Thermal Interface Comparisons Under Flight-like Conditions

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Agenda

- Introduction & Test Goals
- Test Setup
  - Materials & specifications
  - Requirements
  - Configuration
- Original setup lessons learned
- Thermal Interface Materials Background
- Results
- Conclusions & Implementation
Introduction

- Thermal interface materials are used in bolted interfaces to promote good thermal conduction between the two.
- The mounting surface can include panels, heat pipes, electronics boxes, etc...
- On Lunar Reconnaissance Orbiter (LRO) project the results are directly applicable
  - Several high power avionics boxes
  - Several interfaces from RWA to radiator through heat pipe network
Test Goals

- Test interface materials tested were already scheduled to be used on flight or were considered alternatives
- Meet requirements for the Lunar Reconnaissance Orbiter (LRO) project
  - 1W/(in²*K)
- Comparison of commonly used thermal interface materials under more practical conditions
- Test runs according to Lunar Reconnaissance Orbiter Thermal interface material application procedure (451-PROC-001314)
Test Runs

1. Dry joint
2. eGraf HITHERM-1210 (10 mil)
3. NuSil CV-2946 with 5 mil Teflon film
4. ChoSeal -1285
5. Indium
6. Grafoil (5 mil)
7. Copper picture frame with NuSil combination
8. NuSil with spray Teflon
9. Arathane (60% Boron Nitride) with spray Teflon
Test Setup
Tested Surfaces
**Materials And Specifications**

- Thermocouples: Type T (30 AWG) x 35
- Chiller fluid: ~ 30% Propynol & 70% water
- Bolts: Socket-head stainless steel (lubricated with Braycote)  
  *Torque values taken from LRO Torque Spec*  
  - Heat pipe: 10-32 (30 in-lb)  
  - Baseplate: 8-32 (26 in-lb)
- Minco heaters using Pressure Sensitive Adhesive (PSA) and aluminum tape over them. Maximum heater density kept under 3 W/in²  
  - Baseplate: 5” X 5” (113.7 Ω)  
  - Heat Pipe: 1.5” X 12” (260 Ω)
- Data collection software: Labview 7.1
- Setup covered with MLI to prevent heat loss
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LRO Interface Conductance Test

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Test Requirements

- Pressure
  - \(< 10^{-3} \text{ Torr} \) (1 Torr = 133.32 Pa)
  - Controlled by:
    - Mechanical pump
    - LN2 cooled scavenger plate (@ -115°C)

- Steady-state temperature stability criteria
  - \(< 0.5 \ ^\circ \text{C}/\text{hr}\)
Test Configurations

- Two sink temperatures:
  - Cold: -10°C to 0°C
  - Warm: 25°C to 35°C
- Two power levels:
  - Baseplate
    - High: 75 W
    - Low: 50 W
  - Heat Pipe
    - High: 60 W
    - Low: 40 W
Original Setup Lessons Learned!

- No use of scavenger plate
- Software problems
- No thorough sanity check of TC’s
- Cooling heat exchanger with LN2
  - Too powerful (cooling in short bursts)
- Chiller not cooling enough (added Propynol to increase temperature range)
- Taking data every 2 seconds
- Heater power too low
Original Setup Lessons Learned!

- Original base plate used was spare SDO CDH baseplate in an attempt to capture actual box stiffness
  - Uncomfortable and non-uniform heater locations
  - Not very flat surface
Interface Materials
- HITHERM-1210
- Expanded carbon sheet
  - Provides good thermal contact under regular pressure
  - Can be a particulate shedding material
  - 10 mil thick (0.01 in)
- Test setup:
  - Baseplate: Four 6"X 6" sheets
  - Heat pipe: Two 3"X 6" sheets
eGraf

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ChoSeal -1285

- Silicone sheet loaded with silver-plated aluminum particles to provide good thermal and electrical conduction
- Good thermal contact relies on a squeezing pressure so it does not perform well away from bolts and clamps
- 20 mil thick
- Bake out required for better performance (at 175°C in an air oven for 24 hours)
Indium

- 99.99% Indium foil
- No sample shown:
  - Carcinogenic
  - Skin irritant
- Lustrous silver-white metal
- Soft, malleable and ductile
NuSil

- CV-2946
- It is a silicone based fluid (may pose a contamination risk)
- Stored in 5cc syringes at very low temperatures and thawed before application.
- It conforms to the shape of the interface then it solidifies at room temperature.
- Test setup:
  - Teflon film 5 mil (0.005 in)
  - Strips: ~1/8” wide, 1” between strips
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Copper Picture Frame With NuSil
Copper/NuSil 1

- 5 mil Cu sheet
- 5 mil Cu picture frame (taped up)
- 1” separation between strips

Center: 0.10 W/(in²*K)
Perimeter: 0.40 W/(in²*K)
Copper/NuSil 2

- 1/2 mil Cu sheet
- 6 mil Cu picture frame (cut)
- 3/4” separation between strips

Center: 0.10 W/(in²*K)
Perimeter: 0.33 W/(in²*K)
Copper/Nusil 3

- 5 mil Teflon film
- 6 mil Cu picture frame (cut)
- 3/4” separation between strips

Center: 0.22 W/(in²*K)
Perimeter: 0.82 W/(in²*K)

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Results
Results
Interface Conduction Calculation

\[ G_1 := \frac{Q_{\text{diss}}}{(T_{\text{surface}} - T_{\text{sink}}) \cdot \text{Area}} \]

Units: W/(in^2*K)
Heat Pipe interface conductance

h (W/m²K)

Dryjoint  eGraf  NuSil  ChoSeal  Grafoil  Spray teflon nusil  Spray teflon/Arathane

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Heat Pipe % Variation

<table>
<thead>
<tr>
<th>Material</th>
<th>% Variation</th>
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<tbody>
<tr>
<td>Dryjoint</td>
<td>15</td>
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<tr>
<td>eGraf</td>
<td>5</td>
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<tr>
<td>NuSil</td>
<td>45</td>
</tr>
<tr>
<td>ChoSeal</td>
<td>20</td>
</tr>
<tr>
<td>Grafoil</td>
<td>10</td>
</tr>
<tr>
<td>Spray teflon nusil</td>
<td>5</td>
</tr>
<tr>
<td>Spray teflon/Arathane</td>
<td>5</td>
</tr>
</tbody>
</table>

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Baseplate interface conductance

![Graph showing conductance values for different materials]

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Baseplate % Variation

% Variation

- Perimeter
- Center

Dryjoint, eGraf, NuSil, ChoSeal, Indium, Copper/nusil 1, Copper/nusil 2, Copper/nusil 3, Spray/Teflon nusil, Spray/Teflon/Arethane

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Conclusions

- Superiority of NuSil in areas not bolted down vs. solid sheets
- Exceptional performance of eGraf around bolted areas and all around in stiffer surfaces
- On picture frame variation it was found that copper frame did not enhance the perimeter thermal conductance. Performance was best when thin teflon sheet was used instead of copper
- Undergoing supplemental tests
  - Nusil with spray teflon
  - Arathane loaded with 60% Boron Nitride with spray teflon
Implementation

- Avionics on ITP panel
  - CDH, PSE, STRANS (Copper picture frame with NuSil)
  - MiniRF receiver and controller, possibly KaTWT (eGraf)
Implementation

- Avionics on ITP panel
  - CDH, PSE, STRANS (Copper picture frame with NuSil)
  - MiniRF receiver and controller, possibly KaTWT (eGraf)
Implementation

- Heat pipe interfaces
  - RWA heat pipe joints (eGraf)
  - Dual bore heat pipes to radiator (eGraf)

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Appendix
## Heat Pipe

<table>
<thead>
<tr>
<th></th>
<th>Dry joint</th>
<th>eGraf</th>
<th>NuSil</th>
<th>ChoSeal</th>
<th>Grafoil</th>
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<tbody>
<tr>
<td><strong>Cold sink</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Low power</td>
<td>0.60</td>
<td>2.62</td>
<td>1.00</td>
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<tr>
<td>High power</td>
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<td>2.75</td>
<td>1.18</td>
<td>0.58</td>
<td>1.37</td>
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<td>1.58</td>
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<td>1.58</td>
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# Baseplate

<table>
<thead>
<tr>
<th>Baseplate Perimeter</th>
<th>Dry joint</th>
<th>eGraf</th>
<th>NuSil</th>
<th>ChoSeal</th>
<th>Indium</th>
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<tbody>
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<tr>
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<td>0.54</td>
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<table>
<thead>
<tr>
<th>Baseplate Center</th>
<th>Dry joint</th>
<th>eGraf</th>
<th>NuSil</th>
<th>ChoSeal</th>
<th>Indium</th>
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</thead>
<tbody>
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<td><strong>Cold sink</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Low power</td>
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</tr>
<tr>
<td>High power</td>
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<td>0.09</td>
<td>0.13</td>
<td>0.08</td>
<td>0.10</td>
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<tr>
<td><strong>Hot sink</strong></td>
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<tr>
<td>Low power</td>
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<td>High power</td>
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