SAGE III Lessons Learned on Thermal Interface Design

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Outline

• Background
  – SAGE III on ISS
  – Interface Adapter Module (IAM)

• Evolution of IAM-ExPA Thermal Interface
  – Introduction to Thermal Interface Materials
  – Baseline Configuration
  – 2\textsuperscript{nd} Design Iteration
  – Thermal Pad Testing
  – Final Configuration

• Lessons Learned
SAGE III on ISS Overview

- Atmospheric science payload set for delivery to ISS via Space X Falcon 9 launch vehicle in 2016
- Fifth in a series of instruments developed to monitor ozone and other trace gases in Earth’s stratosphere and troposphere
- Three year minimum lifespan, five year goal
Instrument Payload

- Sensor Assembly (SA)
- Hexapod Mechanical Assembly (HMA)
- Contamination Monitoring Package (CMP)
- Disturbance Monitoring Package (DMP)
- Instrument Control Electronics (ICE)
- Hexapod Electronics Unit (HEU)
- Contamination Monitoring Package (CMP)
- ExPRESS Payload Adapter (ExPA)
- Interface Adapter Module (IAM)
Interface Adapter Module

- Serves as on-orbit flight director of Instrument Payload
- Surface properties: AgFEP + MLI
- Power dissipation: +100 W (max design)
- Expected on-orbit operational temperature range: -5°C to +40°C
• **Design Challenges:**
  – Heat rejection via radiation alone insufficient
  – Conduction through dry IAM-ExPA interface also insufficient
  – Large span between fasteners (approx. 20”)
  – Rigid footprint area (no room for expansion)
  – Measured flatness variation larger than expected

• **Driving IAM-ExPA Interface Requirements**
  – High thermal and electrical conductance (for grounding purposes)
  – Low outgassing, silicone-free materials
Interface Materials – What, When, Why?

- **What is a thermal interface material (TIM)?**
  - TIMs, or “gap fillers”, refer to any material placed between objects with the intent of increasing the thermal conductance through the interface.
  - Very common; a large assortment of TIMs are readily available and include compressible metals, elastomerics, epoxies, thermal grease, and more.
  - Increases contact area > increases conductance > decreases delta T through interface.

- **When should you use them?**
  - Any time low thermal resistance is desired through an interface, but is not achievable or guaranteed from bare contact.
  - Example applications:
    - Connecting heat generating components to heat sink.
    - Attaching heat pipes or thermal straps to radiator.
    - Mounting electronics boxes, TECs, many more.

- **Why should you use them?**
  - Can remove uncertainty and increase confidence in analysis.
  - Many are relatively low cost, widely available, and easy to implement.
Baseline Interface Configuration

• Baseline Configuration
  – Bolted interface with 99.9% indium foil, 0.010” thick
  – Chosen for its high conductivity (~80 W/m-K) and space flight heritage

• Concerns:
  – Indium is subject to cold flow, resulting in a loss of preload over time due to thermal cycling, vibration testing
  – By covering blind holes in ExPA, potential for entrapped gas is introduced
2nd Design Iteration

- Replaced indium foil with Gap Pad 2200SF
  - Silicone-free thermal pad available in a wide range of thicknesses; good conductance when compressed
- Added 0.016” thick metal shims to control pad compression (not to exceed 40% of original thickness) and to provide grounding path
- Added filler plate to increase contact area based on results of trade study

Concerns

- Previous experience suggested possible issue with high vacuum environment
- No known spaceflight heritage
Gap Pad Performance Testing

- Subjected uncompressed and compressed GP 2200SF specimens to < 1e^{-5} Torr and 100°C for approximately 72 hours
- Specimens were compressed to 10%, 30%, 50%, and 70% compression
- Following bakeout, test specimens were tested for thermophysical properties testing ($\rho$, $C_p$, $k$) then compared to virgin material
Gap Pad Performance Test Results

- After 72 hours, yellow condensate formed on oven surfaces
- Uncompressed material specimens became hard and brittle and experienced up to 80% increase in conductivity compared to virgin material
- Compressed specimens retained elasticity (diffusion-limited) and experienced up to 30% increase in conductivity compared to virgin material
- Concluded that GP 2200SF was not well suited for the SAGE III mission environment

Compressed specimens

GP 2200SF thermal conductivity test results
Final Interface Configuration

- Replaced GP 2200SF with NuSil CV-2946
  - Thermally conductive, platinum impregnated silicone
  - Lots of spaceflight heritage, good thermal conductance
  - Easily removed from flight hardware without release agent (in absence of primer)
- SAGE team members traveled to GSFC for hands-on NuSil application training
- Performed several practice applications to develop procedure
- Used a combination of application methods:
  - Troweling/screeding method over large acreage
  - Striping method over filler plate
- NuSil interface configuration verified during subsystem-level thermal-vacuum testing
- IAM was successfully integrated with Instrument Payload
Lessons Learned

• Collaborate with other disciplines on the team early in the design phase to ensure thermal considerations are taken into account
• Selecting interface materials with proven track record has its advantages
• Avoid large distances between fasteners
• Tight flatness and surface roughness specification can minimize thickness of interface material and increase available options
• Beware of cold flow when using indium foil; may experience loss of preload during thermal cycling or vibe
• Gap Pad 2200SF loses much of its elasticity from outgassing during bakeout testing, but increases in conductivity