Gas and Moisture Transport through Non-Hermetic Glass-to-Metal Bridge-Wire Initiator Seals

51st Annual Fuze Conference
May 22nd – 24th, 2007
Nashville, Tennessee

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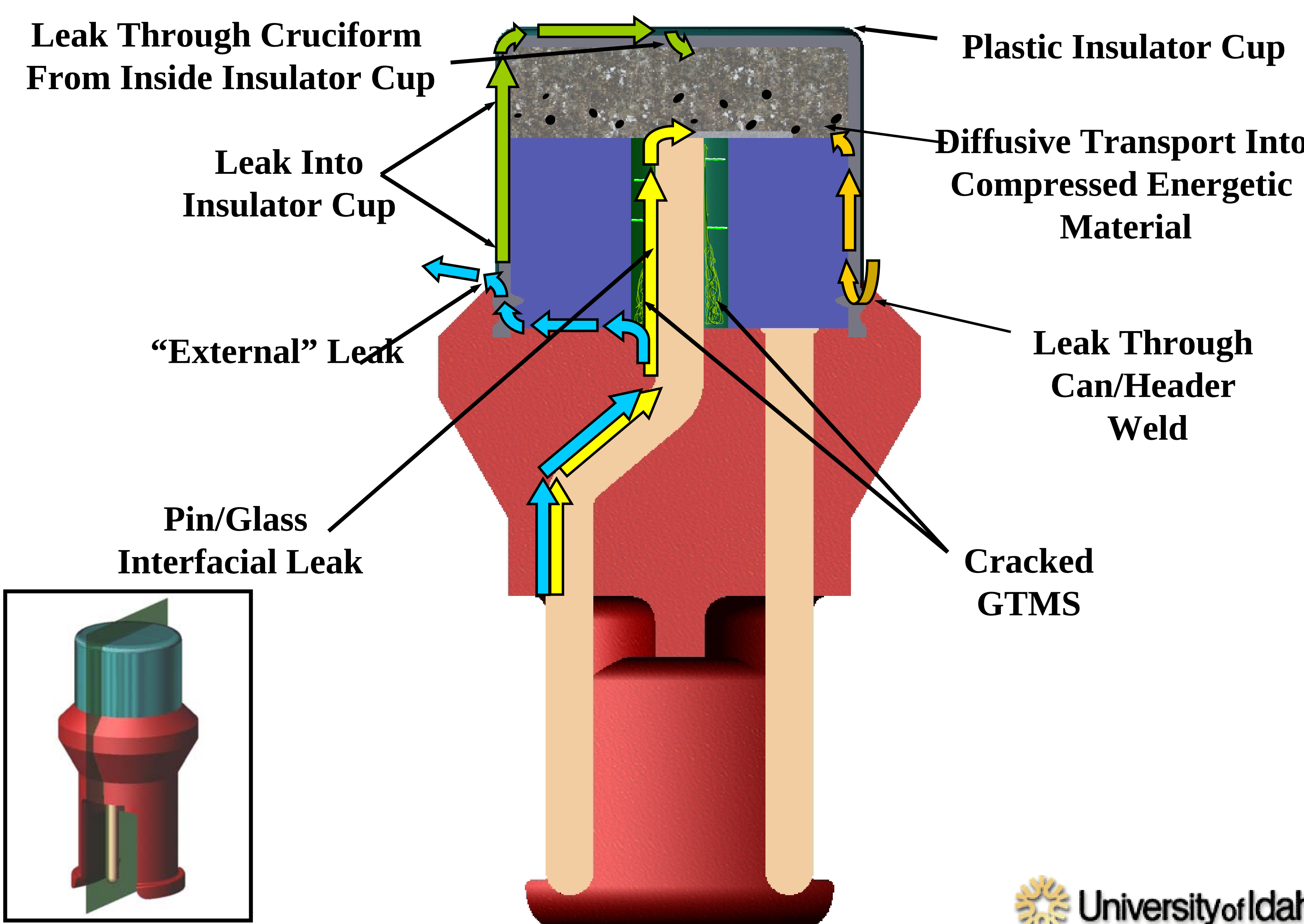
Introduction

Bridge Wire Initiators Are Leak Checked With The Intention of Ensuring Hermetic Devices.

- **Possible corrosion of the bridge-wire, electrical pins, and degradation of energetic materials are of primary concern.**
- **Miniscule "free" volume characteristic of these devices makes leak rate determination difficult, and special precautions must be taken to ensure validity of leak rate measurements.**
- **Initiator leak rate specifications may vary depending on the application, but are *typically* not to exceed 1×10^{-6} std atm cc/s helium.**
- **Of particular concern in bridge-wire initiators (and other electro-explosive and microelectronic devices) is the integrity of the glass-to-metal seals (GTMS).**

Bridge-Wire Initiators: Possible Leak Paths



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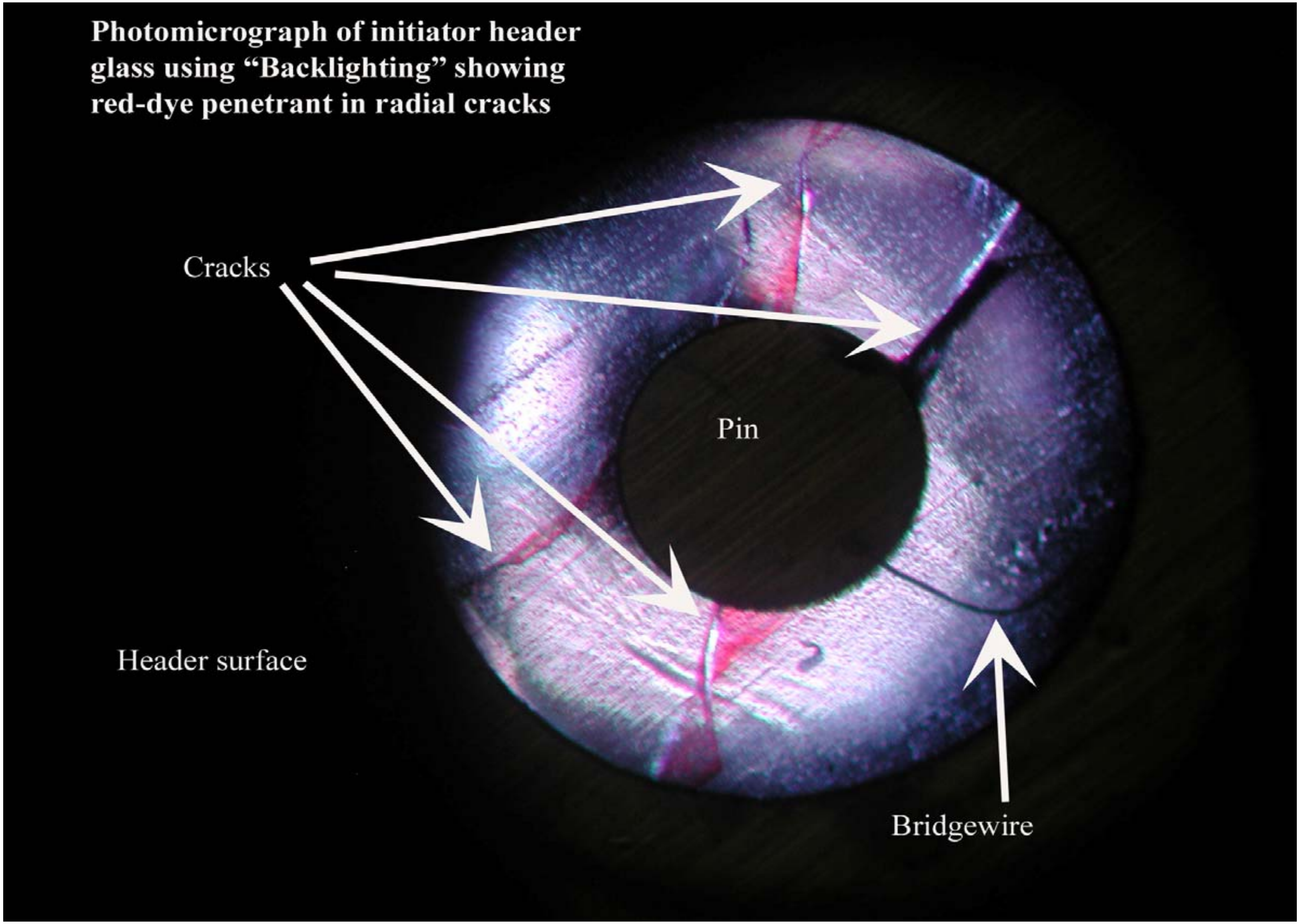
Motivation for This Research

Non Hermetic Initiators Have Been Found That Have Escaped Detection Using Helium Mass Spectrometry During the Manufacturing Process.

- Non-hermetic initiators identified using the Radiflo® process.
- Non-hermetic devices include those tested before application of synthetic over-molding as well as units returned from the field.
- Most of these occurrences can be linked to misunderstanding of leak rate theory and the inherent limitations and misapplication of helium leak detection methods.
- GTMS's are often found to display radial cracks and other flaws.
  - Radial cracks have been linked to thermal stresses induced during welding processes.
- What is the propensity for moisture transport through these cracks?

Example: Radial Cracks in GTMS



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Research Objectives

The Goals of This Work Include:

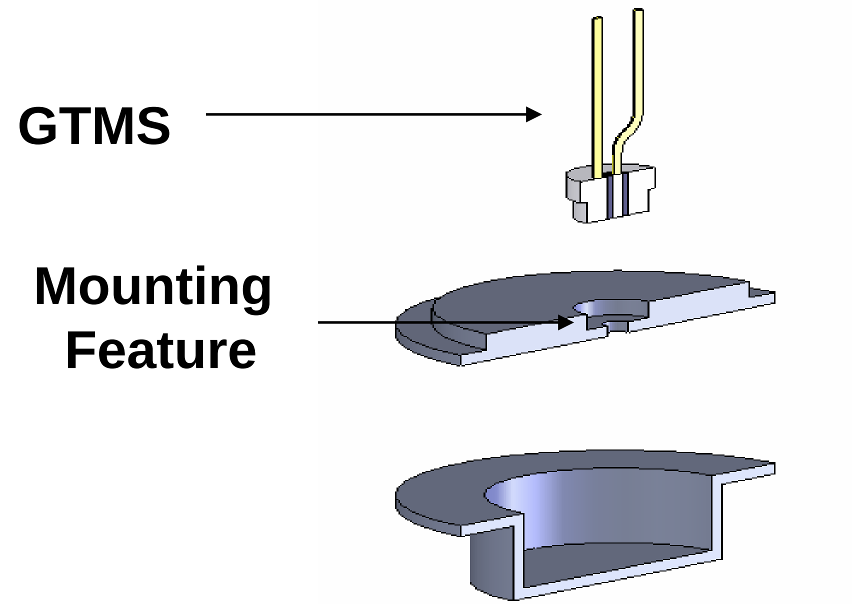
- Phase 1: Identification, characterization, and description of the leak paths found in bridge-wire initiator GTMS's.
  - Measure the leak rates through isolated GTMS's using krypton-85. (Radiflo®) and helium mass spectrometry (HMS) methods.
- Phase 2: Accurately model the relationship between dry gas and humid air transport rates through cracked GTMS's.
- Phase 3: Couple moisture transport rates with known relations for bridge-wire corrosion and pyrotechnic degradation rates.
- Phase 4: Provide a logical basis for leak rate specification in these devices.

Phase 1 Research:

Since Prior Work In This Area Is Limited, Work In Phase 1 Has Been Focused On The Following Topics:

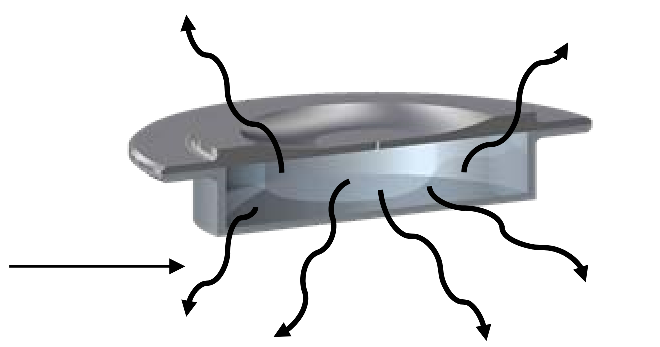
- **Identification, characterization, and description of the leak paths found in a large population of bridge-wire initiator GTMS's.**
  - **Leak rates of isolated GTMS's are measured using krypton-85 (Radiflo®) and helium mass spectrometry (HMS) methods.**
  - **Using simple and well-established viscous and molecular flow relations, assign "effective" areas for GTMS leak passages.**
  - **Check for "variable" and "directional" leaks as reported by prior researchers (Dermarderosian and Ginot, 1979).**
  - **After leak testing has been completed, subject each part to red-dye penetrant tests.**

Experimental Methods: Radiflo Test Fixture

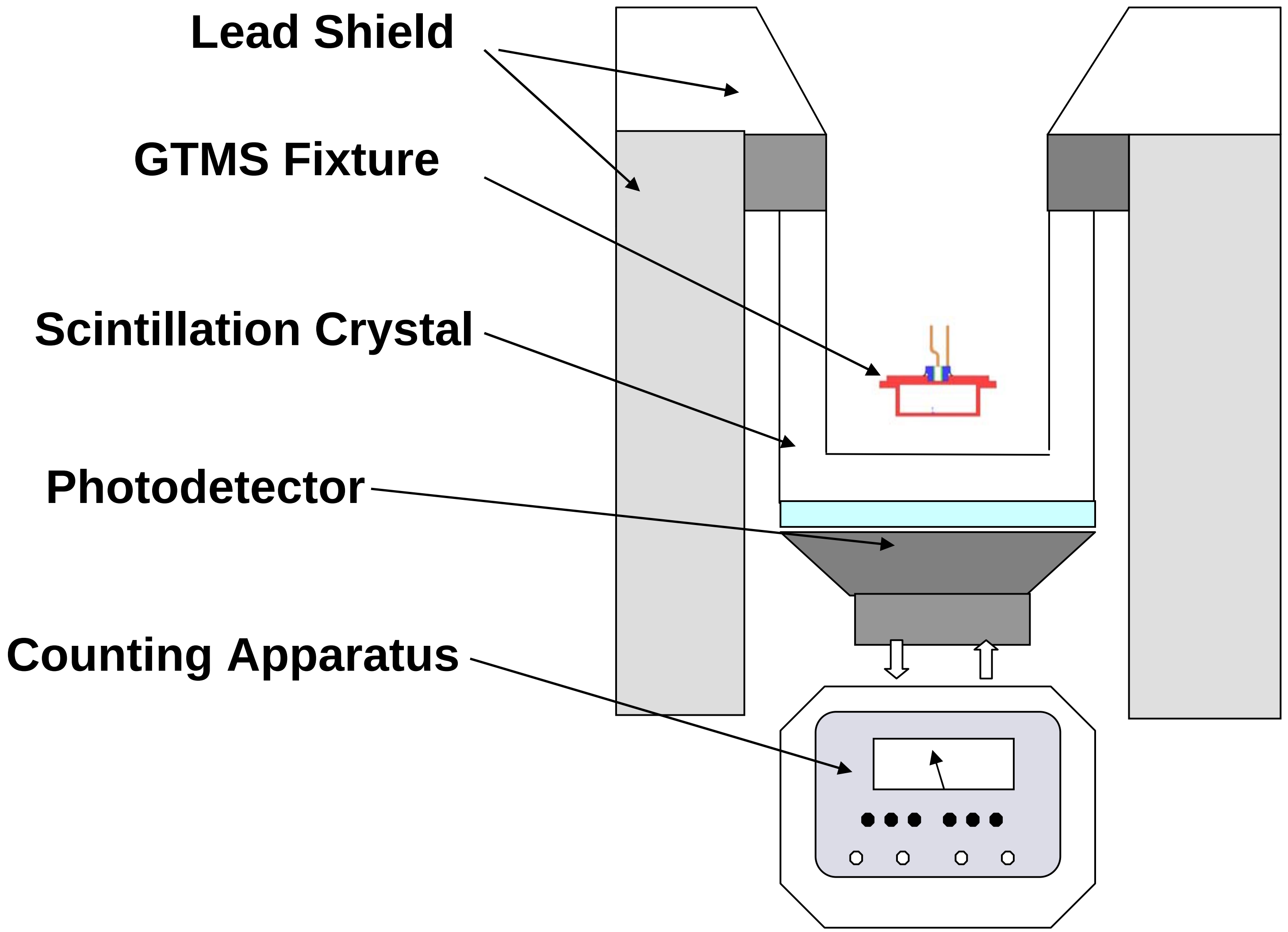


Individual GTMS's are mounted in special, laser-welded test fixtures. Components are then subjected to dilute mixtures of ^{85}Kr in air at specified pressures for known periods of time. Gamma rays are detected and can be related to the amount of gas introduced through the GTMS. Therefore the leak rate can readily calculated.

Gamma Rays

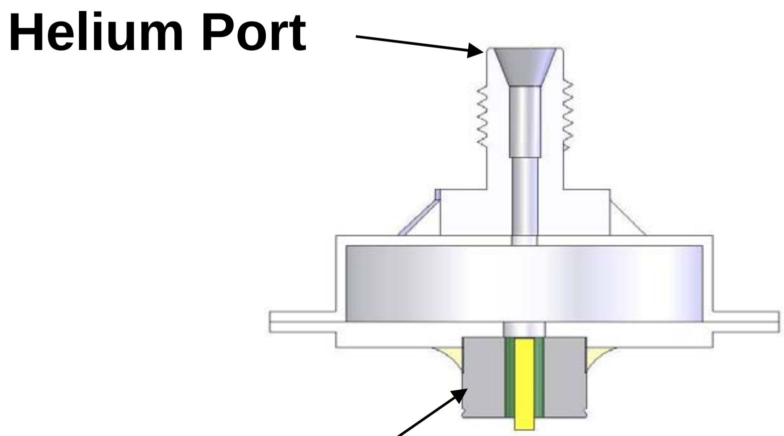


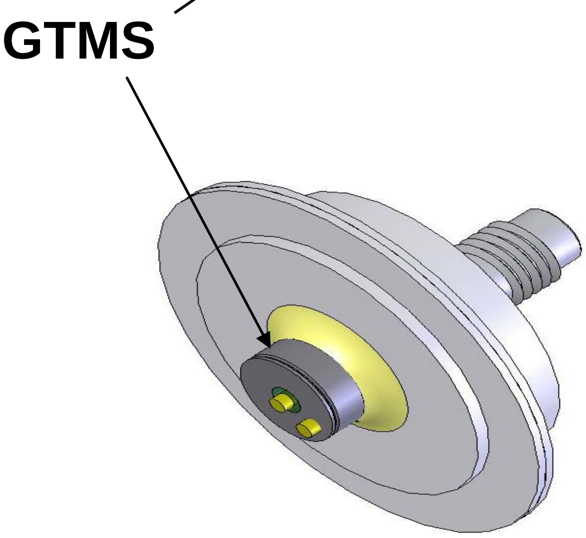
Experimental Methods: Scintillation Crystal



Experimental Method: HMS Test Fixture

Components are mounted in a similar fixture for HMS testing. Helium is supplied at constant upstream pressure while the downstream side of the GTMS is connected to the HMS. Helium leak rates can be measured directly.



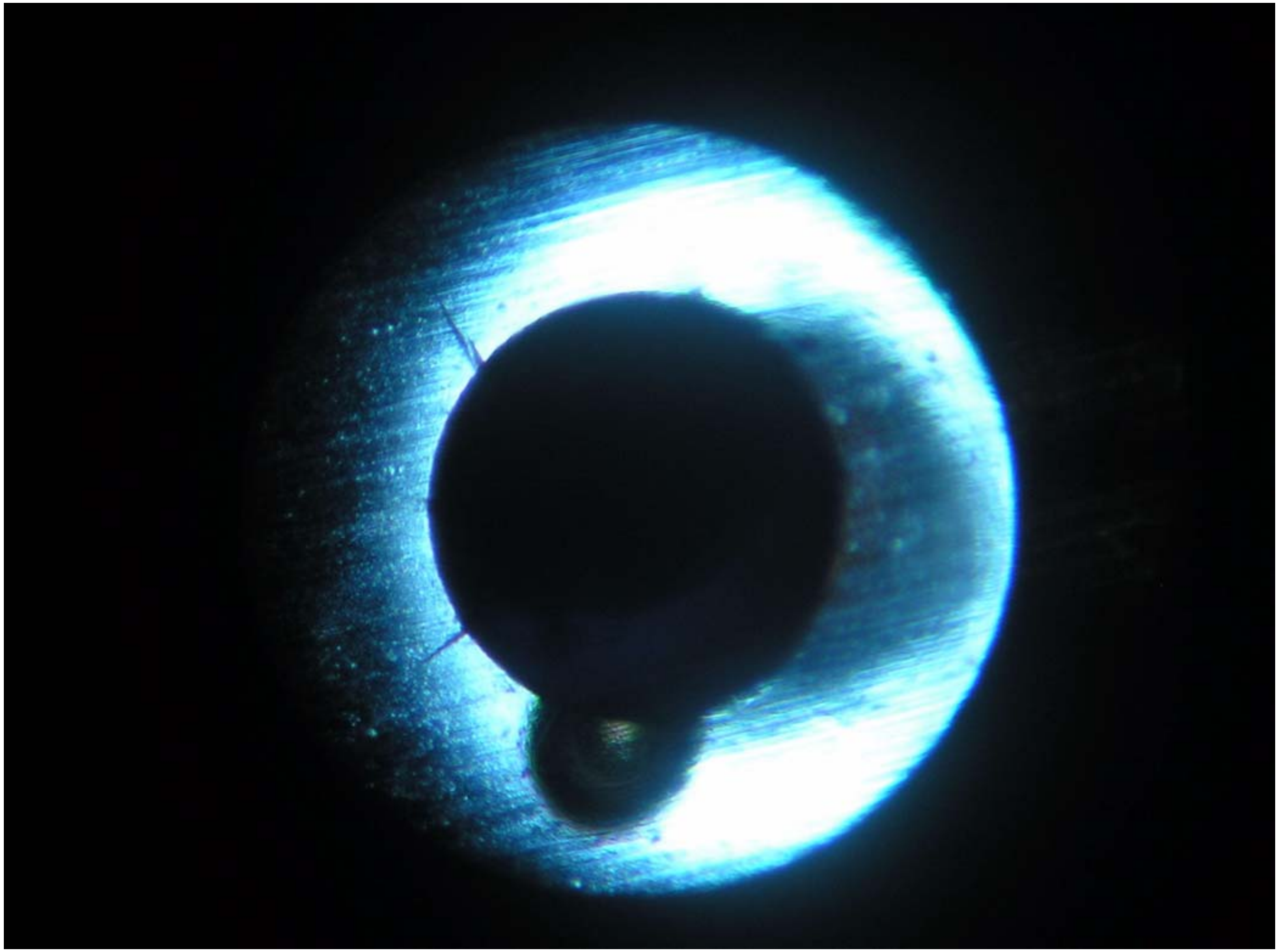


Both fixtures (the Radiflo® and HMS) allow seals to be mounted in either orientation to permit directionality testing.

GTMS Images: Part “A”

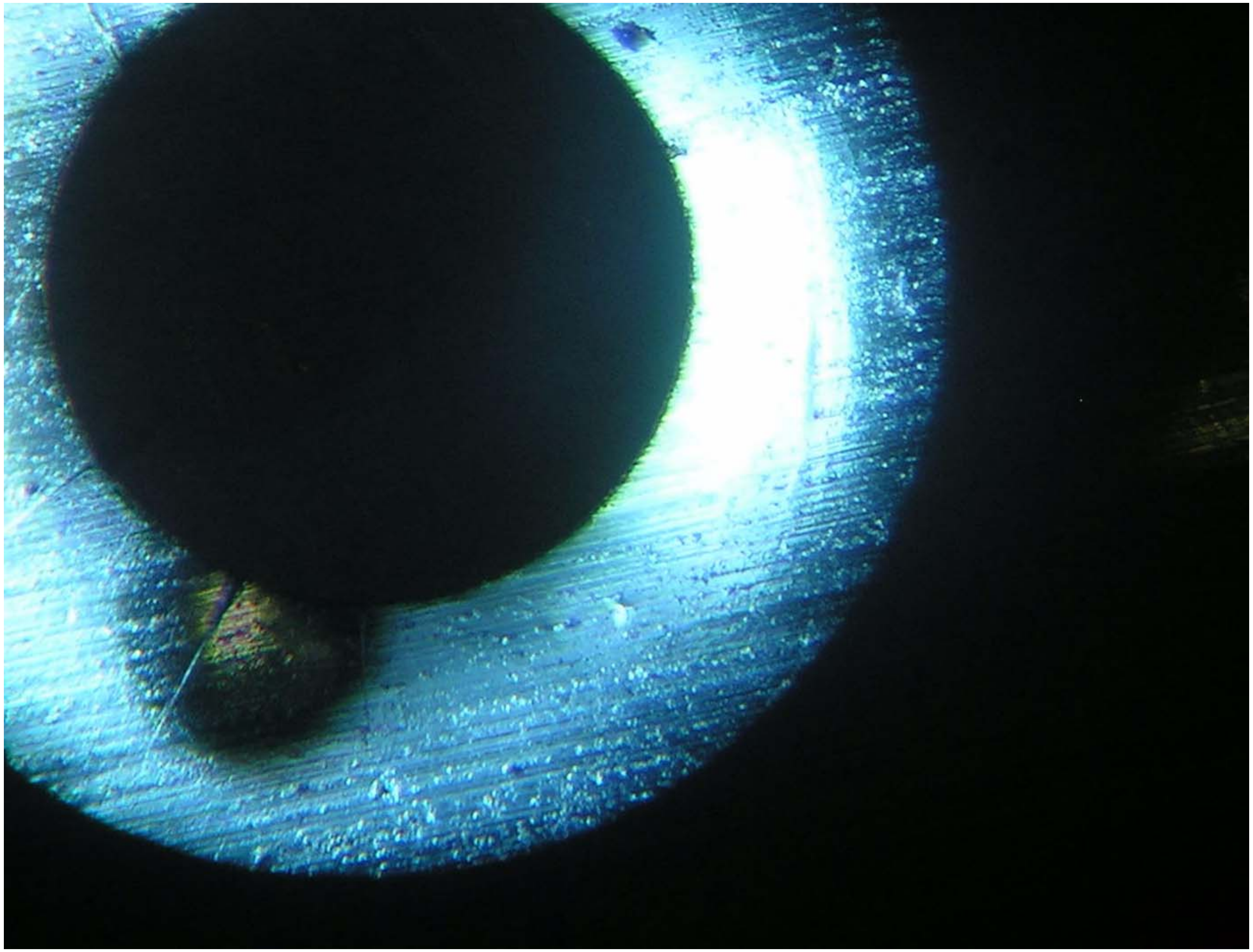
View From Electrical Pin Side

Two Large Radial Cracks and One “Anomaly” are Apparent



GTMS Images: Part “A”

View From Bridge-Wire Side
Note Crack in Glass at 7 O'clock Position



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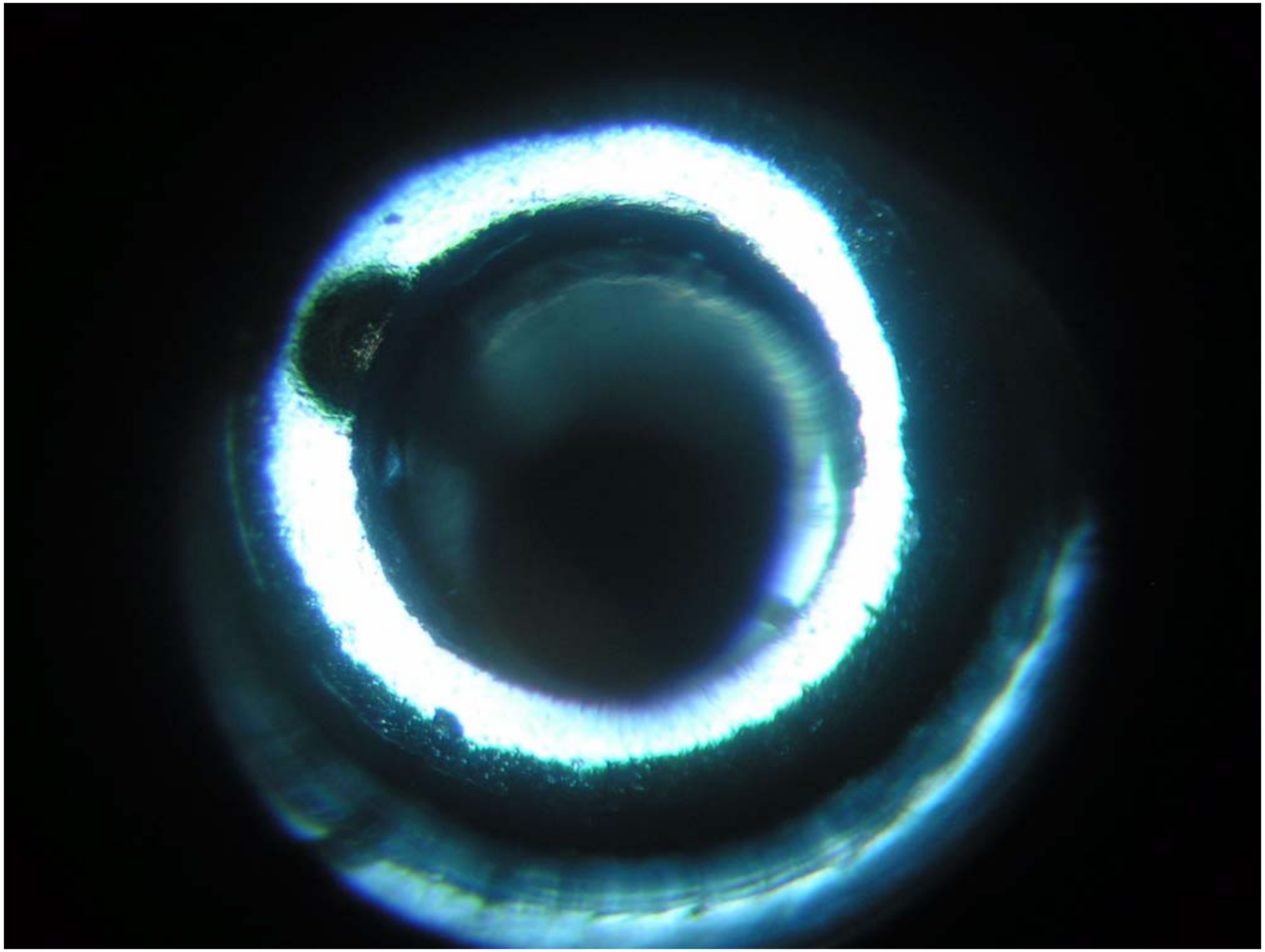
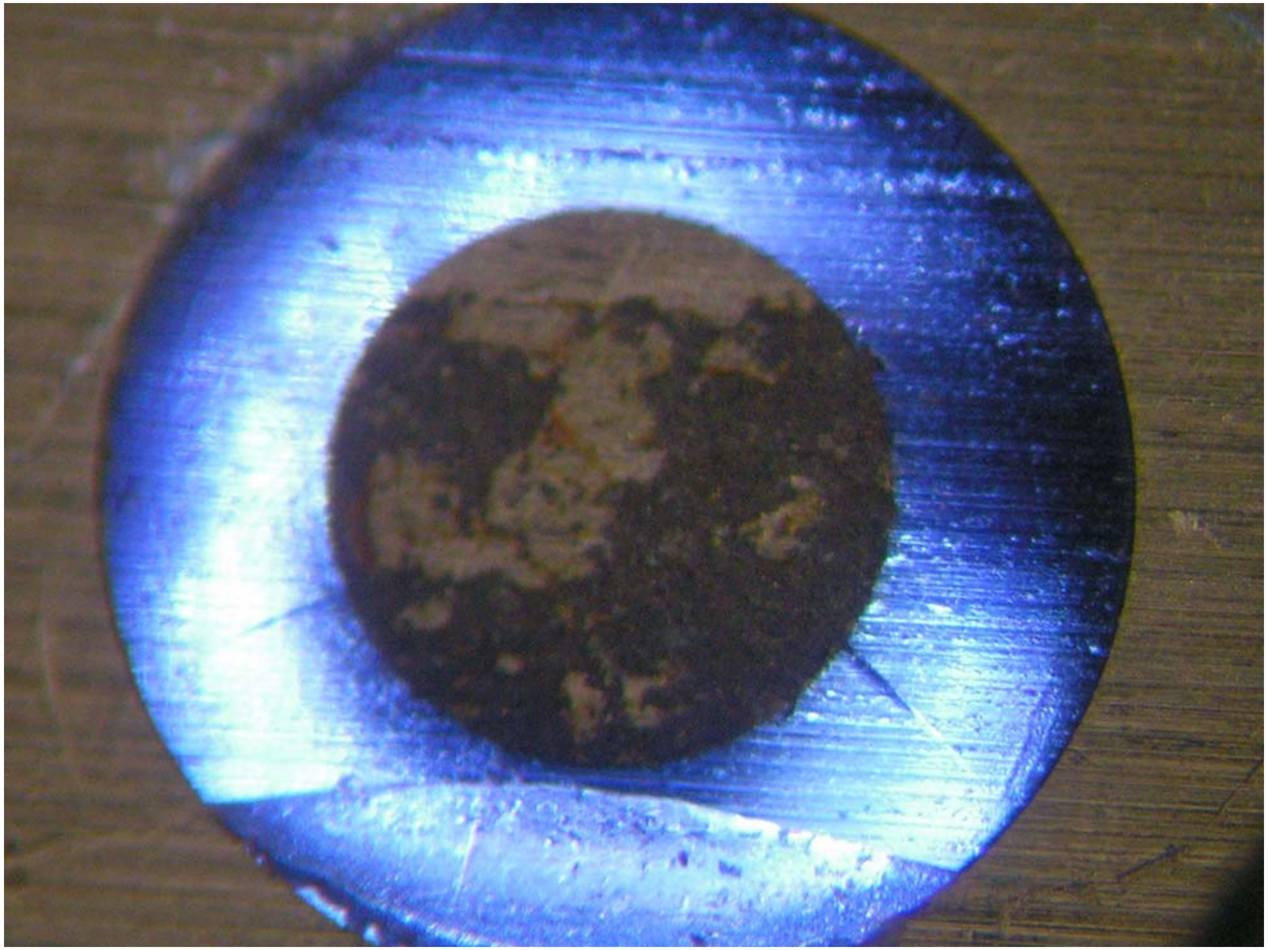
GTMS Images: Part "A"

View From Electrical Pin Side
Note Bubble in Glass at 10 O'clock Position



GTMS Images: Part "B"

View From Electrical Pin Side
Three Large Radial Cracks are Apparent



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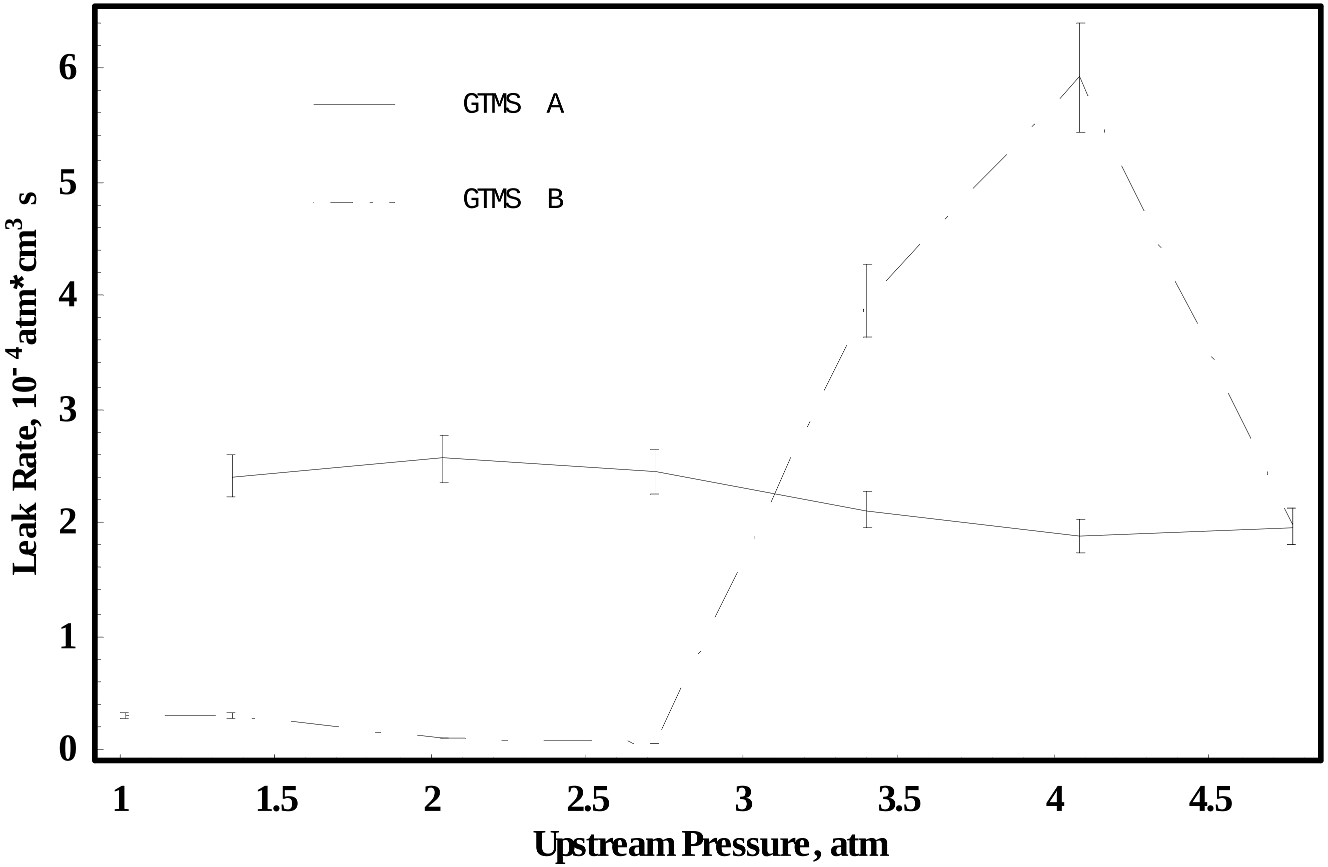
Helium Leak Rates: GTMS's "A" and "B"

Leak rates are in the viscous (gross) range.
GTMS "A" appears insensitive to upstream pressure
GTMS "B" varies in an apparently anomalous manner with pressure



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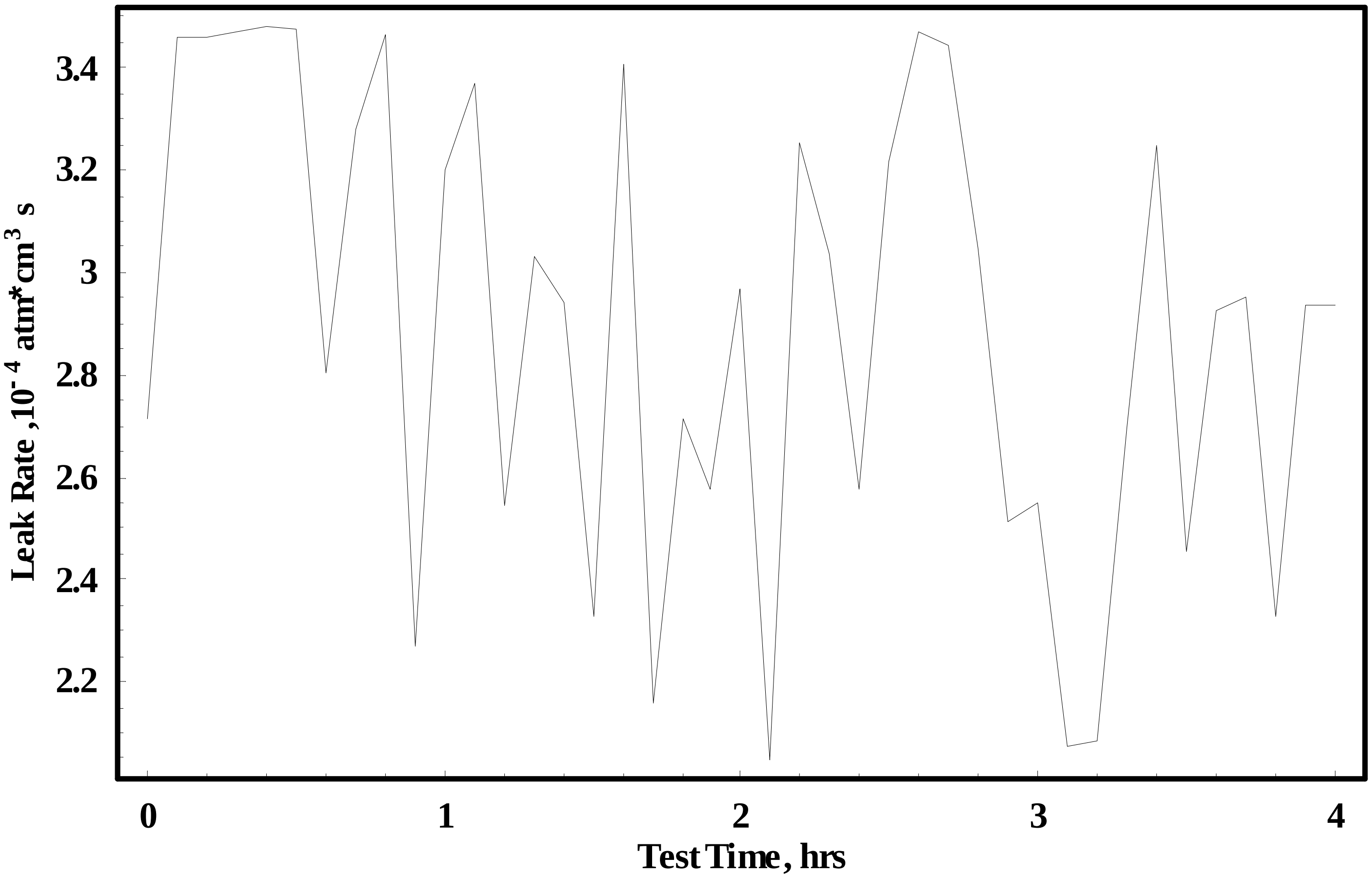
Helium Leak Rate: GTMS "A"

Leak rate over extended time period
Upstream pressure: 3 atmospheres



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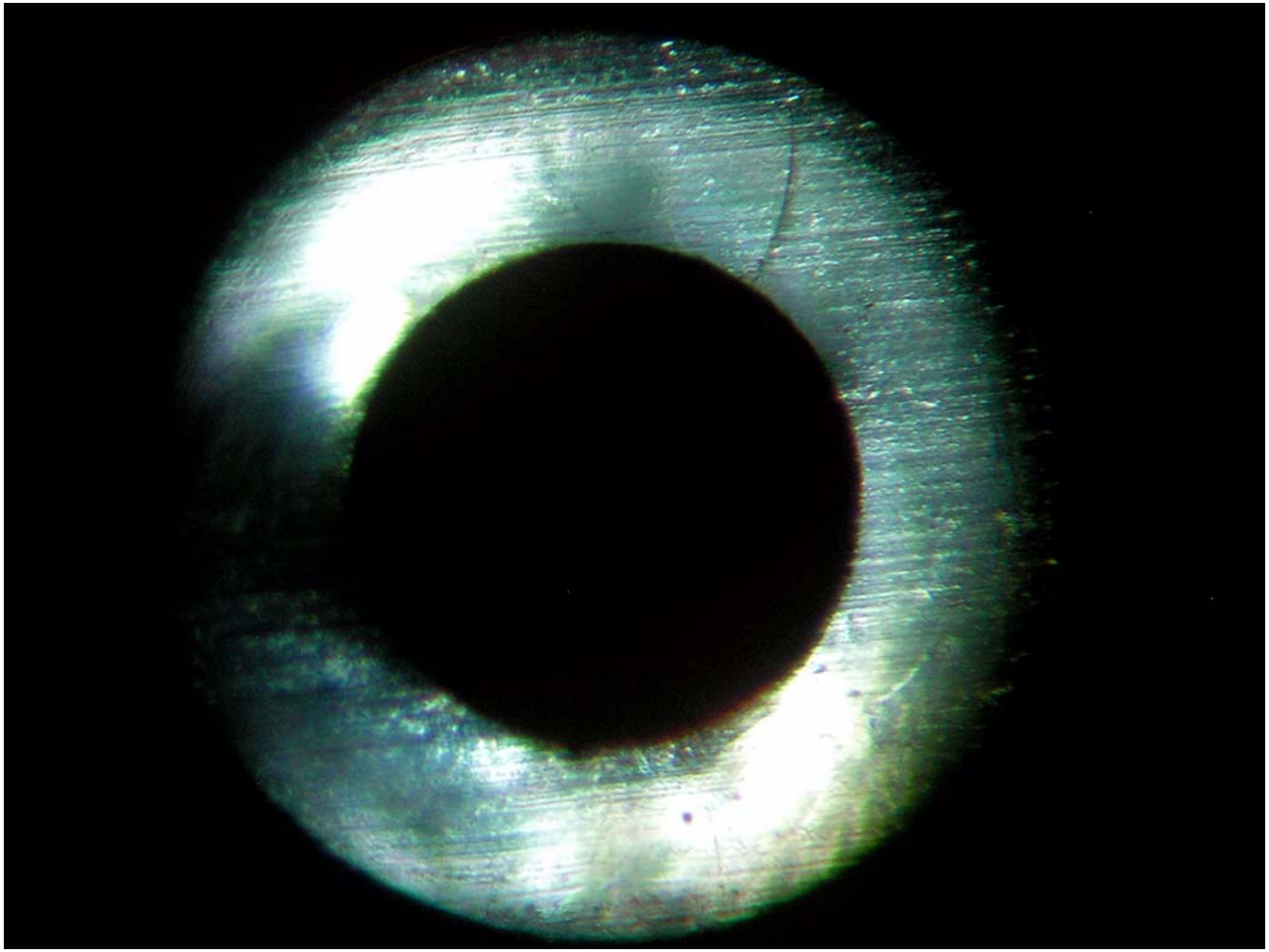
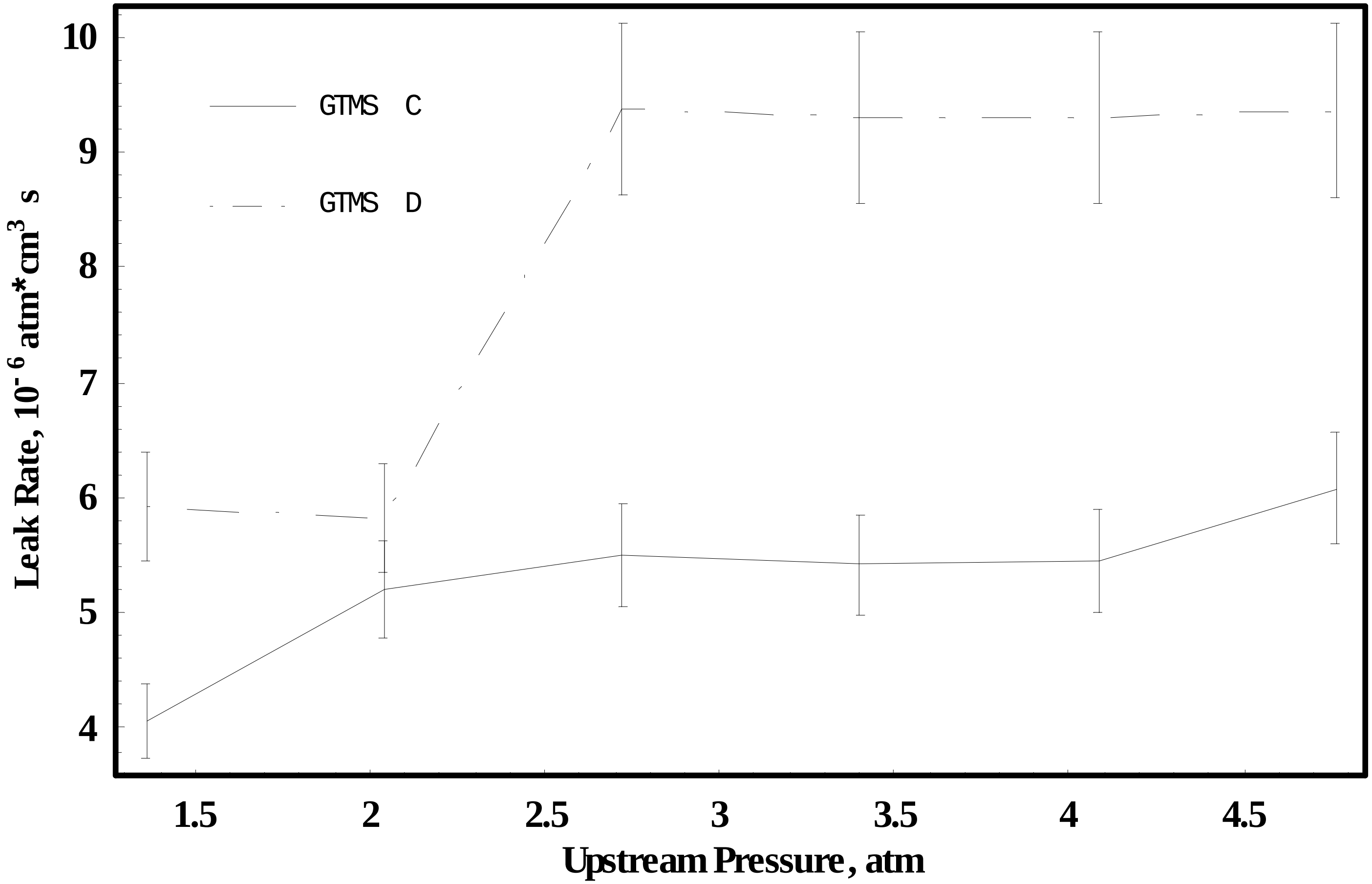
GTMS Images: Part "D"

View From Electrical Pin Side
One Radial Crack Visible



Helium Leak Rate: GTMS "D"

Leak rate is in the viscous/molecular transition range.
GTMS "C" leak rate increases with pressure, as expected
GTMS "D" leak rate increases with pressure initially, then is constant



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Conclusions: Phase 1

- Initiators that have previously passed HMS leak tests have been identified as non-hermetic using the Radiflo® technique.
- GTMS's from these units have been removed, inspected for radial cracks and flaws, and photographed.
- Leak rates through these GTMS's have been measured using both the Radiflo® and HMS methods.
- Leak rates ranging from 1×10^{-3} atm cc/s to 1×10^{-7} atm cc/s have been measured.
- Leak rates do not necessarily correlate with the number or "size" of the radial cracks observed in photographic images.
- Helium mass spectrometer leak rates are strongly dependent on handling and storage conditions of the GTMS.
- Measured leak rates often appear to vary in an anomalous manner with pressure. More research is necessary to understand this effect.