Summary of 2016 Thermal Vacuum Chamber Testing of Shape Morphing Adaptive Radiator Technology (SMART)

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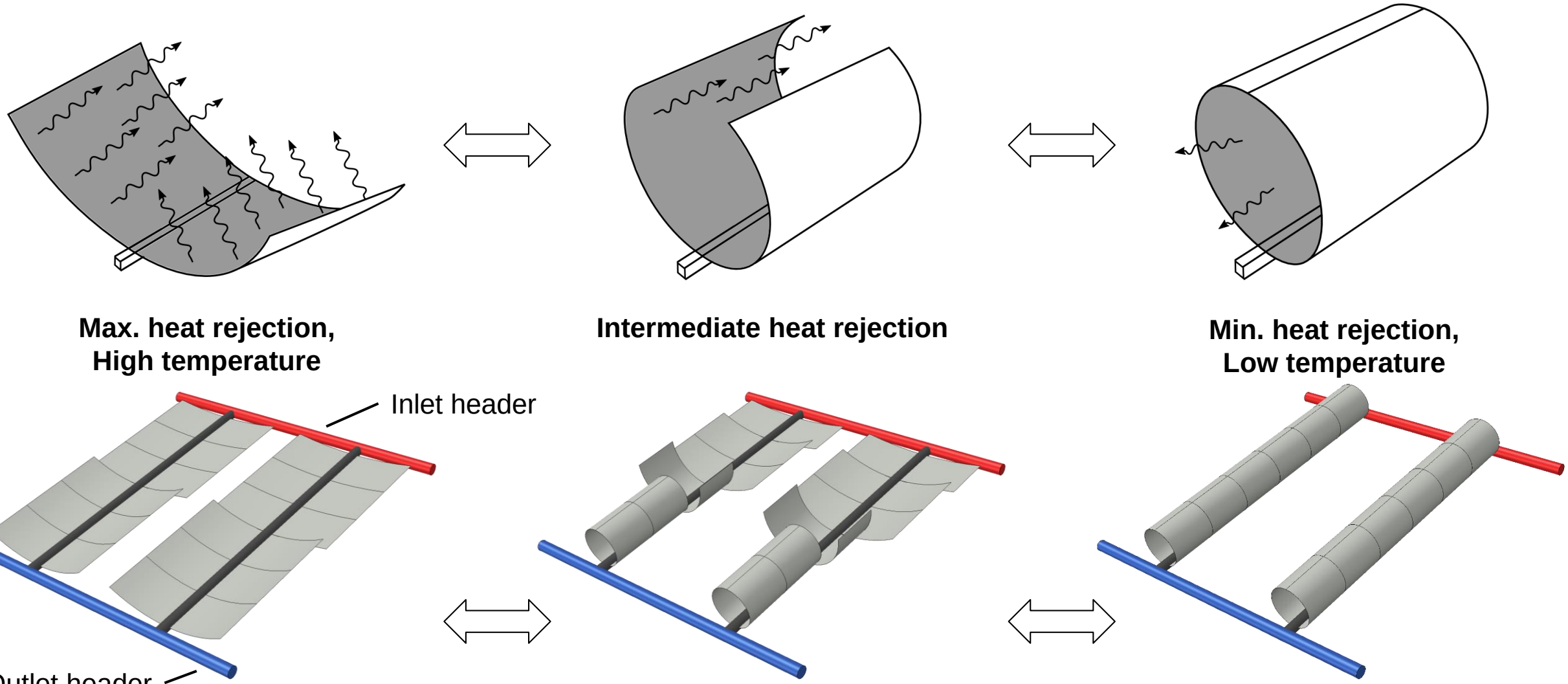
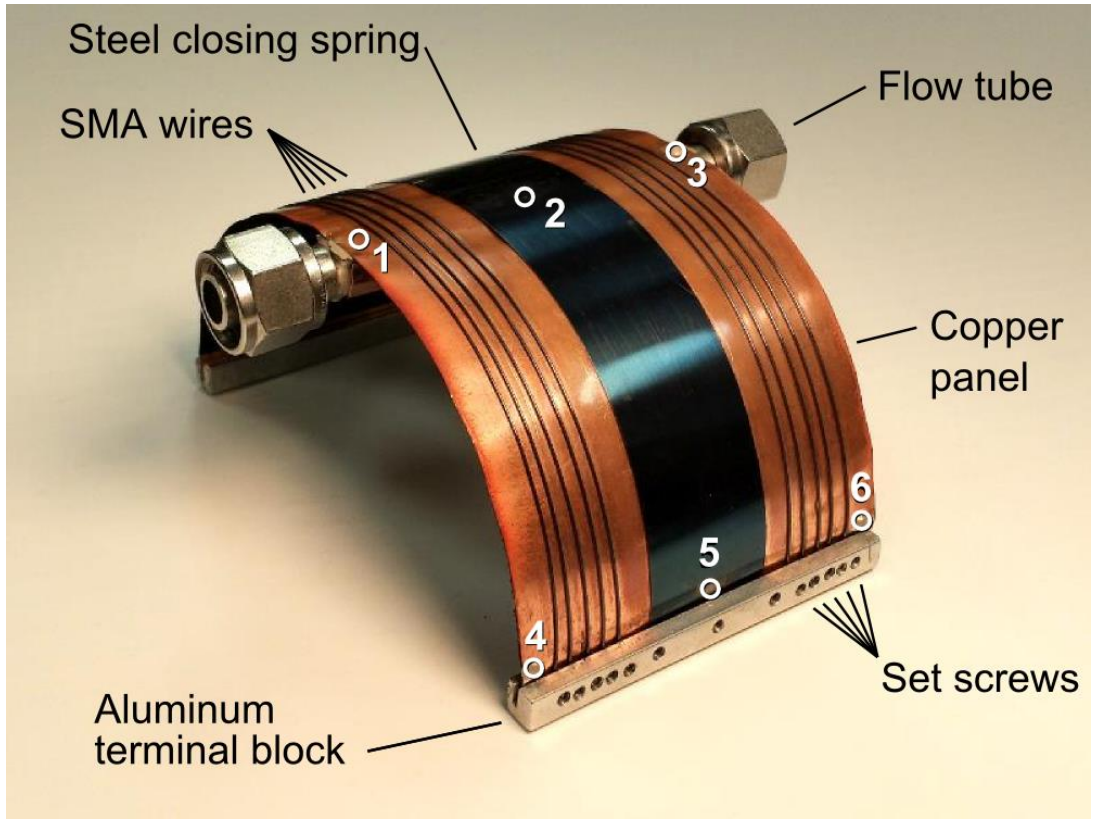
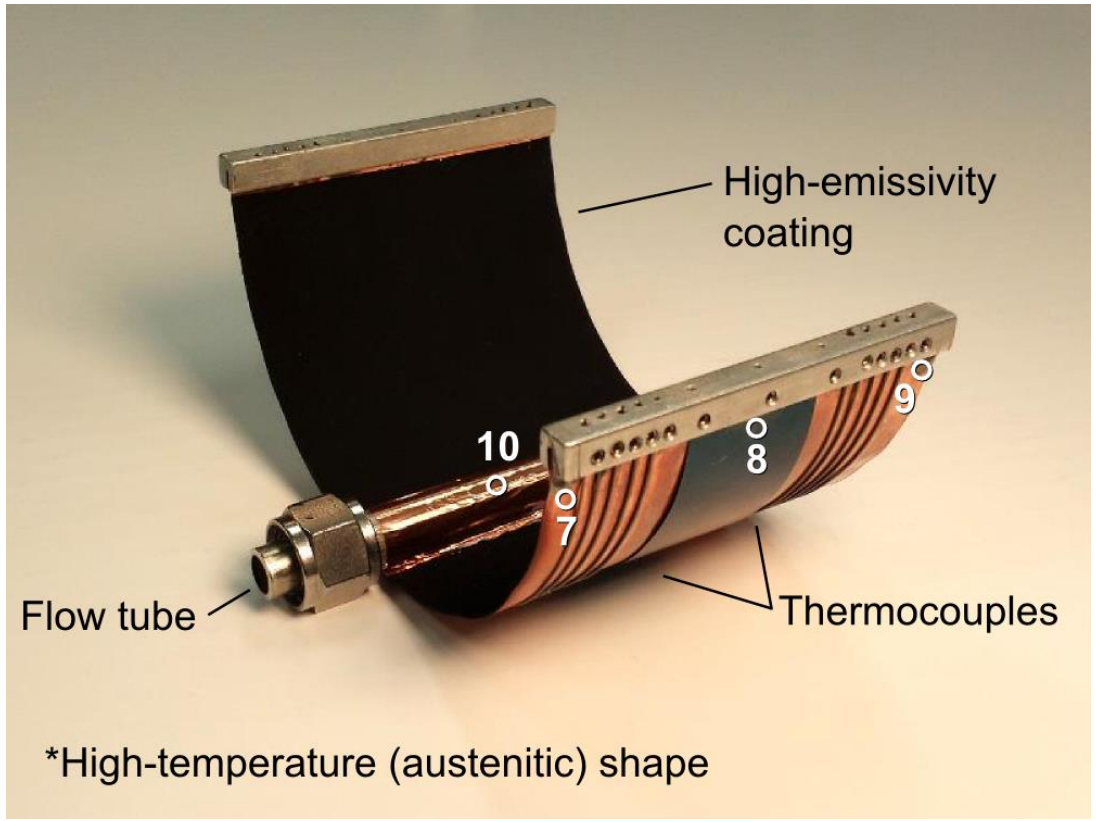
Review of Morphing Radiator Concept



Morphing Radiator Prototype from 2015 Studies

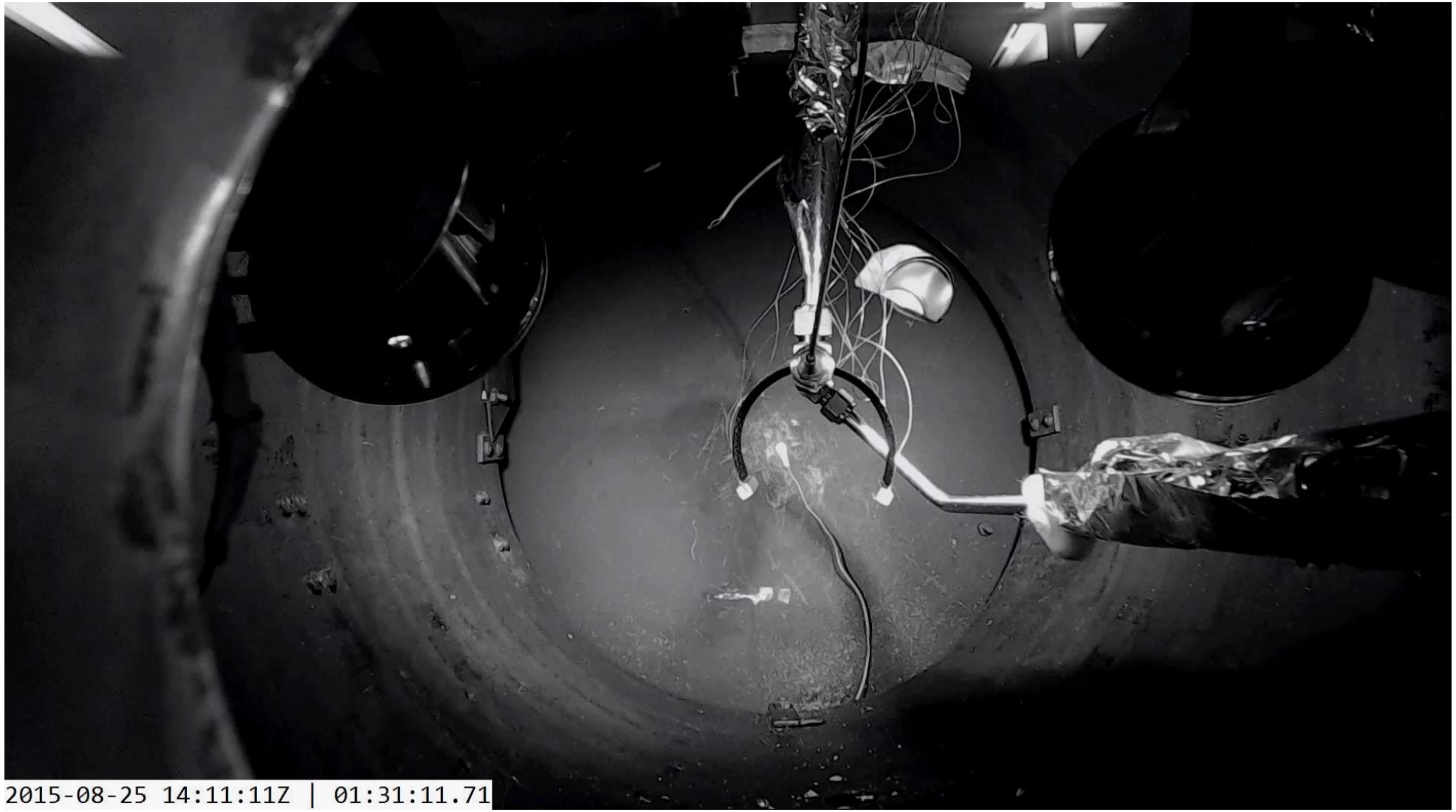




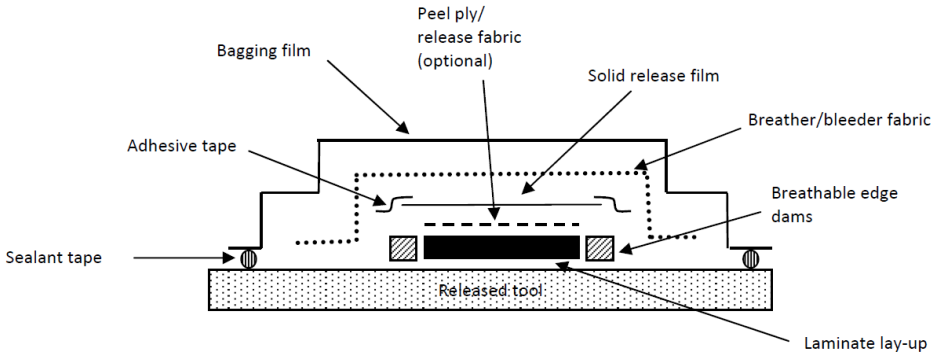
Panel: 7 x 3 x 0.007 in
Closing spring: 7 x 1 x 0.007 in

SMA Wire: 0.36 mm SmartFlex SMA wire provided by SAES Getters

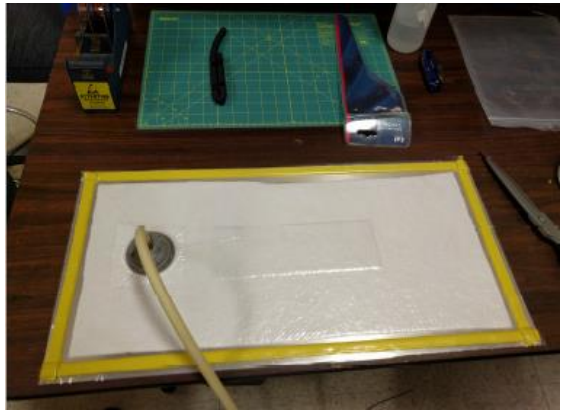
Time Lapse of Experiment from 2015 Studies



Composite Panel Fabrication Procedure



Composite fabrication setup

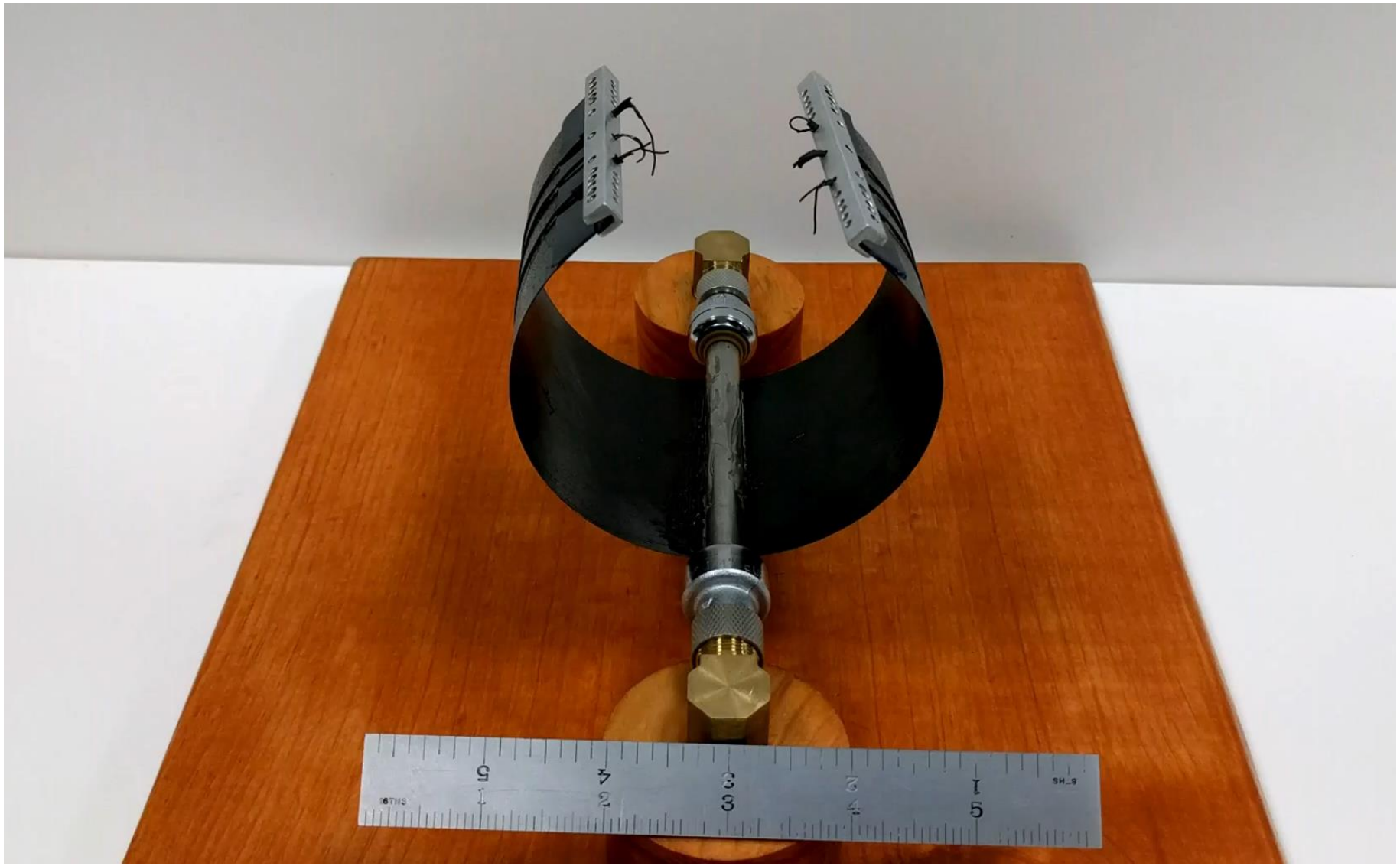


Flat panel fabrication: vacuum bagging

Composite panel surrounded by breather fabric

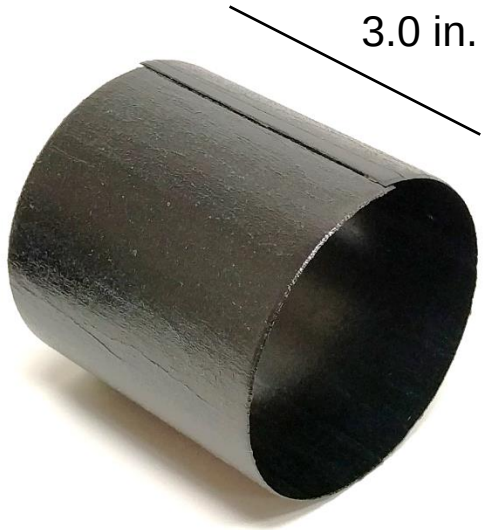
Curing oven: 350°F

Benchtop Demonstration of Composite Radiator Panel



Completed Composite Radiator Panels

Layup:
[90/+-45/0/+-45/90]



Layup:
[90/+-45/0/0/+-45/90]

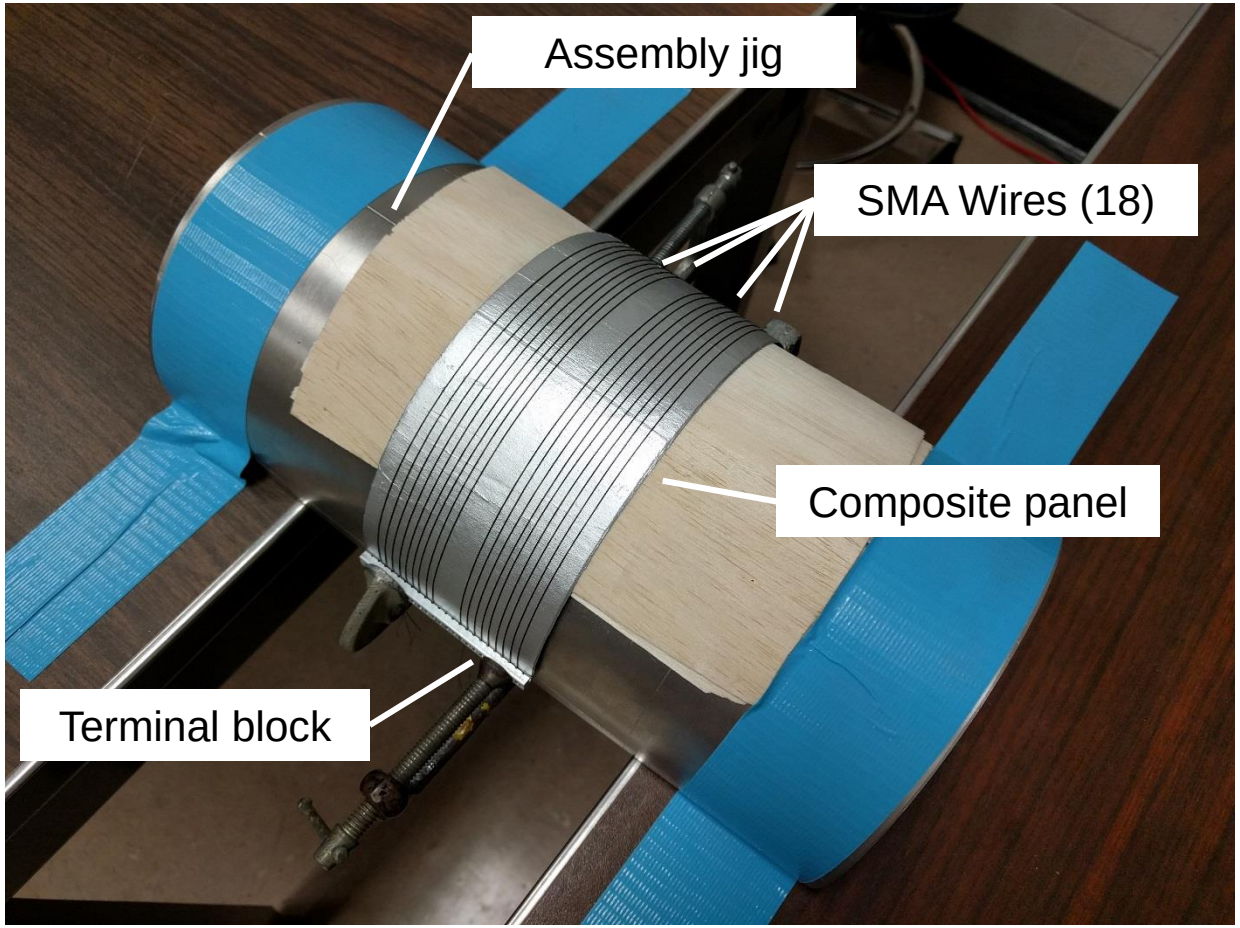
Diameter:
3.0 in

Layup:
[90/+-45/0/0/0/+-45/90]

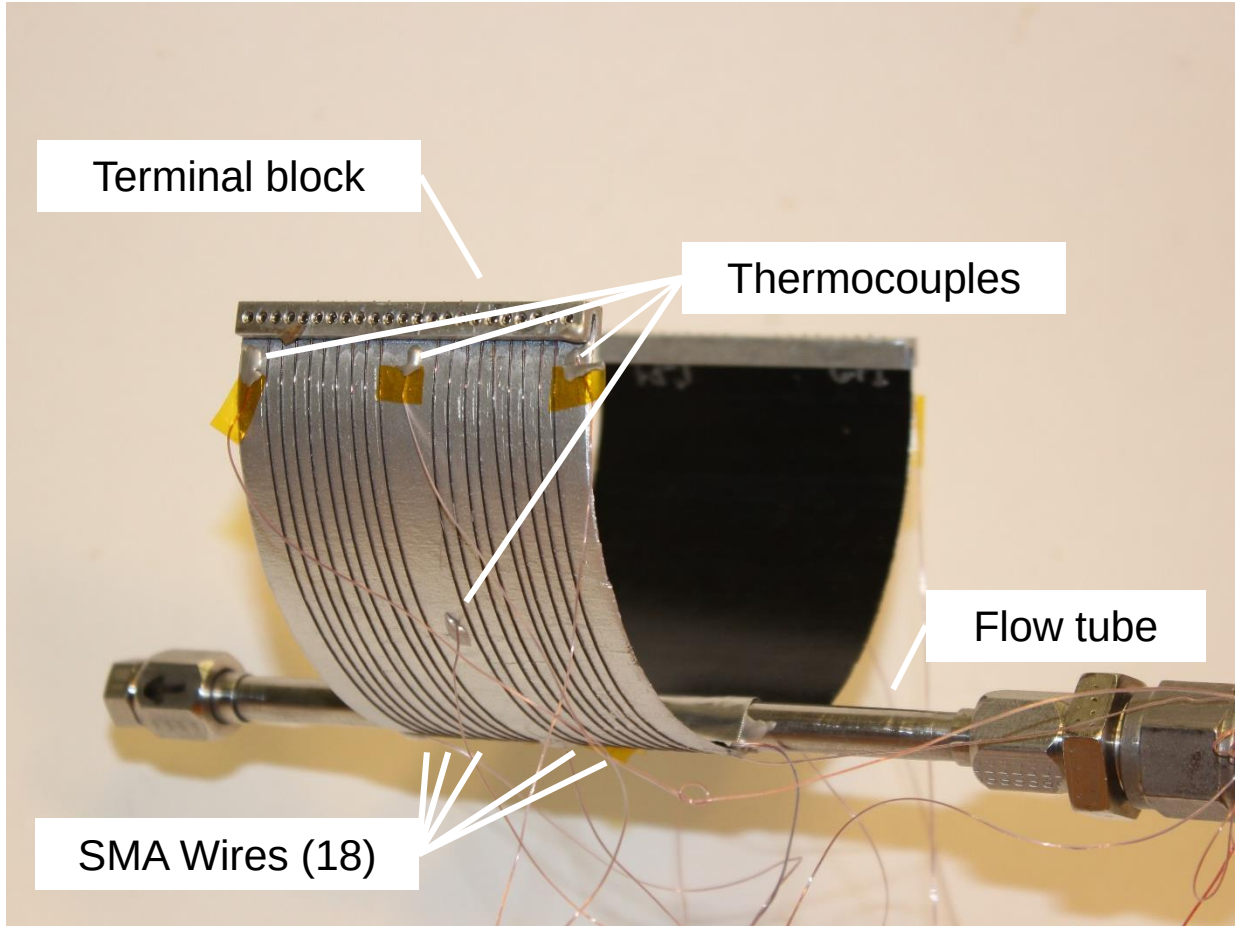
Note: Each panel was subsequently painted with a low-emissivity paint (LOMIT-I) on the outer surface. The inner surface remained unpainted.

Wire Test Article

Note: Wire test article was assembled in warm/austenitic/open configuration at room temperature.



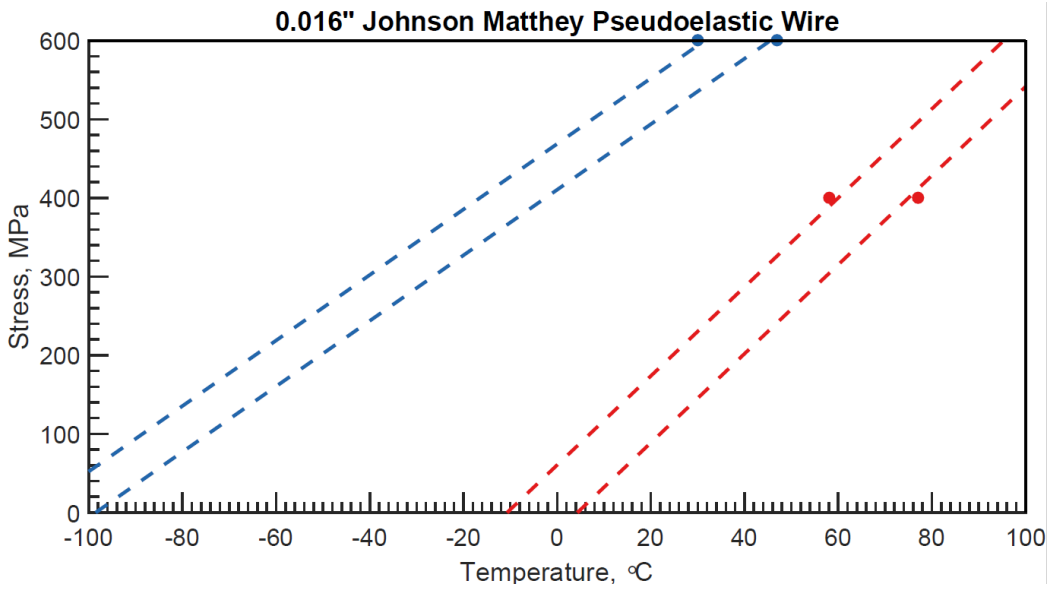
Test article on assembly jig, after attaching wires and before attaching flow tube and thermocouples



Completed test article after attaching flow tube and thermocouples

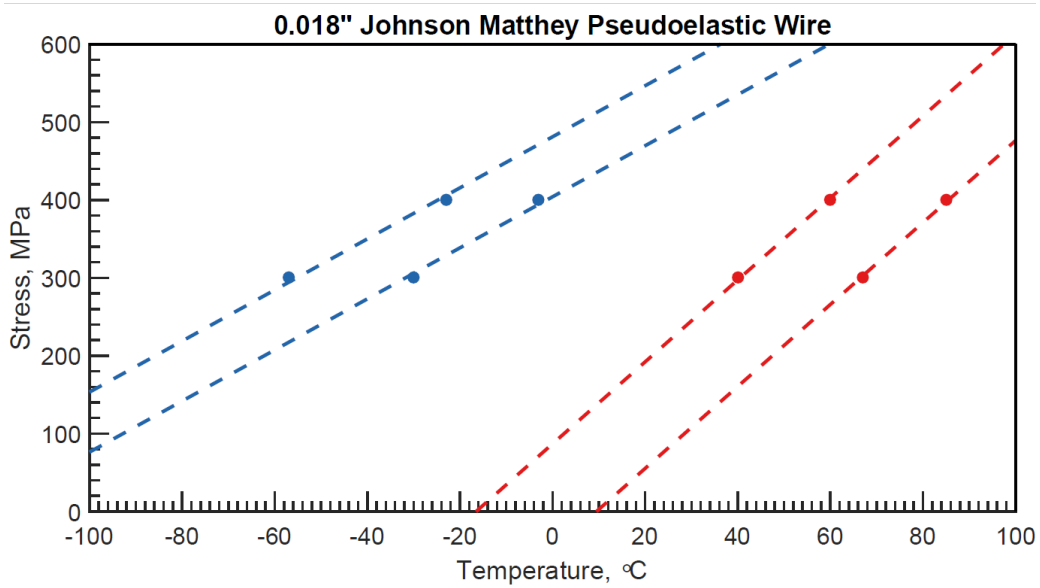
SMA Wires: Additional Details and Approx. Phase Diagram

Approximate phase diagrams determined by isobaric tensile tests



Supplier: Johnson Matthey
Diameter: 0.016”
Af: -21°C

This wire was used for the radiator.

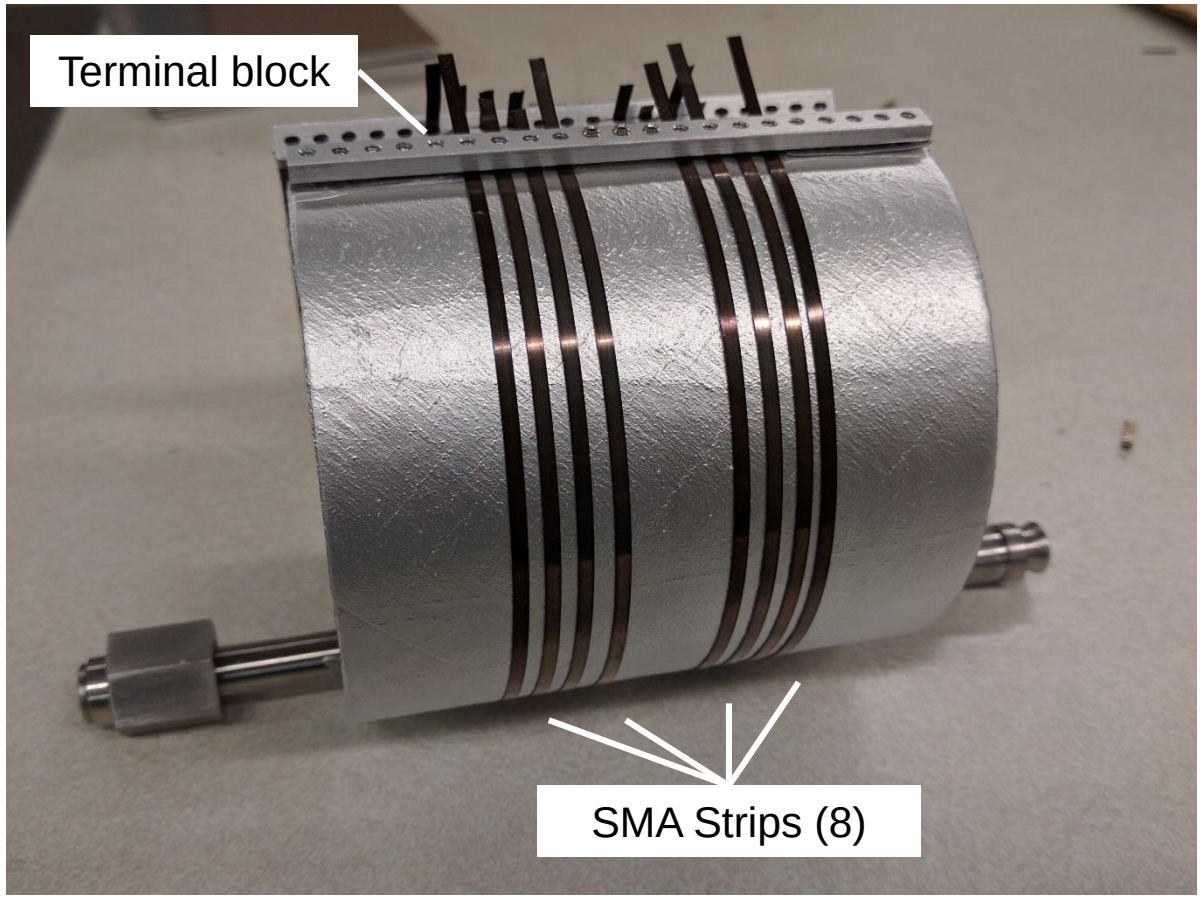


Supplier: Johnson Matthey
Diameter: 0.018”
Af: 2°C

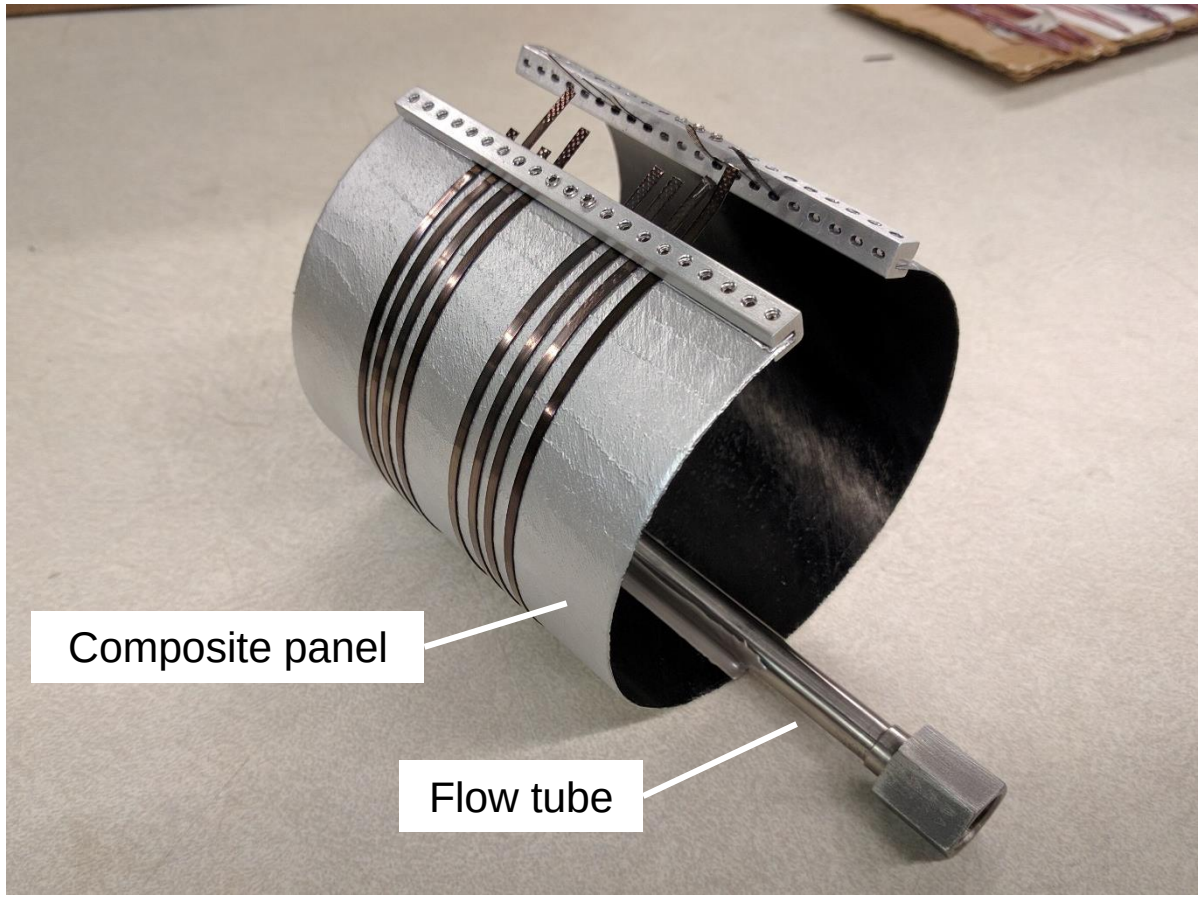
This wire was not used for the radiator due to very low martensite transformation temperatures.

Strip Test Article

Note: Strip test article was assembled in cool/martensitic/closed configuration at room temperature.

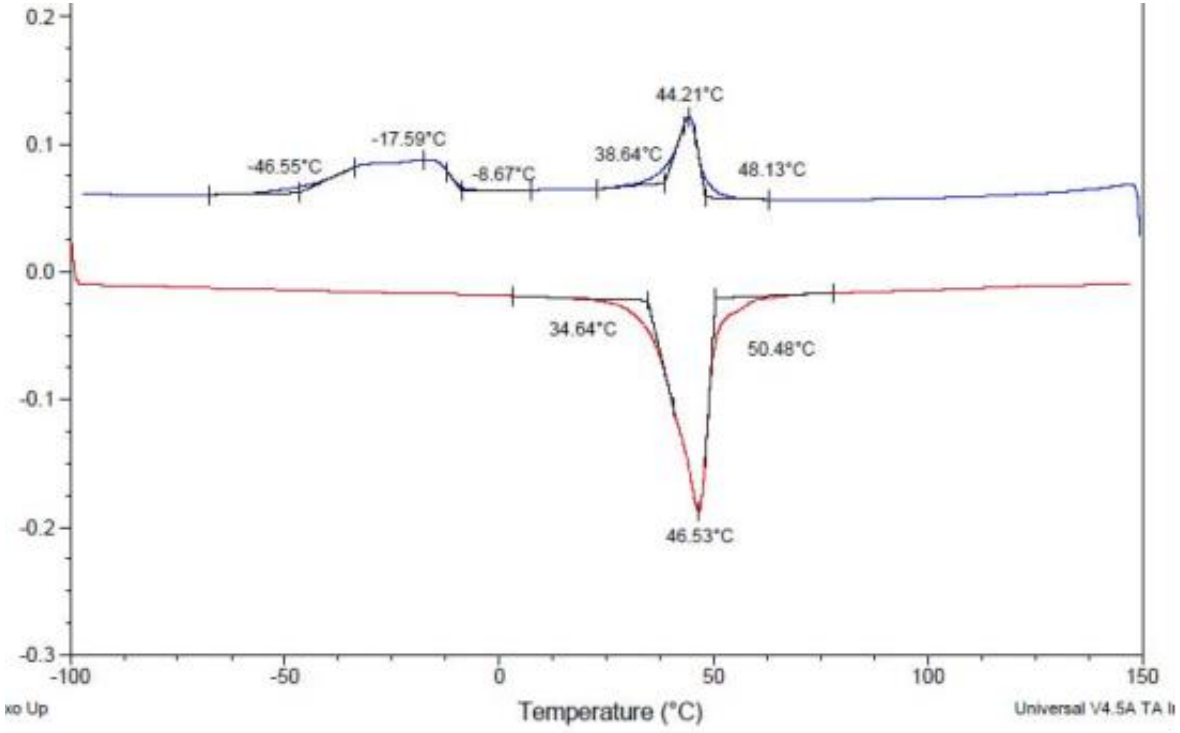


Completed test article prior to attaching thermocouples

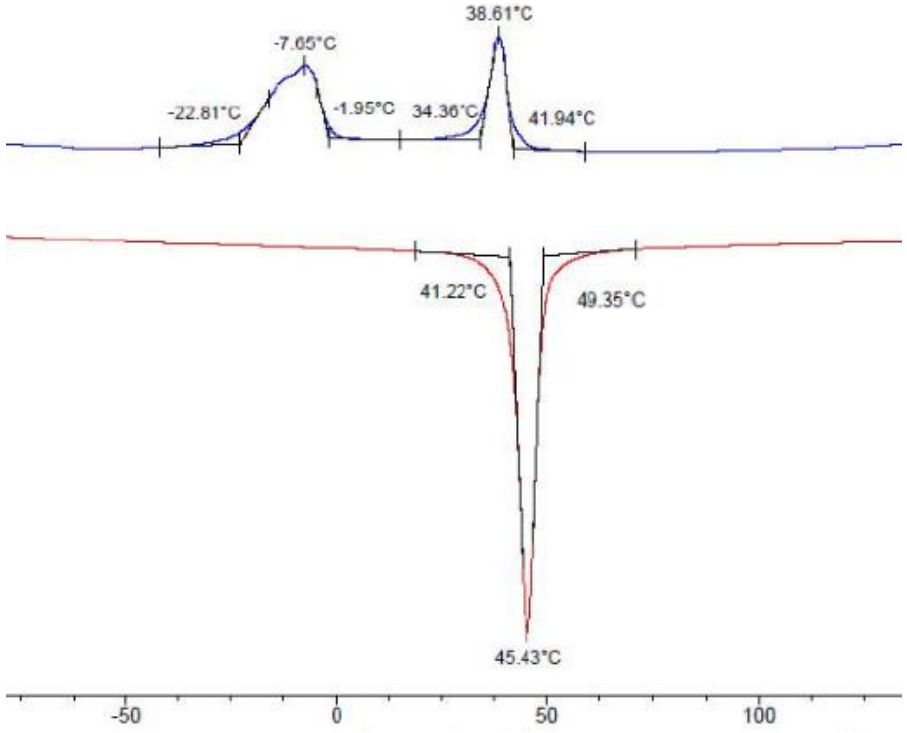


Completed test article prior to attaching thermocouples

SMA Strips: Additional Details and DSC Data

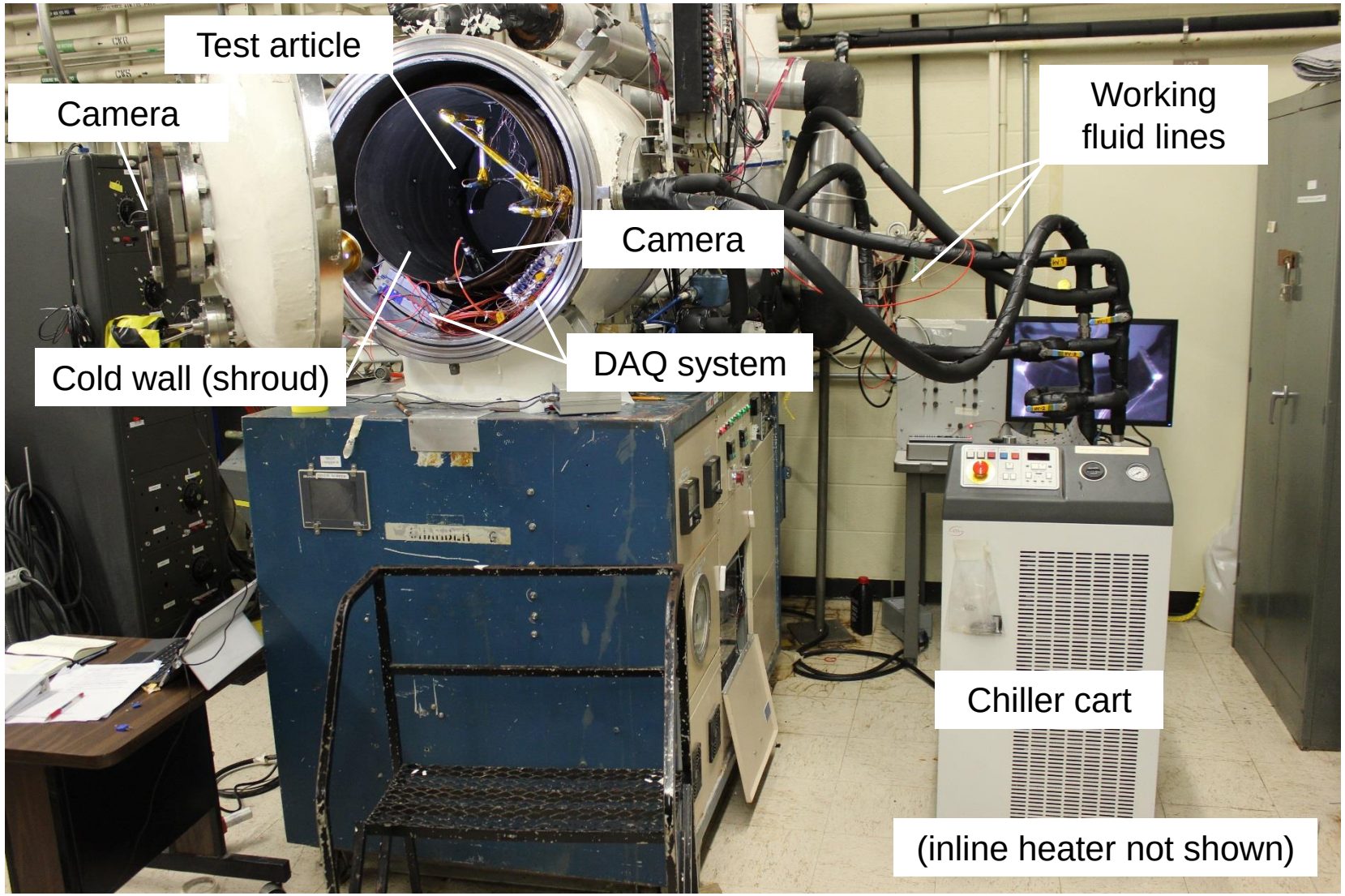


Strip 1
Supplier: Johnson Matthey
Dimensions: 0.3mm x 2.61 mm
Af: 50°C

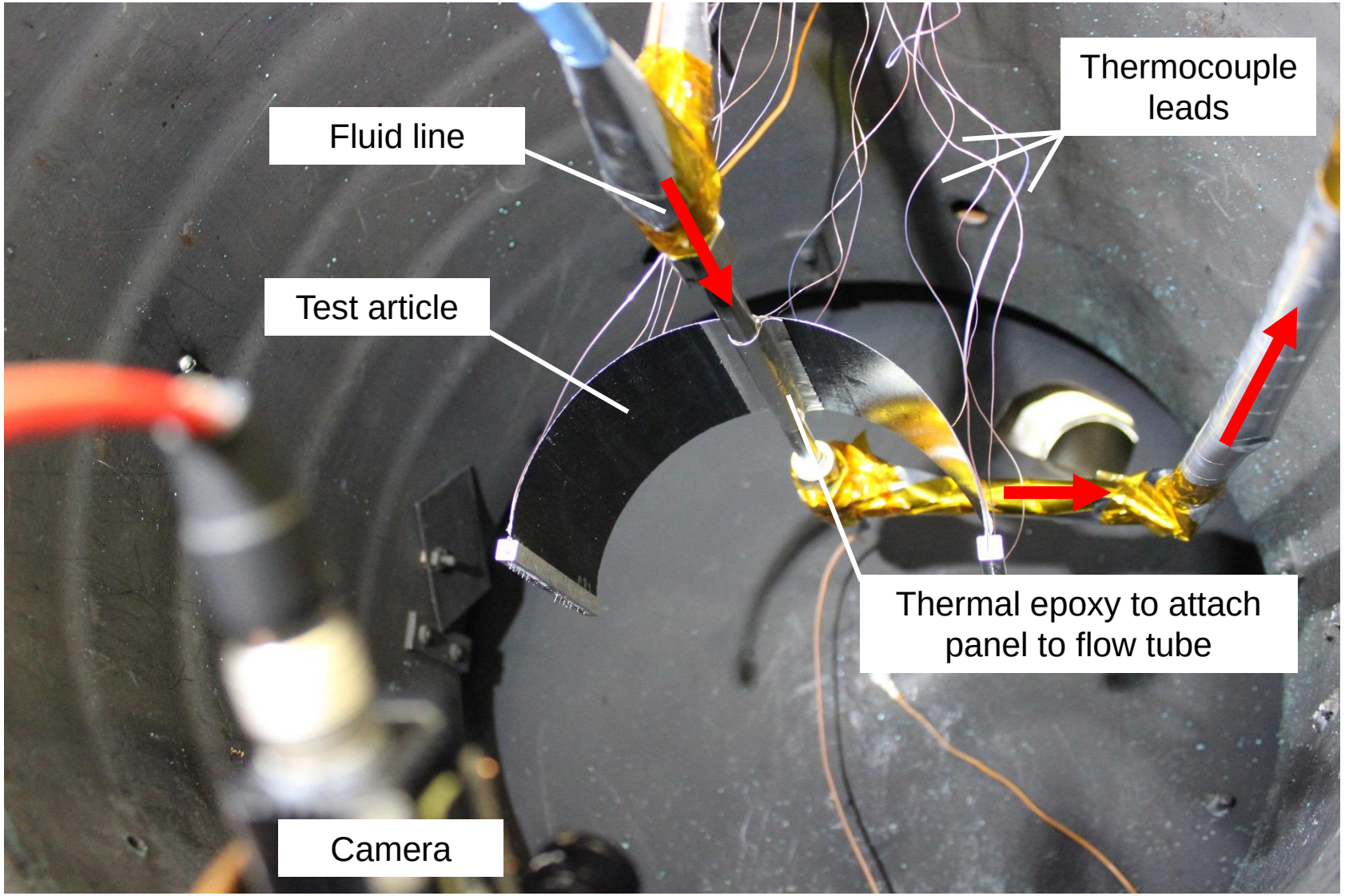


Strip 2
Supplier: Johnson Matthey
Dimensions: 0.3mm x 2.61 mm
Af: 49°C

Thermal Vacuum Chamber Test Setup: NASA JSC Chamber G



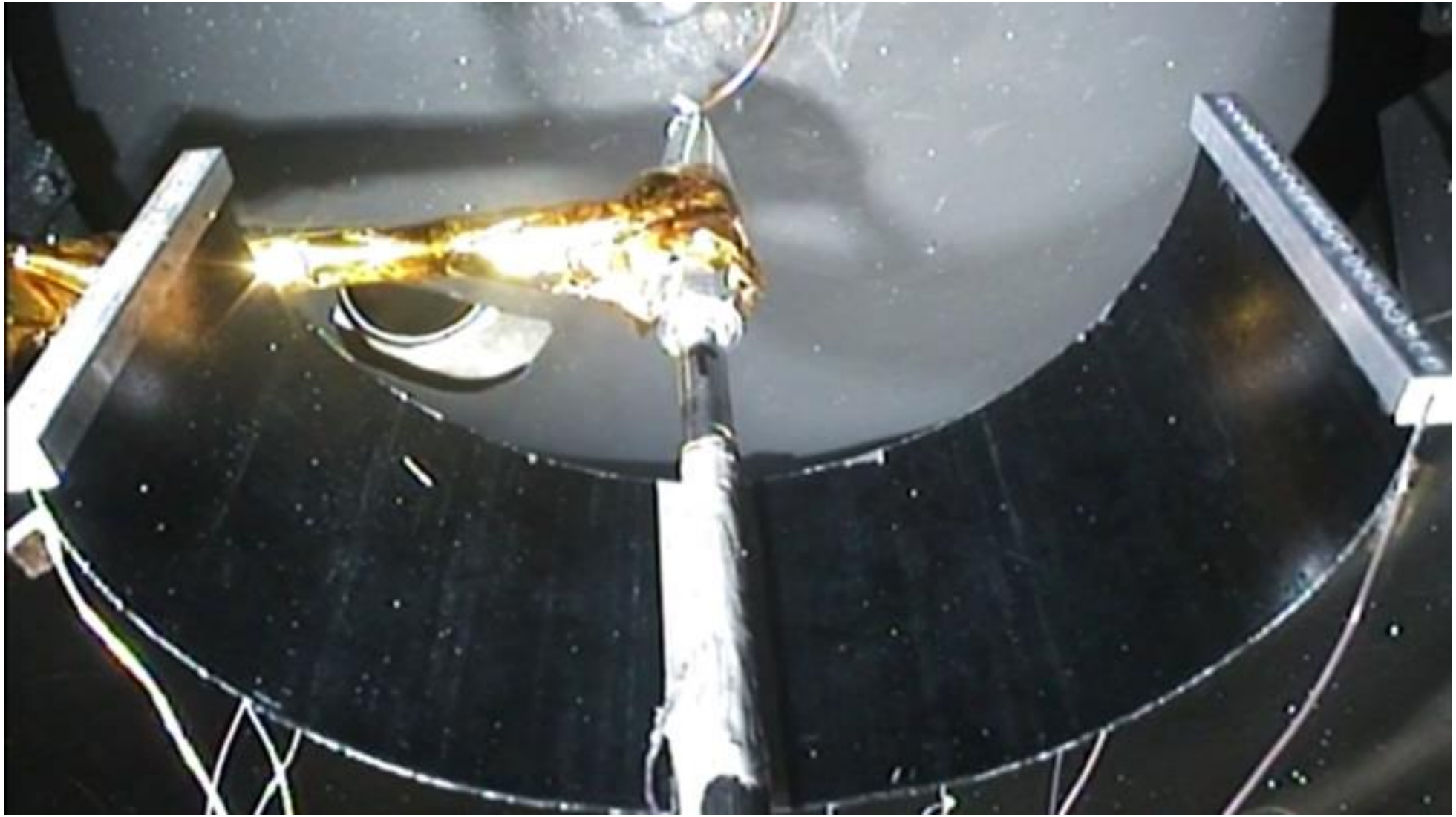
Close-Up of Test Article Installed in Chamber



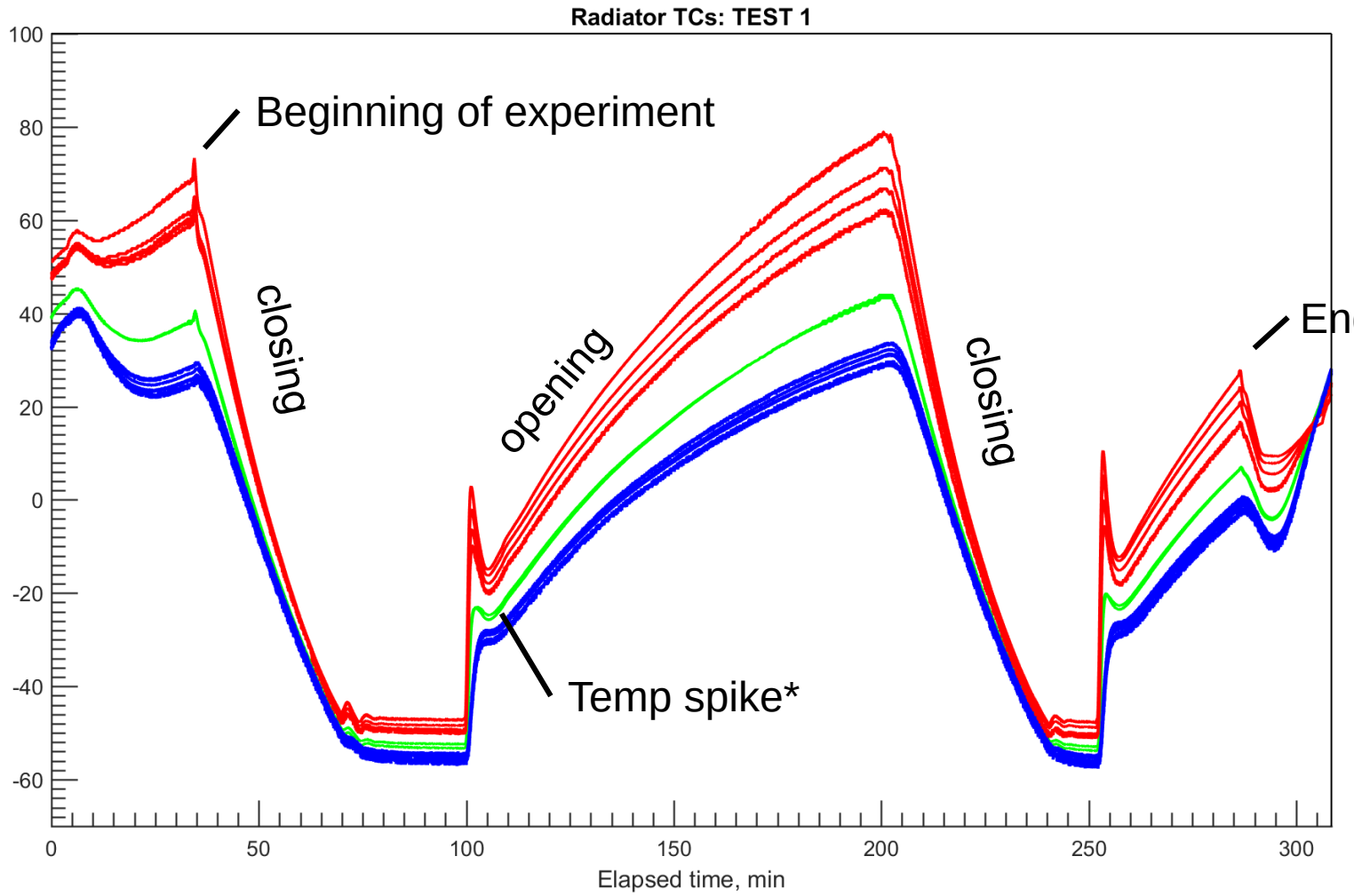
Arrows indicate flow direction

Wire Test Article: External Camera

Wire Test Article: In-Chamber Camera



Wire Test Article: Temperature Data



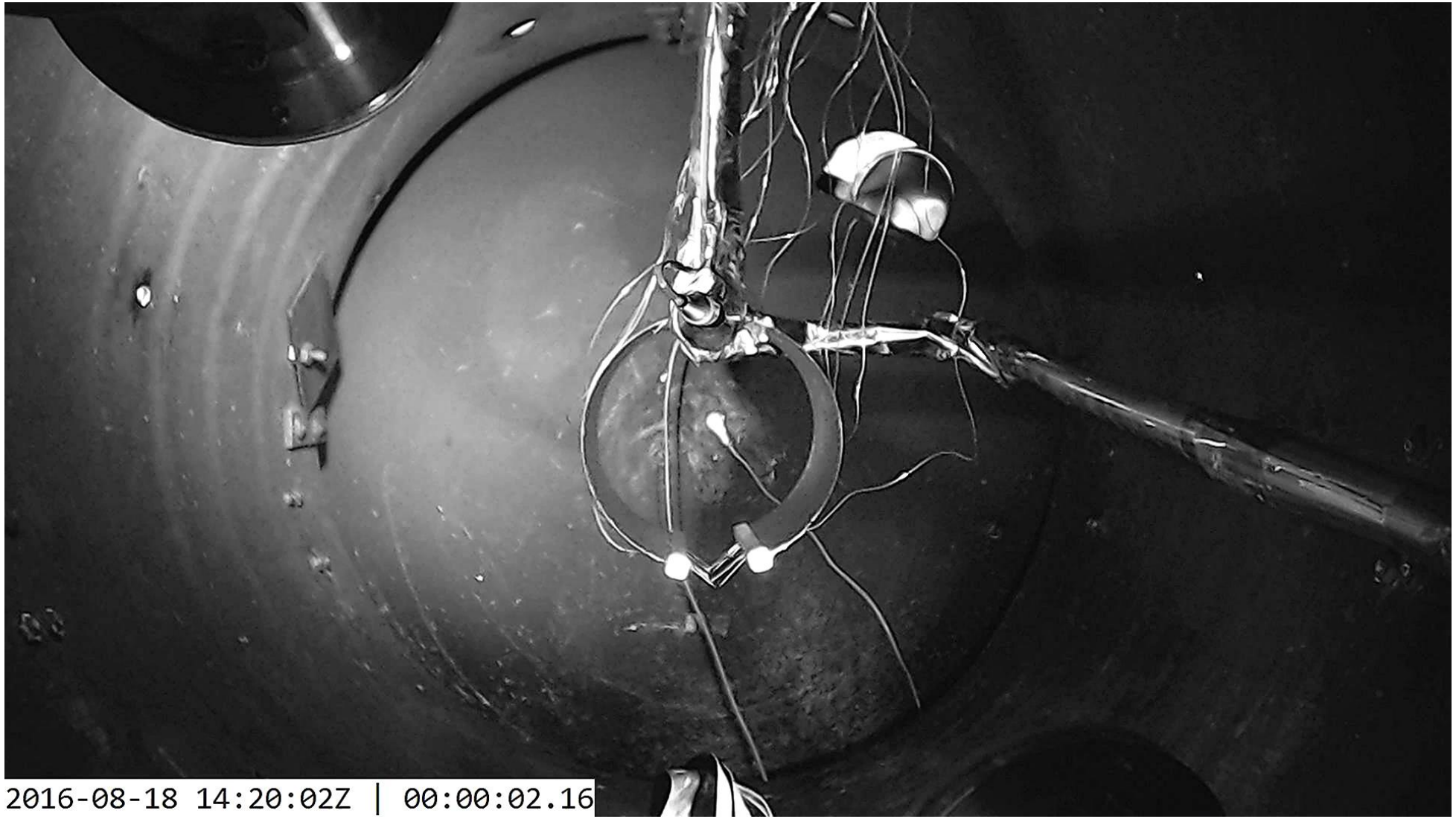
Center of panel: 4 TCs

Middle of panel: 2 TCs

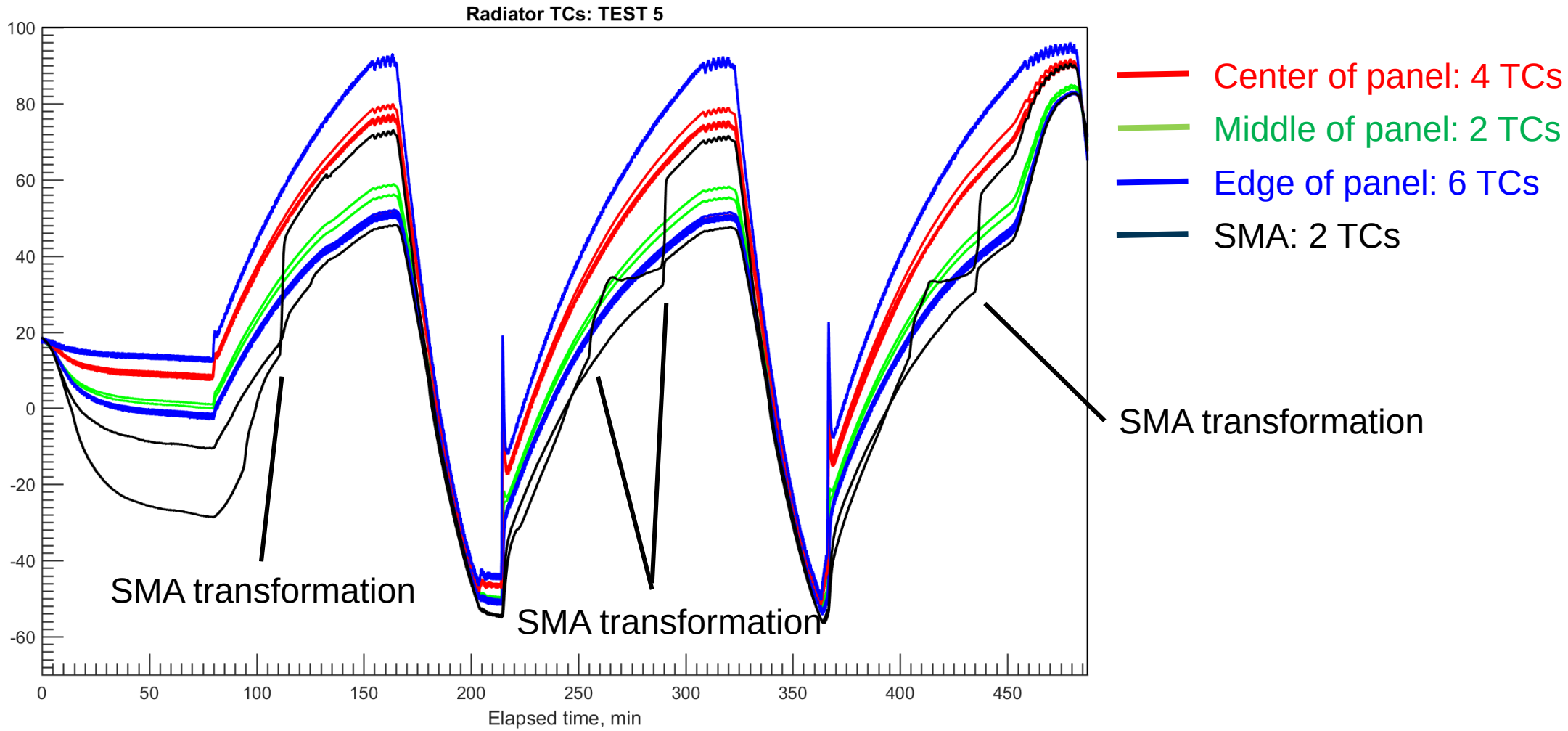
Edge of panel: 6 TCs

* Temp spikes caused by opening valve to heater, sending a pulse of warm fluid through the system.

Strip Test Article: External Camera



Strip Test Article: Temperature Data



Preliminary Conclusions

- Composite morphing radiator prototypes exhibited the desired temperature-induced actuation behavior in a relevant environment without failure.
- Wire test articles:
  - The minimum temperature achieved during the test (-45°C) was too high to achieve full transformation into martensite, thus the radiator did not close fully.
  - The radiator was able to return to the fully open configuration before the maximum temperature (100°C) was reached.
- Strip test article:
  - The radiator was unable to fully open as the stress in each strip was too high; additional strips would have allowed the radiator open more.
  - The radiator was able to return to the fully closed configuration before the minimum temperature (-45°C) was reached
- Further SMA development is needed to achieve full range of actuation (open/closed) within the temperature range achievable during the experiment (-45°C to 100°C).

Acknowledgments

Special thanks to:

- Othmane Benafan (NASA Glenn) for providing the SMA wires and strip.
- James Brown, Tobin Barnes, and Peter Grenfell (NASA JSC, Innovation Design Center) for fabricating the terminal blocks for the radiator prototypes.
- Joe Settles (NASA JSC) for assistance in detwinning the SMA strips prior to assembling the strip test article.
- Everyone in Building 33 (NASA JSC) who helped with setting up and running these experiments in Chamber G.