Cryogenic Multi-layered Insulation Seam Studies and Experiments

Justin P. Elchert
Wesley L. Johnson
NASA Glenn Research Center

Presented by
Justin P. Elchert
• Introduction
• Calorimeter overview
• Calorimeter photos
• Test results
• Thermal model discussion
Seams

Skirt Integration

Penetration Integration
- Fill line
- Drain line

MLI Blanket Type
- Traditional
- SS-MLI
- Hybrid

Pins & Attachments

Repeatability

Lockheed Concept - 1969
Calorimeter Overview

- Vacuum tank
- Copper auxiliary wall
- Test section
Calorimeter

Copper

Black paint AZ-306

Water/glycol cooled jacket
Calorimeter

G-10 support

insulation
Desire to model staggered over lap and butt seams
Typical Solution for MLI Heat Load

- There are multiple 1-D MLI solution methods
  - Direct (a.k.a. “Layer by Layer”)
  - Semi-Empirical (“Lockheed”, “Modified Lockheed”, “Cunnington”)
  - Polynomial fits

- These solutions assume blankets are “ideal” and from laboratory calorimeter data
  - Historical tank data off by factor of 2 – 10

- Cannot use these methods to predict heat load from a seamed blanket
## Comparison to predictions and test data

### Table

<table>
<thead>
<tr>
<th>Test</th>
<th>Configuration</th>
<th># of layers</th>
<th>layer density</th>
<th>$Q_{\text{flux}}$</th>
<th>$Q_{\text{seam}}$</th>
<th>$Q_{\text{pred}}$</th>
<th>DF</th>
<th>dDF</th>
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<td>Overlap</td>
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<td>0.044</td>
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<td>0</td>
<td>0.116</td>
<td>4.6</td>
<td>-</td>
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<td>0.576</td>
<td>0.061</td>
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<td>5</td>
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</table>

*Q_{\text{pred}}* using “Layer by Layer” method
Thermal Desktop model assumptions

- Steady state
- Water cooled jacket approximated with isothermal boundary node and conductor
- Cryocoolers approximated as isothermal boundary nodes at the test condition
- Temperature dependent properties (including emissivity)
- Diffuse radiation
- Optically thick layers
Thermal Desktop Model

100,000 rays
Bij cutoff = 0

aluminum 6061 rod
Cold guard
Test section
Q = 0.30 W

\( Q_{\text{flux}} = 0.216 \, \text{W/m}^2 \)
Staggered, two inch spacing, actual gap

\[ Q = 0.37 \text{ W} \]
\[ Q_{\text{flux}} = 0.27 \text{ W/m}^2 \]
\[ Q_{\text{seam}} = 0.06 \text{ W/m} \]

2.3 times lower than measurement
Conclusions and Forward Work

- TD can be used to model MLI in detail, including seams, to within a factor of ten of the true answer.
- When correlated / validated, the model will be used to tabulate a set of results useful for first order estimates at the system level.
Acknowledgements

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Questions
References