Nuclear Energy University Program

- (NEUP Project 20-19735) Experiments for Modeling and Validation of Liquid-Metal Heat Pipe Simulation Tools for Micro-Reactor – Prof. Yassin Hassan (Texas A&M University)
- (NEUP Project 21-24152) Direct heating of chemical catalysts for hydrogen and fertilizer production using Microreactors – Prof. Hitesh Bindra (Purdue University)

MRP Microreactor Program

Demonstration and Support Capabilities Summary

Piyush Sabharwall, Ph.D. | Technical Area Lead, DOE NE-MRP

MRP Microreactor Program

SPHERE – PROGRESS *(from initial startup)*

- Demonstrate initial startup (shake-down testing) and operation of a single heat pipe experiment in the SPHERE test bed
- Develop coupled thermal and structural analysis for high temperature heat pipe experiments
- Complete engineering design of test article, develop test plan and instrumentation needs for gap conductance testing
- Complete fabrication and procurement of test article, perform test for gap conductance testing and report on findings (worked closely with NRC)
- Create, maintain and add experimental data to shareable database on transient heat pipe performance in coordination with NEUP heat-pipe projects
- Work with industry under WFO Program – Heat Pipe Performance
- Advanced internal characterization of in operando heat pipes
  - In operando heat pipe testing to begin shortly

SINGLE PRIMARY HEAT EXTRACTION AND REMOVAL EMULATOR (SPHERE) – FY 24

Complete power transient testing matrix (will support V&V of Sockeye by providing the results of heat pipe performance under various power transients): Due May 31st 2024

Complete testing on LANL high capacity heat pipes for steady state thermal heat transfer characterization: Due August 31st 2024

MRP Microreactor Program

MAGNET – PROGRESS *(from initial startup)*

- Complete shakedown and preliminary testing of MAGNET facility with test article bypass
- Complete test matrix for seven-hole test article
- Complete engineering design for PCU integration (on track for Aug 18th)
- MAGNET modification to support proprietary HX testing (from a commercial developer).
- Demonstrated digital twin of a single-heat-pipe test article in MAGNET with autonomous, self-adjusting capability.
- Mezzanine construction completed (replaced temporary scaffolding)
- Advanced Heat pipe Interface Heat Exchanger Testing (NEUP with University of Wisconsin)

MAGNET – FY24

- Integrate PCU with MAGNET to allow Integrated Microreactor Heat T/F System Testing (M2; Due Aug 30th 2024)
  - Award Construction Contract for Integrating PCU (M3; 28th March 2024)
  - Complete Enclosure Installation (M4; 20th June 2024)
  - Complete Piping Installation (M4; 31st July 2024)
- Integrate PCU with MAGNET (M3; Due Sept 30th 2024)

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Demonstration Support Capabilities – *Activities & Milestones Planned (FY-24)*

- **SINGLE PRIMARY HEAT EXTRACTION AND REMOVAL EMULATOR (SPHERE)**
  - Complete power transient testing matrix (will support V&V of Sockeye by providing the results of heat pipe performance under various power transients): Due May 31st 2024
  - Complete testing on LANL high capacity heat pipes for steady state thermal heat transfer characterization: Due August 31st 2024

- **MICROREACTOR AGILE NON-NUCLEAR EXPERIMENTAL TESTBED (MAGNET)**
  - **Integrate PCU with MAGNET to allow Integrated Microreactor Heat T/F System Testing (M2; Due Aug 30th 2024)**
    - Award Construction Contract for Integrating PCU (M3; 28th March 2024)
    - Complete Enclosure Installation (M4; 20th June 2024)
    - Complete Piping Installation (M4; 31st July 2024)
  - Integrate PCU with MAGNET (M3; Due Sept 30th 2024)

- **HELIUM COMPNENT TESTING OUT-OF-PILE RESEARCH (HECTOR) FACILITY**
  - Complete Engineering Design for High Temperature and High Pressure Gas Test Loop (8MPa and 800 deg C) – M3 Milestone (Completed 11/30/2023)
    - Manuscript being drafted

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Partnerships and Collaborations

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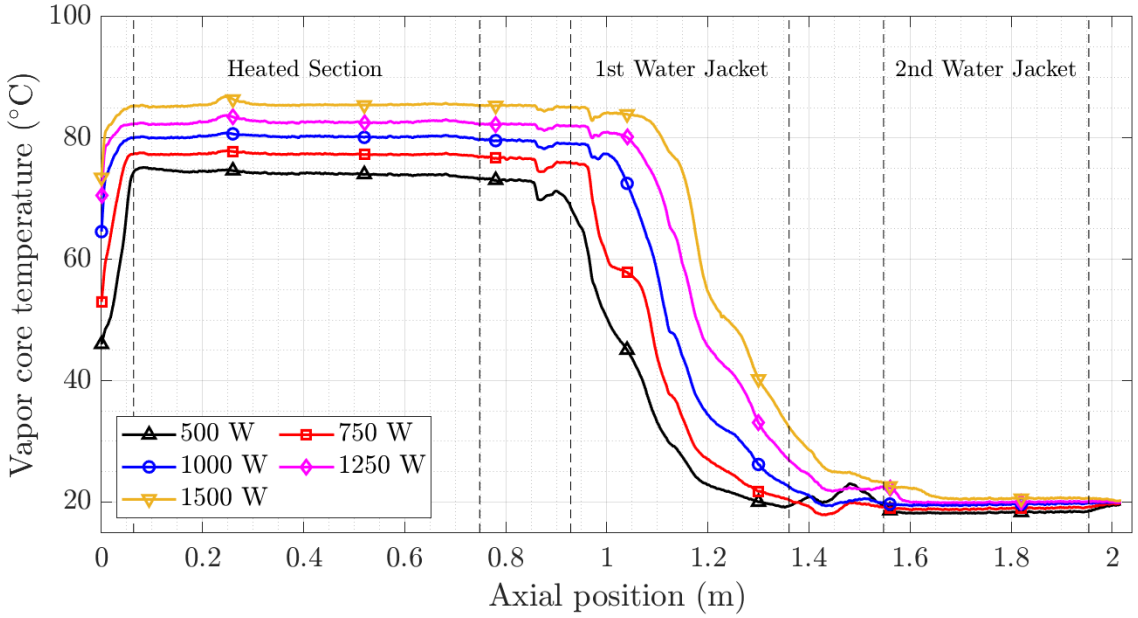
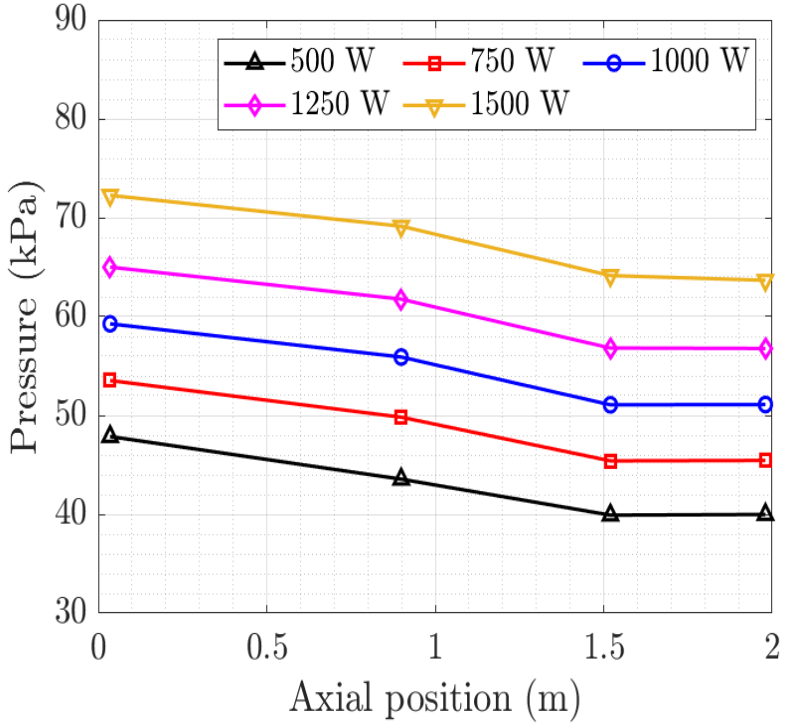
Experimental Work in University Partners - RPI

- Low-Temperature Heat Pipe Test Facility (LTHPF)
  - Fiber optic vapor core axial temperature profiles
  - Axial pressure profiles
  - High-speed flow visualization in the adiabatic section and condenser
  - Film thicknesses for thermosyphons





I. Yilgor, *and S. Shi, "Experimental Investigation of Heat Pipe Flow Dynamics and Performance," 20th Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-20), 2023.*

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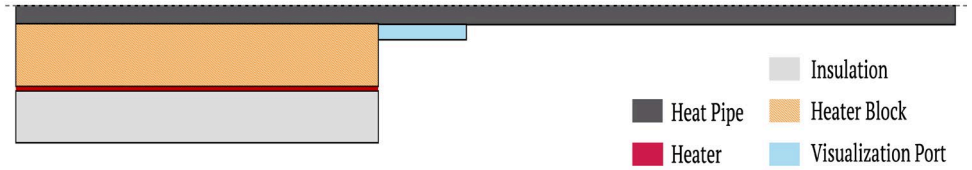
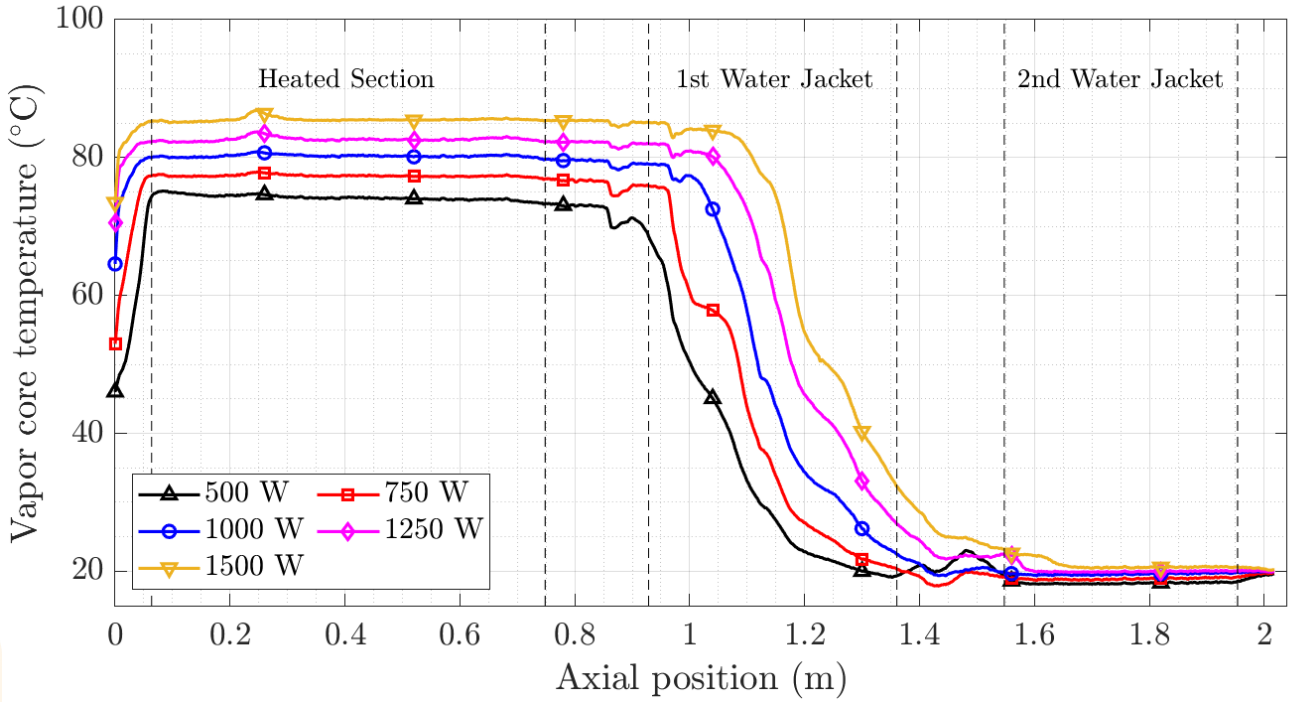
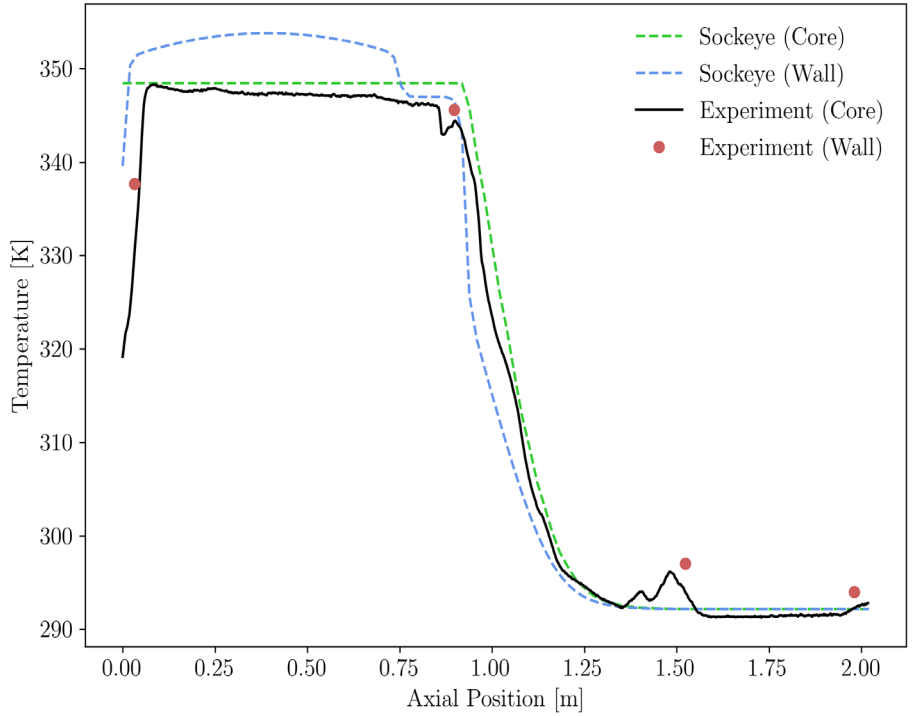
Sockeye Verification & Validation (Ongoing)

- Axial temperature profile validation via fiber optic distributed temperature sensor measurements
  - **Dataset from RPI** including cases with different evaporator power inputs and condenser flow rates
  - Initial investigations show good agreement with experimental data
  - The model considers the presence of non-condensable gases, and convection in the condenser section





Axial vapor core temperature profiles for the 0.10 kg/s condenser flow rate case at steady state



Sockeye simulation of the 500 W case

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NEUP Program

Experiments for Modeling and Validation of Liquid-Metal Heat Pipe Simulation Tools for Micro-Reactors

Technical Point Of Contact: Piyush Sabharwall

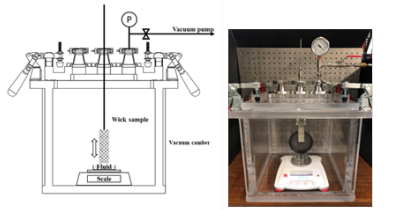
Federal Manager: Diana Li

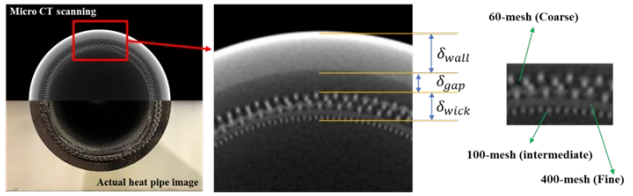
Investigator: Yassin. A. Hassan | Texas A&M University

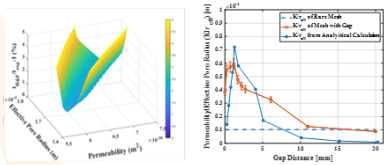
Collaborators: INL, UWM

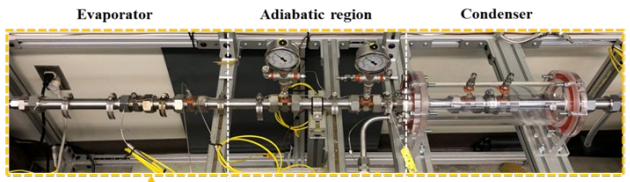
Center for Advanced Small Modular and Micro Nuclear Reactors

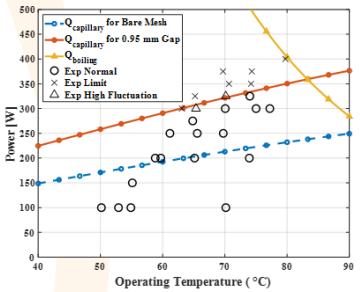
1ST FY

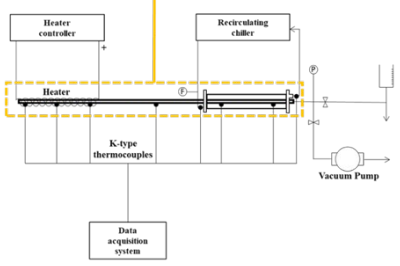


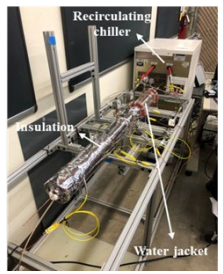




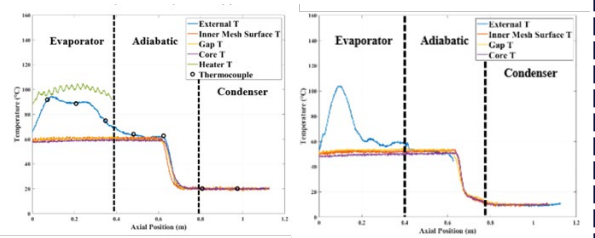


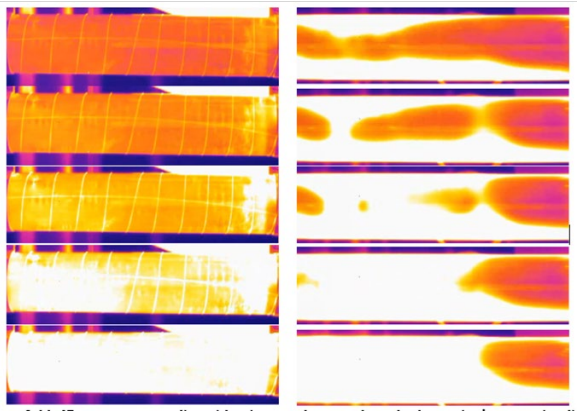


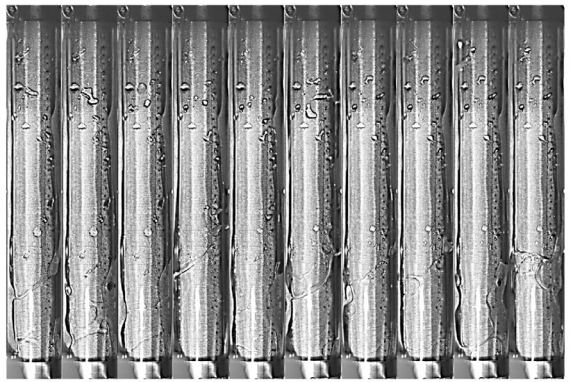




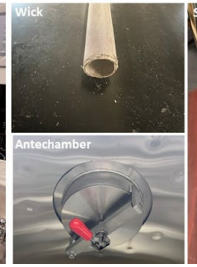
2nd FY

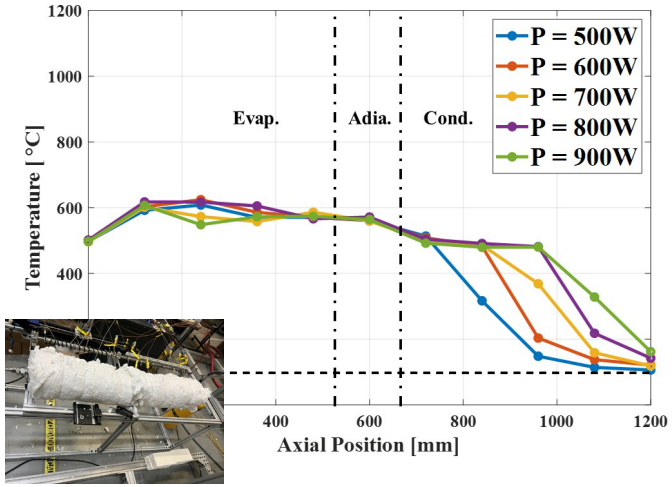






3rd FY





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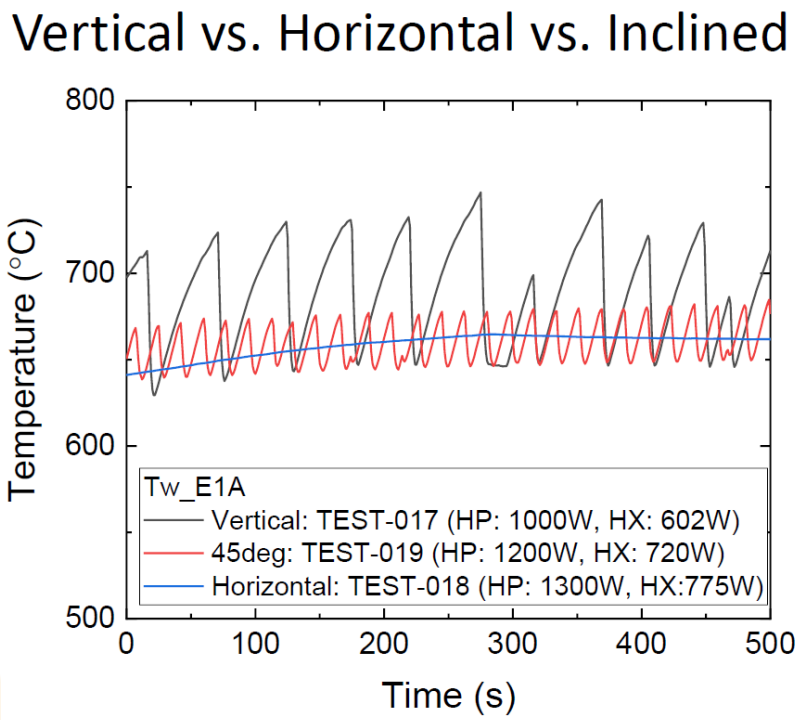
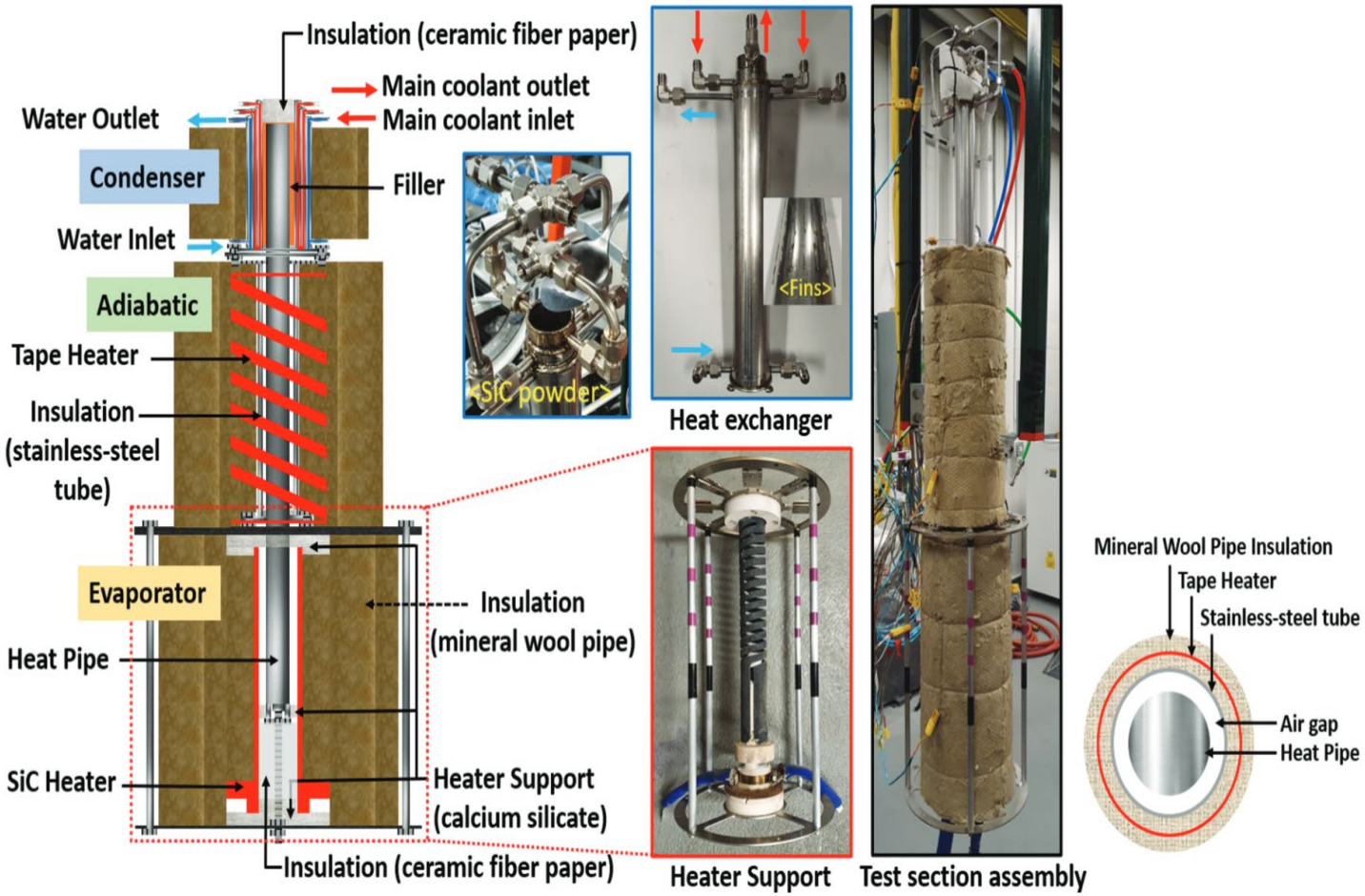
Experimental Work in University Partners - UMich

- High-temperature facility
- X-ray imaging
- Variable heat pipe orientation





Carolina da Silva Bourdot Dutra et al., "High-Fidelity Modeling and Experiments to Inform Safety Analysis Codes for Heat Pipe Microreactors", Nuclear Technology, 2023

MRP Microreactor Program

Data Warehouse for Validation Effort

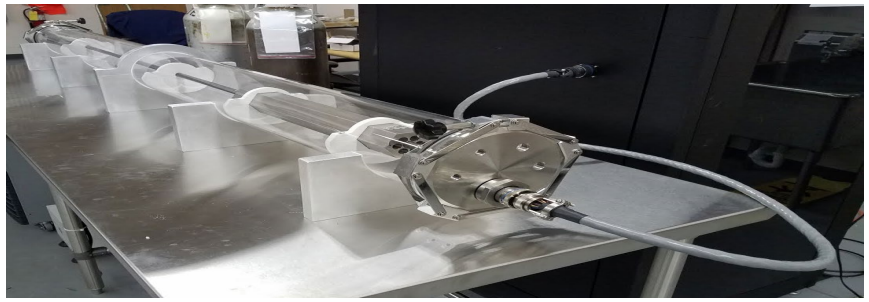
SPHERE Shakedown Testing

Objective:

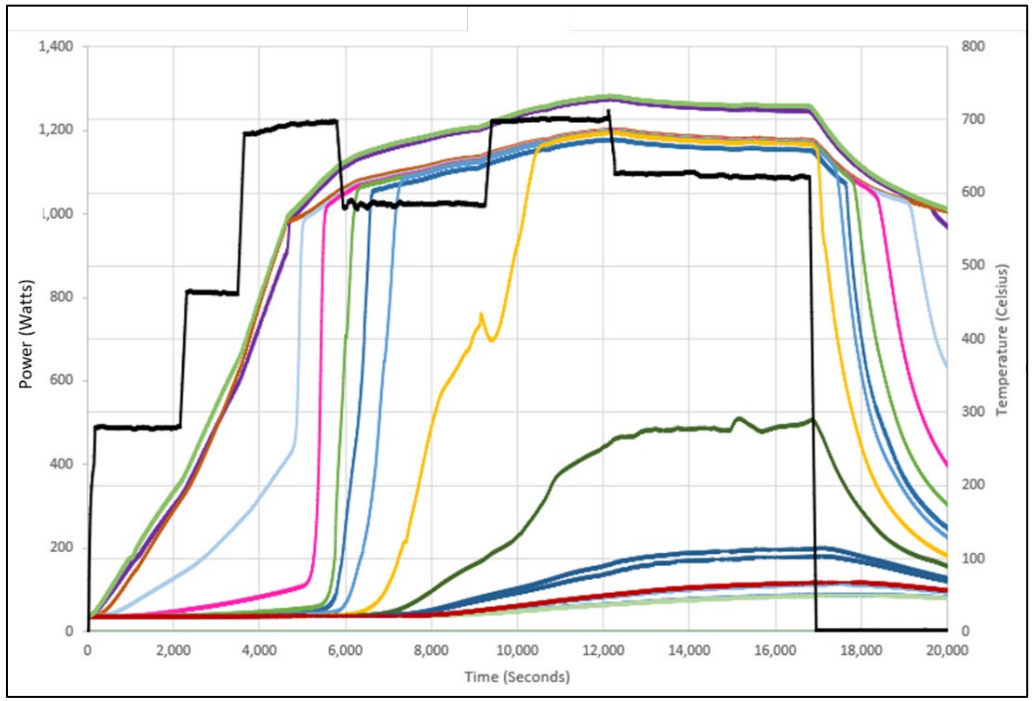
The objective of the shakedown test was to complete SPHERE assembly and demonstrate the operation of the SPHERE facility.

SPHERE Shakedown Test Plan

SPHERE TEST Plan				
SHAKEDOWN TEST	Conditions	Measurements	Instruments	Objective
300 C/hour heat up to 650 C operating temperature	Vacuum	Temperature, heater power	Type K Thermocouples	Heating and control check
Hold for 2 hours		Visual inspection	Watt-Transducers	
100 C/hour cool down to sub 400 C		absolute pressure	IR-Camera	
Passively cool to ambient				
oberserve material bonding quality				



SPHERE test bed and seven-hole test article

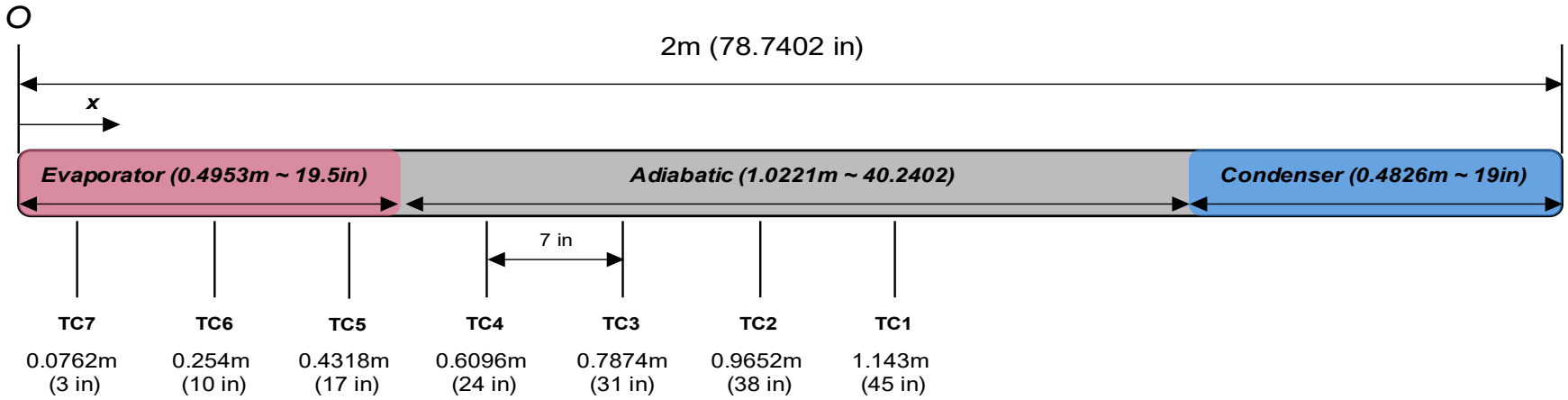


Data from INL testing of ACT heat pipe

Gap Conductance Testing

Objective:

The objective of the SPHERE gap conductance test was to obtain data on the heat losses through the annular gap (0.025-inches radially) formed by the outer wall of the heat pipe and the inner diameter of a stainless-steel core block through radiative and conductive heat transfer with varying gas compositions.



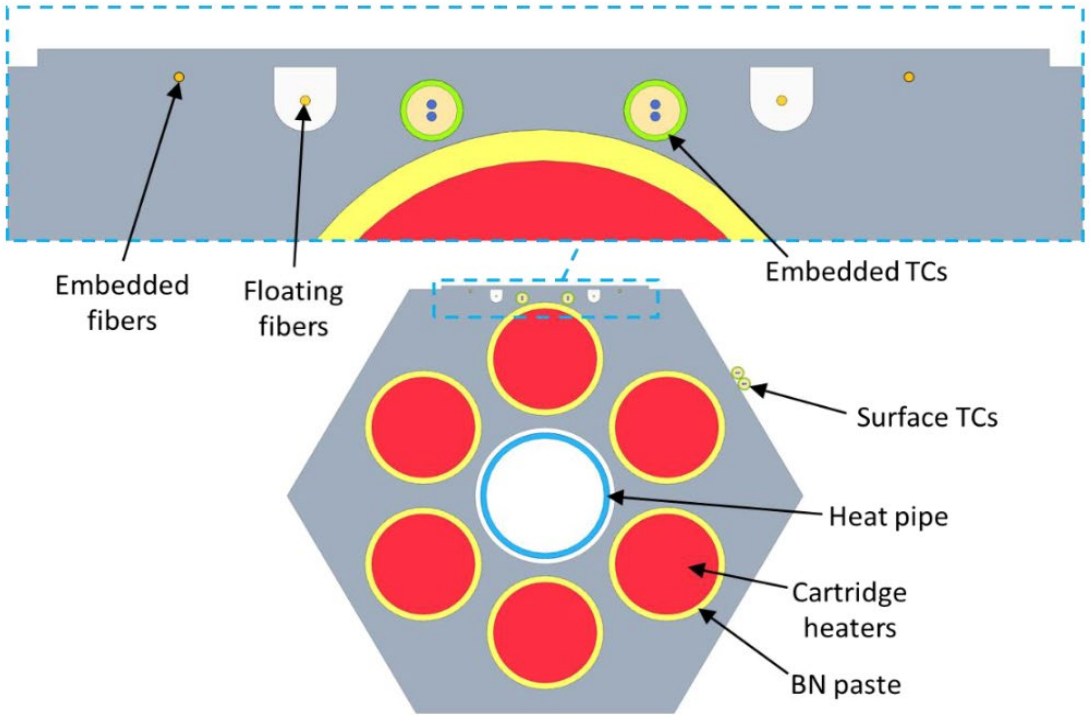
This experiment was set up and run to accomplish the task of finding the heat losses through the annular gap that is formed between the wall of the core block and the heat pipe outer wall with varying gas compositions and power levels. ***The theory and experimental results agree closely. This gives confidence in using standard assumptions for modeling the heat transfer between a heat pipe and a fuel rod.*** The heat losses through the gap were in close agreement with what was expected. For every gas composition and power level, the power loss through the gap was consistent.

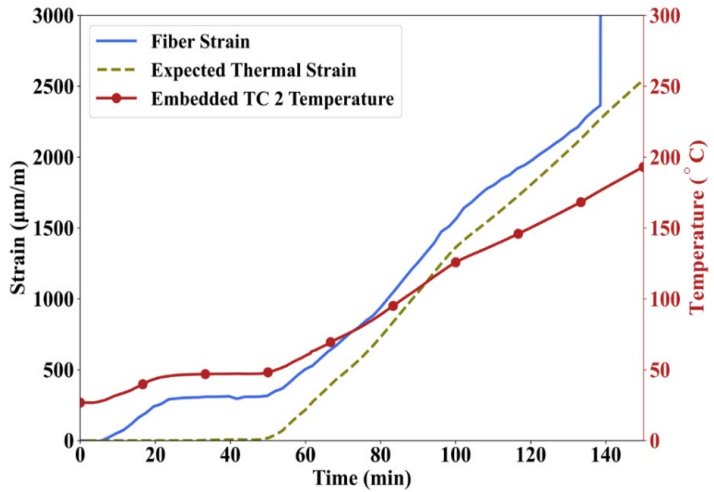
Link: https://inlbox.box.com/s/56lox85auklrtmtlis8fv3nzknbyoyql

Oak Ridge Embedded Sensor - Test

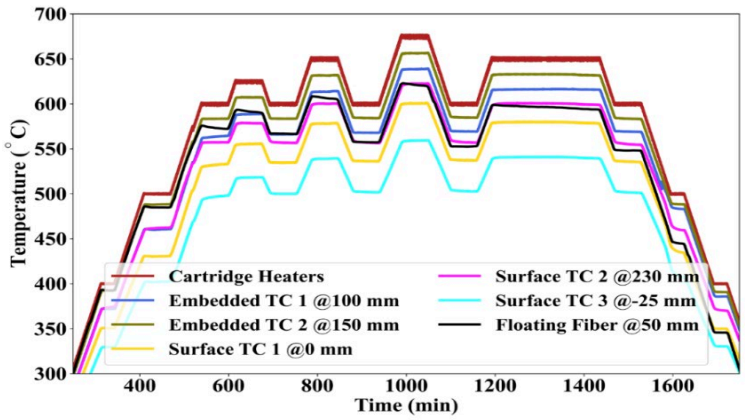
Objective:

The tests aimed to demonstrate the reliability of embedded sensors for microreactor applications. Measurements included strains which are caused by thermal gradients and the thermal expansion of dissimilar materials present in the block. The fibers were a mixture of strain and temperature sensors. Figure showcases the location of the sensors within the block.





Measured strain, analytical strain, and temperature as a function of time



Temperature as a function of time for both the embedded and non-embedded sensor data

Link: https://inlbox.box.com/s/56lox85auklrtmtlis8fv3nzknbyoyql

Conclusions

- Working closely with other DOE Programs to leverage and support joint efforts
- Regular interaction with industry through programs such as NRIC
- Interaction with Academia through DOE-NEUP program
- Bi-Monthly Meetings with PI's of NEUP's who are involved in experimental work
- Successful demonstration are needed to gain utility, regulator, and public confidence

Path Forward

SPHERE

- Complete testing on LANL high capacity heat pipes for steady state thermal heat transfer characterization
- V&V support for Sockeye

MAGNET

- Integrate PCU with MAGNET to allow Integrated Microreactor Heat T/F System Testing

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Thank You..!

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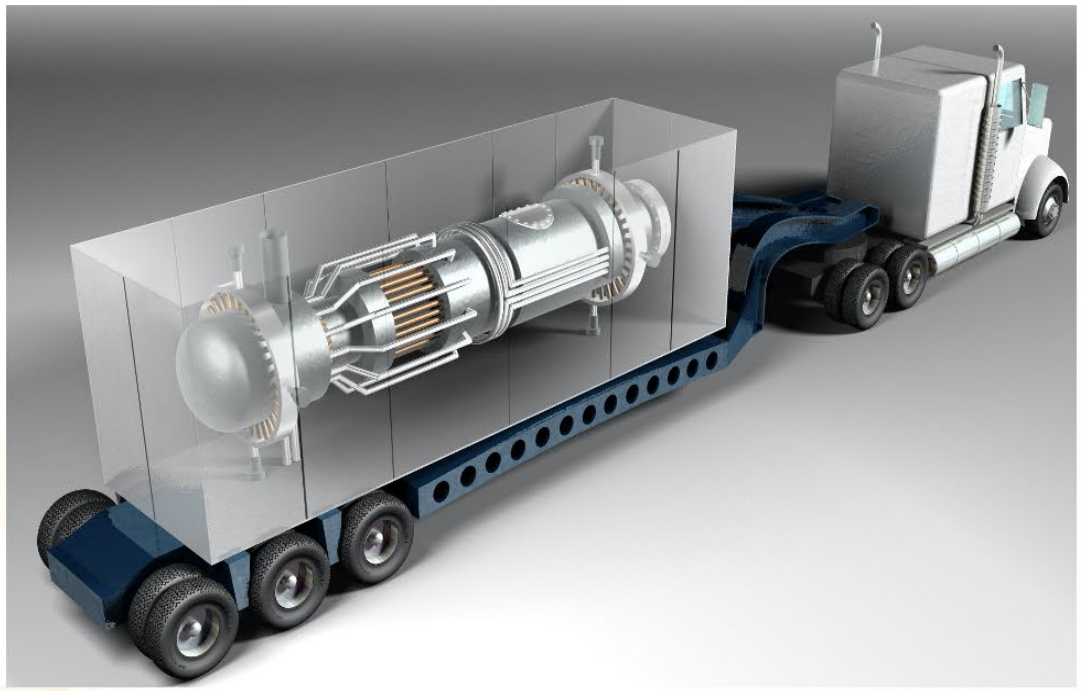

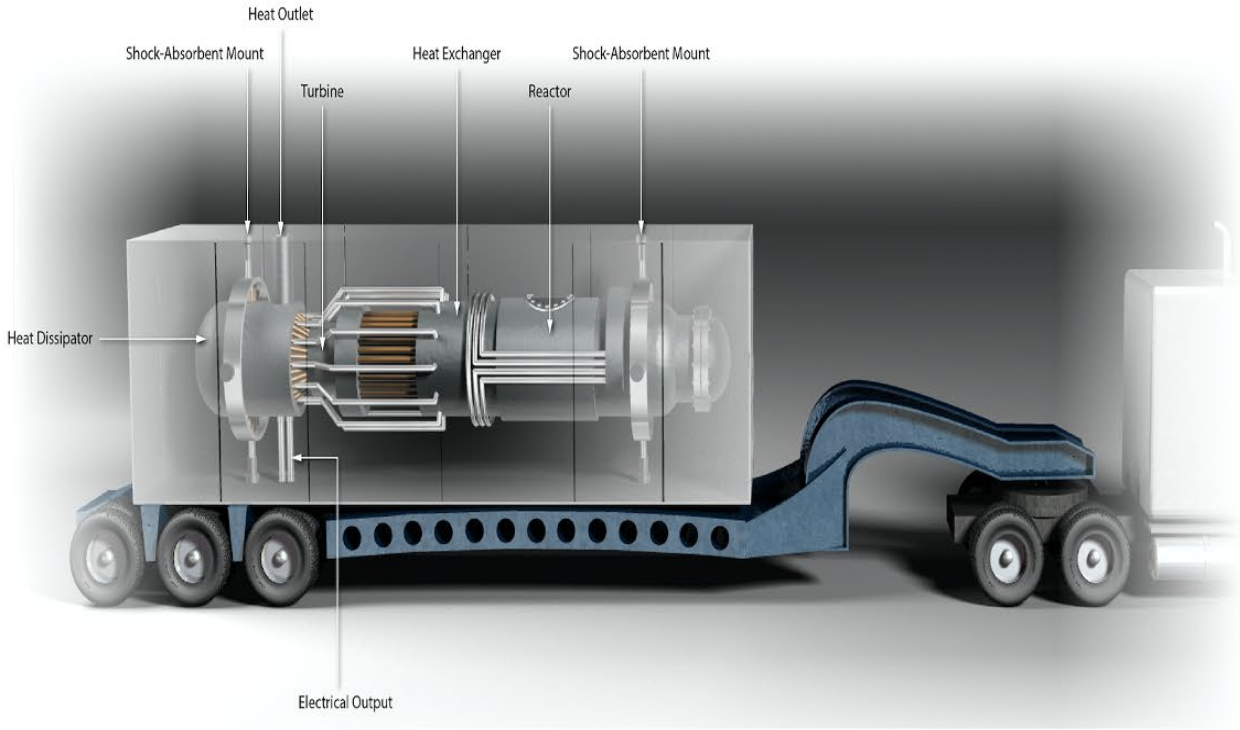

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Credit & Acknowledgement

U.S. DEPARTMENT OF ENERGY Nuclear Energy

INL Idaho National Laboratory

Los Alamos NATIONAL LABORATORY

OAK RIDGE National Laboratory

Argonne NATIONAL LABORATORY

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