AVIATION

8–12 JUNE 2026 | SAN DIEGO, CA

09 JUNE 2026

Extending mARC II Arc-Jet Test Duration via Design and Implementation of Model System Cooling Sleeve

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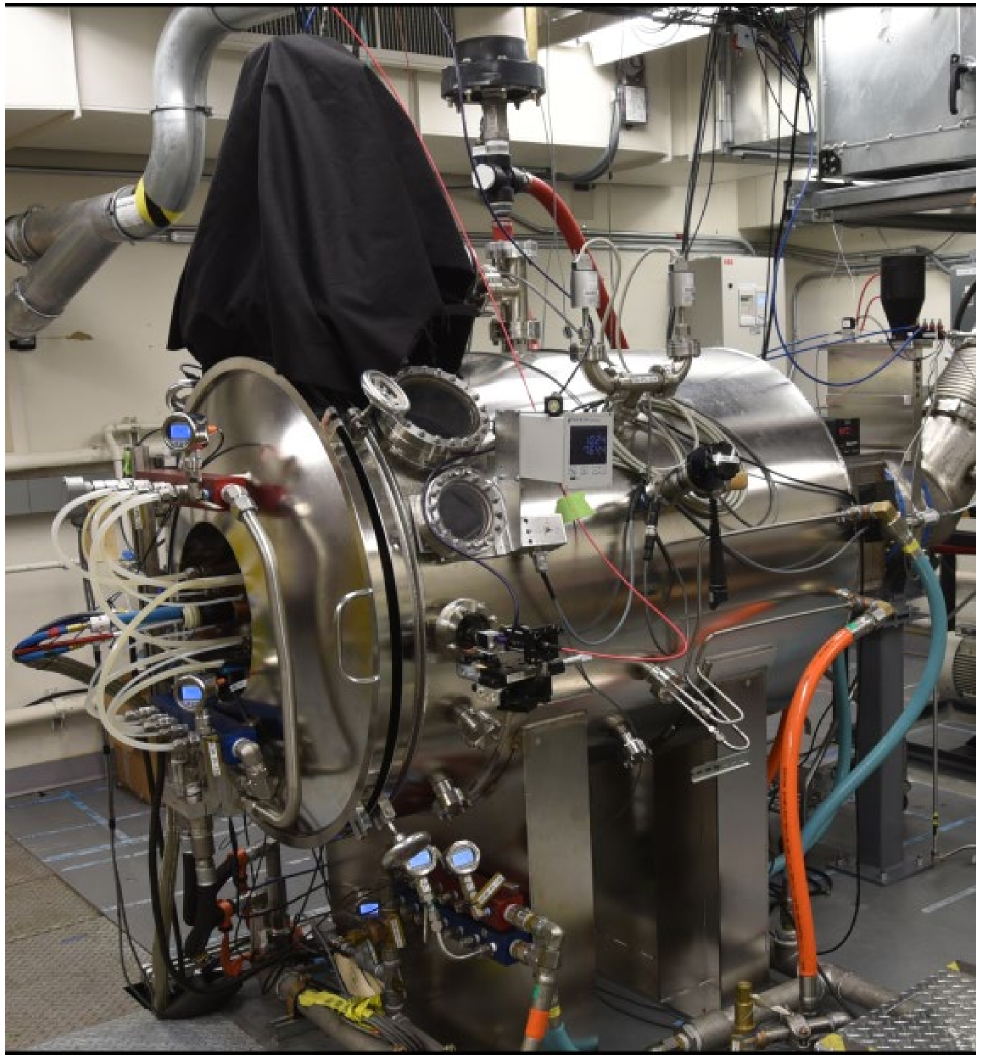
Facility Overview

mARC Overview

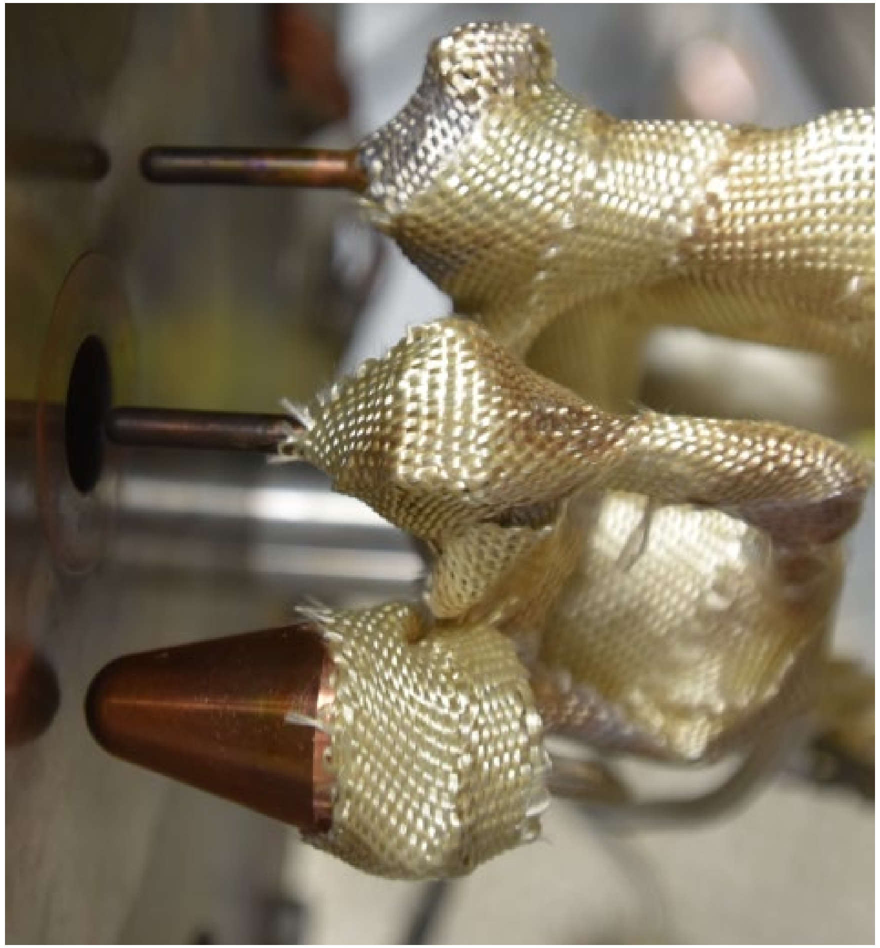
- Up to 4-30kW power
- Up to 69mm model position from nozzle
- Up to 1” diameter models
- Two motors for model positioning
- See previous AIAA papers for more details:
  - MacDonald 2023 (AVIATION)
  - MacDonald 2019 (AVIATION)
  - Rodrigues 2024 (AVIATION)
  - Palmer 2025 (AVIATION)
  - Rodrigues 2025 (SciTech)



Project Objectives

Uncooled Model System

- Heat transfers from model, though swing arm, to shaft and feedthrough.
- Ferrotec ferrofluidic feedthrough used for vacuum sealing motor shaft.
- Max operating temperature of 80^{o}C.



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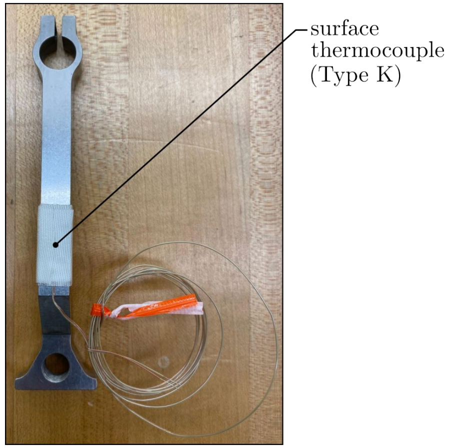
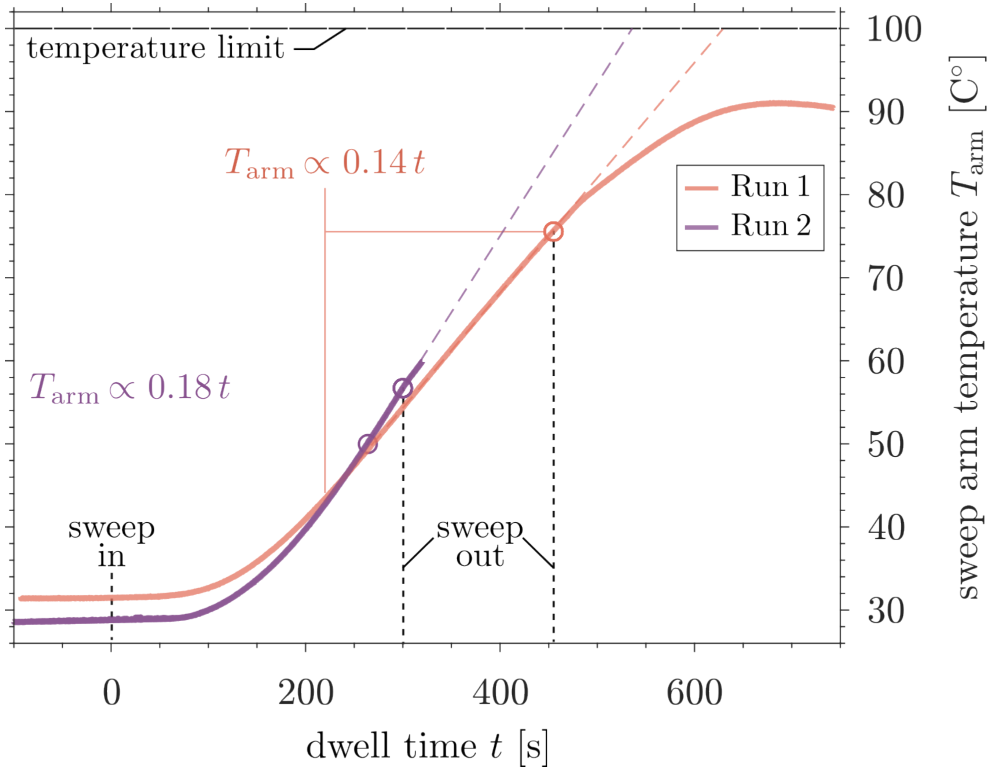
Initial Heating Data

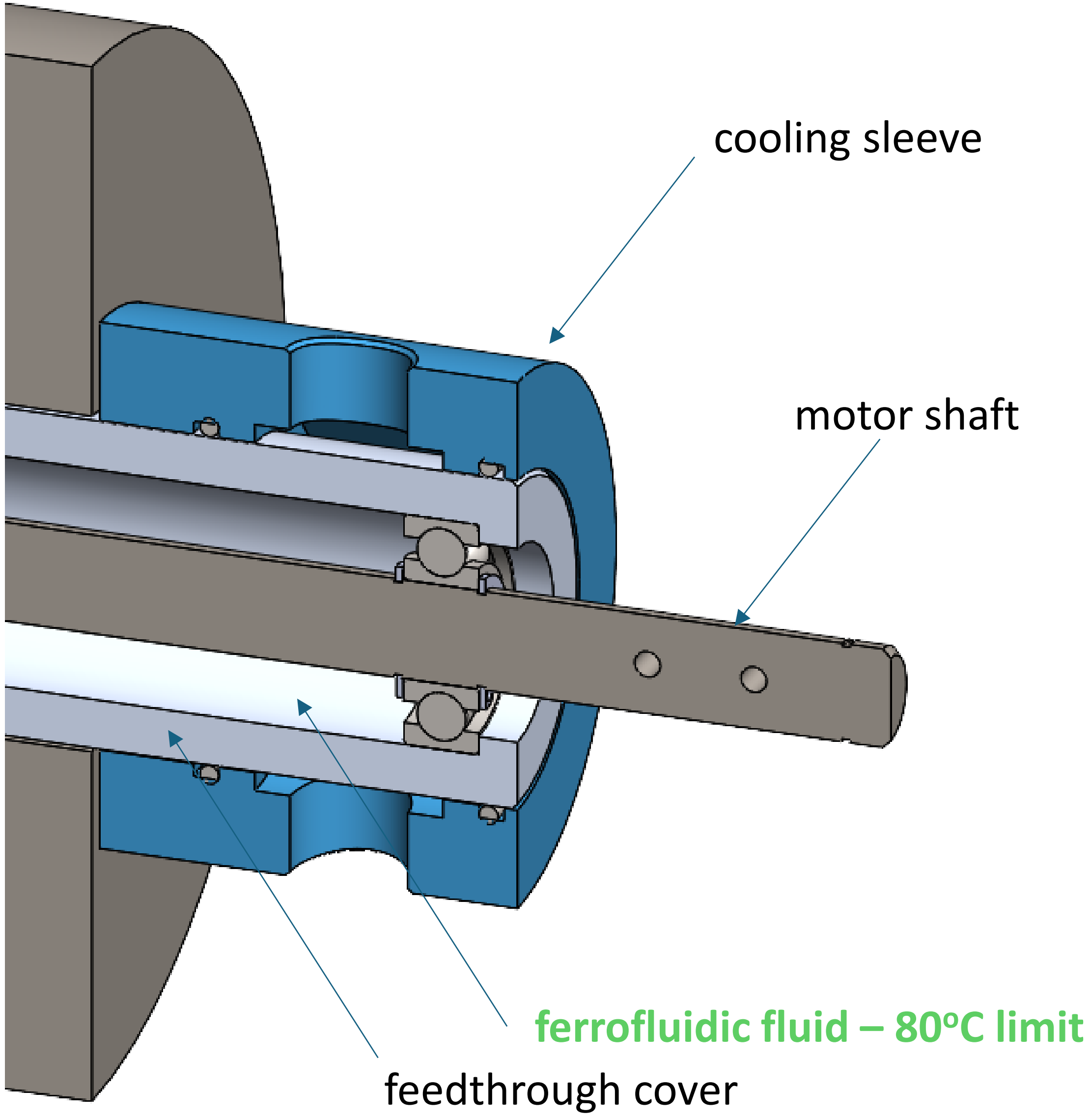
- Thermocouple data at support arm to find max run time.
- Limited to 450s or 7.5m with self-imposed 100°C limit at support arm.
  - Minimum power 4kW (current and flow rate)
  - Maximum distance
- System insulated with Refrasil





Proposed Solution

- Aluminum sleeve to be installed over feedthrough.
- Advantages:
  - Fast turnaround
  - Simple design – no moving parts
  - Inexpensive
  - Balance of conductivity and strength
- Disadvantages:
  - Small cooling area
  - Far from heating source



Analysis Overview

Big Questions

- Will the existing pump be able to handle the additional flow?
- Will the sleeve sufficiently cool the feedthrough at highest heating conditions?
- Will the sleeve be able to mechanically withstand the pressure/temperature?

- AFT Fathom
  - Incompressible Flow Solver
- ANSYS Fluent
  - Steady State Fluid Flow
- ANSYS Mechanical
  - Static Structural FEA

Analysis Map

- Inlet & outlet manifold pressure
- Piping geometry
- Sleeve flow coefficient

→ **AFT Fathom** →

- Sleeve inlet/outlet pressure
- System volume flow rate

ANSYS Fluent

- Material properties
- Heat Flux
- Inlet water temperature

ANSYS Fluent →

- Water temperature
- Material temperature

ANSYS Mechanical

- Material properties
- MAWP + Vacuum

→ ANSYS Mechanical →

- Deformation
- Stresses on cooling sleeve

Piping Analysis

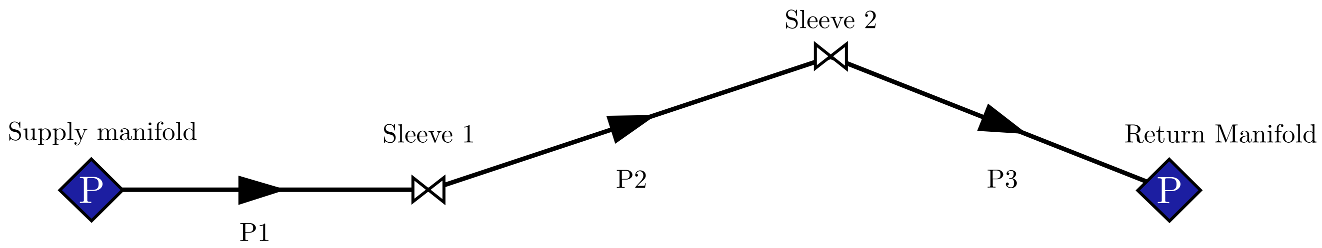
AFT Fathom

Setup

- Input supply & return pressure
- Piping material, lengths, heights, inner diameters, bends
- Sleeve flow coefficient
- $C_v = K\dot{V}\sqrt{\frac{SG_w}{\Delta P}}$

Results

- Flow rate
- Sleeve inlet & outlet pressure
- $\Delta P_{Sleeve1} = \Delta P_{Sleeve2}$
- $error_{Cv} = \frac{C_v^* - C_v}{C_v} = .16\%$



CFD & Thermal Analysis

ANSYS Fluent

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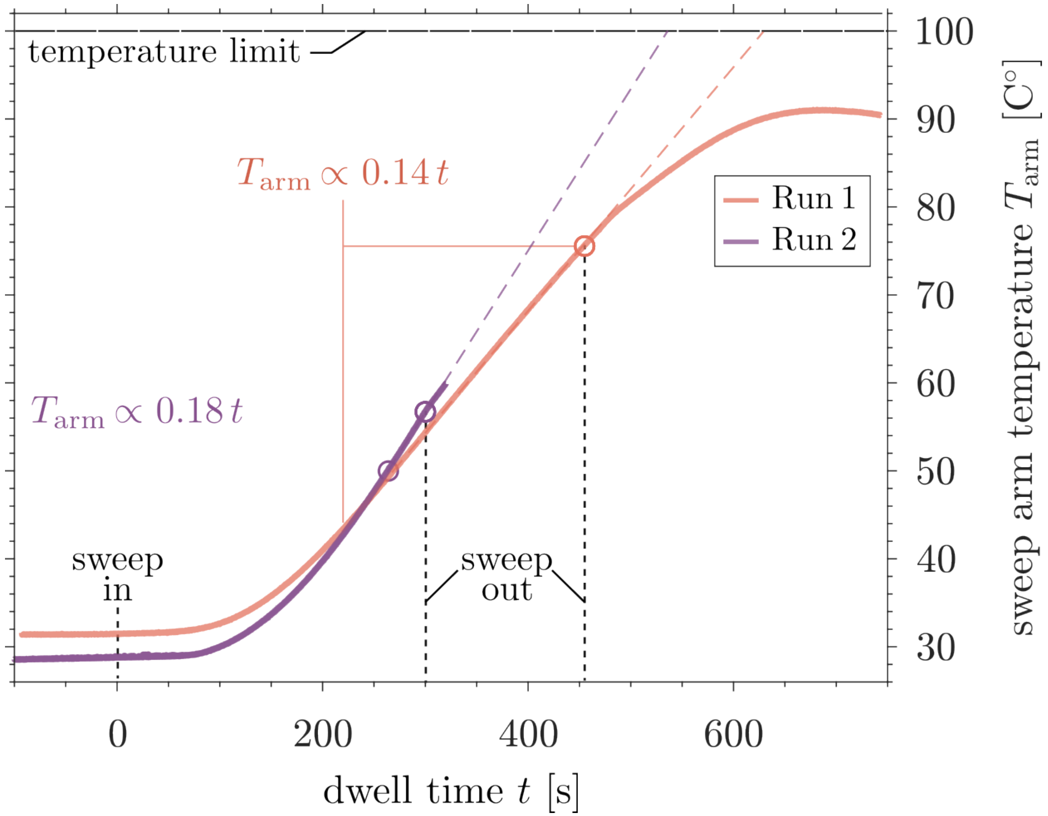
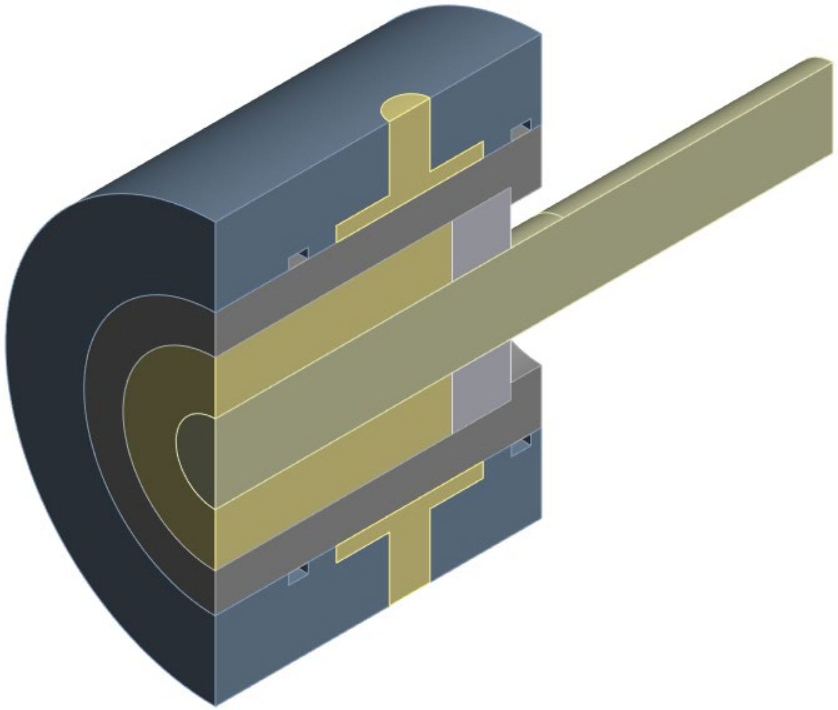
Inputs

- Water inlet temperature
- Material properties
- Heat flux
  - $Q = mc_p\Delta T$
  - $\dot{Q} = \frac{Q}{350s}$
  - $\dot{Q}_{max} = \dot{Q} * \frac{30kW}{4kW}$
  - $\dot{q} = \frac{\dot{Q}}{A} = 45\ \mathrm{kW/m^2}$



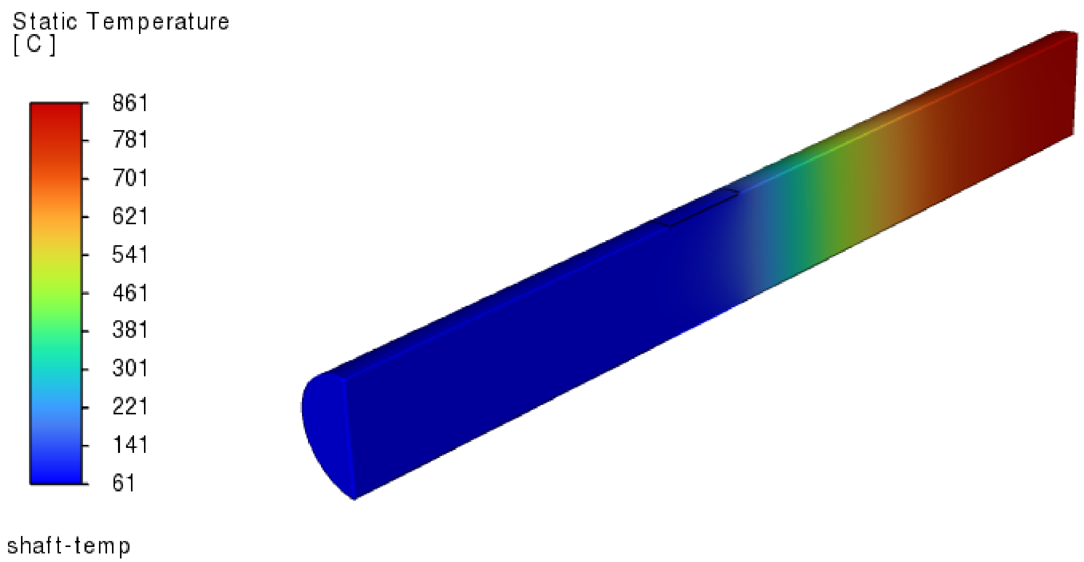
Model Assumptions

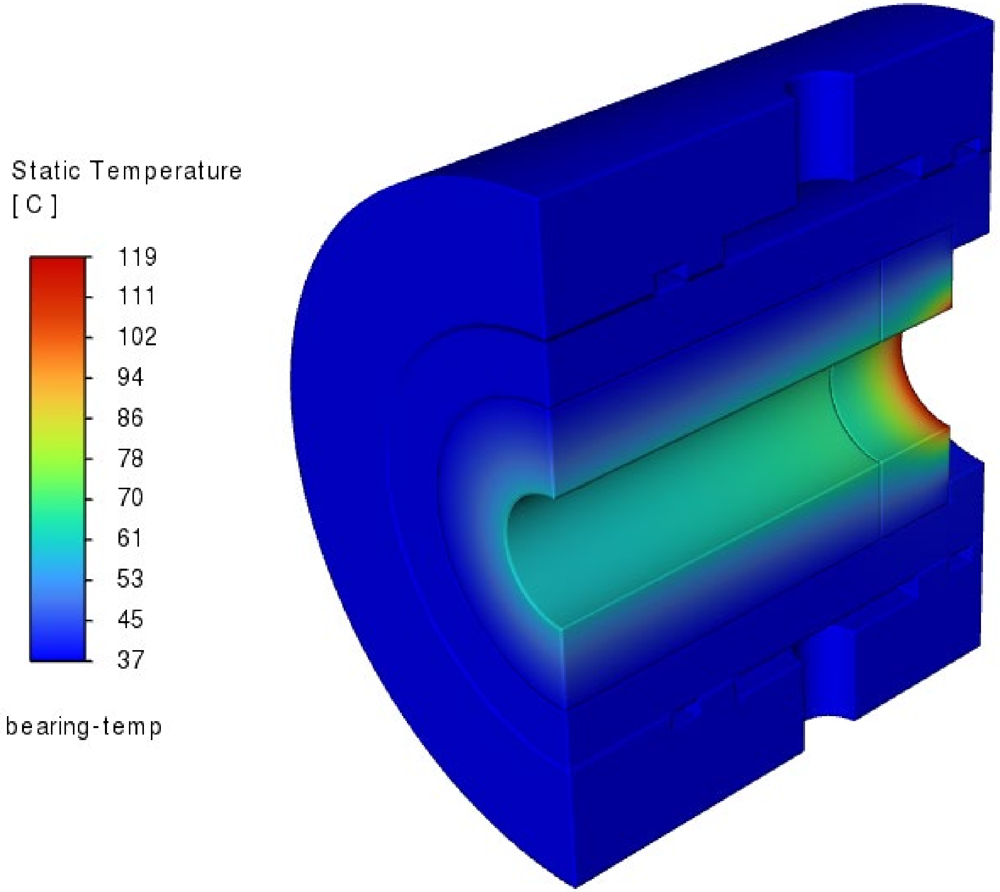
- Only model section within test box
- Assume bearing as solid steel
- Shaft is only heated surface



Results

- Ferrofluid all remains below 80°C
- Edge of bearing reaches 120°C
- End of shaft reaches 860°C



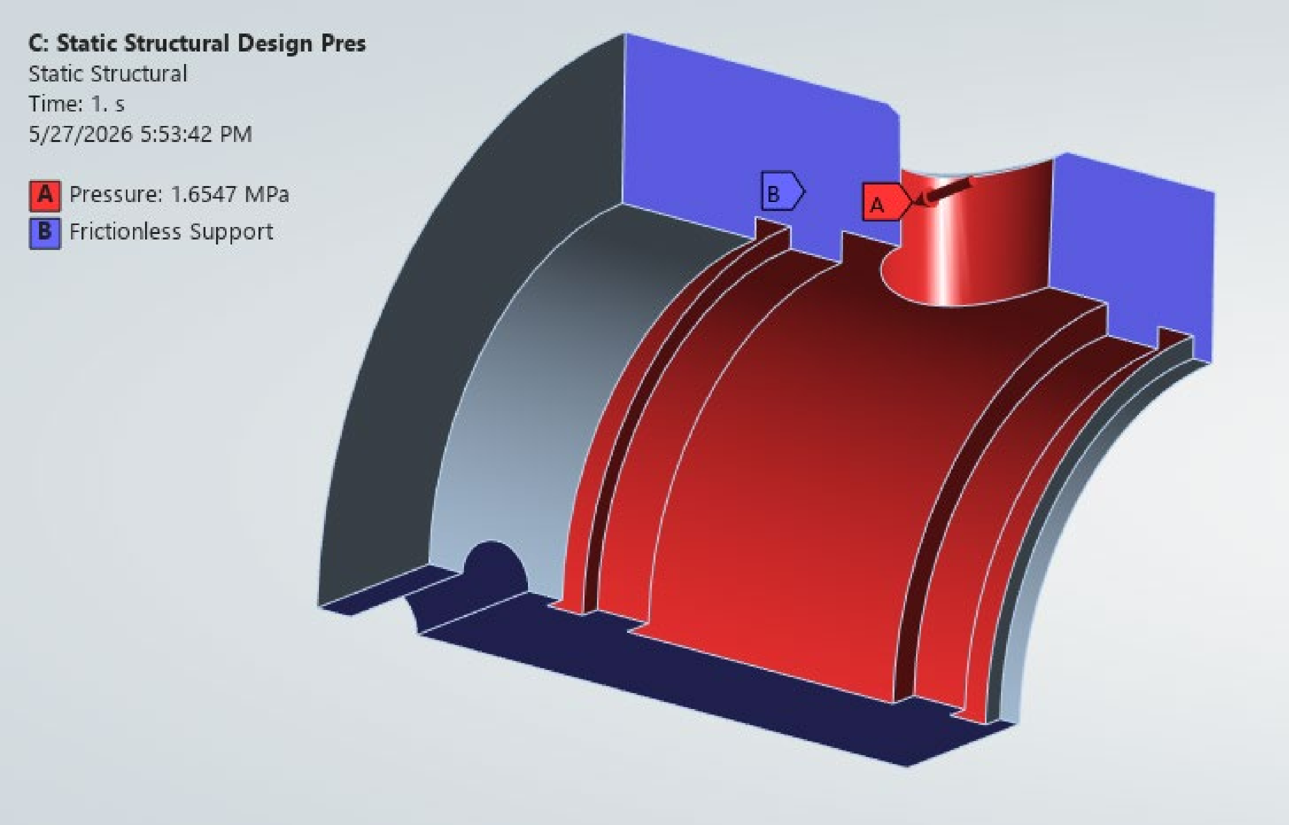


Static Structural FEA

ANSYS Mechanical

Boundary Conditions

- Frictionless support
  - Quarter symmetry
  - Set screw
- MAWP + Vacuum
- Elastic modulus at maximum temperature used
  - Stays near room temperature



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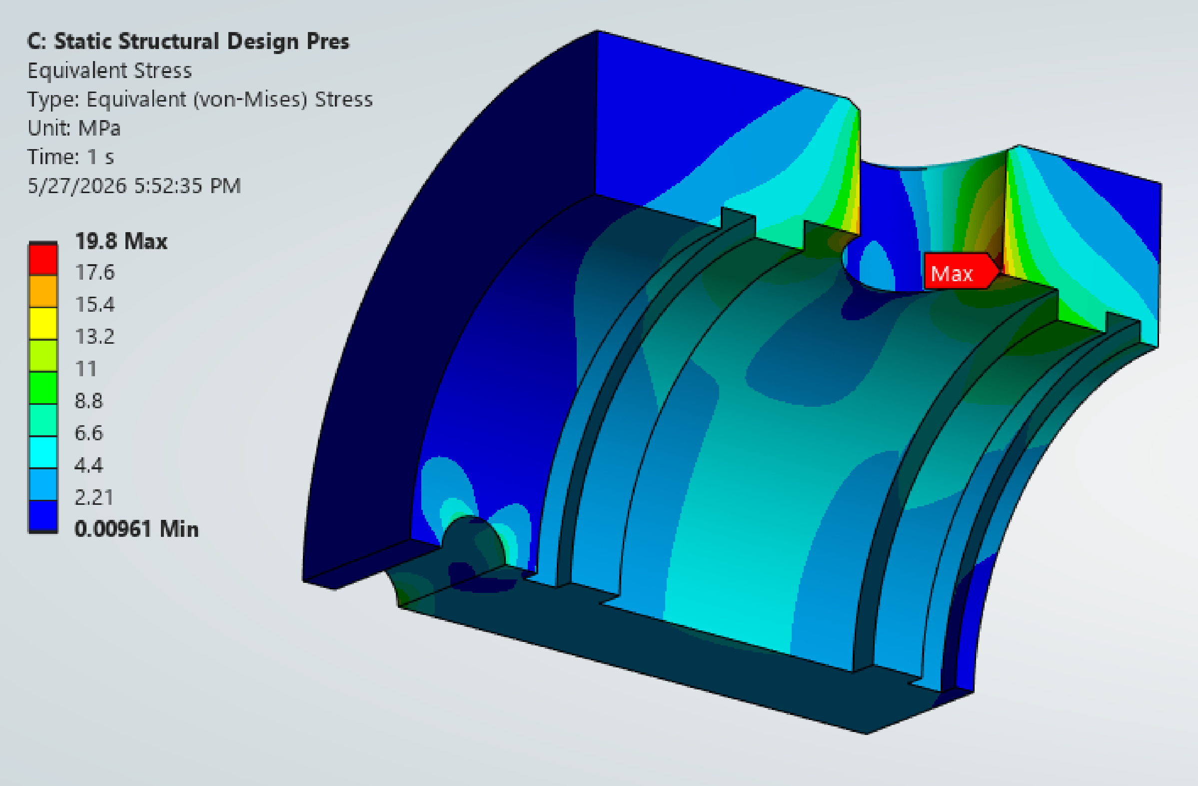
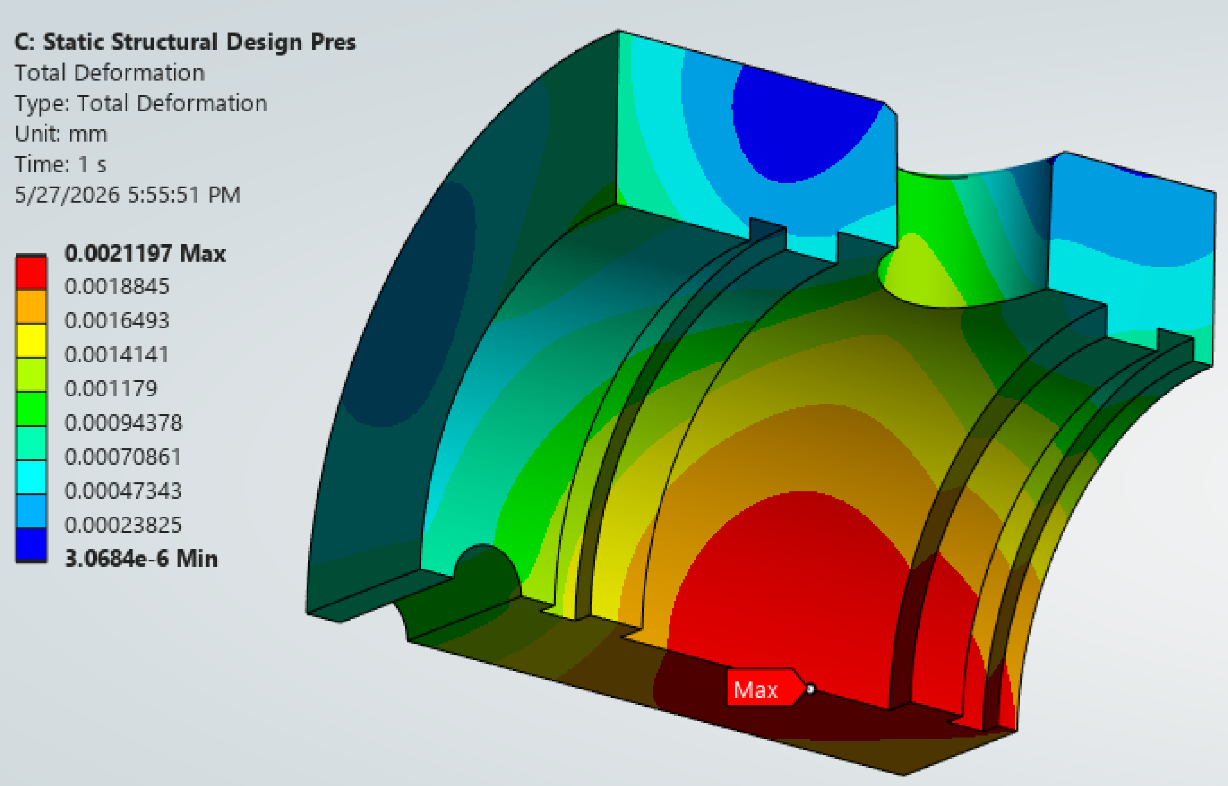
Results





19.8 MPa less than ASME allowable 75 MPa

2.2×10^{-3} mm deformation

Installation and Outcome

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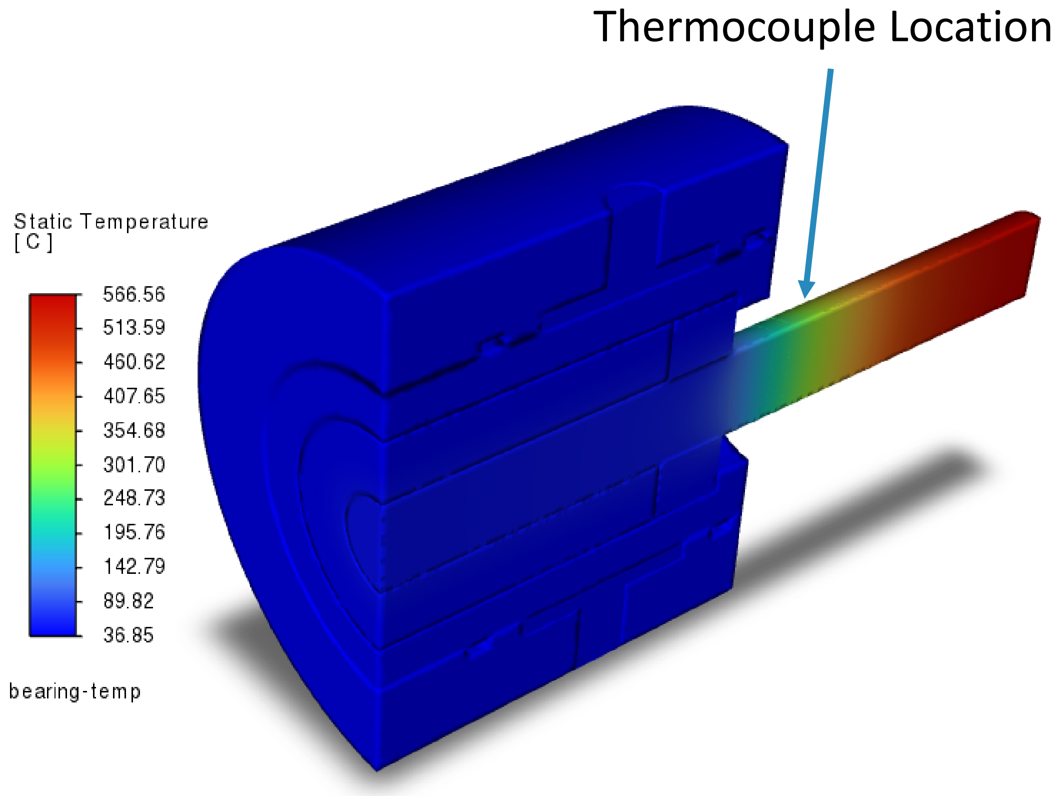
Two Sleeves Successfully Installed

- Pressure test passed
- Ran Space X and Blue Origin tests successfully
- Durations up to 750s at higher power and closer to the nozzle
- Placed thermocouple between feedthrough and model support

Further Analysis

- Thermocouple reached steady state at 160°C
- Re-ran CFD analysis to reflect test conditions
- Analysis thermocouple temperature was higher
  - 247°C
- Points to conservative analysis as expected



Future Work

Operational

- Install flow meter
  - Operational need to guarantee cooling
- Extra surface thermocouple
  - Inform future modeling and understanding of heating

Design

- Short term
  - Increase number of models held by support arm
- Long term
  - Remote axial movement
  - Expanded cooling

Come Test with Us at the Mini Arc!

To schedule testing at the arc jets:

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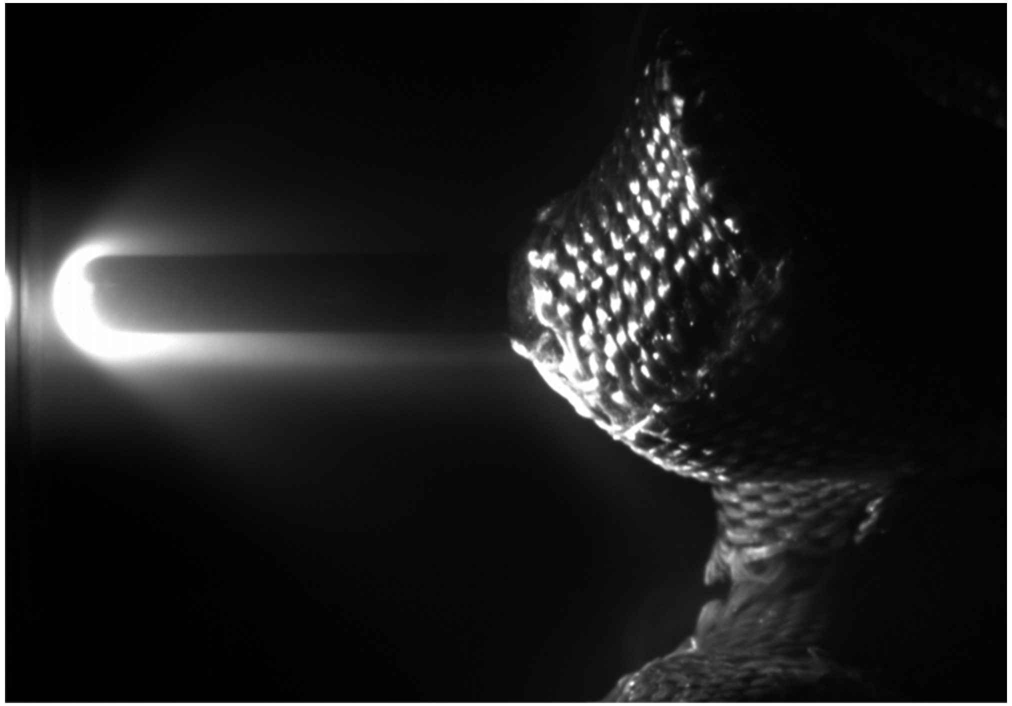

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