Thermal Design and Analysis

Sang Park
Thermal Engineer

July 6th, 2004
Agenda

• Camera Section
  – Requirements
  – Thermal Design
  – Operational Profile (hold time, observation)
  – Optical Bench
  – Optical Assembly
  – Thermal Math Model
  – Cooling profile
  – Lens temperature profiles

• MOS Section
  – Thermal Design
  – Operational Profile (Transition time, Hold time)

• Planned Activities
Camera Section
Optical Assembly:

- Lens Temperature Gradient Requirements (degrees C):

<table>
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<tr>
<th>lens number</th>
<th>radial gradient</th>
<th>axial gradient</th>
<th>dimetral gradient</th>
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<td>14</td>
<td>5.05</td>
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Camera Section Thermal Features

- Multi-layer insulation
- GRISM Thermal Shield
- Optical Assembly Lenses 9-14 Thermal Shield
  Low e exterior, high e interior
- Optical Assembly Lenses 3-8 Thermal Shield
  Low e exterior, high e interior
- Camera Detector
- LN2 Reservoir
- Kapton Heaters On Lens cells
- Optical Bench in intimate Contact with the Vee-Block eGraf 1205
Optical Bench Thermal Design

• 100w Heater power total
  • 2x 50w heater zones
  • Proportional heater controller
    CryoCon Model 34 (Baseline)
  • MINCO Kapton Heaters

• 12 temperature sensors
  • 8 sensors from the controller
  • 4 sensors from data logger

• Rate of cooling: Approximately 72 hours
  • Maintain less than 2 degree C gradient in lenses
Optical Bench Thermal Design

• Thermal Shroud, internal surface finished with black hard anodize
  • Emissivity = 0.9
  • Thermal radiation dominant design

• Thermal Shroud, external surface finished with Low “e” tape (Aluminized Kapton, low outgas)
  • Emissivity = range 0.03 - 0.05

• Multi-layer Insulation (effective emissivity = 0.02 – 0.03) to cover internal surface of the most outer housing structure

• Intimate contact with the LN2 reservoir
  • GrafTech eGraf 1205 thermal interface material
Optical Bench Thermal Design

- Camera section Dewar has 100+ liters of LN2 capacity
  - Integrated vertical internal fins
    - Thermal path
    - Liquid baffles
  - Hold time: approximately 48 hours
    - Boil-off rate: .022 liter/hr-watt
    - Approximately 100w absorbed from the local ambient at 20C
    - Based on effective emmitance of 0.03 (multi-layer insulation)
  - Continuous supply of LN2 during the cool down period
Optical Assembly

Thermal Math Model:
Thermal Desktop/SINDA (Finite Difference Analyzer)
Optical Assembly
Results Thermal Math Model

Worst case: 100% radiation heat transfer Shown
Requires Conductive path,
Design to be determined
# Thermal Properties

<table>
<thead>
<tr>
<th>Description</th>
<th>Material</th>
<th>Thermal Conductivity</th>
<th>Specific Heat</th>
<th>Density</th>
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<td>K at Temperature (k)</td>
<td>Cp at Temperature (k)</td>
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Thermal Properties

*eGraf™ 1200 Thermal Resistance vs. Pressure*

Graftech Inc. teamed with a leading university to measure the specific thermal resistance of eGraf 1200 Series Thermal Interface Material versus pressure. The results of these tests are shown in the graph below.

**Testing parameters:**
- Test Method: ASTM D5420 modified
- Test range: 10 to 100 Psi
- Cut of Flatness of test blocks: < 0.000015 inches out of flat

GrafTech eGraf 1205 as a thermal interface material between the Optical assembly/Optical bench and MOS Dewar/the wheel support plate
Optics Thermal Math Models

Lens #3 CaF2
Optics Thermal Math Models

Lens #3: Cool down Profile to maintain less than 2 deg C gradient
Based on 8 hour shroud temperature transition

Temp (k) vs. time (sec)
(259.2ksec = 3 calendar days)
Optics Thermal Math Models

Lens #4 CaF2
Optics Thermal Math Models

Lens #4: Cool down Profile to maintain less than 1.4 deg C gradient
Based on 8 hour shroud temperature transition

Temp (k) vs. time (sec)
(259.2ksec = 3 calendar days)
Optics Thermal Math Models

Lens #5 BaF2
Lens #5: Cool down Profile to maintain less than 4.0 deg C gradient. Based on 8 hour shroud temperature transition.

Temp (k) vs. time (sec)
(259.2ksec = 3 calendar days)

BaF2 is known to be susceptible to Thermal Shock.
Optics Thermal Math Models

Lens #3 CaF2

Lens Valve Temperature = 20 degC (293k)

\[ T_f = 86.6K \]

Lens #3: Lens Valve Temperature Response Profile
Assumption: Initial Temperature=80K
Temp (k) vs. time (sec)
(28.8ksec = 8.0 Hours)

Lens #3 Temperature profile
MOS Section
MOS Section

- MOS Section has 45+ liters of LN2 capacity
  - Integrated internal fins
    - Thermal path
    - Liquid baffles
  - Hold time: approximately 40 hours at Max capacity
    - Potentially only 15 liters may be filled based on a fill orientation
      - Approximately 13 hours hold-time (horizon pointing, fill-tube at bottom)
    - Boil-off rate: 0.022 liter/hr-watt
    - Approximately 50w absorbed from the local ambient at 20C
    - Based on effective emittance of 0.03 (Thermal shields plus Multi-layer insulations)
  - Continuous supply of LN2 during the cool down period
MOS Section Thermal Design

• Surface finishes
  – Internal to thermal shield: Black Anodize finishes
  – External to the thermal shield: Low “e” tape (Aluminized Kapton, low outgas)

• Thermal shield locations

• Dewar location

• 4 temperature sensors
  – 4 sensors from data logger
MOS Section

Results of Preliminary Thermal Analysis
Heritage: FLAMINGOS2 Cooling profile

Cool down rate for MOS Wheel: MAIN.T3

Cool down rate for Dekker Wheel: MAIN.T2

Temp (K) vs. Time (Sec)
Planned activities

• Camera Section
  – Analyze Detector Assembly
  – Improve transition time to cool down
  – Generate detailed thermal math model (TMM)
    • Analyze individual lens thermal performances
    • Grism wheel thermal profiles
  – Characterize thermal interaction between the camera and MOS sections

• MOS Section
  – Improve transition time to cool down
  – Design thermal shield
  – Determine temperature stability due to the environmental conditions

• Integrated Thermal-Stress Model

• Specify and order thermal related components (heater, MLI materials, surface finishes/tapes etc.)