Development of NASA’s Sample Cartridge Assembly: Design, Thermal Analysis, and Testing
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Outline

• Background of ISS Material Science Research Rack
• SCA Design Overview
• Thermal Modeling and Analysis Method
• Development Testing Activities
• Brazing Process
• Summary
• Future Work
• References
ISS Material Science Research Rack

- MSRR provides materials science research in low gravity
- Housed inside the Destiny Laboratory
- Developed by NASA and ESA, launched in 2009
- Contains ESA’s Materials Science Lab
Material Science Lab

- Built by ESA
- Process material samples. For example: directional solidification, crystal growth, etc.
- Two furnace inserts available: Low Gradient Furnace (LGF) and the Solidification and Quenching Furnace (SQF)
- Multiple experiments that have been processed using ESA’s SCA
Low Gradient Furnace (LGF) Insert

• Vacuum furnace
• Bridgman style furnace with multiple heater zones
  – Two hot cavities separated by an adiabatic zone
• Max operating temperature of 1400°C
• Thermal gradients up to 40°C/cm
Thermal Environment

- The two heated sections inside the LGF allows for a long sample to have a solidification front.
- By translating the furnace allows for directional solidification.
- The furnace can also be operated as an isothermal furnace.
Sample Cartridge Assembly (SCA)

- Holds the principle investigator (PI) material sample.
- Provides one level of containment for the sample.
- Provides instrumentation (e.g. temperature sensors and pressure sensor).
SCA Project Background

• NASA started developing a SCA in early 2000’s
  – Project was canceled in 2005, just after its critical design review (CDR)
• Restarted around 2010
  – Inherited the earlier design
• During build up of the first unit numerous problems arose that caused a redesign
  – Discussed more in coming slides
Design Drivers

- Reusability
- \(<10^{-8}\text{sccs}\) helium leak rate
- \(1300^\circ\text{C}\) processing temperature
- Compatible with science samples
- Head temperature \(<90^\circ\text{C}\) during processing
- Large volume in the head for instrumentation wires
- Nominal helium fill gas (assessing Argon)
Design Overview

• Head:
  – Two conflat flanges
  – Two major welds
  – One braze
  – RTD and pressure sensor separated from tube heat flow

• Tube:
  – Vapor plasma sprayed Mo-Re
  – Inner coating of alumina
  – Outer coating of zirconium boride
Thermal Analysis

- Thermal Desktop®
- Some components meshed in FEMAP©
- Redesign relied on thermal analysis
- Thermal design approach
  - Isolate mounting collar from cartridge tube heat load
  - Increase front flange thickness to wick heat away from braze area
Thermal Analysis

• Major goals
  – RTD temp < 90°C
  – Heat flow to ISP <100W
  – Minimize braze temperature
• Assess isothermal performance for isothermal PIs
• Assess gradient performance for gradient PIs

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Development Testing

- SCA mounted into a commercial furnace
  - Different heating profile than LGF
  - Heated tube to 1280°C, and head to 125°C
  - Pressurized inside SCA to 125 psia using helium
  - Verified leak rate He < $10^{-8}$ sccs
  - Measured data compared to modeled
Updated Braze Process

- Original design used BAg-8 braze
  - Required copper coating for wettability
  - Eutectic liquid temperature of 1435°F (779°C)
  - Used a thermal profile with a hold below the liquid temperature
  - Resulted in a few unsuccessful brazes
- Redesign used BAG-13
  - Has a solidus temperature of 1420°F (771°C) and a liquid 1640°F (893°C)
  - Does not require a copper coating
  - Used a no-hold thermal profile
  - Has resulted in a number of successful brazes
Original BAg-8 Braze Profile
Updated BAg-13 Braze Profile
Summary

• SCA project started with an inherited design:
  – Design was at CDR level, but limited development testing had been done. Also a SCA had never been built.
• During build-up of first SCA numerous problems were encountered
  – Unreliable braze process
  – Not enough internal volume for instrument integration
• Launched into a redesign activity to improve design
  – Designed a reusable SCA to help save costs
  – Thermal analysis helped guide the design to meet temperature requirements
  – Development braze program selected a new braze filler metal and process
• Successfully built up a SCA and performed development tests
  – Heated SCA to off-nominal temperatures
  – Over pressurized the internal with helium
  – Maintained helium leak rate <10^-8 sccs
Future Work

- Starting qualification testing program
- 1\textsuperscript{st} Principle investigator (PI) integration and testing
  - Fall 2015
  - Experiment launch summer of 2016
- 2\textsuperscript{nd} PI Integrated Design Review (IDR)
  - September 2015
- 3\textsuperscript{rd} PI IDR
  - Late 2015/early 2016
- 4\textsuperscript{th} PI Requirements Definition Review (RDR)
  - August 2015
References