gross & Fine leak testing
- Testing small (0.02cm$^3$) to large cavities.
Radioisotope Test Method

“Back-Pressurization”

0.01% Kr85 tracer-gas mixture

Measured “In-Place” (In Device Cavity)

Detectability: ~ $10^{11}$ molecules Kr85

Bomb Times:

“Gross-Leaks” ~36 sec. (> $5 \times 10^{-6}$)

“Fine-Leaks” ~6 min.
Technical theory of the test

- The gamma rays from Kr85 gas trapped within a leaker, will penetrate the walls of normal devices, and are easily detected by the scintillation crystal at the counting stations.
Dye Penetrant Failure Analysis

Purpose

- Verification of gross leakage
- Detectability to $\sim 1 \times 10^{-7}$ std cm$^3$/s
- Isolation of leak sites
  - Glass header cracks
  - Glass-to-metal seals
  - Weld defects
- Destructive test
Vacuum Decay Equation

\[ P_t = P_o e^{-kt} \]

Where:
\[ P_t \] = Partial press Kr85 at time “t”
\[ P_o \] = Original partial press Kr85
\[ k \] = leak rate (std \( cm^3/s \))
\[ cavity \] vol. \( cm^3 \)
\[ t \] = time in vacuum (sec)
The “Gettering” Technology

“Charcoal Gettering” of Kr85
1. Steam Activated Charcoal
2. High surface area: 500m$^2$/gm
3. Mixed with ordnance
4. One Particle of Charcoal:
   0.003” size, 0.243 µgm, vol. $\sim 10^{-7}$ cm$^3$

“Provides 133 mm$^2$ surface area”.
“Gettering” of Kr85

“Steam-Activated Coconut-Shell Charcoal”

1. “Adsorbs” Kr85 tracer gas
2. Holds Kr85 by van der Waals forces
3. Does not effect ordnance materials
4. Adsorbs 27% by wt of water
5. Assures detection of ‘wide open leak’
6. Used in 50+ million Ordnance parts/year
Leak Test Standards

MIL-STD-883
MIL-STD-750
MIL-STD-202
MIL-STD-S-19500
MIL-13474c-Squibs
S-113 Ordnance

+ Others, (Military & Company Specs)
Mostly: based on MIL-STD 202
Leak Test Ranges for U.S. Specification Callouts

**Mil Std. 883**

- **Bubble or Dye Penetrant Test**
- **Helium Test**
- **Radioisotope Gross Leak Test**
- **Fine Leak Test**

Leak Test Ranges:

- **Gross Leak**: 0 to $10^{-5}$
- **Fine Leak**: $10^{-8}$

Leak Rate std-cc/sec
Leak Test Ranges for U.S. Specification Callouts

Mil Std. 750

Bubble or Dye Penetrant Test & Helium Test
Radioisotope Gross Leak Test & Fine Leak Test

Leak Rate std-cc/sec

Gross Leak: 0
Fine Leak: $10^{-5}$
Leak Test Ranges for U.S. Specification Callouts

- **Bubble or Dye Penetrant Test**
- **Helium test**
- **Radioisotope Test**

Leak Test Ranges:

- **Gross Leak**
- **Fine Leak**

Leak Rate std-cc/sec

- $10^{-5}$
- $10^{-8}$
Leak Test Ranges for U.S. Specification Callouts

MIS-13474C (Missile Inspection Systems-Squibs)

Radioisotope Gross Leak Test

Radioisotope Fine Leak Test

Gross Leak 10^-5 Fine Leak 10^-8

Leak Rate std-cc/sec

May 9-11, 2006  Presented @ 50th Annual NDIA Fuse Conference, Norfolk, VA
Red-Dye in “Header Gross-Leak”
Header Leaks

The feed through shown above has several radial cracks from the pin out to the header body.
The stresses in this glass were viewed with polarized lens, and the stresses were evident before it was welded into an initiator.
It failed a Radiflo gross leak test and was red-dye bombed.
The ‘back-lighted’ photomicrograph clearly shows the radial cracks.
Pin-Glass “Gross-Leak”

- Pin
- Glass
- Header
- Bridge-wire
- Red-Dye penetrant
Pin-Glass Gross Leak

The glass to metal feed-through above was found in an initiator with a gross leak. The device had passed a misapplied helium leak test. It was detected using Kr85 and an extended bomb time. The device was red-dye bombed and opened. The red-dye shows gross leakage around the pin. Note the bridge-wire is wetted with red-dye.
“Pin-Glass Gross-leaks”
Pin-glass gross leak

The photomicrograph above shows red-dye leaking into an initiator around the pin. This device passed a misapplied helium leak test and was failed using Kr85 with an extended bomb time. The initiator was red-dye bombed and opened. There is red-dye leaking in around the pin. There is also corrosion seen on the pin surface.
“Fungus-Growth” on Ordnance
The above photomicrograph shows fungus growing on the surface of a compressed ZPP charge.

This device had passed a helium leak test, and was failed on a radioisotope gross leak test with an extended bomb time.

When the device was opened, the powder appeared to be moist, and showed fungus growth.

The device was less than two years old.
Charcoal mixed in ordnance

Bridge-Wire Impression

Charcoal Particles

Compressed ZPP
Impulse Cartridge
Non-Functional Cartridge

The cartridge shown above and below, is a BBU cartridge built for the Air Force less than two years ago.
This was one of several defects in one lot.
The device had an open circuit.
Tear-down showed a completely corroded bridge-wire.

A complete presentation of the findings on these devices will be presented at the AIAA Joint Propulsion Conference in Sacramento, July 2006
Residue of corroded bridge-wire
Need to Establish a Guaranteed Leak Test Method

- **Leak testing of energetic products** is inherently more complicated than a simple vacuum decay equation implies.

- Need to **research known leakers** with proposed approach to ensure that the method works.
  - Investigate devices with known leaks in **glass-to-metal seals** and **defective welds**.
  - Verify that the method can detect such leaks.
Use of Academia

University of Idaho has developed some

Unique Engineering Capabilities

Fully equipped for “Fundamental Research”

- Skilled in Ordnance technologies
- Sophisticated Ballistic testing
- All leak testing methodologies
- Hermetic seal mechanics studies
- Gas and Moisture transfer through leaks
- Ordnance material behavior