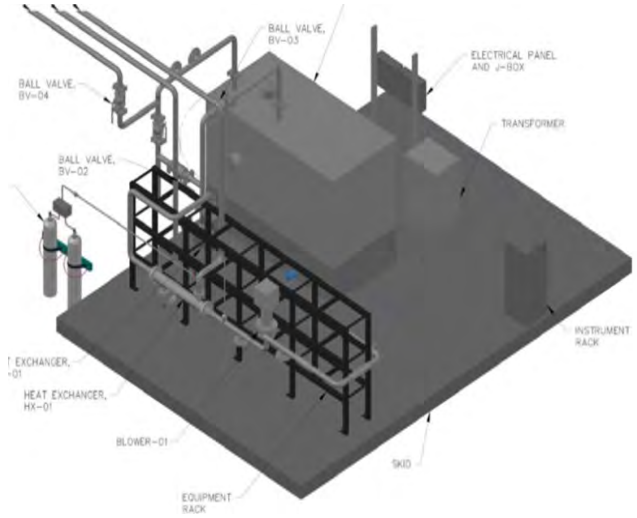
DOE-NE Microreactor Program Winter Review Meeting

Demonstration Capabilities Overview



March 4, 2022

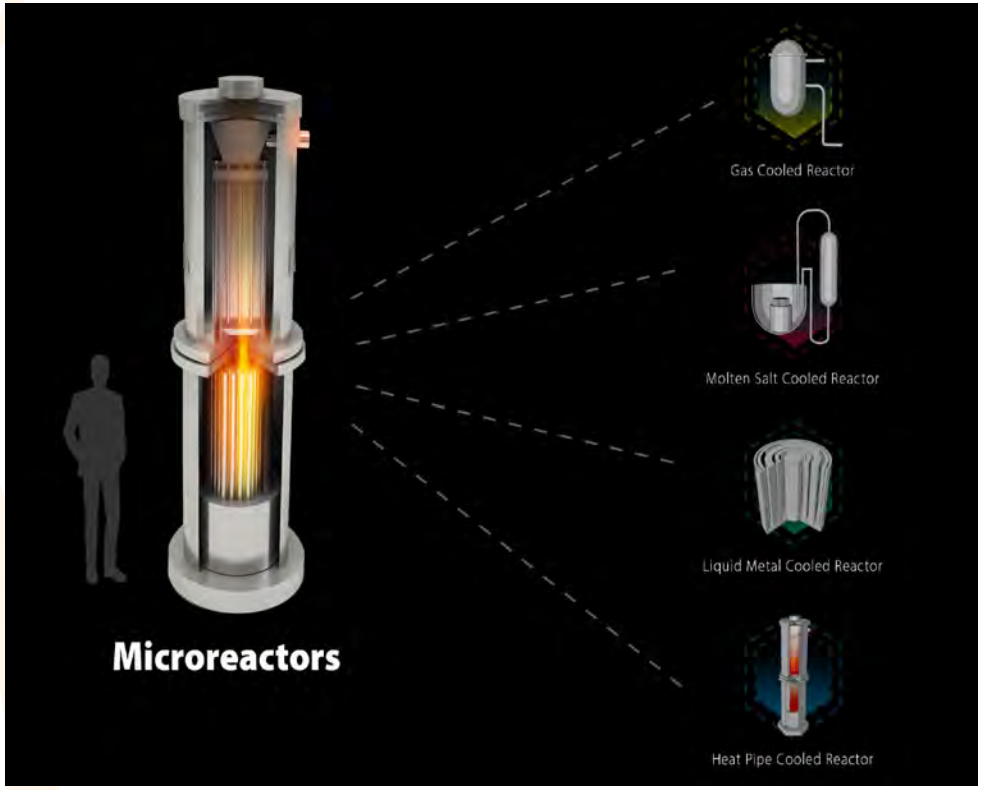
Piyush Sabharwall, Ph.D. | Technical Area Lead

Technical Area Overview

Demonstration Capabilities Technical Area includes two major R&D activities:

Non-Nuclear Testing and Demonstration:

- **Single Primary Heat Extraction and Removal Emulator (SPHERE)**
- **Microreactor AGile Nonnuclear Experiment Testbed (MAGNET)**



Team at INL: Piyush Sabharwall, TJ Morton, Helen Guymon, Jeremy Hartvigsen, Zachary Sellers, Troy Unruh, JunSoo Yoo, Donna Guillen, Sunming Qin, and Minseop Song.

INL Idaho National Laboratory

Los Alamos NATIONAL LABORATORY EST. 1943

OAK RIDGE National Laboratory

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Demonstration Support Capabilities – Subdivided into 4 main areas to support testing needs to deploy microreactors.

- Single Primary Heat Extraction and Removal Emulator (SPHERE) – Development of a platform to support non-nuclear thermal and integrated systems testing capabilities. This capability shall provide a better understanding of thermal performance of the heat pipe under a wide range of heating values and operating temperatures, further enhancing the understanding of heat pipe during startup, shutdown and transient operation.
- Microreactor Agile Non-nuclear Experimental Testbed (MAGNET) – Development of a thermal-hydraulic and integrated systems testing capability, called the MAGNET, to simulate core thermal behavior, heat pipe and primary heat exchanger performance, and passive decay heat removal will support verification and validation of detailed microreactor thermal hydraulic models. This is applicable under startup, shutdown, steady-state, and off-normal transient behavior in steady-state operation, transient operation, and load-following conditions. This testing is to be done in advance of nuclear system demonstration. The test bed will ultimately be integrated into the broader INL Systems Integration Laboratory, which includes thermal and electrical energy users such as steam electrolysis, real-time digital simulators for power systems emulation, a microgrid test bed, and renewable energy generation.
- Evolving Demonstration Support – Demonstration and testing infrastructure needs are expected to evolve as technology readiness of microreactors advance. Development of capability necessary to support this evolution is covered under this sub-area. Currently, MAGNET is undergoing modifications to support component testing for gas cooled systems.
- Verification and Validation Support – This subarea focuses on targeted testing to support verification and validation to meet industrial needs and licensing organization (such as NRC) needs to enhance understanding of a phenomenon of interest and reduce uncertainty.

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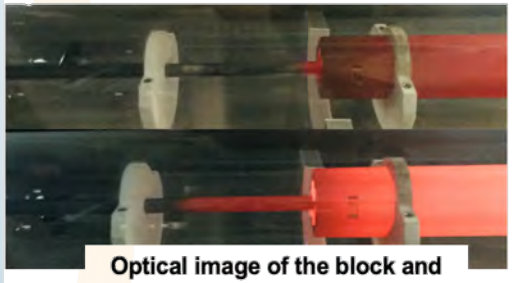
Single Primary Heat Extraction and Removal Emulator (SPHERE)

- Provide capabilities to perform steady state and transient testing of heat pipes and heat transfer:
  - Wide range of heating values and operating temperatures
  - Observe **heat pipe startup and transient operation**
- **Develop** effective thermal coupling methods between the heat pipe outer surface and core structures
- **Measure** heat pipe axial temperature profiles during **startup, steady-state, and transient operation** using thermal imaging and surface measurements

Parameter	Value
Length	243 cm
Diameter	15 cm
Tube material	Quartz
Connections	Flanged for gas flow and instrumentation feed through
Maximum power	20 kW
Max Temperature	750 C
Heat Removal	Passive radiation or water-cooled gas gap calorimeter

SPHERE Test Bed



Optical image of the block and heat pipe operation

Key Accomplishments

- SPHERE Initial Startup and Operation
- Complete Engineering Design of Gap Conductance Test Article

In Progress

- Gap Conductance Testing for NRC
- Working for Industrial Partner on understanding the effect of orientation on heat pipe performance
- Database Accessibility

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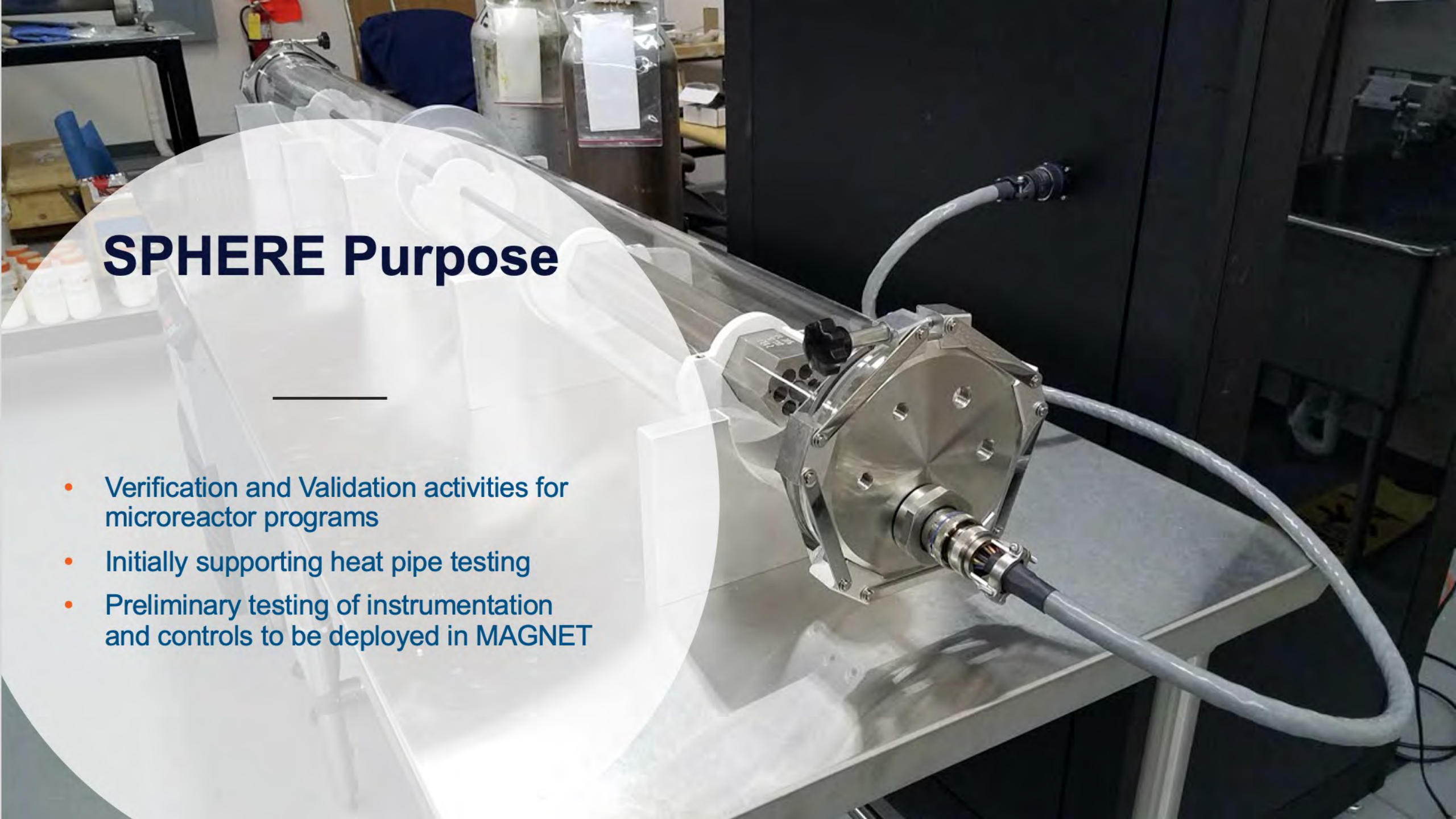
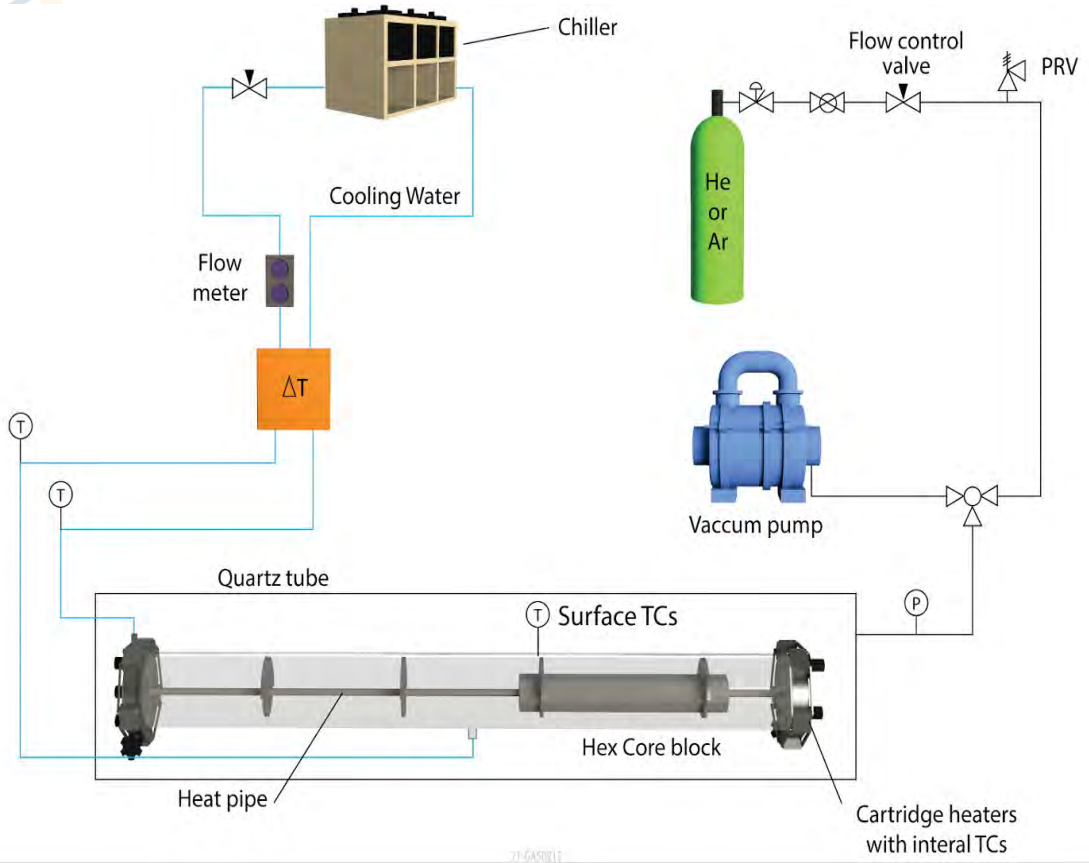
SPHERE Purpose

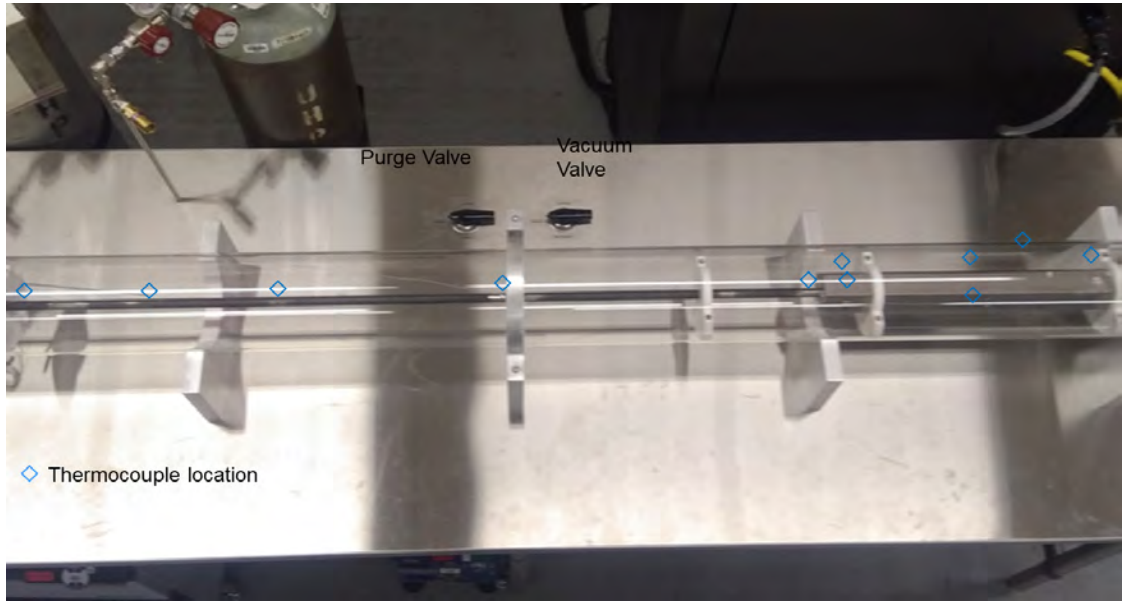


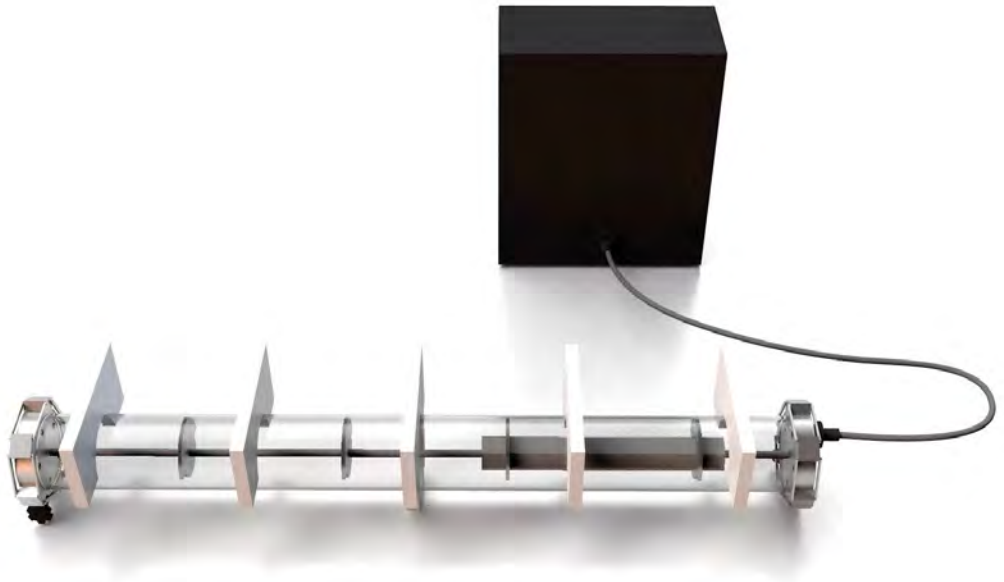
- Verification and Validation activities for microreactor programs
- Initially supporting heat pipe testing
- Preliminary testing of instrumentation and controls to be deployed in MAGNET

SPHERE System Design

- 6” diameter 8’ long quartz tube
- Maximum power rating of 20 kW
- Vacuum, Helium, Nitrogen, or Argon atmosphere



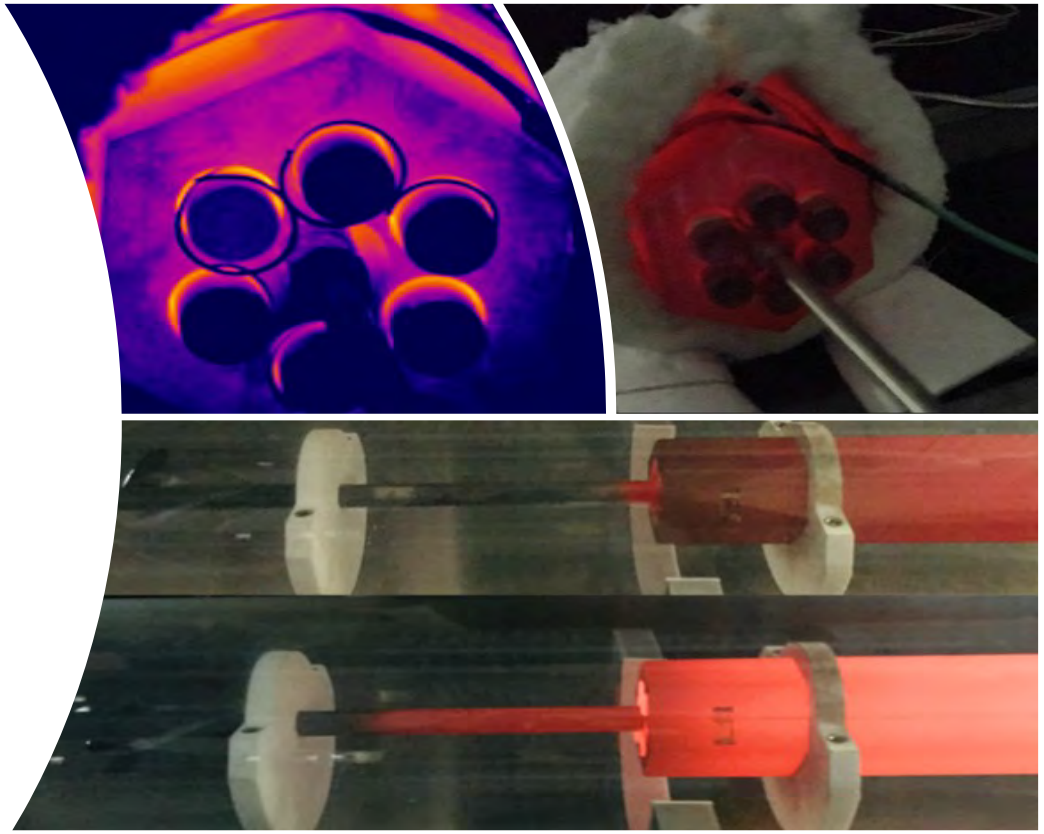




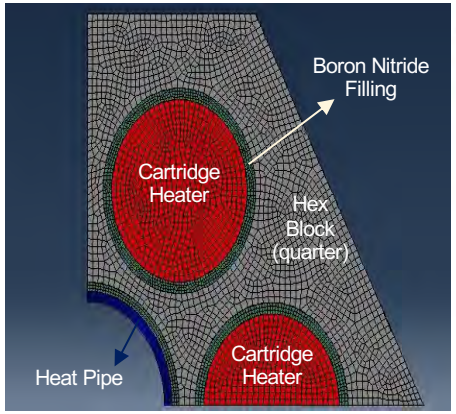
SPHERE: ACT Heat Pipe

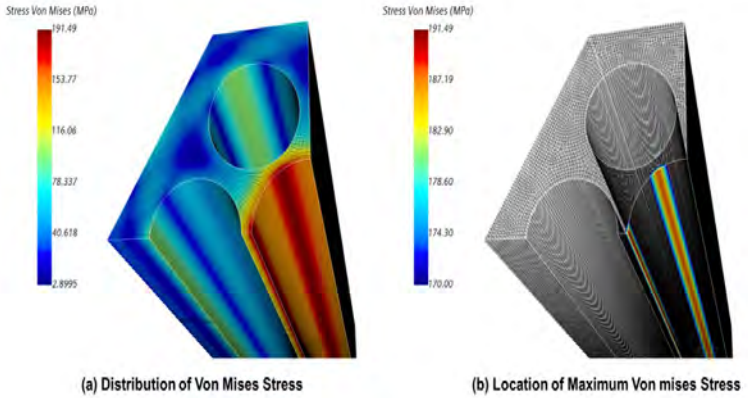
ACT Heat Pipe

- Pipe material: SS 316
- Geometry: smooth-wall tube, proprietary wick
  - Wick: sintered stainless steel
- Length: 2 m, Diameter: 0.625-in.
- Working fluid: sodium, non-condensable inert gas
- Operating temperature, ~740°C
- Heat-removal rating: 1 kW



Coupled Thermal and Structural Analysis for Heat Pipe Experiments: To guide experiment testing

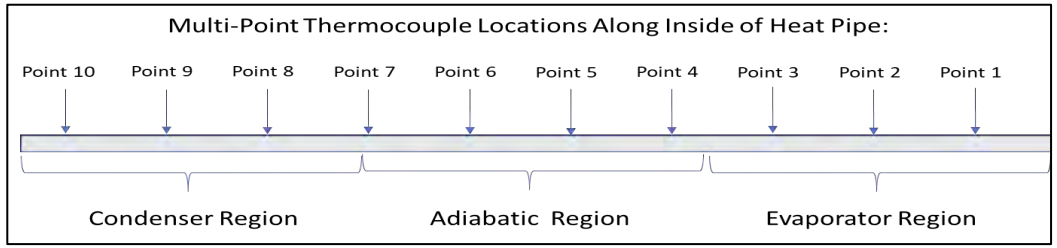


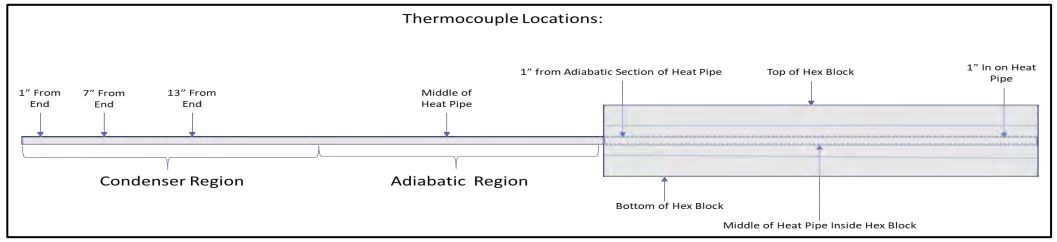


(a) Distribution of Von Mises Stress

(b) Location of Maximum Von mises Stress

Testing of Commercial Heat Pipe – Shakedown Testing





The ACT heat pipe has an internal thermowell running down the center of the heat pipe. A multi-point thermocouple is inserted into the heat pipe.

Small fine gauge wire thermocouples are attached externally to the heat pipe and hexblock, as well as inside the gap between the hexblock and the heat pipe.

Verify instrumentation and controls

Experimental data correlates with manufacturer data

Initial data from shakedown testing being used to help with tool validation

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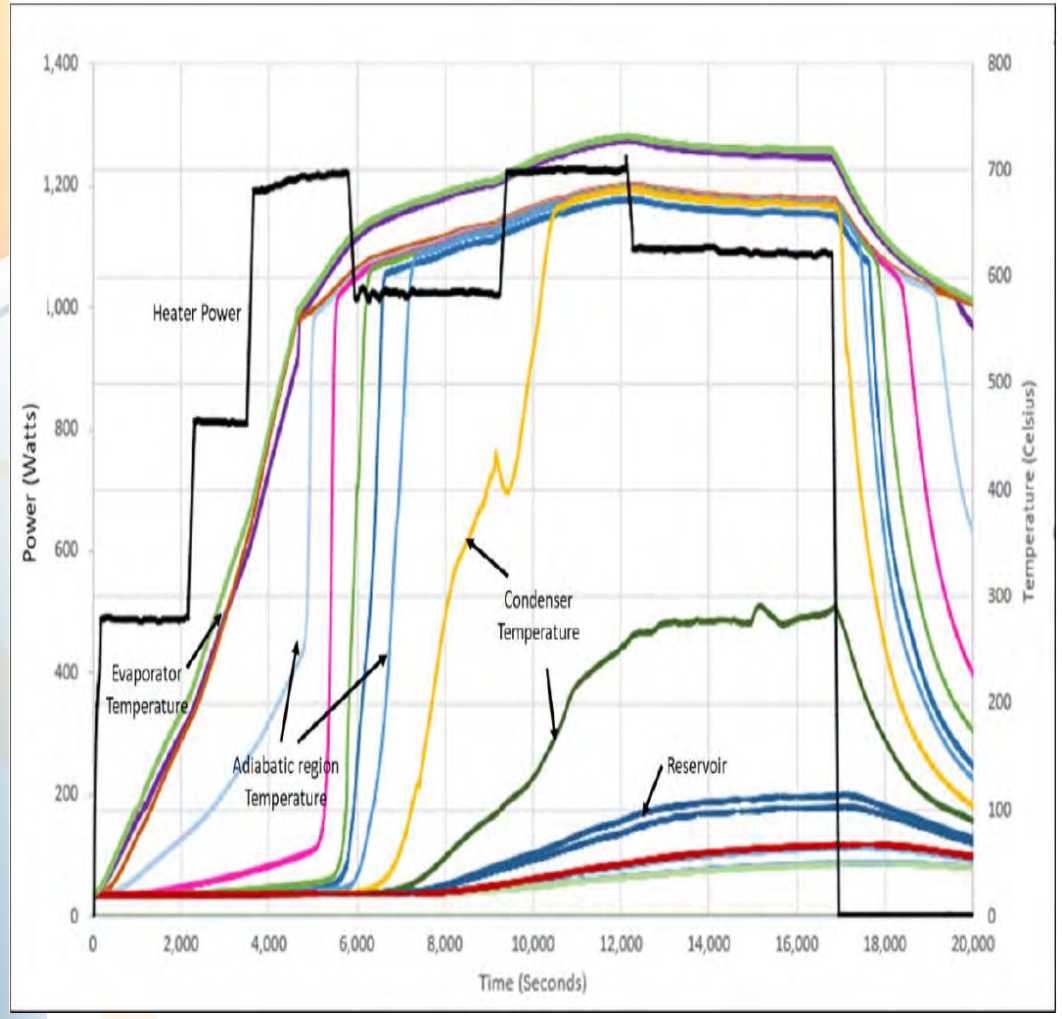
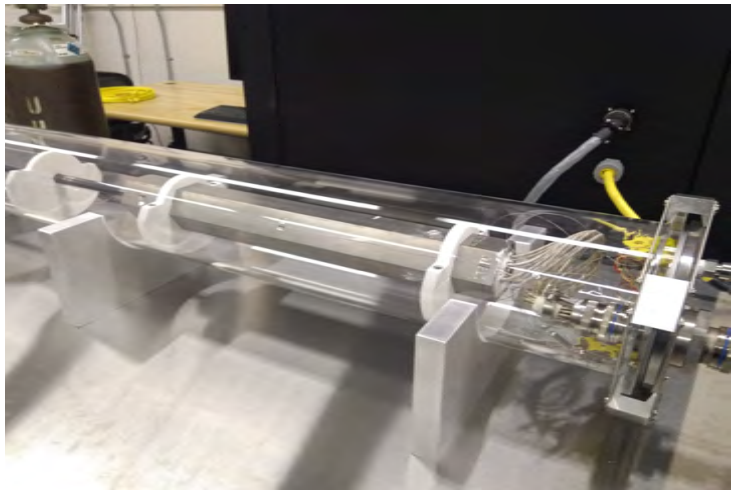
Testing of Commercial Heat Pipe



Accomplishments

- Verify instrumentation and controls
- NEAMS and SOCKEYE use the data from the testing to validate and tune their models
- Experimental data correlates with manufacturer data
- Initial data from shakedown testing being used to help with tool validation



Ongoing Activities

- Interlayer gap conductance testing
- Heat pipe orientation experiments

Sabharwall, P., J. Hartvigsen, T. Morton, Z. Sellers, and J. S. Yoo, *SPHERE Assembly and Operation Demonstration*, INL/EXT-20-60782, Idaho National Laboratory, December 2020.

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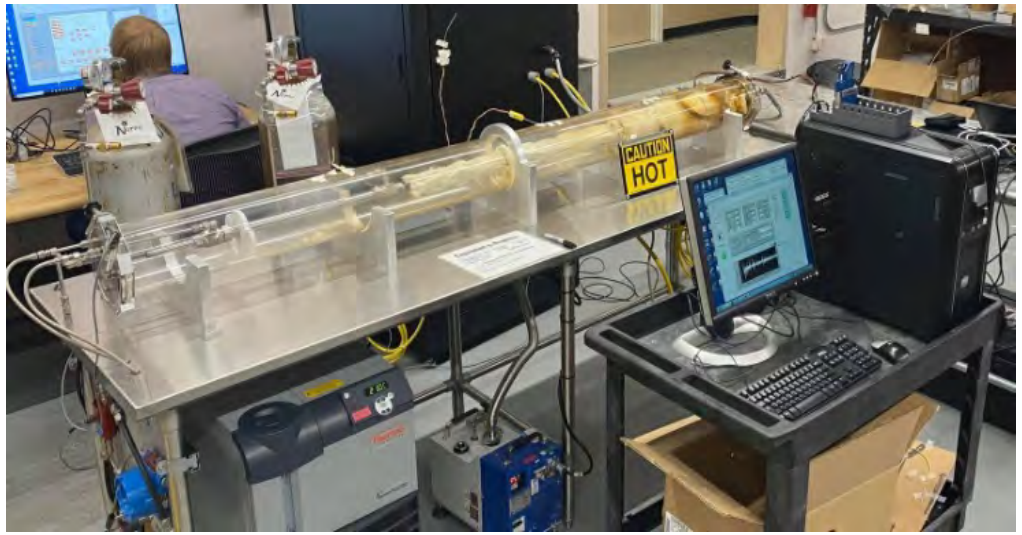
SPHERE Facility – Modifications (Ongoing)

- **Objective**
  - Obtain data on the thermal conductivity of the gap between the heat pipe and the hex block center hole with various gas compositions
- **Challenges**
  - Quartz tube was too small
    - Led to thermocouple burnout at the junctions
  - Unexpected manufacturing lead times
    - Led to using a different setup then initially designed
- **Solutions**
  - Replacing quartz tube with sanitary, clamp style tubing
  - Manufactured parts completed



Initial SPHERE gap conductance test with quartz tube

Example of sanitary tubing that is replacing quartz tube

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Microreactor AGile Non-nuclear Experimental Testbed (MAGNET)

- General-purpose test bed for performance evaluation of microreactor design concepts (heat pipe, gas-cooled, other).
- Provide detailed reactor core and heat removal section thermal hydraulic performance data for prototypical geometries and operating conditions.
- Demonstrate interface of heat removal section to power conversion system for power generation.
- Provides for integrated materials, instrumentation testing
- Co-located with integrated energy systems R&D capabilities

Parameter	Value
Chamber Size	5 ft x 5 ft x 10 ft
Heat Removal	Liquid-cooled chamber walls, gas flow
Connections	Flanged for gas flow and instrumentation feed through and viewing windows
Coolants	Air, inert gas (He, N2)
Gas flow rates	Up to 43.7 ACFM at 290 psig
Design pressure	22 barg
Maximum power	250 kW
Max Temperature	750 C
Heat Removal	Passive radiation or water-cooled gas gap calorimeter

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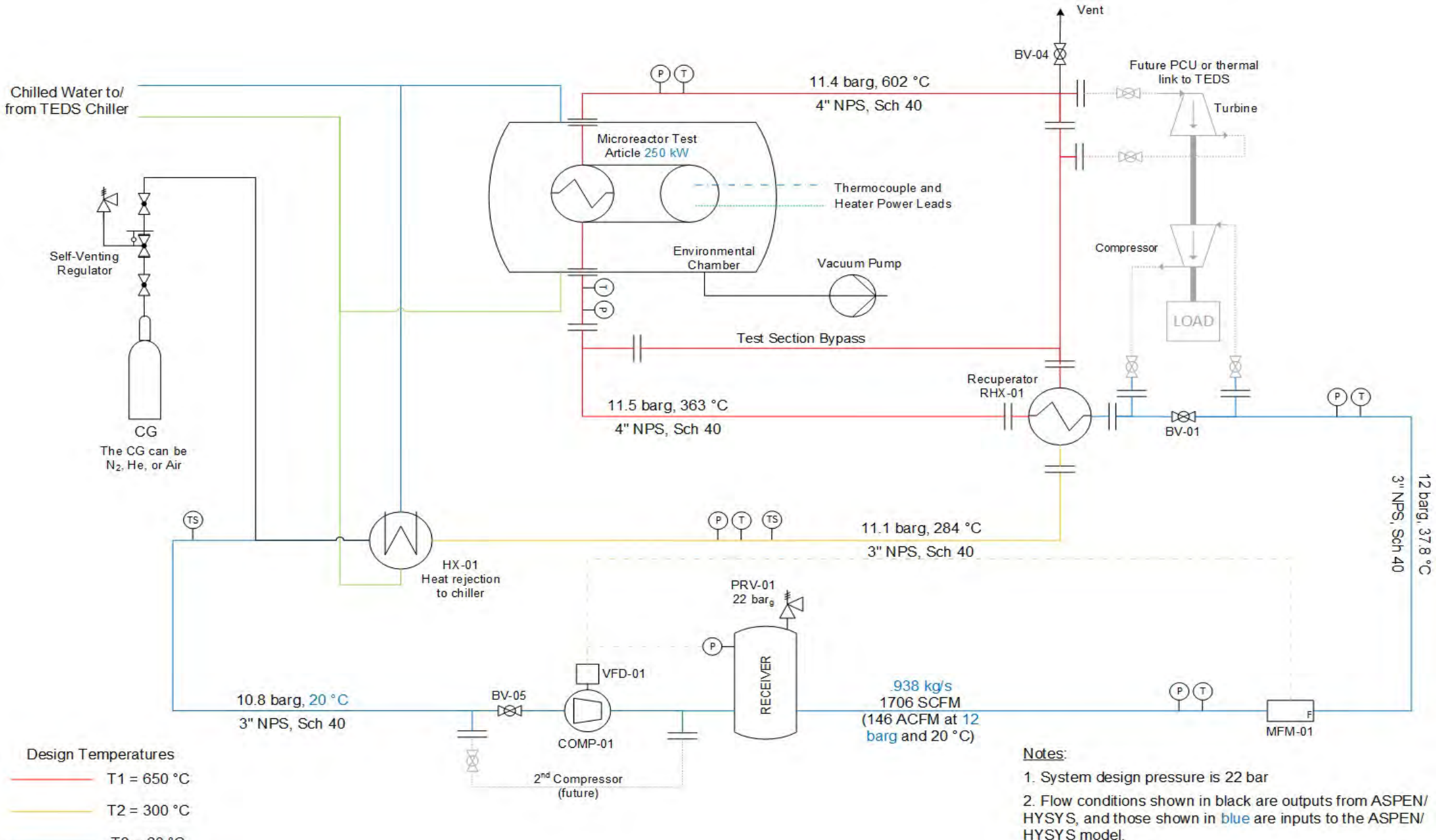
MAGNET Process Flow Diagram (PFD)



FY-22 Plans

Single Primary Heat Extraction and Removal Emulator (SPHERE)

- **M3** – Complete Fabrication and procurement of test article, perform test for gap conductance testing and report on findings (March 30th 2022)
- **M4 –** Provide NEAMS tool developers experimental data under different gas compositions and power levels (April 30th 2022)
- **M3 –** Provide NEAMS tool developers experimental operating curve for heat pipe to support validation effort for Sockeye (August 30th 2022)

Microreactor Agile Nonnuclear Experiment Testbed (MAGNET)

- **M3** - Complete Single Heat pipe Test Campaign (Feb 24th 2022)
- **M2** - Installation of 75 kW (37 Heat Pipe) Test Article in MAGNET (Sept 22nd 2022)

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