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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

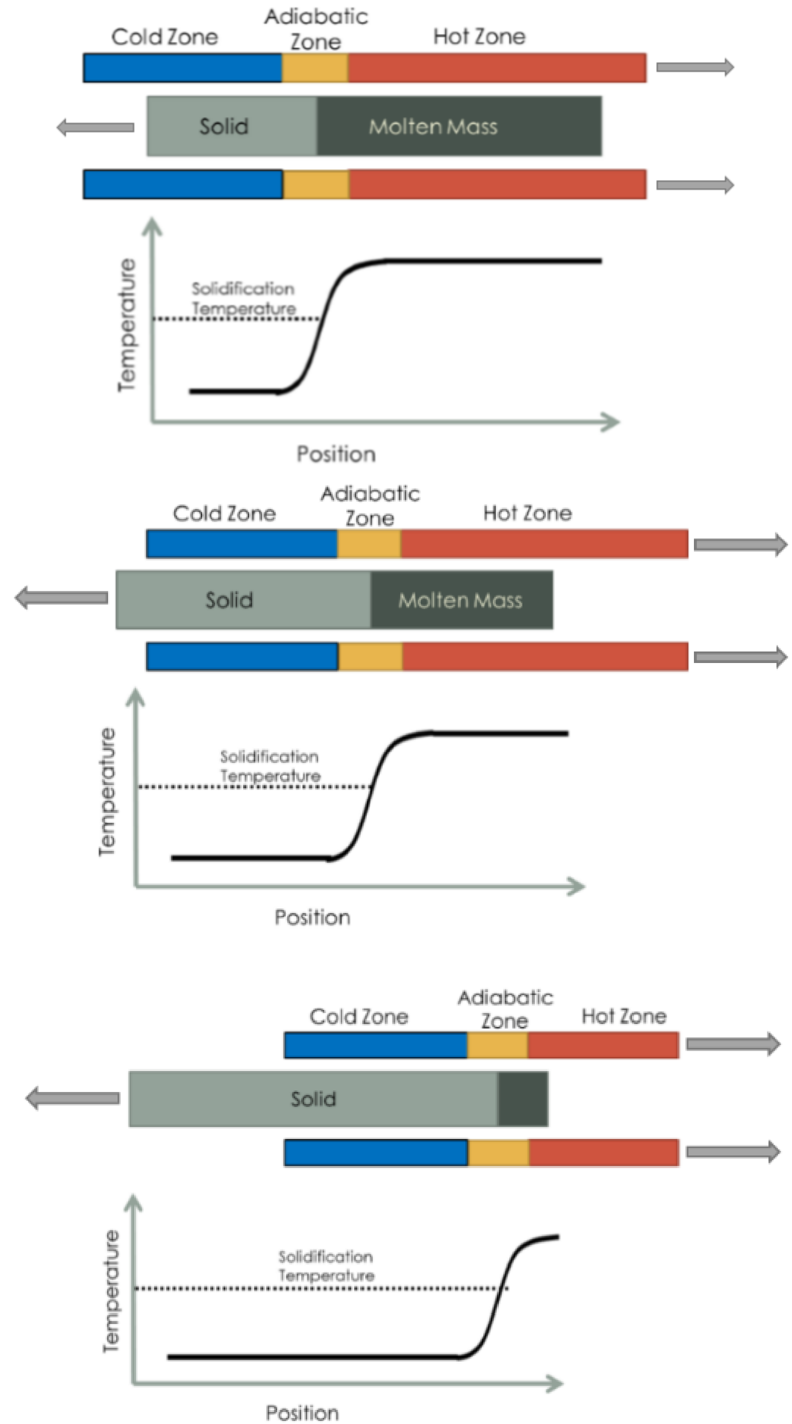
- Built by ESA
- Process material samples. For example: directional solidification, crystal growth, etc.
- Two furnace inserts available: Low Gradient Furnace (LGF) and the Solidification and Quenching Furnace (SQF)
- Multiple experiments that have been processed using ESA's SCA

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

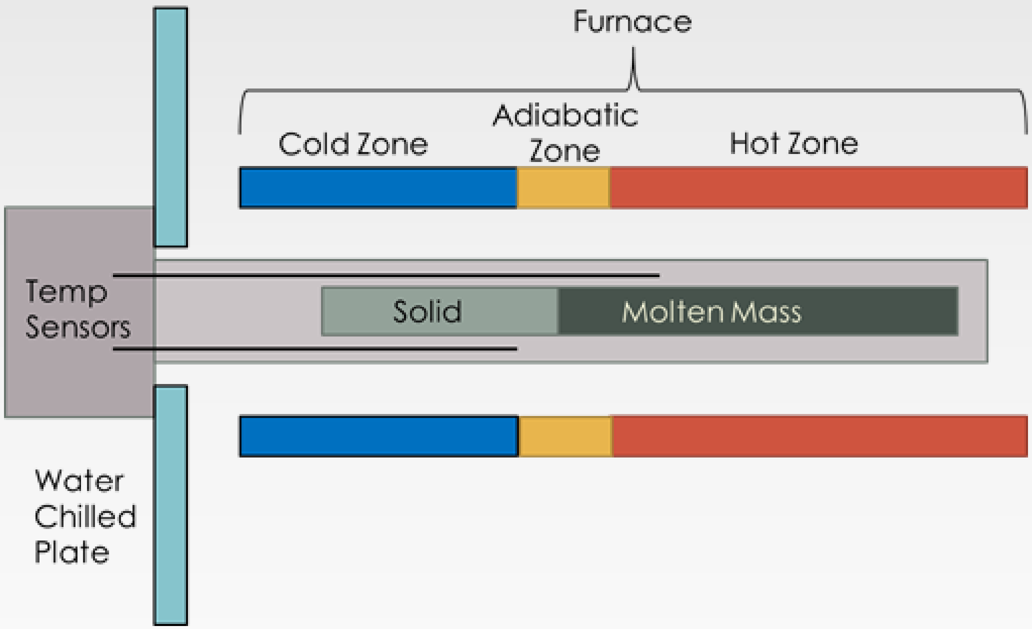
Thermal Environment

- 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).

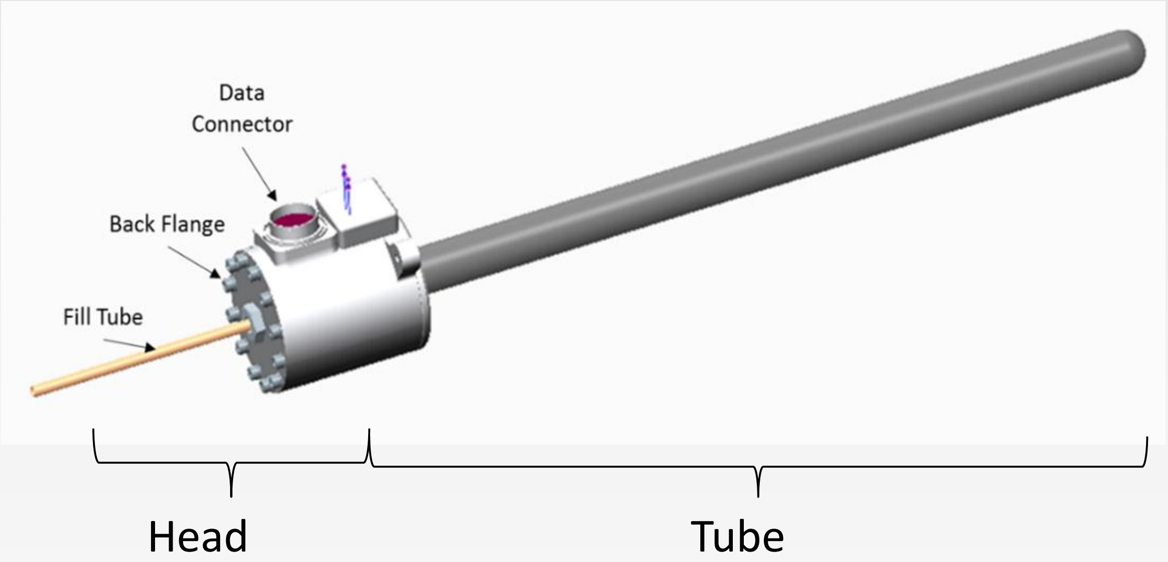


SCA Project Background

- 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

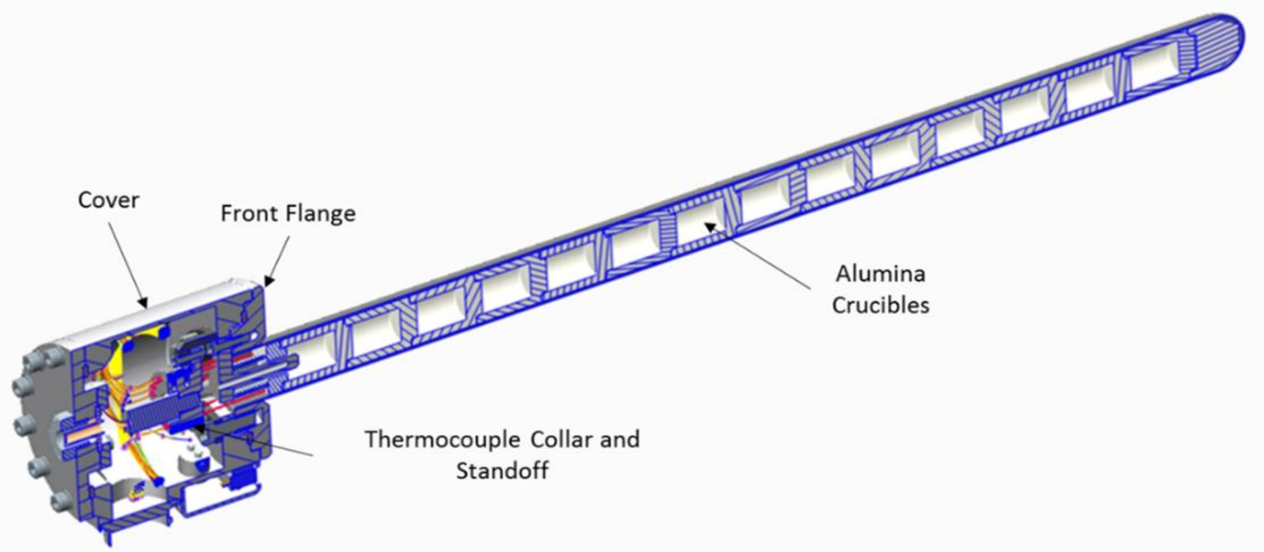
Design Drivers

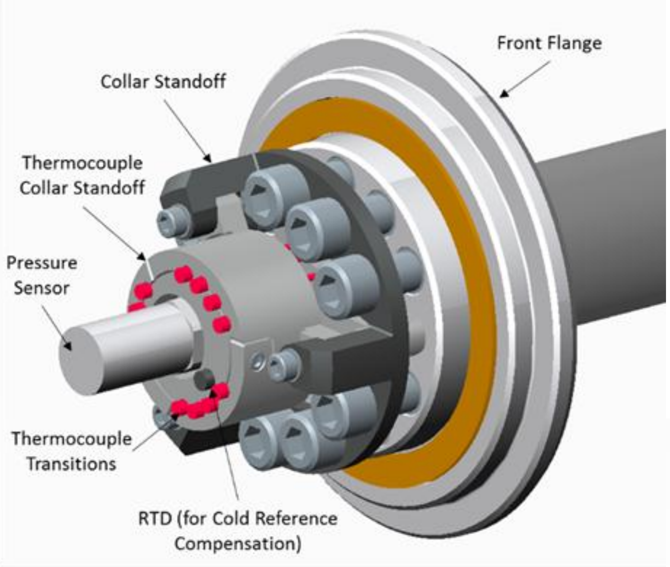
- Reusability
- <10^-8sccs helium leak rate
- 1300°C processing temperature
- Compatible with science samples
- Head temperature <90°C during processing
- Large volume in the head for instrumentation wires
- Nominal helium fill gas (assessing Argon)

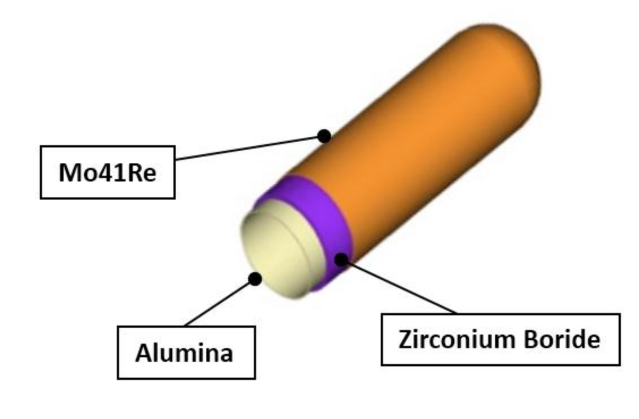


Design Overview

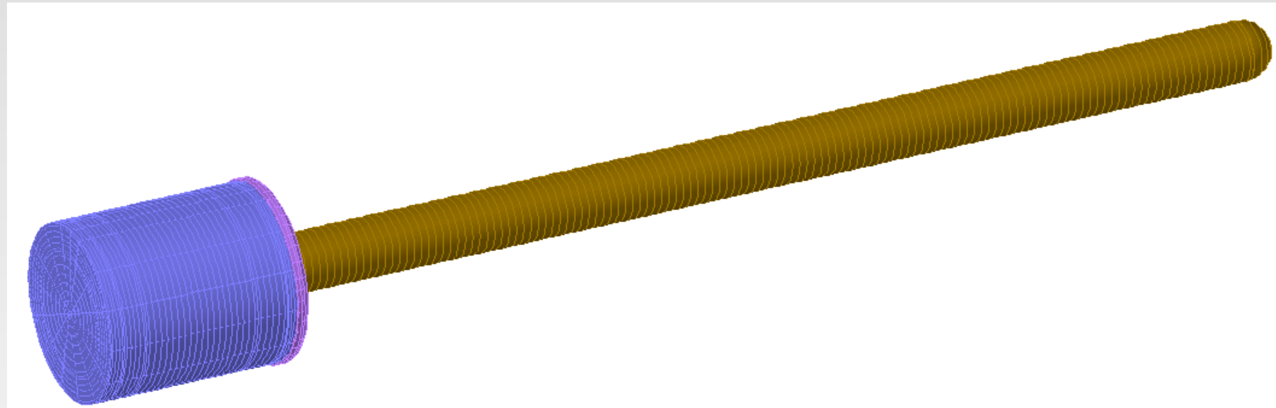
- Head:
  - Two conflat flanges
  - Two major welds
  - One braze
  - RTD and pressure sensor separated from tube heat flow
- Tube:
  - Vapor plasma sprayed Mo-Re
  - Inner coating of alumina
  - Outer coating of zirconium boride



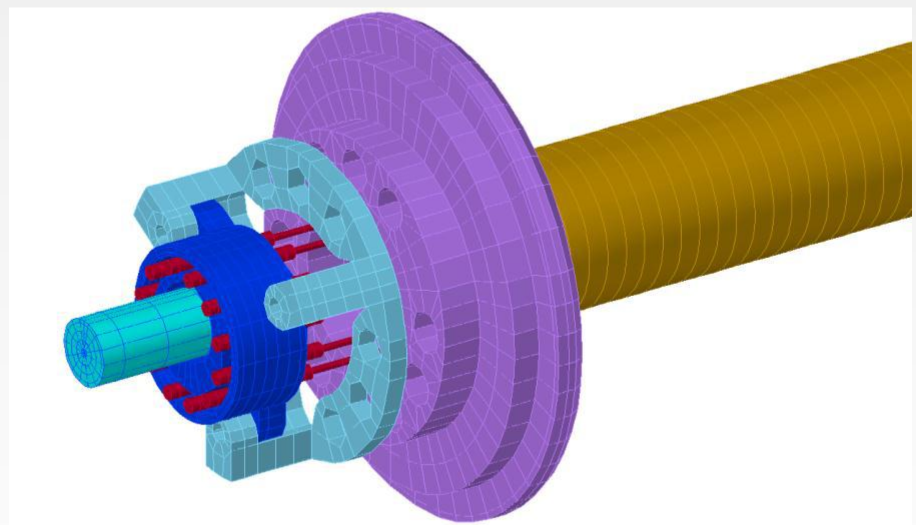




Thermal Analysis

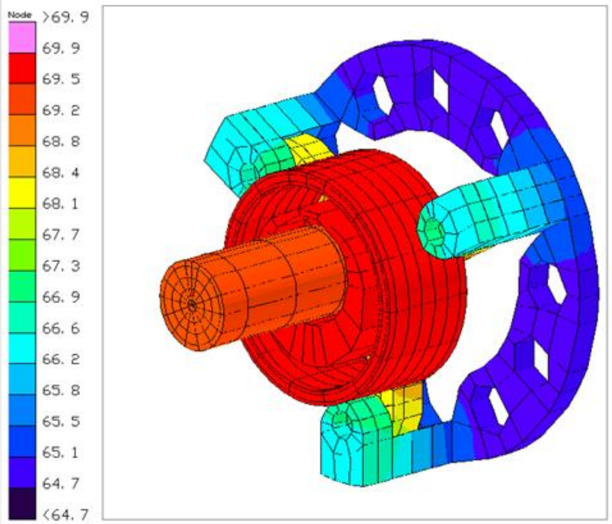


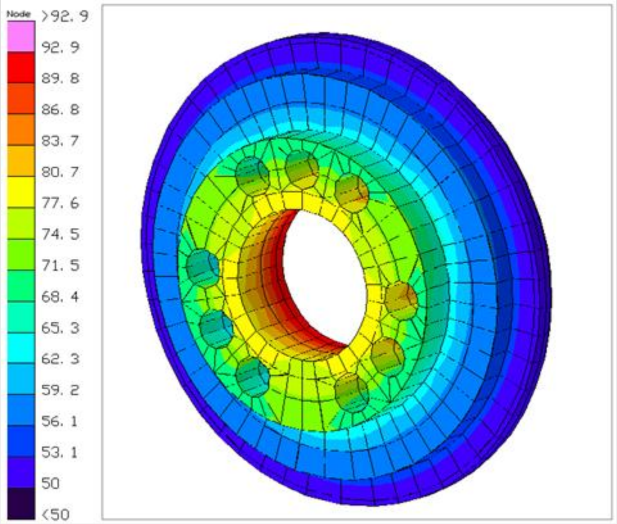
- Thermal Desktop®
- Some components meshed in FEMAP©
- Redesign relied on thermal analysis
- Thermal design approach
  - Isolate mounting collar from cartridge tube heat load
  - Increase front flange thickness to wick heat away from braze area

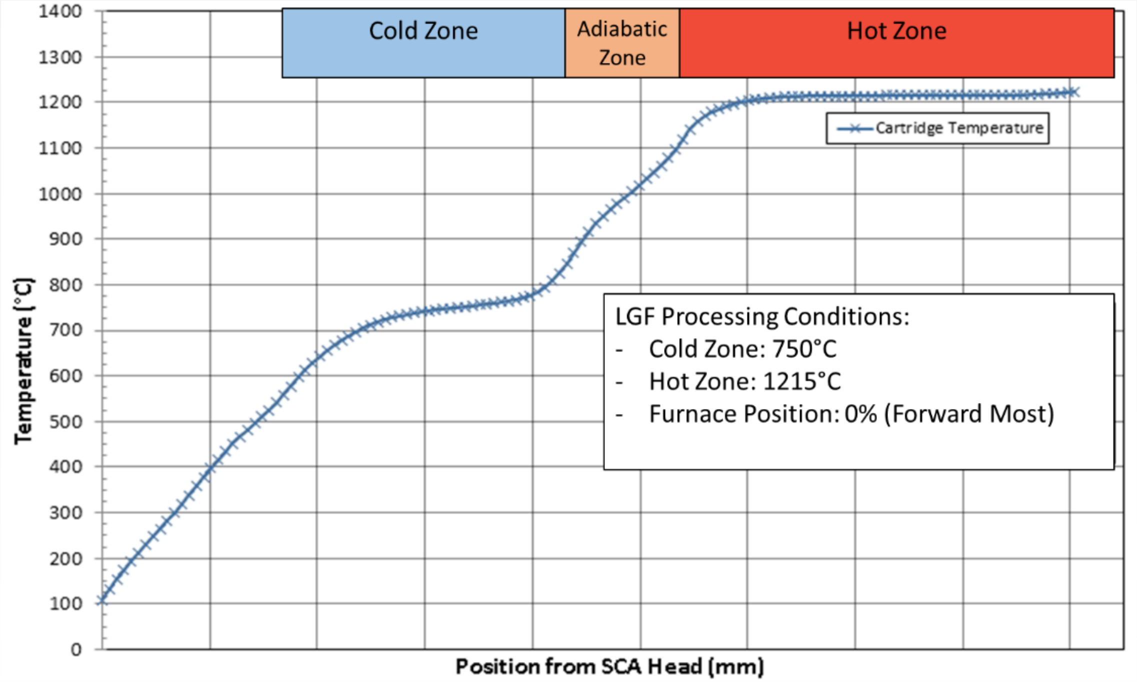


Thermal Analysis

- 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

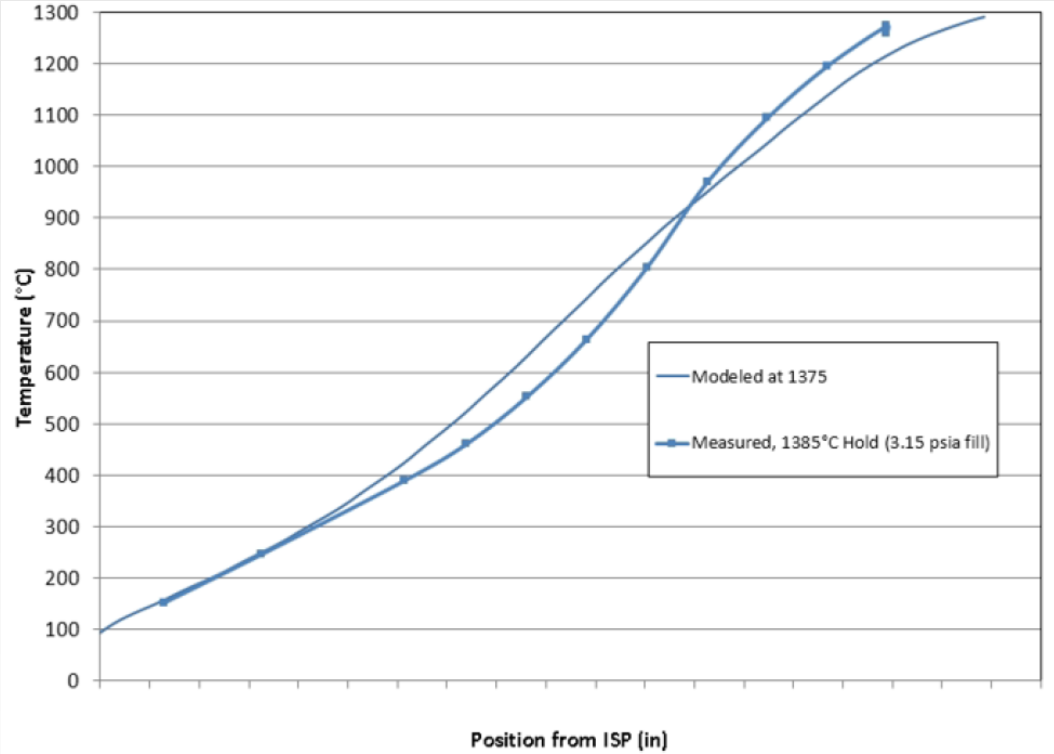






Development Testing

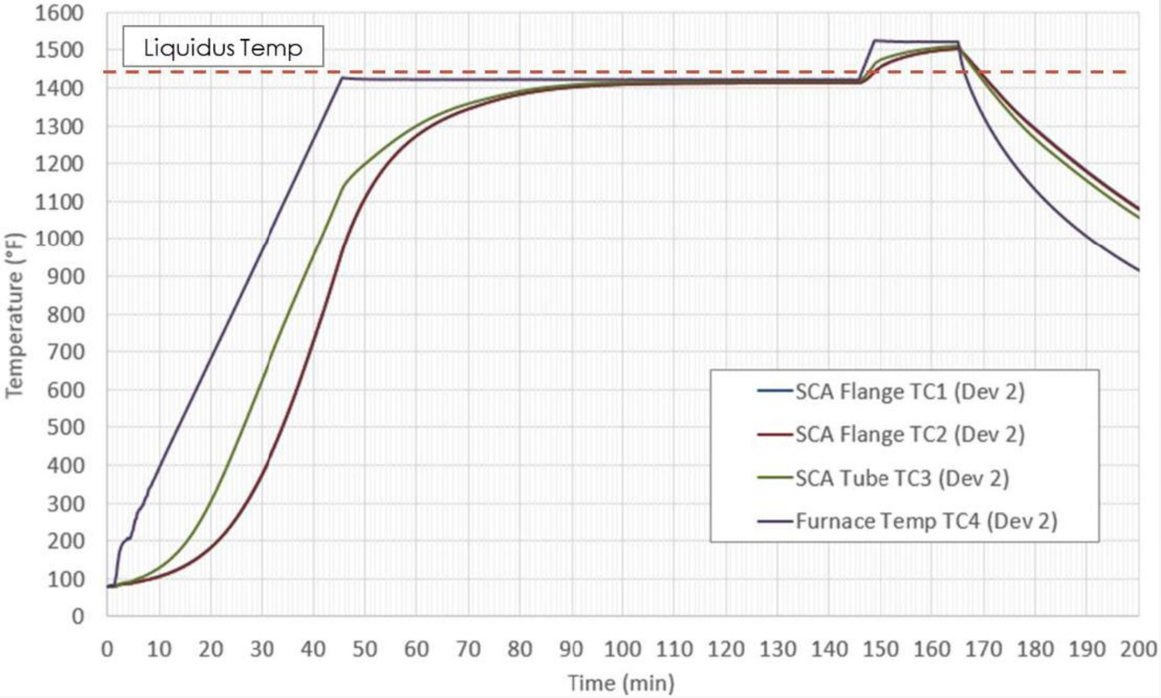
- SCA mounted into a commercial furnace
  - Different heating profile than LGF
  - Heated tube to 1280°C, and head to 125°C
  - Pressurized inside SCA to 125 psia using helium
  - Verified leak rate He < 10^-8sccs
  - Measured data compared to modeled



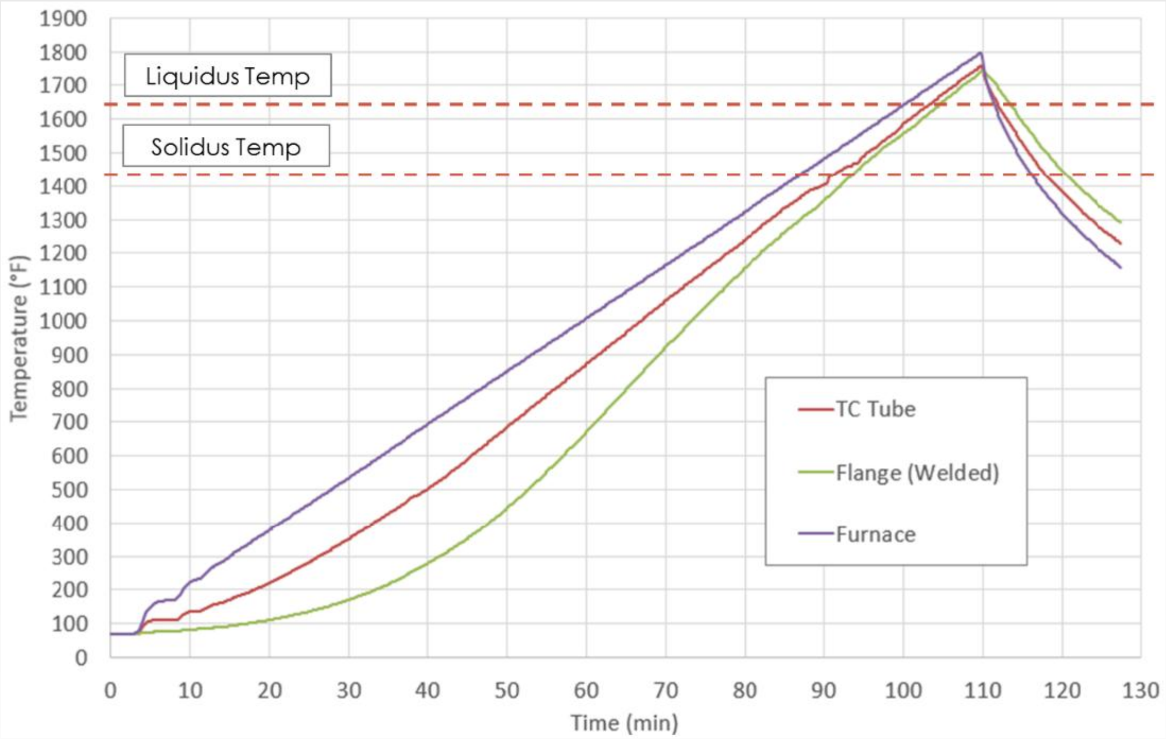
Updated Braze Process

- 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 in to 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
- 1st Principle investigator (PI) integration and testing
  - Fall 2015
  - Experiment launch summer of 2016
- 2nd PI Integrated Design Review (IDR)
  - September 2015
- 3rd PI IDR
  - Late 2015/early 2016
- 4th PI Requirements Definition Review (RDR)
  - August 2015

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