# Testing of SHIIVER MLI Coupons for Heat Load Predictions

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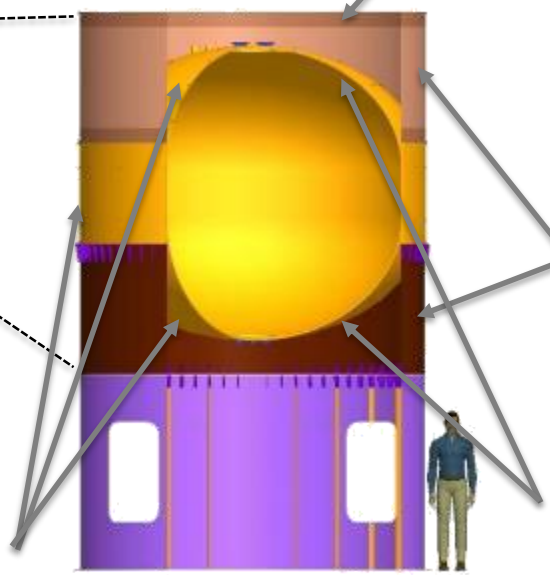
# SHIIVER Overview

SLS

EUS

SHIIVER

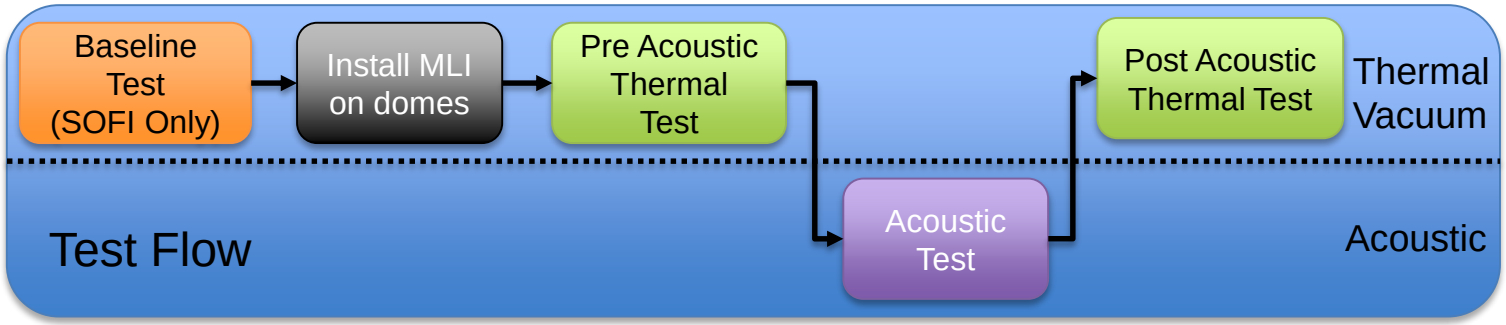


Boil-off vapor cooling on forward skirt

Forward and Aft structural skirts
- Baselined for EUS

Traditional MLI on top and bottom domes

Spray on Foam Insulation on barrel and top and bottom domes
- Baselined for EUS



# SHIIVER Blanket Testing

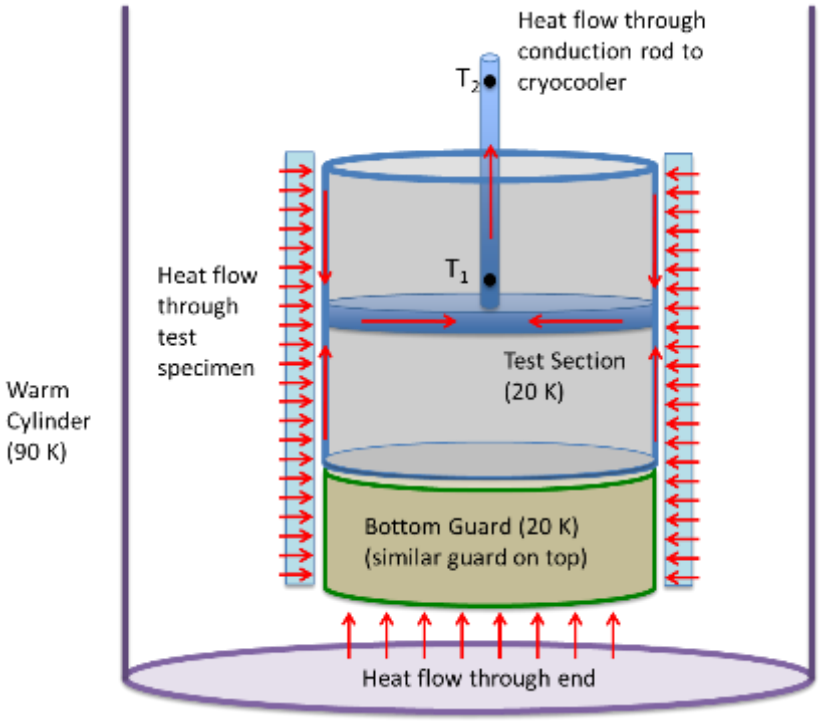
**Objective: Perform coupon testing to enable prediction performance of SHIIVER MLI blankets as well as scaling of the performance to larger applications**

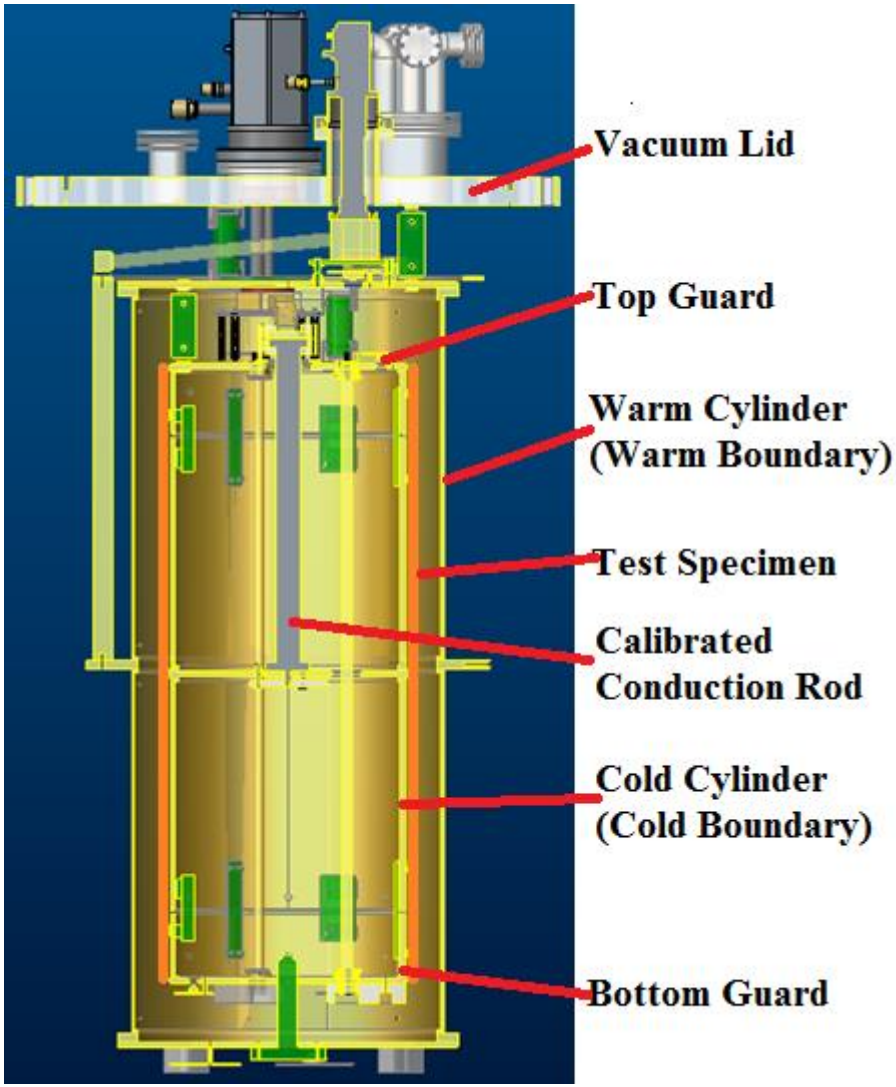
**Considered several different types of test to run, settled on four tests:**

- Two different numbers of reflective layers
- Adding a seam
- Effect of structural attachments

| Test Number | Description | Number of MLI Layers | # of Seams | # of Structural Patches |
|---|---|---|---|---|
| 1 | Baseline Test | 50 | 1 | 0 |
| 2 | Reduced layer Count | 30 | 1 | 0 |
| 3 | Two Seams | 30 | 2 | 0 |
| 4 | Structural Attachments | 30 | 1 | 4 |

# CoMPACT Calorimeter



# MLI Design and Construction

- **Each blanket comprised of 10 layer sub-blankets (50 layer had 5, 30 layer had 3)**
  - Sub-blankets held together by fastener tape strip with ~2 inch overlap, held by clothing tags, not sewn
  - Seams clocked at least 4 inches from previous sub-blanket seam
- **Inner and Outer sub-blanket had reflective covers facing the outside of the blanket**
  - Other blankets had laminated netting on outer reflector
- **Layer density varied between 15 lay/cm and 18.5 lay/cm**
- **Anchored to calorimeter via 6 click-bond 9208 (through inner sub-blanket only)**

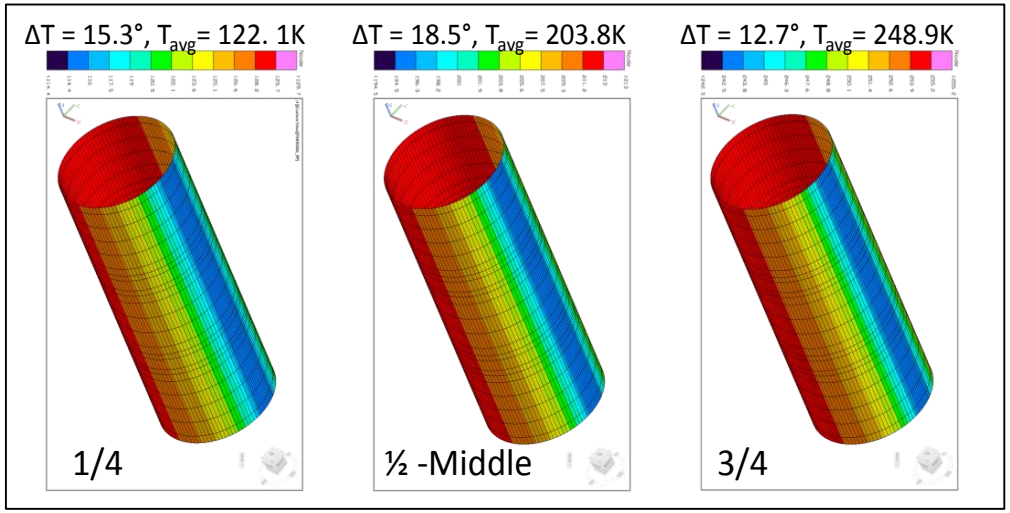
# Effect of number of layers

- **First two tests were focused on effect of layers**
  - 50 layers
  - 30 layers
- **Results showed nearly identical heat fluxes between the two blankets**
- **As a result of testing, 30 layers was chosen for SHIIVER application**

| Configuration | $Q_{total}$, W | $Q_{net}$, W | Thickness, cm | Layer Density, Lay/cm | $q_{net}$, $W/m^2$ |
|---|---|---|---|---|---|
| 50 Layers | 0.937 | 0.931 | 2.7 | 18.5 | 0.670 |
| 30 Layers | 0.928 | 0.923 | 1.9 | 15.8 | 0.674 |

# SHIIVER Seams Testing

- **Effect of seam measured by putting two seams into blanket**
- **Lockheed ATC analysis showed that two seams didn't interfere with each other thermally.**
- **Effect of seam approximately 0.15 W/m in this configuration**
- **SHIIVER MLI designed to minimize seam length on 8.4 m tank**




Thermal Model by Lockheed ATC

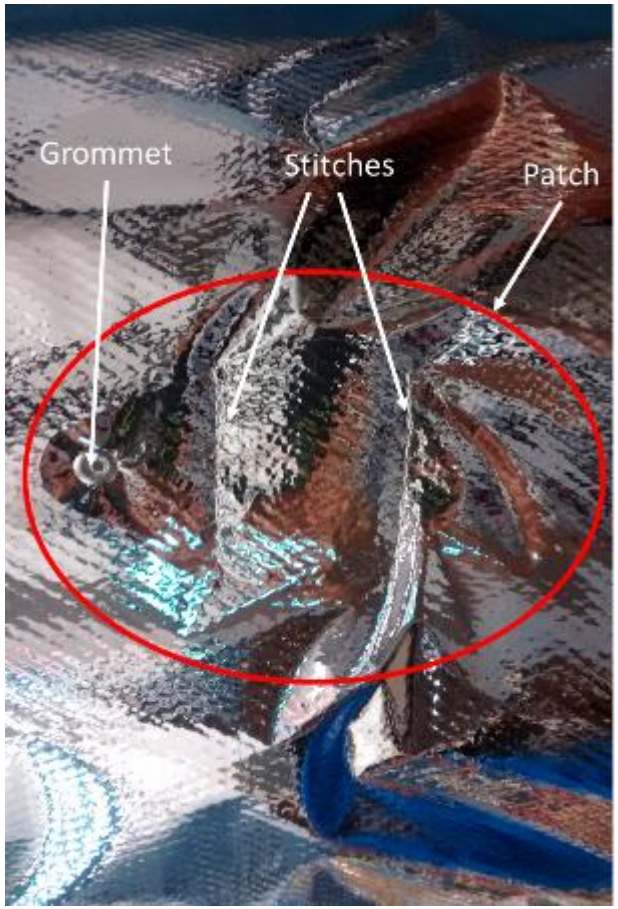
| Configuration | $Q_{total}$, W | $Q_{net}$, W | $Q_{seam}$, W/m | % change |
|---|---|---|---|---|
| Single Seam | 0.928 | 0.923 | 0.147 | |
| Double Seam | 1.062 | 1.057 | 0.394 | 14.6% |

# SHIIVER Structural Attachments

Test article included 4 patches as shown in the pictures to the right.

Stitching only in outer sub-blanket

Thermocouples on the inside of the blanket as shown below.




# SHIIVER Attachment Thermal Results

Thermal Testing:

| Configuration | $Q_{total}$, W | $Q_{net}$, W | $Q_{attach}$, W | WBT, K | $T_{stitch}$, K | $T_{blanket}$, K |
|---|---|---|---|---|---|---|
| Baseline | 0.928 | 0.923 | | 261 | | |
| Attachments | 0.979 | 0.974 | 0.052 | | 235 | 207 |

Thermal Penalty of 52 mW for four patches

Thermal Modeling:

| Heat Loads for one stitch or hole | WBT = 260 K CBT = 230 K | WBT = 260 K CBT = 200 K | WBT = 260 K CBT = mixed* |
|---|---|---|---|
| Conduction (mW/thread) | 0.10 | 0.21 | 0.10 |
| Radiation (mW) all holes | 3.4 | 5.7 | 5.7 |
| Total (mW) | 11.8 | 22.6 | 13.8 |

*Radiation cold boundary of 200 K, conduction cold boundary of 230 K

Thermal Penalty of 55 mW for four patches

Johnson, W.L., Heckle, K.W., and Fesmire, J.E., **Heat Loads Due to Small Penetrations in Multilayer Insulation Blankets**, *IOP Conf. Series: Materials Science and Engineering* **278** 012197, 2017.

# Pull Test on Attachments

- **MLI tabs expected to take approximately 284 N each**
- **Low temperature pull testing at -80 ° C to determine failure load**
- **Five coupons tested**
  - All five exceeded 498 N (1.75 Safety Factor)
  - Due to test hardware issues, two took 4-5 loading cycles at 498 N
  - Highest failure: 655 N (two failed here)
  - Other failed at 509 N

# Video of Testing

# Questions?


Evolvable Cryogenics (eCryo)
GRC
MSFC
DVAT ♦ JEUSI ♦ MDHV9R ♦ RFMG ♦ IVP