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
• Baseline for EUS

Traditional MLI on top and bottom domes

Spray on Foam Insulation on barrel and top and bottom domes
• Baseline for EUS

Test Flow

Baseline Test (SOFI Only) → Install MLI on domes → Pre Acoustic Thermal Test → Post Acoustic Thermal Test → Acoustic Test → Thermal Vacuum

Acoustic
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

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Description</th>
<th>Number of MLI Layers</th>
<th># of Seams</th>
<th># of Structural Patches</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Baseline Test</td>
<td>50</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Reduced layer Count</td>
<td>30</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Two Seams</td>
<td>30</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Structural Attachments</td>
<td>30</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
CoMPACT Calorimeter
• 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

<table>
<thead>
<tr>
<th>Configuration</th>
<th>$Q_{\text{total}}, W$</th>
<th>$Q_{\text{net}}, W$</th>
<th>Thickness, cm</th>
<th>Layer Density, Lay/cm</th>
<th>$q_{\text{net}}, W/m^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 Layers</td>
<td>0.937</td>
<td>0.931</td>
<td>2.7</td>
<td>18.5</td>
<td>0.670</td>
</tr>
<tr>
<td>30 Layers</td>
<td>0.928</td>
<td>0.923</td>
<td>1.9</td>
<td>15.8</td>
<td>0.674</td>
</tr>
</tbody>
</table>
SHIIIIVER 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
- SHIIIIVER MLI designed to minimize seam length on 8.4 m tank

<table>
<thead>
<tr>
<th>Configuration</th>
<th>$Q_{\text{total}}$, W</th>
<th>$Q_{\text{net}}$, W</th>
<th>$Q_{\text{seam}}$, W/m</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Seam</td>
<td>0.928</td>
<td>0.923</td>
<td>0.147</td>
<td></td>
</tr>
<tr>
<td>Double Seam</td>
<td>1.062</td>
<td>1.057</td>
<td>0.394</td>
<td>14.6%</td>
</tr>
</tbody>
</table>

$\Delta T = 15.3^\circ$, $T_{\text{avg}} = 122.1K$

$\Delta T = 18.5^\circ$, $T_{\text{avg}} = 203.8K$

$\Delta T = 12.7^\circ$, $T_{\text{avg}} = 248.9K$
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:

<table>
<thead>
<tr>
<th>Configuration</th>
<th>$Q_{\text{total}}$, W</th>
<th>$Q_{\text{net}}$, W</th>
<th>$Q_{\text{attach}}$, W</th>
<th>WBT, K</th>
<th>$T_{\text{stitch}}$, K</th>
<th>$T_{\text{blanket}}$, K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.928</td>
<td>0.923</td>
<td>261</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attachments</td>
<td>0.979</td>
<td>0.974</td>
<td>0.052</td>
<td>235</td>
<td>207</td>
<td></td>
</tr>
</tbody>
</table>

Thermal Penalty of 52 mW for four patches

Thermal Modeling:

<table>
<thead>
<tr>
<th>Heat Loads for one stitch or hole</th>
<th>WBT = 260 K CBT = 230 K</th>
<th>WBT = 260 K CBT = 200 K</th>
<th>WBT = 260 K CBT = mixed*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduction (mW/thread)</td>
<td>0.10</td>
<td>0.21</td>
<td>0.10</td>
</tr>
<tr>
<td>Radiation (mW) all holes</td>
<td>3.4</td>
<td>5.7</td>
<td>5.7</td>
</tr>
<tr>
<td>Total (mW)</td>
<td>11.8</td>
<td>22.6</td>
<td>13.8</td>
</tr>
</tbody>
</table>

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

Thermal Penalty of 55 mW for four patches

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?