Heat Transfer

Graphite Test Articles and Heat Pipes

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Outline

- Objective
- SPHERE Heat Pipes
- Graphite Test Article
- Heat Exchanger
  - Concept
  - Performance
- Molybdenum Heat Pipes
  - Filling
- Path Forward
- Milestone Status

MRP Microreactor Program

Objective

- Heat transfer in a microreactor overcomes unique challenges due to the compact footprint, radiation field, transportability, and high temperatures present.
- High temperature operation preferred to give higher power production efficiencies. Objectives for this work are as follows:

- Fill individual stainless steel heat pipes with sodium and provide them to SPHERE for testing.

- Develop techniques for fabrication of individual high-capacity heat pipes using refractory metal (molybdenum) heat pipe tubes.

- Design and fabricate a heat exchanger for the heat pipe and graphite core block system.

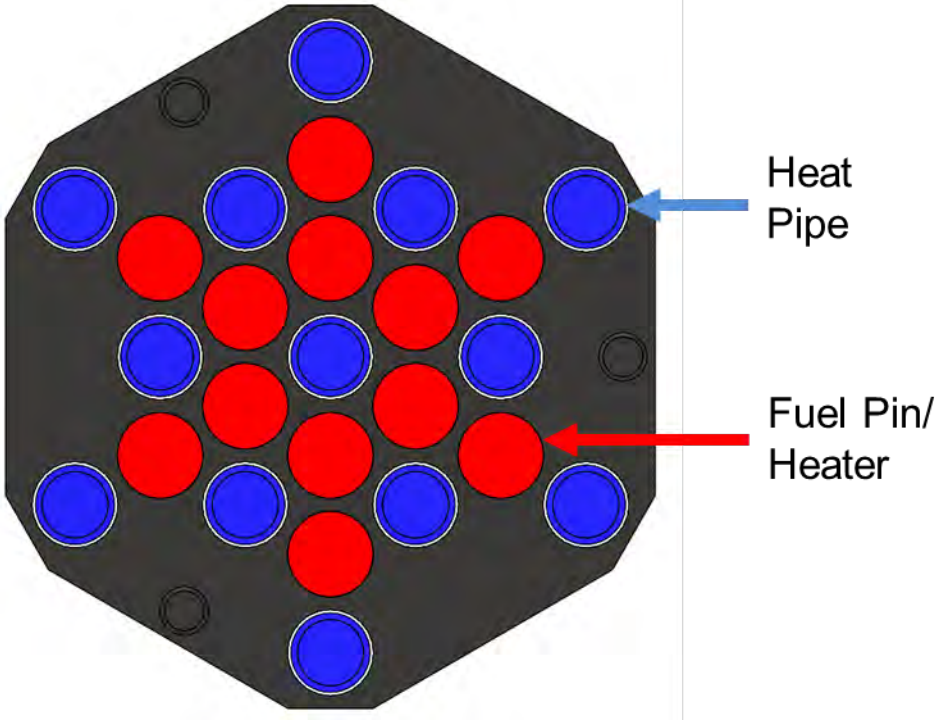
- Incorporate the heat pipes into a graphite core block to create a graphite nonnuclear microreactor test article for testing.

SPHERE Heat Pipes

- Updates:
- Tubes have been designed and machined
- Evaporator end plugs have been identified
- Wicks have been selected
- Drawing that modify the condenser end plugs have been completed and the required parts for fabrication have been acquired
- A 15 ft long vacuum tube furnace has been fabricated from existing parts to allow for necessary cleaning steps.

Graphite Test Article

- Three 10” long blocks fabricated by Mersen
- Thirteen heat pipes
- Twelve fuel pin/ heater holes
- Heat pipes slot into graphite core with .030” radial gap



Heat Pipe Hole Diamter	0.810	in	0.021	m
Heat pipe to heat pipe pitch	1.608	in	0.041	m
Heat pipe to fuel pin pitch	0.928	in	0.024	m
Graphite web thickness	0.118	in	0.003	m
Flat to flat width	6.134	in	0.156	m
Corner to corner width	6.615	in	0.168	m

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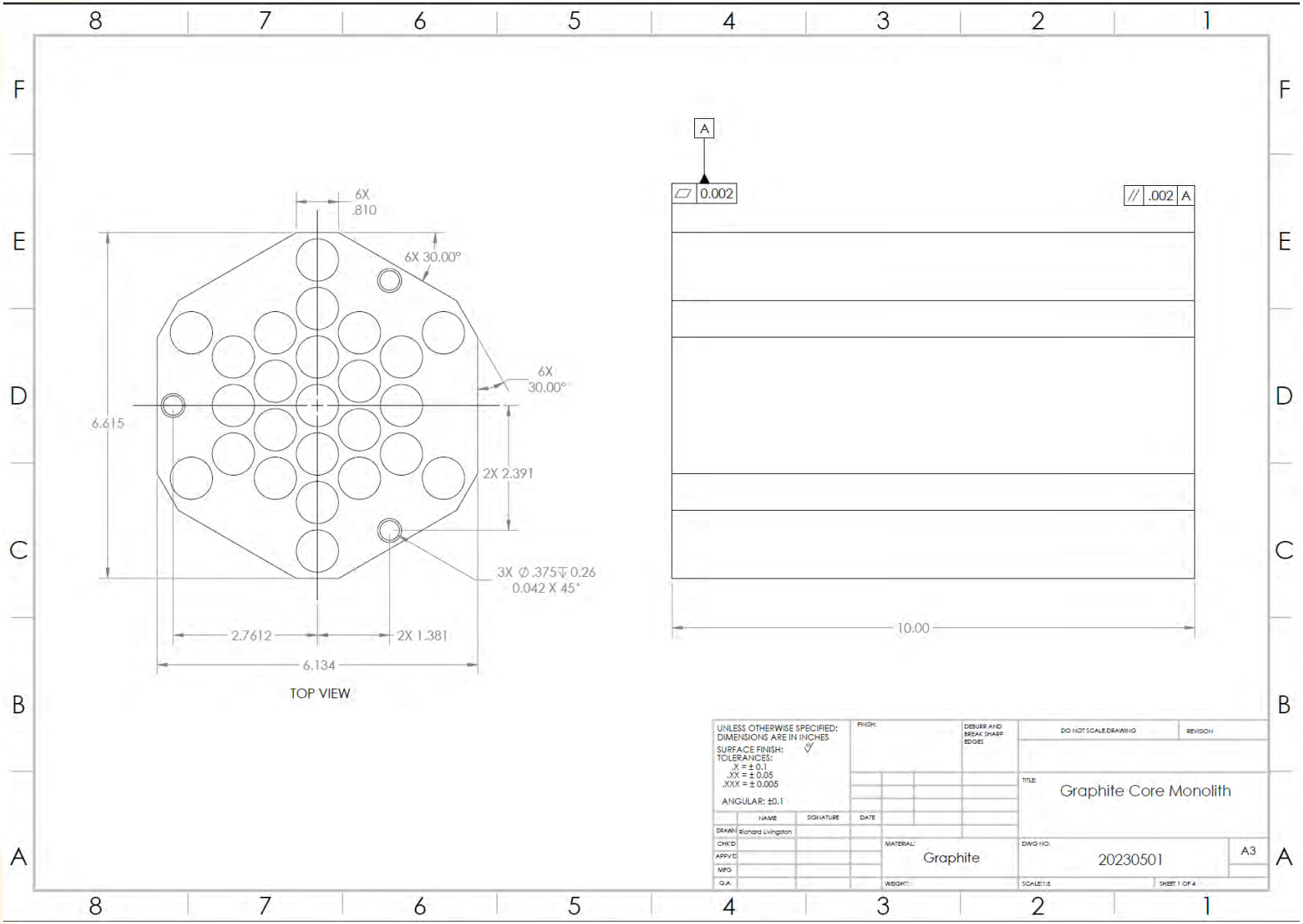

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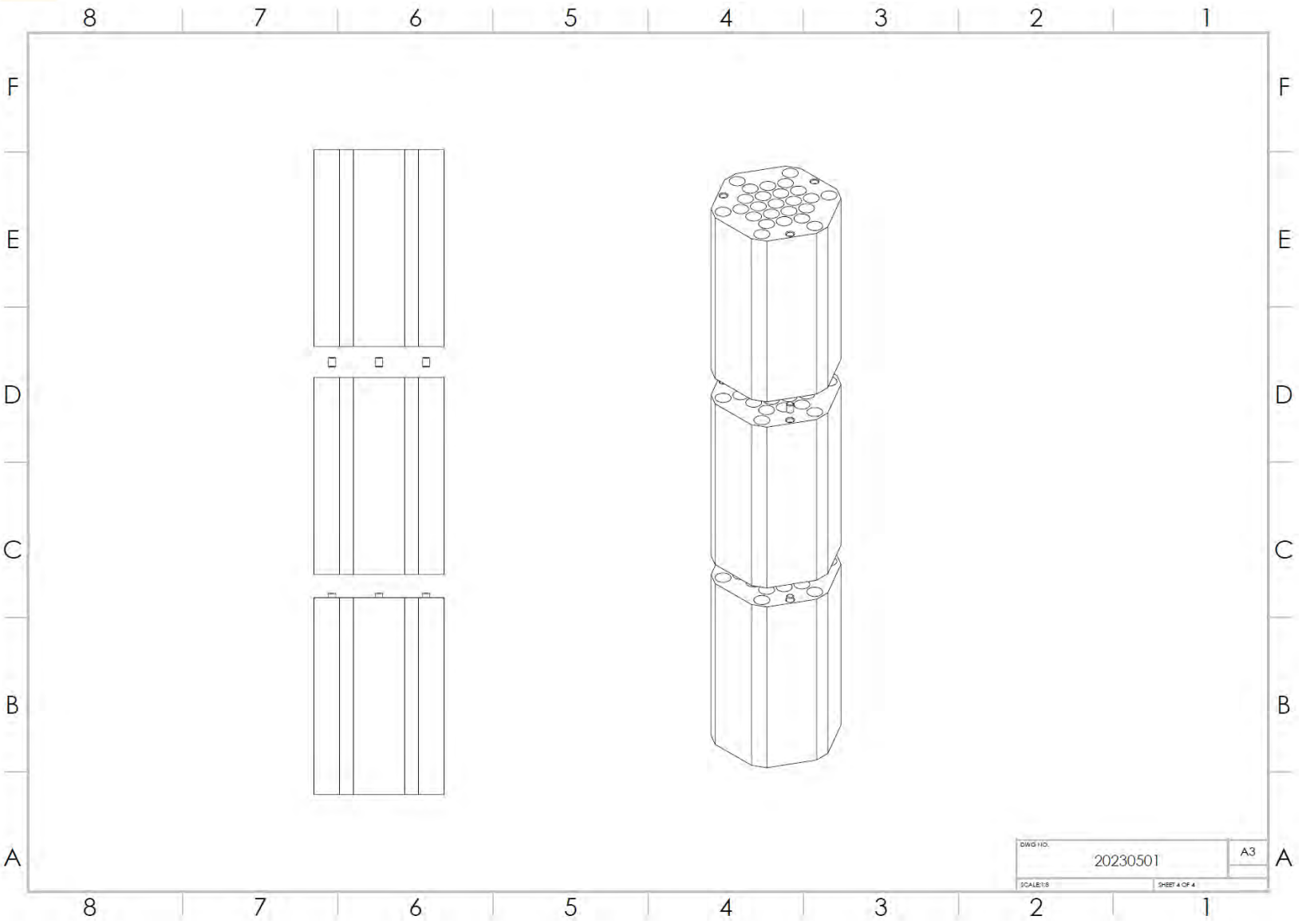

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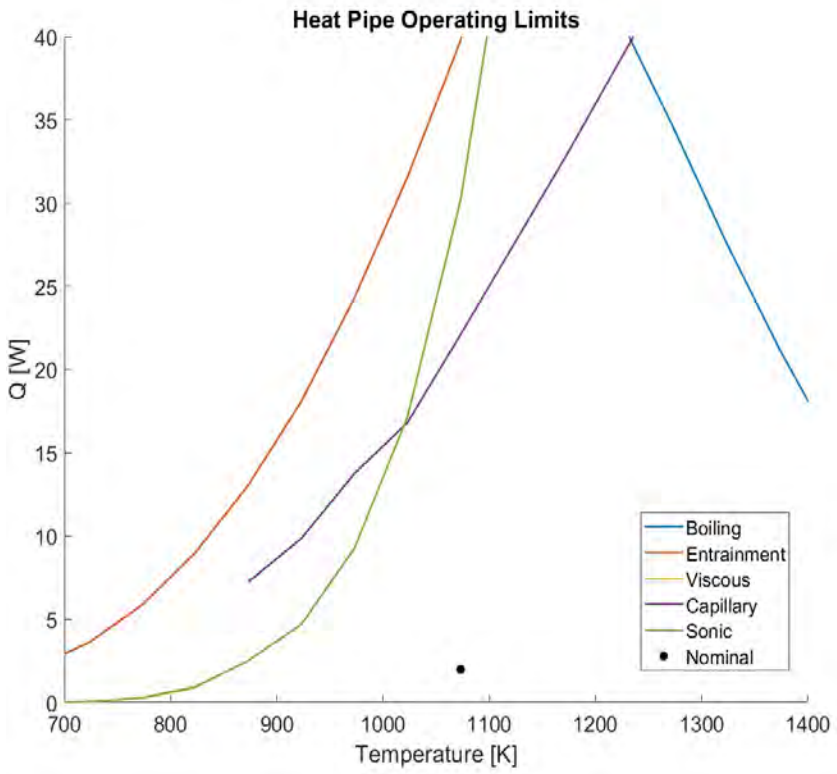
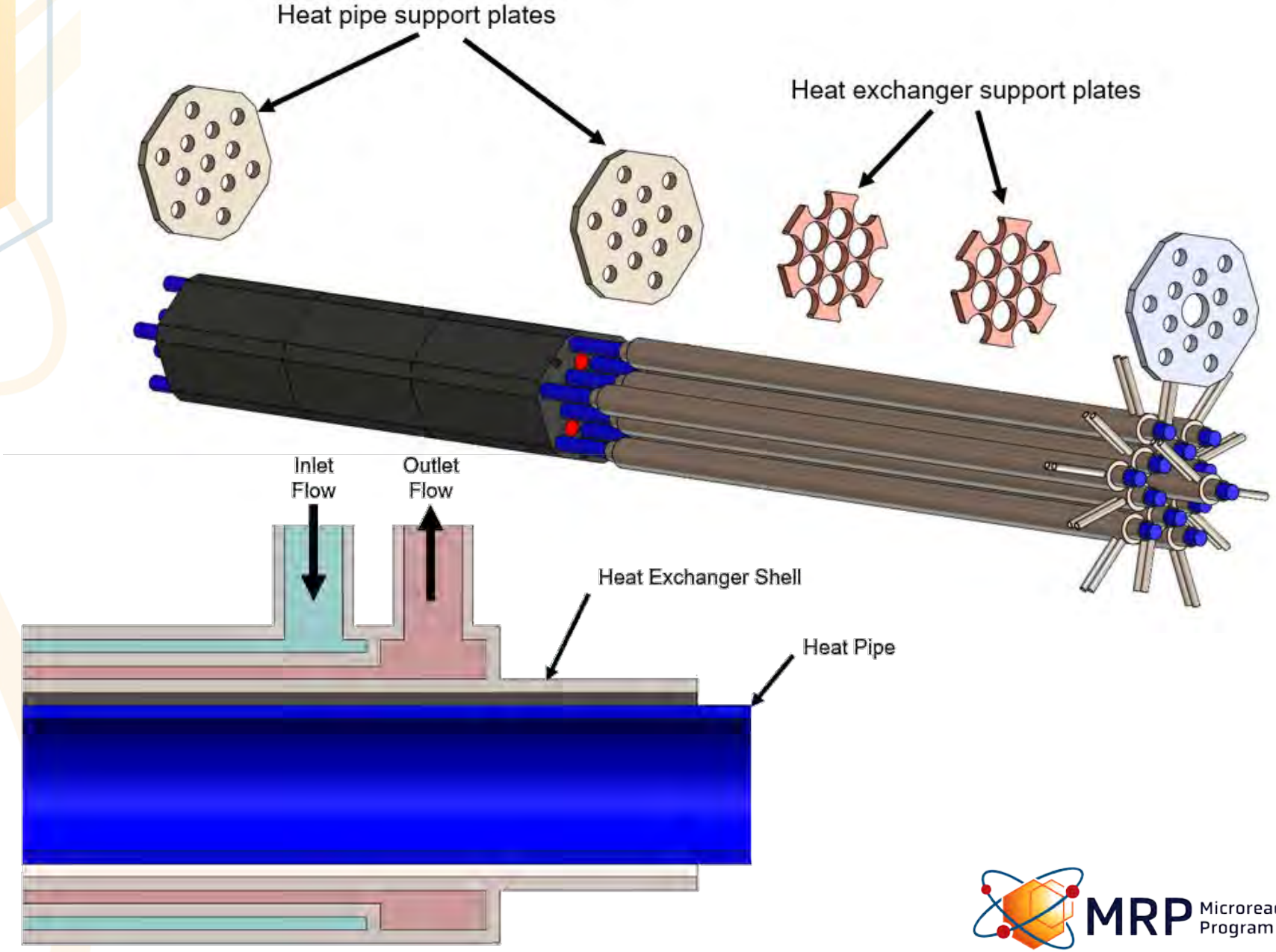
Heat Exchanger

Requirements:

1. Remove a nominal thermal power of 2.0 kW from each heat pipe when the heat pipes are 800°C.
2. Interfaces with graphite core block geometry.
3. Desing incorporates supports to limit structural loading on the graphite core block
4. Design allows for thermal expansion of the heat pipes
5. Compatible with MAGNET facility



Double Pass Heat Exchanger Concept



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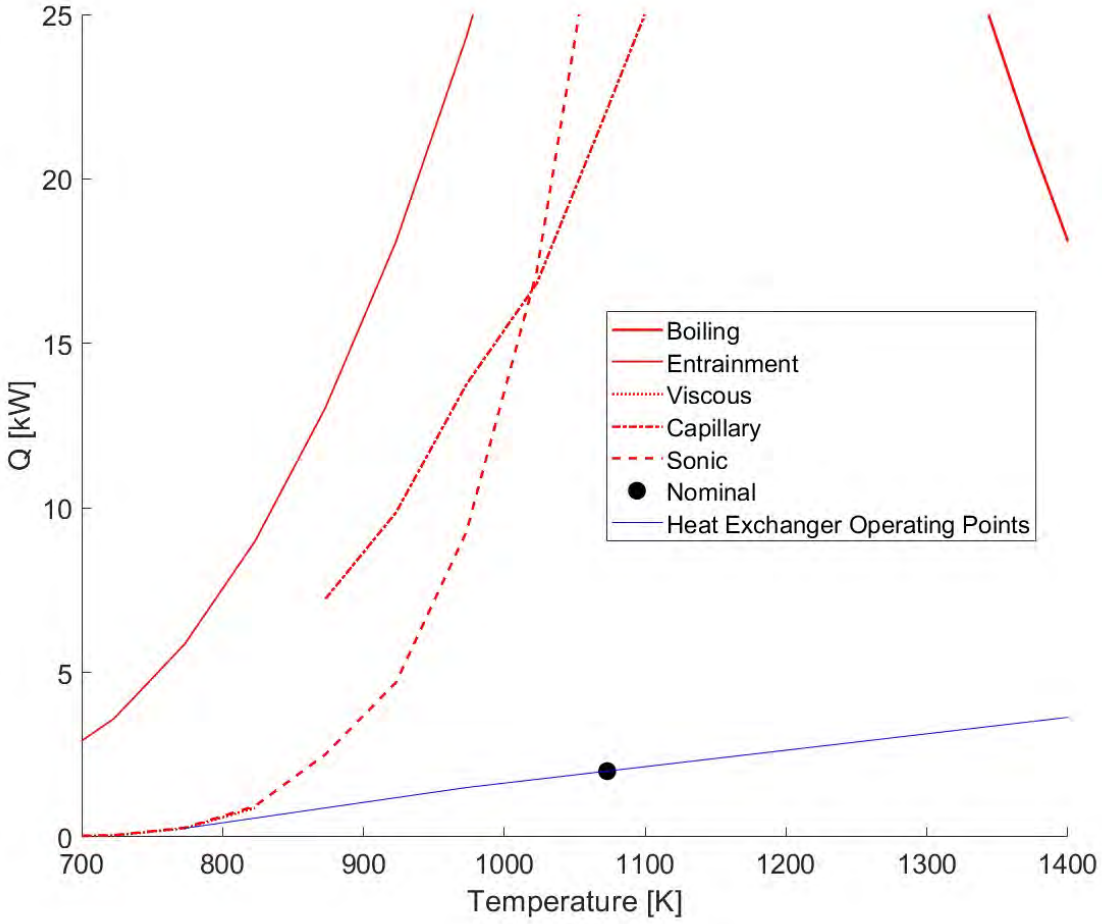
Double Pass Heat Exchanger Performance

- Ability to control heat exchanger coolant inlet pressures and temperatures.
- Ability to control He/Ar gas mixtures in chamber.



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Molybdenum Tube Heat Pipes

- Updates:
- Molybdenum tubes have been delivered
- Drawings for laser weld trials (plugs and tube endings) have been completed.
- Wicks have been selected.
- Drawing that modify the condenser end plugs have been completed and the required parts for fabrication have been acquired.
- A 15 ft long vacuum tube furnace has been fabricated from existing parts to allow for necessary cleaning steps.

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Molybdenum Heat Pipe Filling

- Molybdenum-SS heat pipes will be filled with sodium using the eFill.
- During previous tests we faced four obstacles to successfully fill and seal heat pipes.
  1. Sodium splattered on the rim of the heat pipe tube leading to unseated plugs.
  2. The fill stem lacked centering mechanisms that led to misalignment.
  3. The system lacked the ability to verify heat pipe plug placement.
  4. The known volume lacked sodium level detection feature.
  5. The height of the known volume assembly made the manual valves inaccessible without step stools leading to additional hazards.

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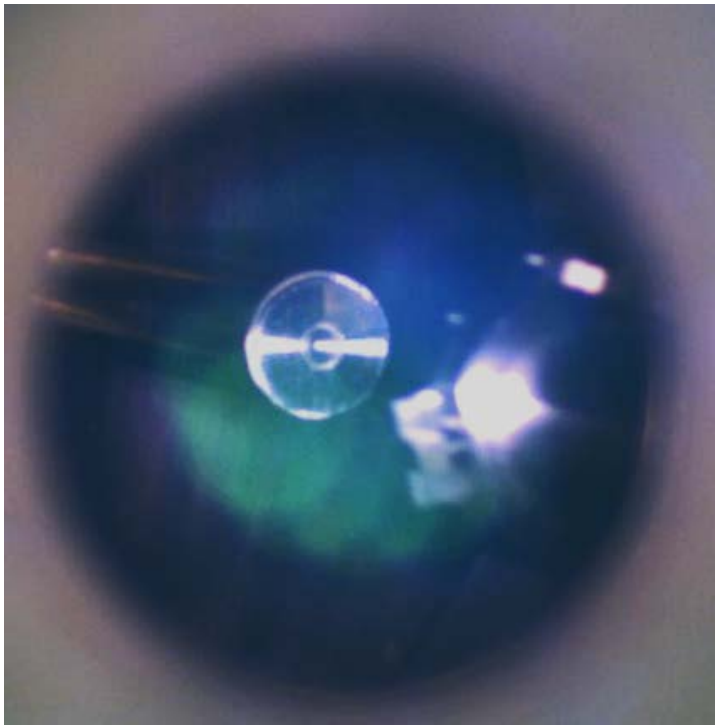
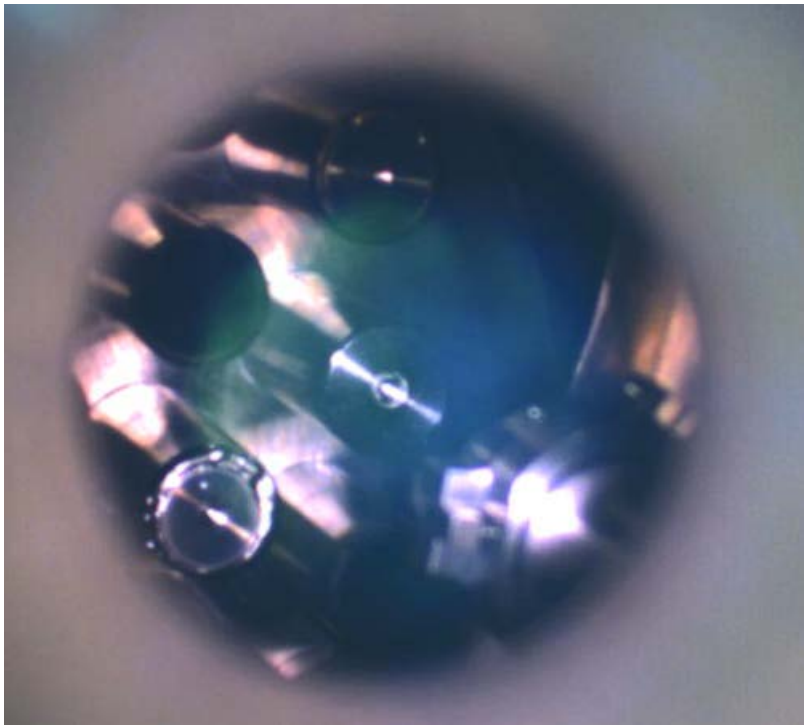
Plug Placement Original Process

- Angle of view in original system was not sufficient for determining if the plug was seated in the tube.

Unseated



Seated



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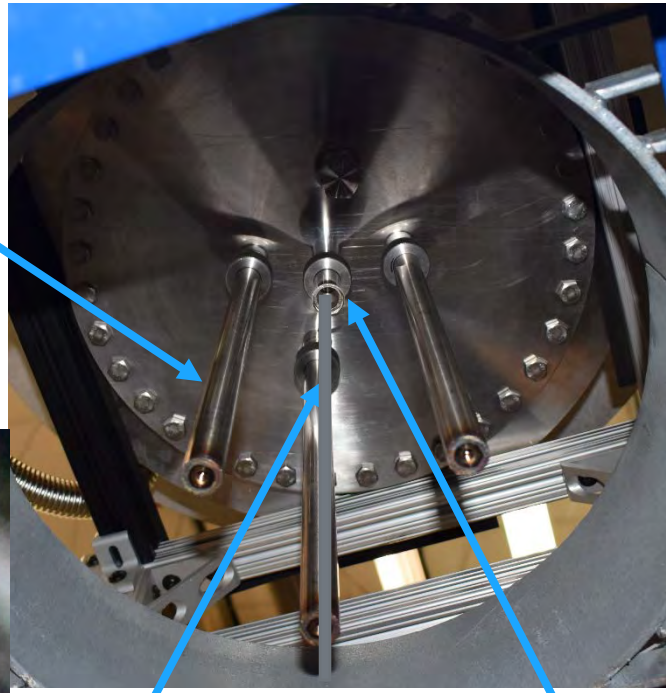
Plug Placement Updated Process

Heat Pipes



Borescope Arm

Quartz Tube

Unseated

Seated

View of plugged heat pipes through single ended quartz tube

Borescope

Fill Stem Modifications

- During previous sodium testing with the eFill system images showed a change in reflection on the rim of the heat pipe after the fill, potentially sodium splatter.
- The images show that the fill stem was not aligned with the heat pipe.
- The fill stem has been modified to prevent this spray from hitting the rim as well as adding a conical feature that will help center the fill s splash gua
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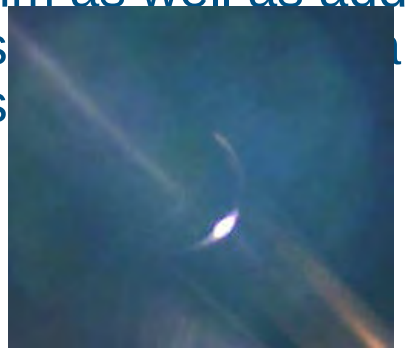
Before Fill



After Fill

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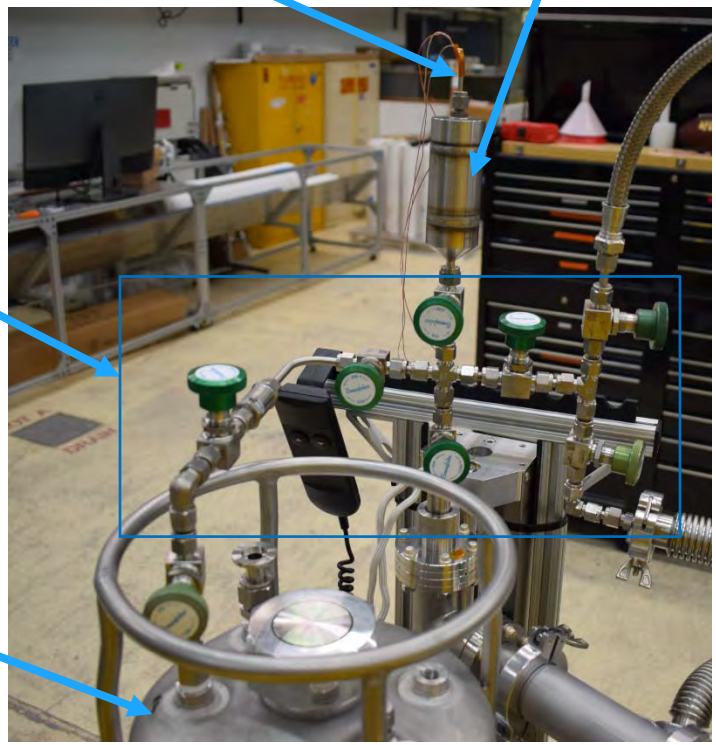
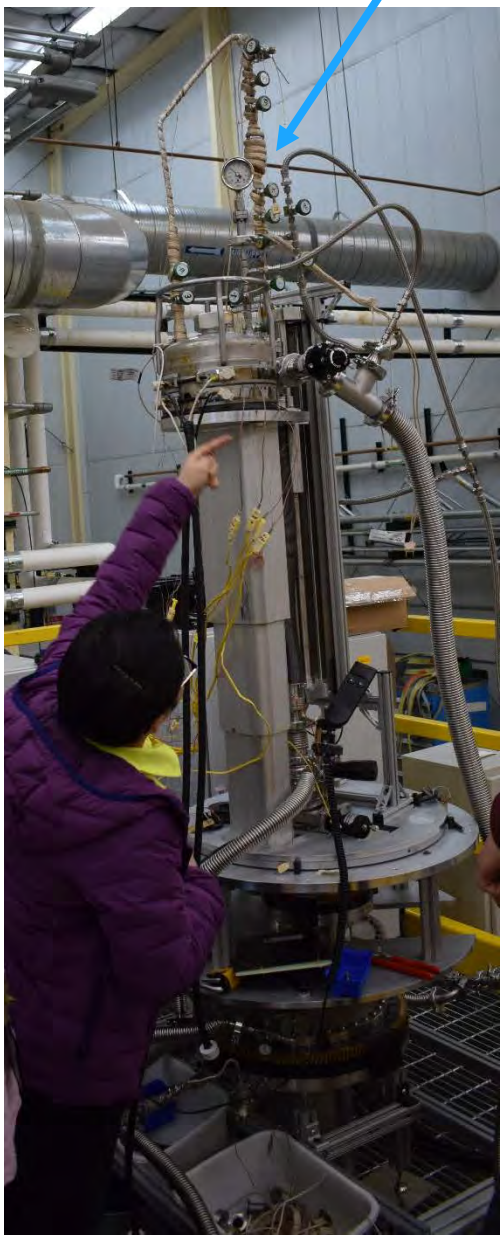
Known Volume (KV) Modifications

- An updated known volume was fabricated to allow for a thermal well with multiple thermocouples along the center of the known volume.
- Updated known volume reduces height of assembly by approximately 1 foot.





Path Forward

- Complete SPHERE Heat Pipe Fabrication
  - Chemically clean and vacuum fire components in modified furnace (in Progress)
  - Fill and seal heat pipe with pinch then weld process (Upcoming)
- Graphite block procurement (Complete)
- eFill37 Subassembly
  - Molybdenum tube purchase(Complete)
  - Install modifications to fix issues observed in previous runs (Complete)
  - Complete full modification test run with sodium(in Progress)
  - Laser welding trial with Molybdenum (Upcoming)
  - Fabricate and fill Molybdenum/SS/Sodium heat pipes (Upcoming)
- Heat Exchanger
  - Concept designs (Complete)
  - Critical Design Review (Upcoming 03/2024)
  - Order finalized heat exchanger design (Scheduled 3/28/2024)

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Milestone status

- **M3AT-24LA0804052**-Perform fill of heat pipe with molybdenum tubing and sodium working fluid. (In progress and on schedule to be completed by June 2024)
- Potential delay exists in part shortages for valves compatible with sodium. The project has worked to procure substitute valves.

- **M3AT-24LA0804055**-Complete design of heat exchanger and submit to vendor to build plus procure graphite block components. (In progress and on schedule to be completed by the end of March 2024)
- The heat exchanger costs are expected to be substantial and may have long lead times.

- **M4AT-24LA0804057**-Generate report on single heat pipe testing results both at LANL and INL. (In progress, heat pipes will be fabricated by end of March 2024 and report on heat pipe tests completed by August 2024)
- Heat pipe manufacturing was delayed, due to need to modify vacuum tube furnace.

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End of Presentation

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