Variable-View-Factor Two-Phase Radiator

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Outline

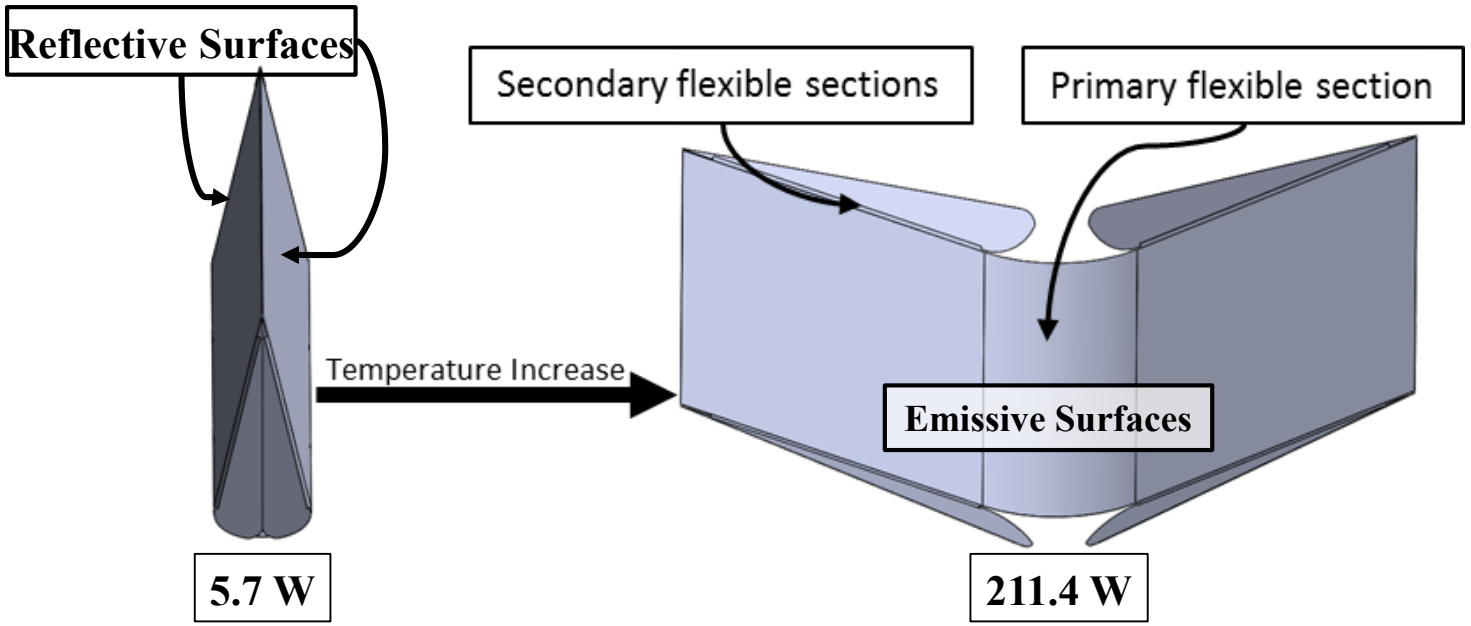
- Topic Background and Introduction to the Problem
- Proposed Concept
- Structural Design Study Overview
- Envelope Material Selection Considerations
- Working Fluid Material Selection
- Prototyping, Structural Development, and Experimental Results

Passive Variable View Factor 2-Phase Radiator

- NASA Roadmap: Looking for Variable Geometry Radiators with a 6:1 turndown capability, with 12:1 as a stretch goal
- The proposed concept is passive, with significant potential for a large turndown ratio
  - Radiator is hollow and curved (packed), wicked inside, contains saturated working fluid.
    - As sink temperature increases, radiator will need to increase its temperature to reject the same power.
    - Similarly, as power increases, radiator will need to increase its temperature to reject the higher power into the same sink temperature.
  - Then the increasing vapor pressure will open the radiator (increasing view factor) and, consequently reducing thermal resistance ….**minimizing** the vapor temperature increase
  - In other words, we have a Variable Conductance Radiator …that is **Passive** and **Deployable**
  - **Its sensitivity can be controlled and/or improved through design/analysis/improved geometric configurations.**

Proposed Concept

- **Variable-View-Factor Two-Phase Radiator:**

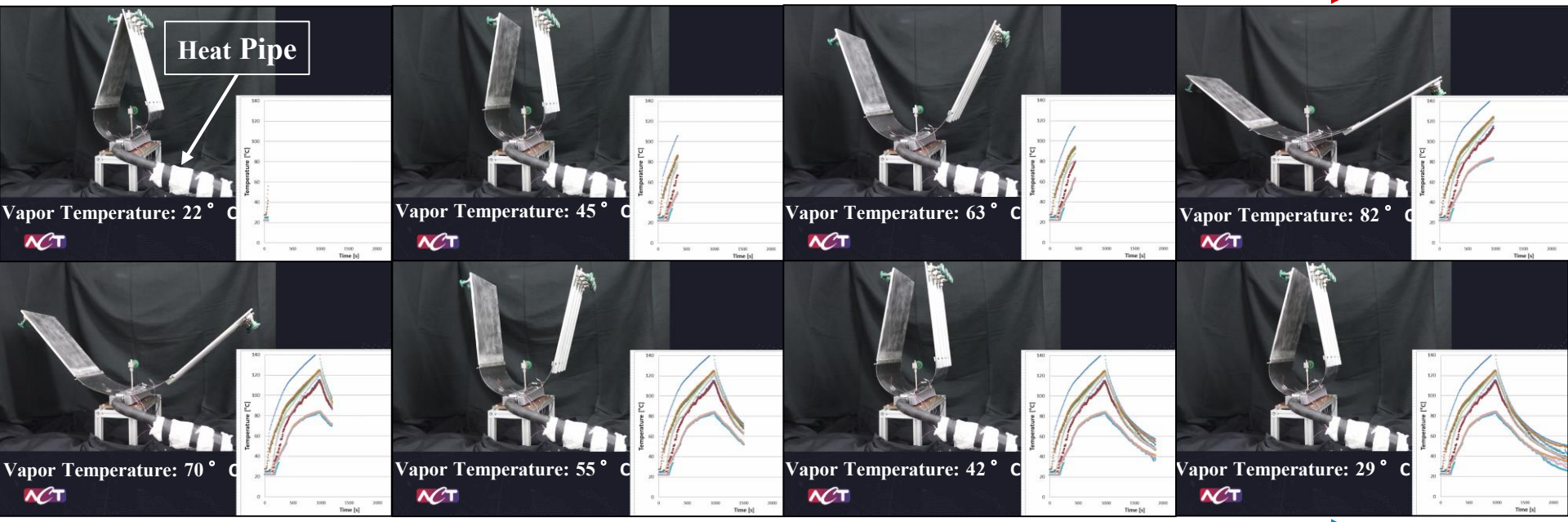


NASA Roadmap: Looking for Variable Geometry Radiators with a 6:1 turndown capability, with 12:1 as a stretch goal

- **Phase I structural simulations and design study yields geometries that achieve > 37:1 thermal turndown ratio**

Passive Variable View Factor 2-Phase Radiator

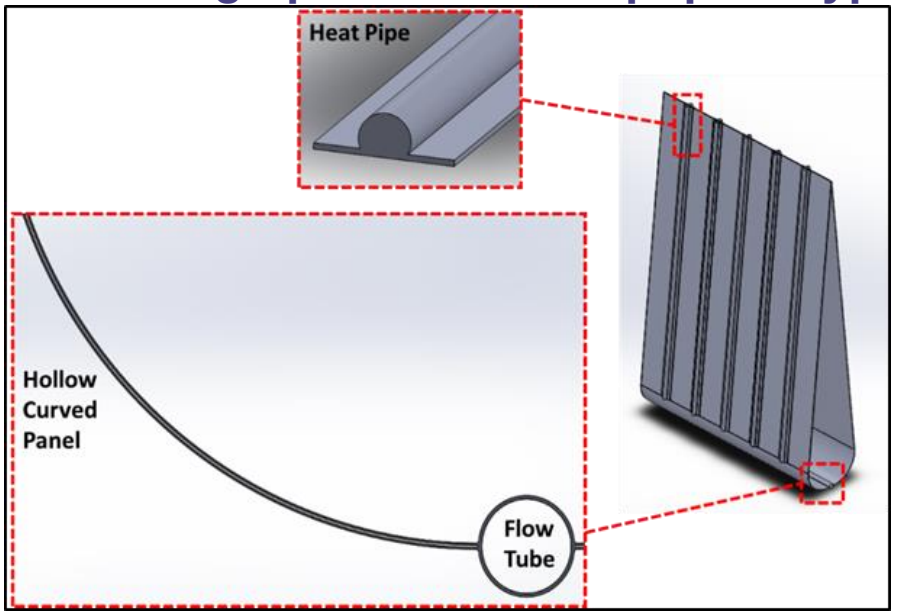
Opening (Heating)

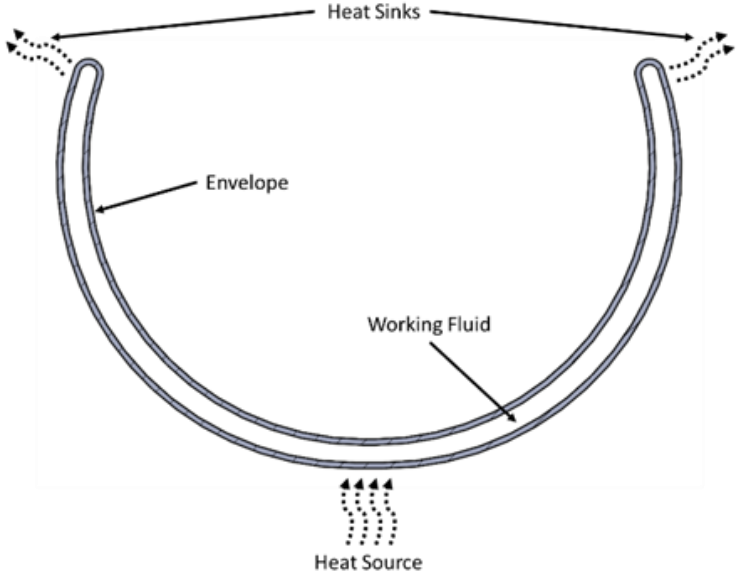


Closing (Cooling)

Proposed Concept Introduction

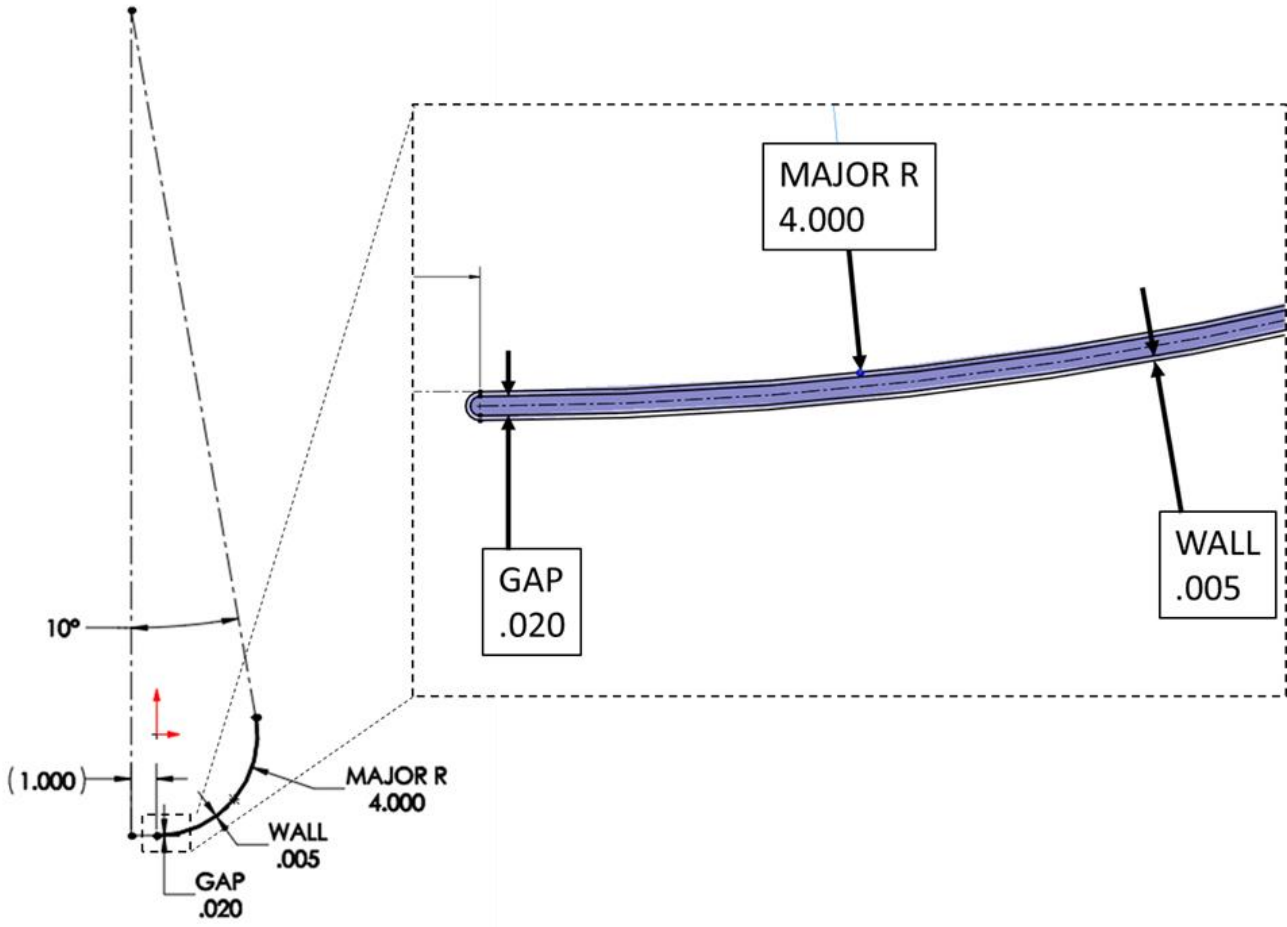
- **Trade study and structural/thermal analysis of baseline radiator design**
  - **Radiator material selection**
    - **Key parameters: Elasticity, thermal conductivity, compatibility with working fluid**
  - **Structural analysis of baseline design**
    - **Analyze the theoretical effect of wall thickness / vapor gap thickness**
    - **No geometric sensitivity enhancement features analyzed under this task**
  - **Design proof-of-concept prototype (baseline design)**





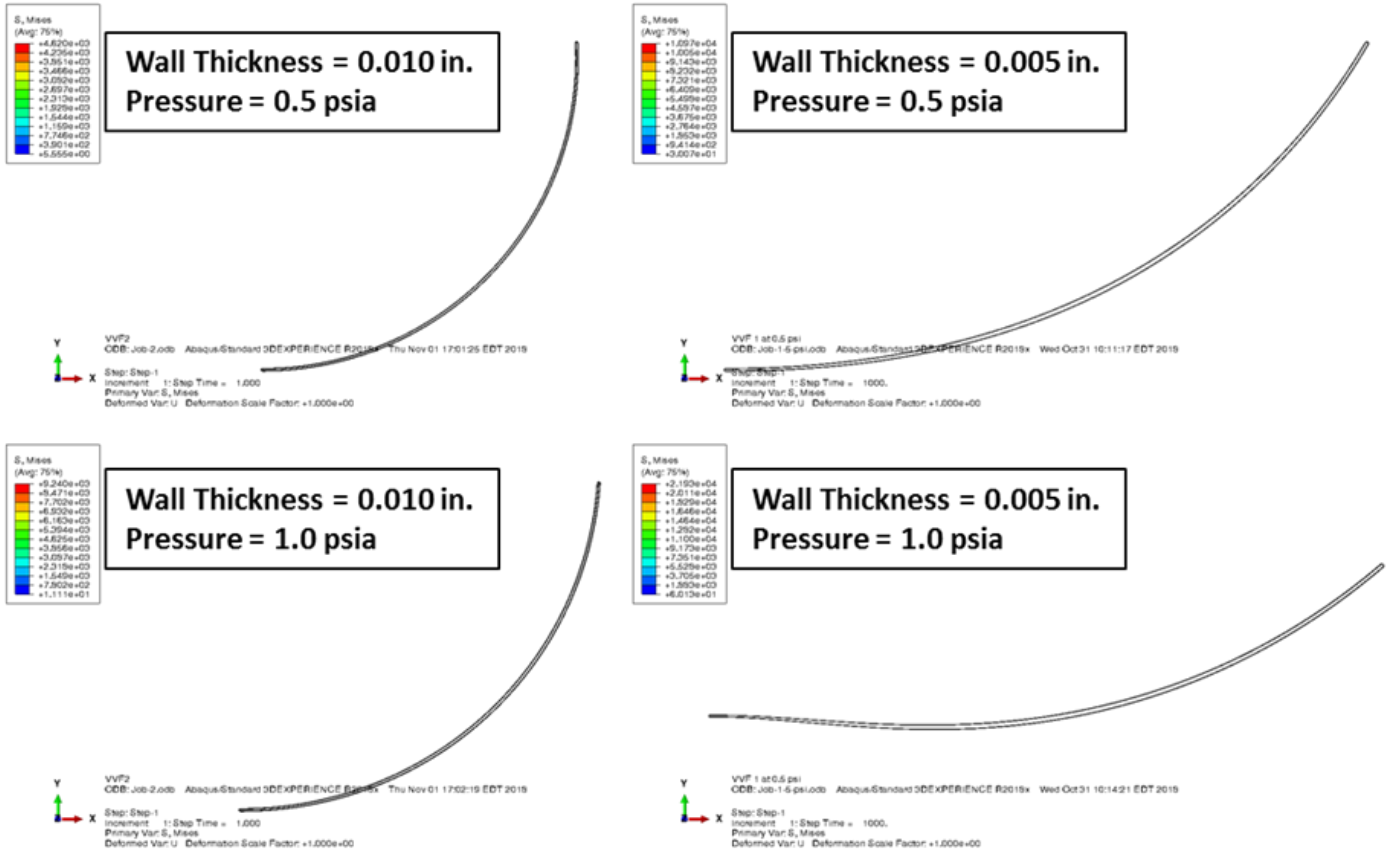
Design Study Setup

- Trade study and structural analysis of baseline radiator design
  - Design Parameters:
    - Major Radius
    - Wall Thickness
    - Gap Width
    - # of Features
    - Feature Radius



Structural Study Results

- **Trade study and structural analysis of baseline radiator design**
  - **Wall Thickness:**



Structural Study Results

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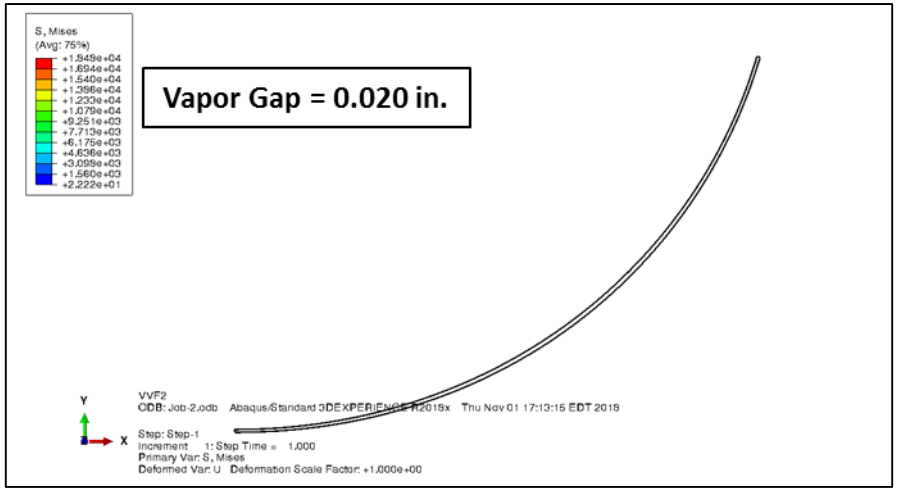
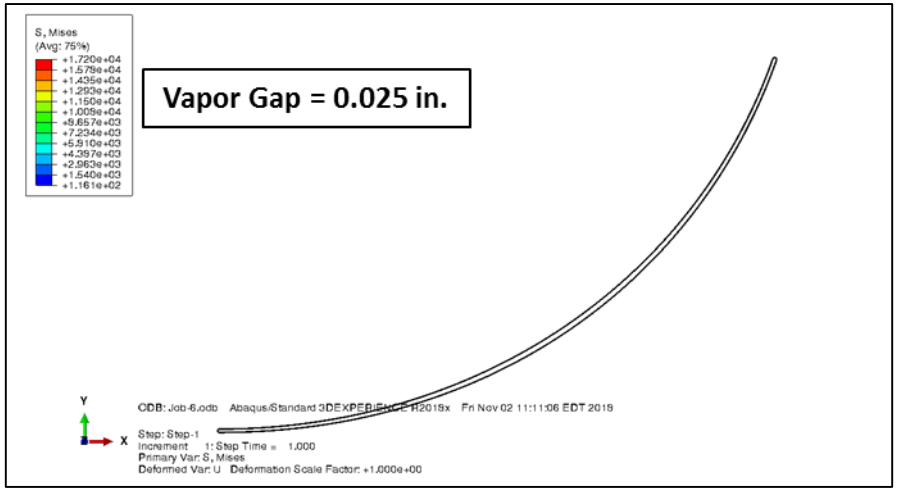
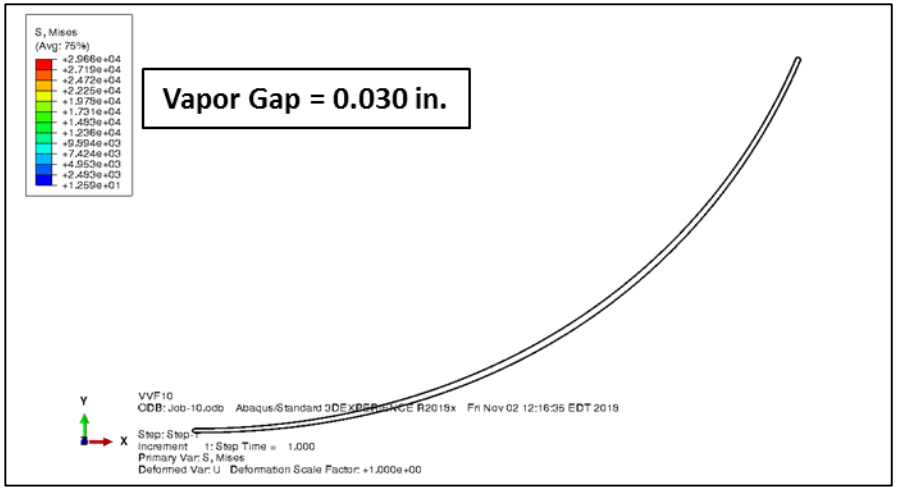
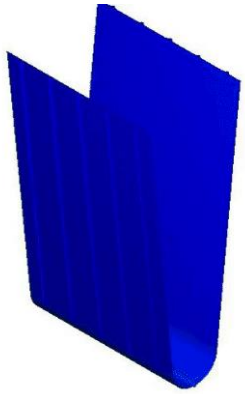


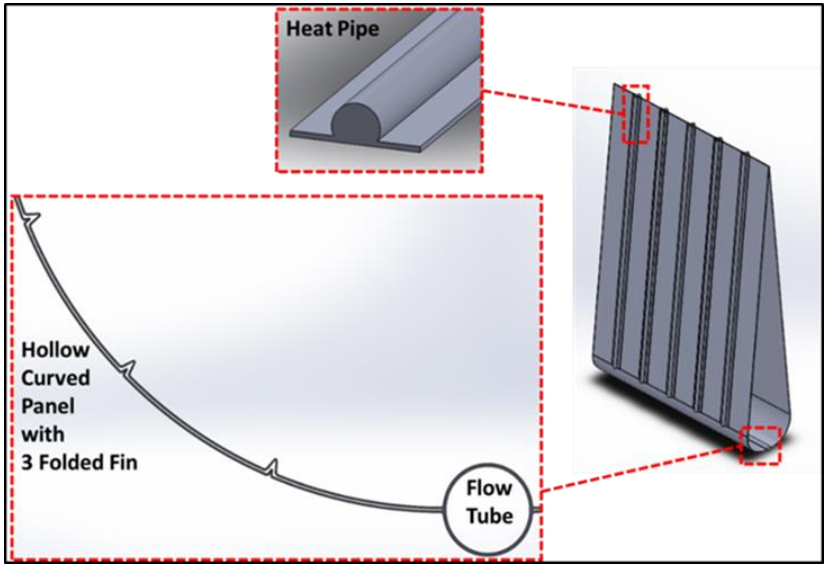


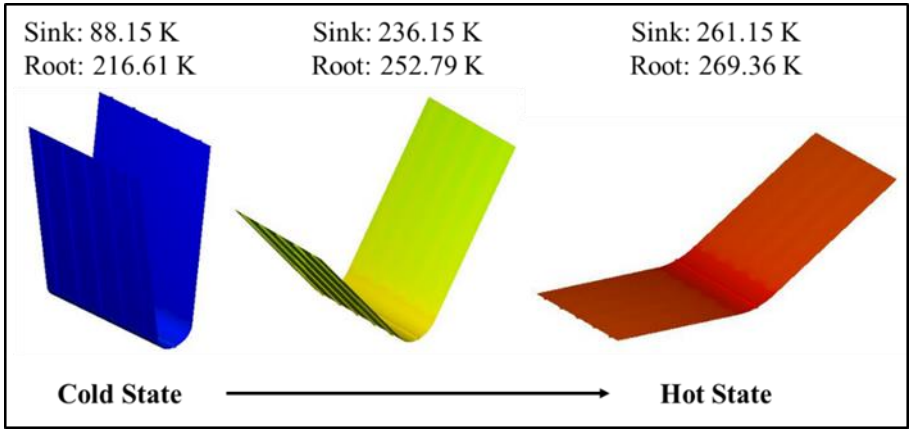


Structural Enhancements

- **Development of optimal radiator design**
  - **Analyze the effect of features to enhance opening sensitivity**
    - **Axial stiffeners**
    - **Formed sheet metal**
    - **Initial free state shape**
  - **Liquid return strategies (wick design)**
  - **The conclusion of this task will show a path for ser enhancements**



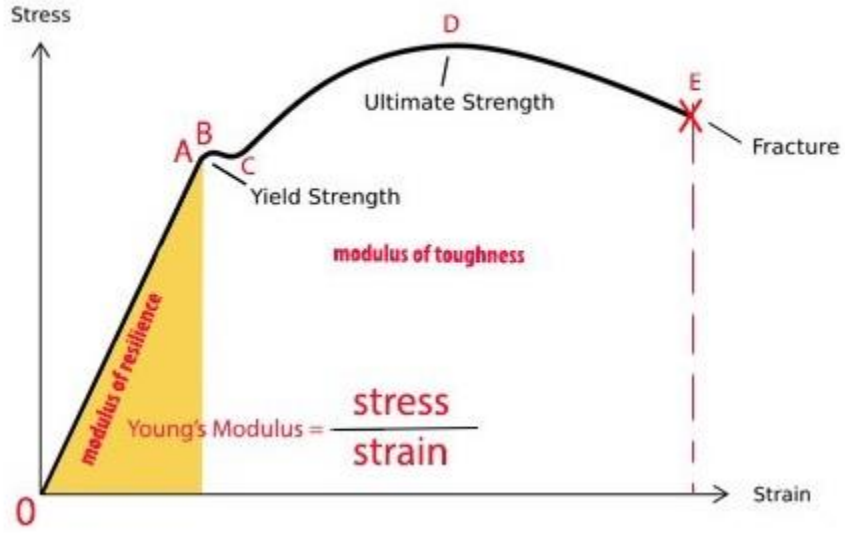




Envelope Material Selection

Desirable traits of an envelope material:

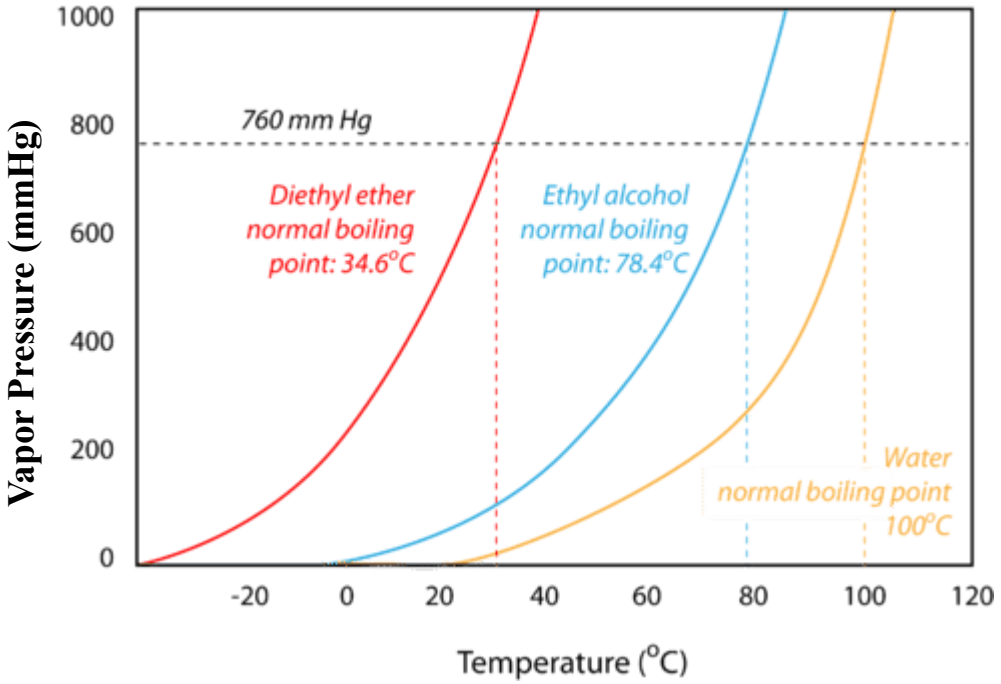
- **High Yield Strength**
  - Contain working fluid pressure
  - Undergo high bending deformation
- **Low Elastic Modulus**
  - Develop lower stress when deformed
- **Low Density**
- **High Thermal Conductivity**
- **Long Fatigue Life**
- **Compatibility with Working Fluid**



Working Fluid Selection

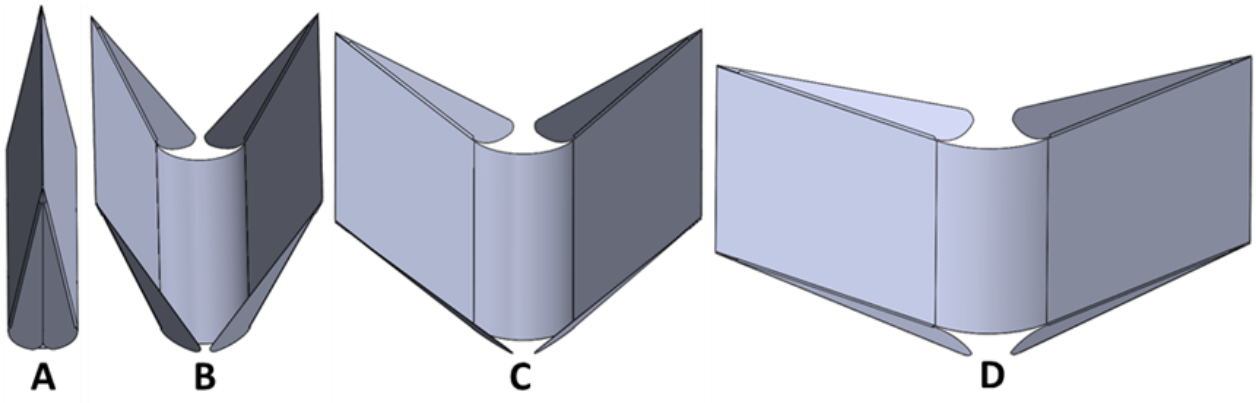
Desirable traits of a working fluid:

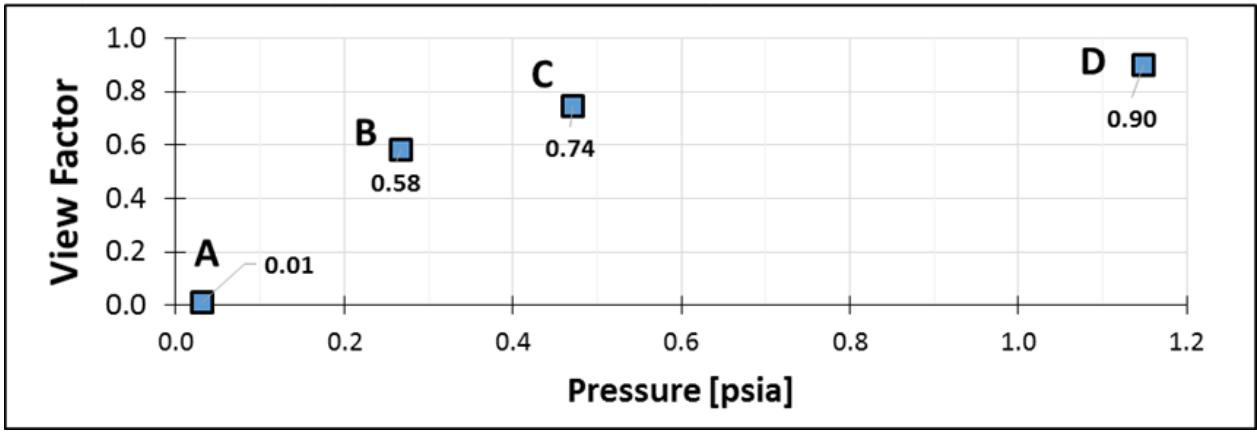
- Compatibility with Envelope Material
- Suitable Vapor Pressure in Thermal Control Range
- High Heat Pipe Merit Number



Near-Zero View Factor

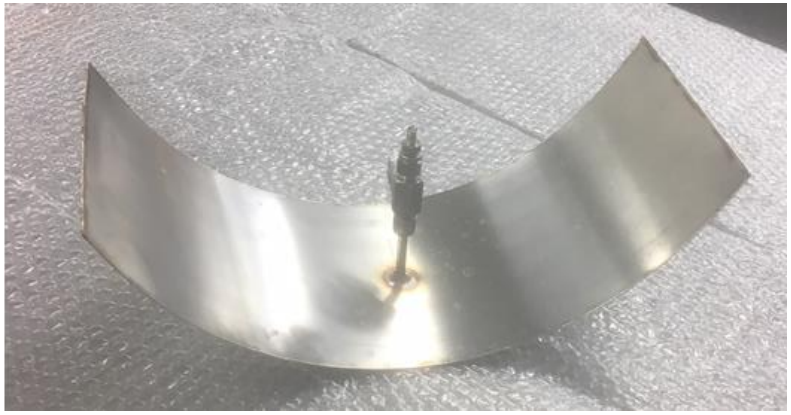
- **Development of optimal radiator design:**
  - Additional panels that block radiation in closed configuration can be added to reduce view factor to near zero
  - These panels can also be attached by flexible passive actuator

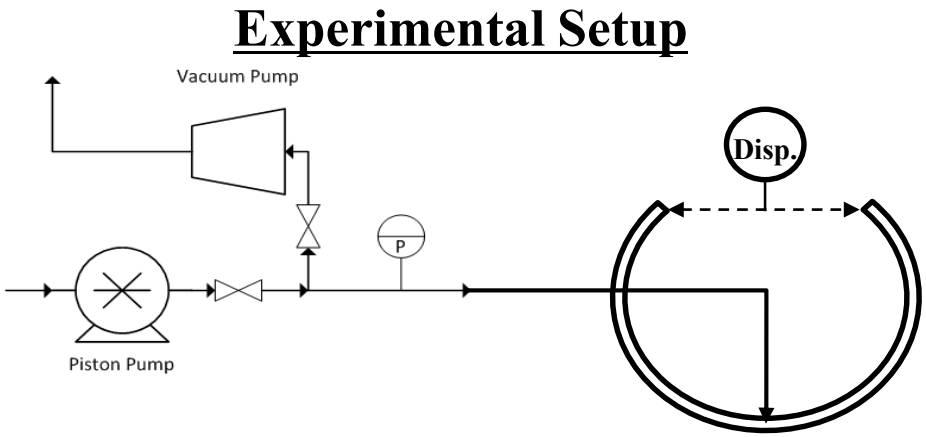




Prototyping

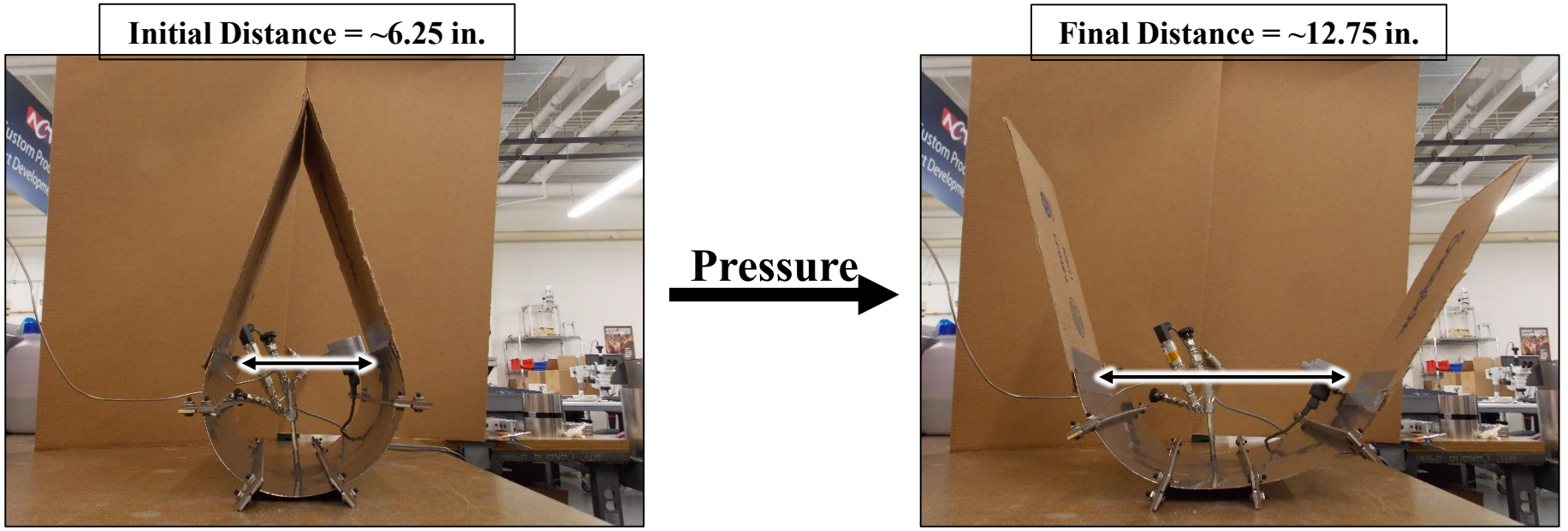
- **Design proof-of-concept prototype (baseline design)**
  - **Prototype #1**
    - **Initial Distance = ~13.75 in.**
  - **Inflated by pumping water**
    - **Final Distance = ~16 in.**
    - **Observed ballooning behavior**
      - » **Fabricated linear clamps to resist ballooning in future experiments**





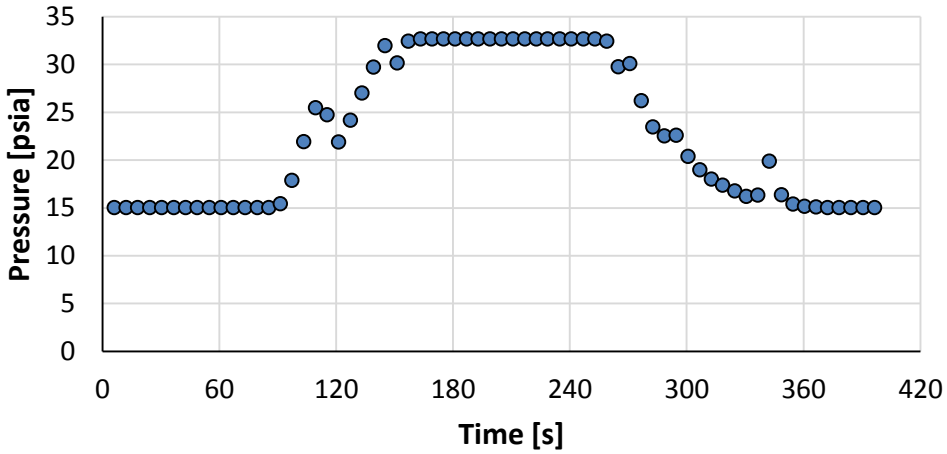
Prototyping

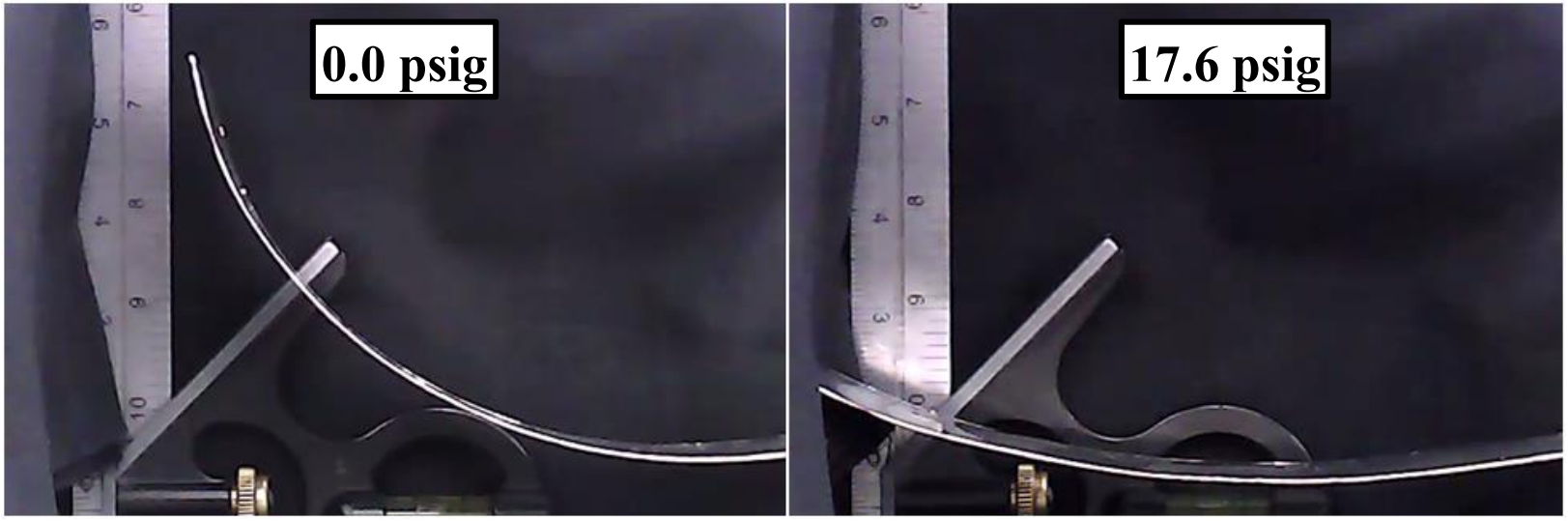
- **Fabrication and testing of a proof of concept variable view factor radiator**
  - **Design proof-of-concept prototype (baseline design)**
    - **Prototype #2**
      - **Wall thickness = 0.015 in.**
      - **Material = 316 Stainless Steel Coil Shim**
      - **Width = 12 in.**
      - **Major Radius = 4 in.**
      - **Gap Thickness = 0.020 in.**
      - **Angle at fully closed position = 32˚**



Structural Development

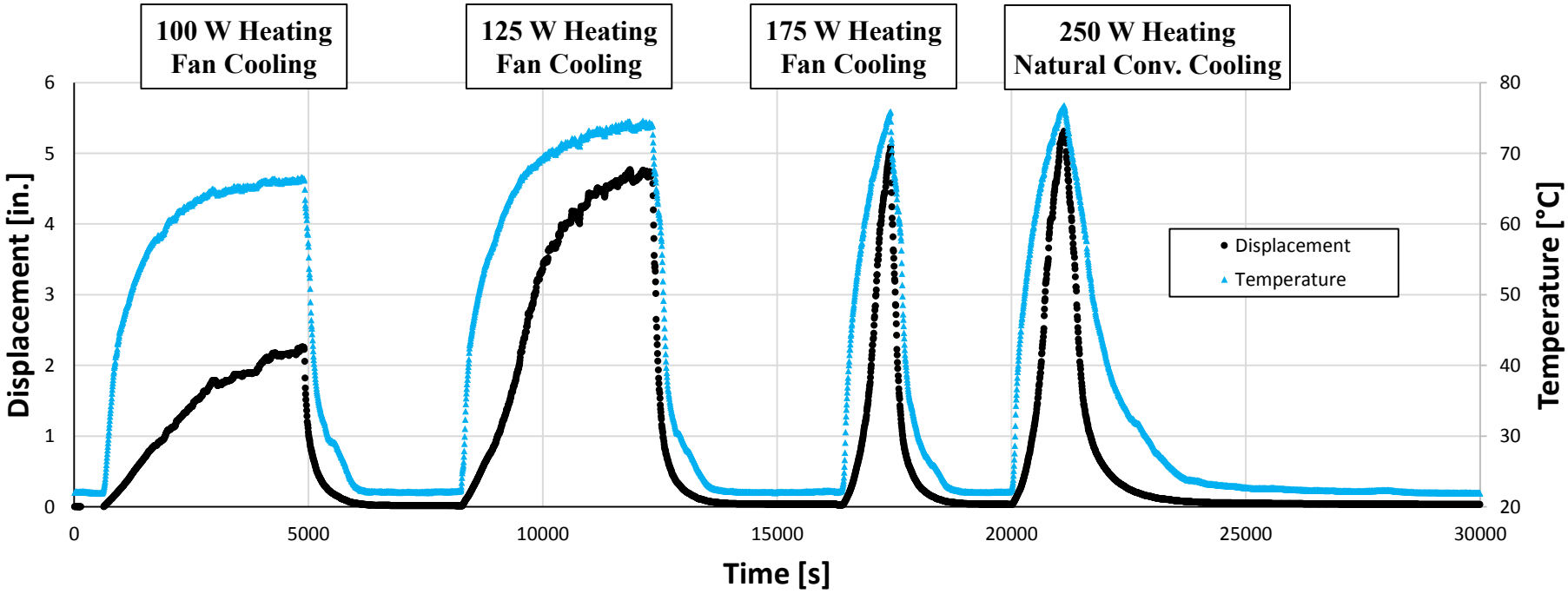
- **Fabrication and testing of a proof of concept variable view factor radiator**
  - **Internal Connecting Structure Sample**
    - **Pressurized by pumping water**





Experimental

- Fabrication and testing of a proof of concept variable view factor radiator
  - Prototype #5
    - Time/Heating or Cooling Rate Independent



Experimental

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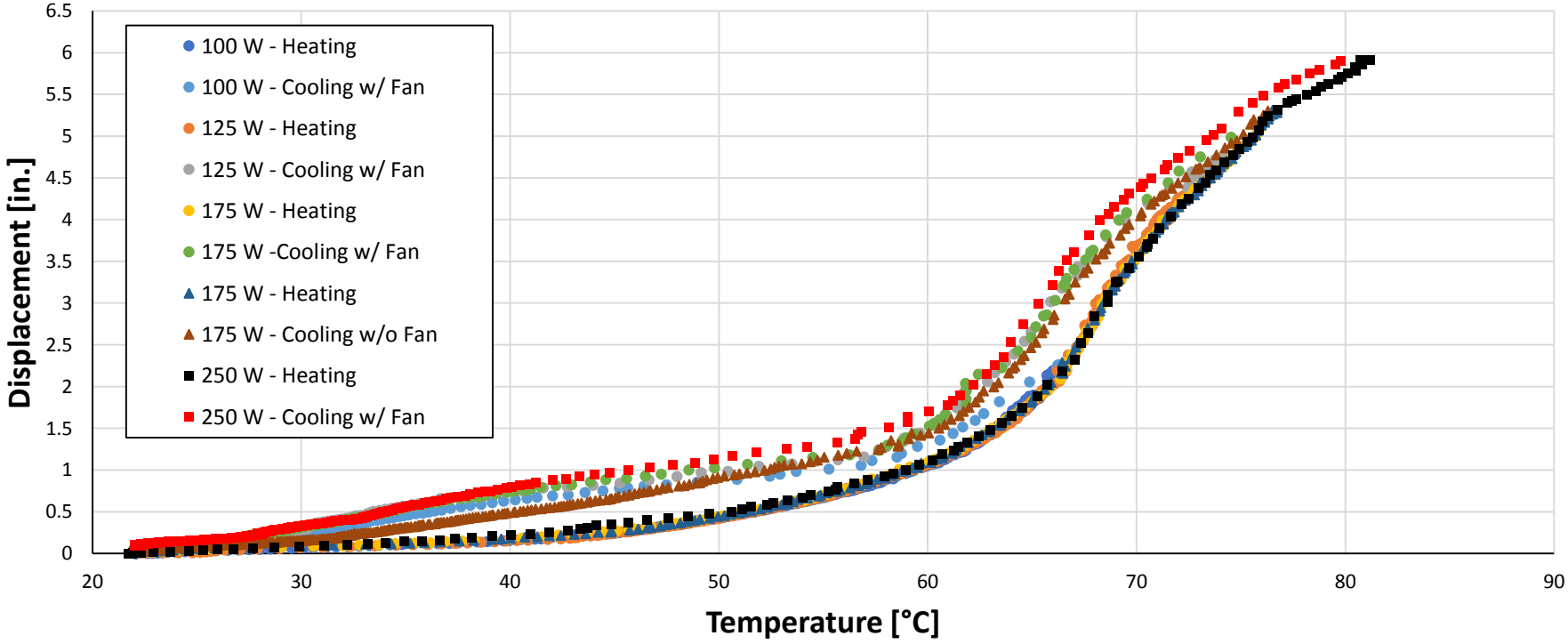
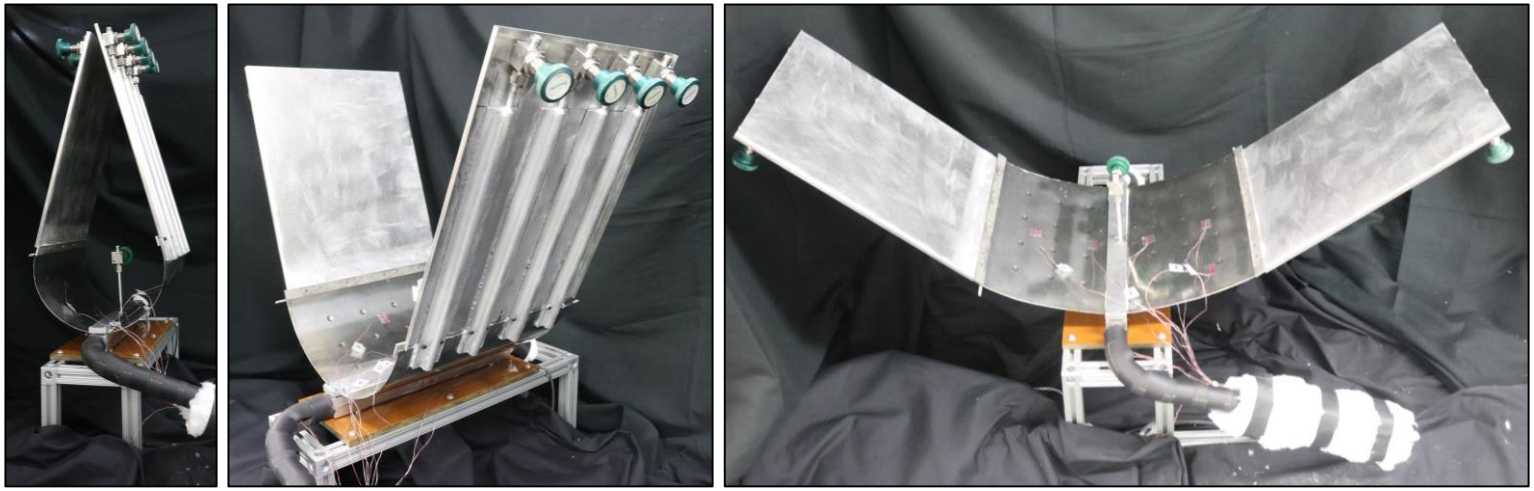


Conclusions

- **Fabrication and testing of a proof-of-concept variable-view-factor two-phase radiator**

Final Prototype:



Key Results:

- **Thermal turndown ratio up to 37:1 demonstrated**
- **Scalable design parameters allow for wide range of radiator size**
- **Continuous, passive temperature dependent view factor adjustment**

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