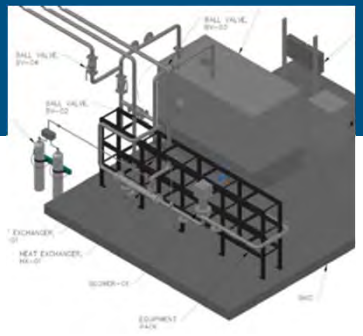
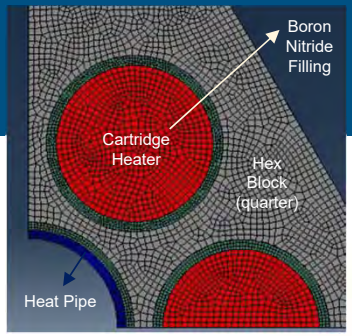
DOE-NE Microreactor Program Winter Review Meeting

March 9, 2023

INL Idaho National Laboratory
Oak Ridge National Laboratory
MRP Microreactor Program
Los Alamos National Laboratory
Argonne National Laboratory

Demonstration & Support Area





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Demonstration and Support Area – *Presentation Outline*

- **Overview**
- **Non-Nuclear Test Beds**
  - High Pressure Helium Loop Facility……..Zach Sellers
  - Single Primary Heat Extraction and Removal Emulator (SPHERE)…Jeremy Hartvigsen
  - Microreactor Agile Non-nuclear Experiment Testbed …..……..T.J. Morton
- **NEUP Projects (University Partnerships)**
  - Experiments for Modeling and Validation of Liquid-Metal Heat Pipe Simulation Tools for Microreactor..Yassin Hassan
  - Direct heating of chemical catalysts for hydrogen and fertilizer production using Microreactors……. Hitesh Bindra
- **Summary/Wrap-Up**

MRP Microreactor Program

Focus Areas – *Enabling non-nuclear demonstration to support microreactor development and deployment.*

Single Primary Heat Extraction and Removal Emulator

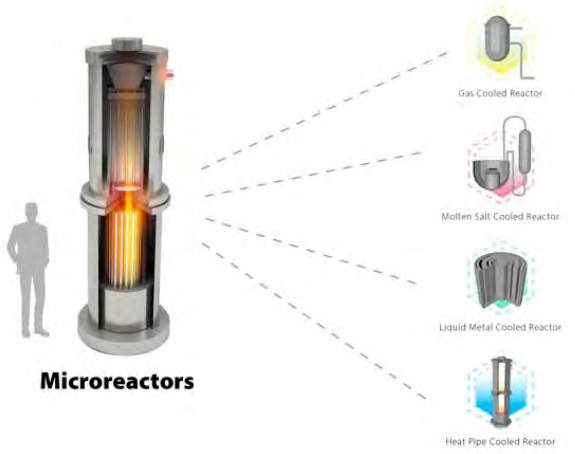
- Update and current status
- In operando Heat Pipe Operation Study

Microreactor Agile Non-nuclear Experiment Testbed (MAGNET)

- Update and current status
- eBlock 37 Testing (Mid-year 2023)

HElium Component Testing Out-of-pile Research (HECTOR) Facility

- Update and current status



Idaho National Laboratory

Piyush Sabharwall, TJ Morton, Jeremy Hartvigsen, Zachary Sellers, Troy Unruh, JunSoo Yoo, Sunming Qin, Mauricio Retamales, Silvino Balderrama Prieto, Brad Couch, Trenna Muckleroy and Edward Beverly

Los Alamos NATIONAL LABORATORY

Bob Reid, Katrina Sweetland and Holly Trellue

OAK RIDGE National Laboratory

Christian Petrie and Holden Hyer

MRP Microreactor Program

Demonstration Support Capabilities – *Subdivided into four 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**, 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 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 will be done before nuclear system demonstration. The test bed will ultimately be integrated into the 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 subarea**. MAGNET was modified to support component testing for gas cooled systems.
  - High Pressure and High Temperature Helium Facility (HECTOR; 8MPa and 800 C)
- **VERIFICATION AND VALIDATION SUPPORT –** This subarea focuses on targeted testing supporting verification and validation to meet industrial 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

Provide capabilities to perform steady-state and transient testing of heat pipes and heat transfer:

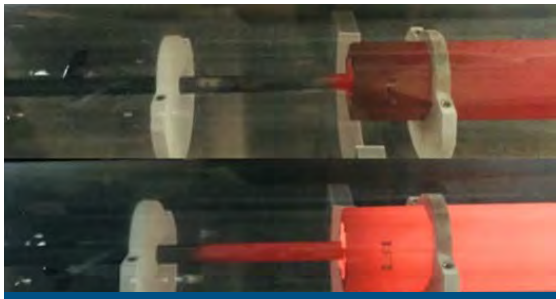
- Wide range of heating values and operating temperatures
- Observe **heat pipe startup and transient operation**

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 feedthrough
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 operations

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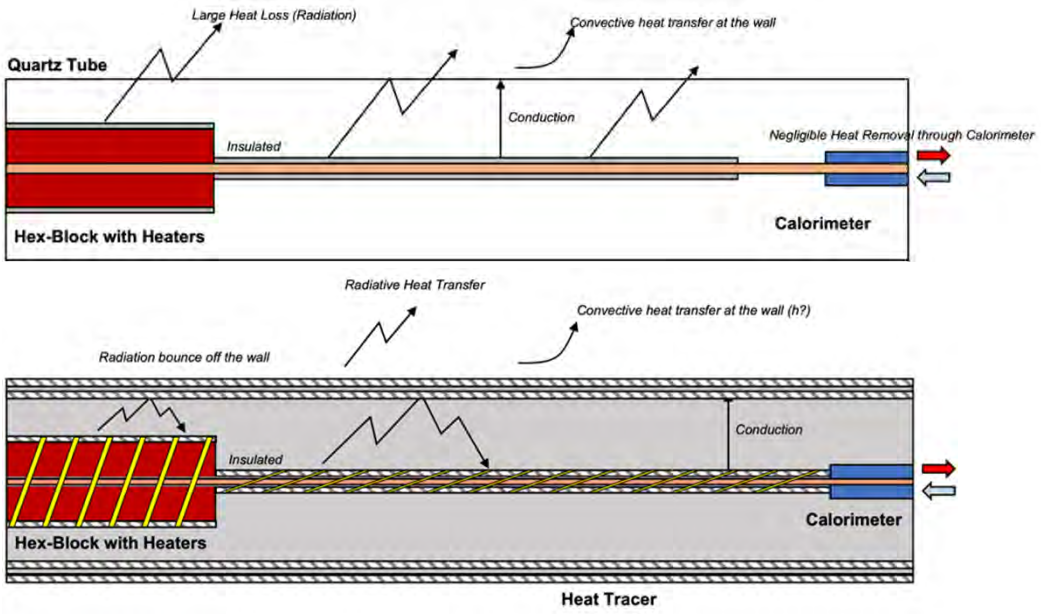
Experimental Setup Changes

- Quartz tube to stainless steel tubing
- Wrapped the hex block and adiabatic section of the heat pipe in heat trace to limit heat loss in those regions
- Wrapped inside of the stainless tubing with a layer of insulation to further reduce heat loss



Parameter	Value
Length	10 ft
Diameter	12 in
Tube material	Stainless steel
Connections	Flanged for gas flow and instrumentation feedthrough
Maximum power	20 kW
Max temperature	900 C
Heat removal	Passive radiation or water-cooled gas gap calorimeter

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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 (ongoing)
- Procure, operate and test advanced heat pipes for SPHERE test bed (ongoing)

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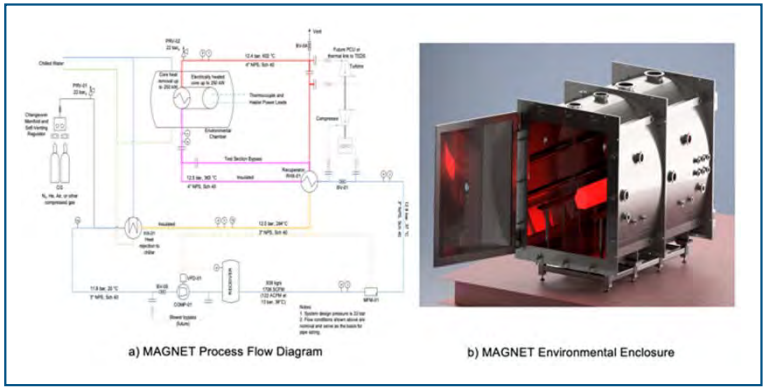
Microreactor AGile Non-nuclear Experimental Testbed *(MAGNET)*

- 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



a) MAGNET Process Flow Diagram

b) MAGNET Environmental Enclosure

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 feedthrough 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 – 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
- MAGNET modification to support proprietary HX testing (from a commercial developer).
- Test heat exchanger
- Demonstrated digital twin of a single-heat-pipe test article in MAGNET with autonomous, self-adjusting capability.
- 37 Heat Pipe Test Article (installation and testing – ongoing)

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HElium Component Testing Out-of-pile Research *(HECTOR)* Facility

Test bed being designed to enable testing of components such as heat exchangers, valves, circulators, etc., at operating conditions up to 8MPa and at 800 C.

US Reactor Design Concepts

Developer	Name	Power Output (Mwe/NWth)	Fuel	Coolant	Moderator	Gas Pressure	Outlet Temperature
BWXT	BANR	17/50	TRISO	He	Graphite	–	–
HolosGen	Holos Quad	10-13/–	TRISO	He/CO_2	–	7 MPa	620ºC
NuGen, LLC	NuGen Engine	2-4/–	TRISO	He	–	–	–
Radiant Nuclear	Kaleidos	1.2/–	TRISO	He	Graphite	–	700ºC
Ultra Safe Nuclear	Micro Modular Reactor	5/15	TRISO	He	Graphite	3 MPa	565ºC
X-energy	Xe-100	80/200	TRISO	He	Graphite	6 MPa	750ºC
General Atomics	GA-EMS	50/112	UO_2	He	–	7 MPa	800ºC

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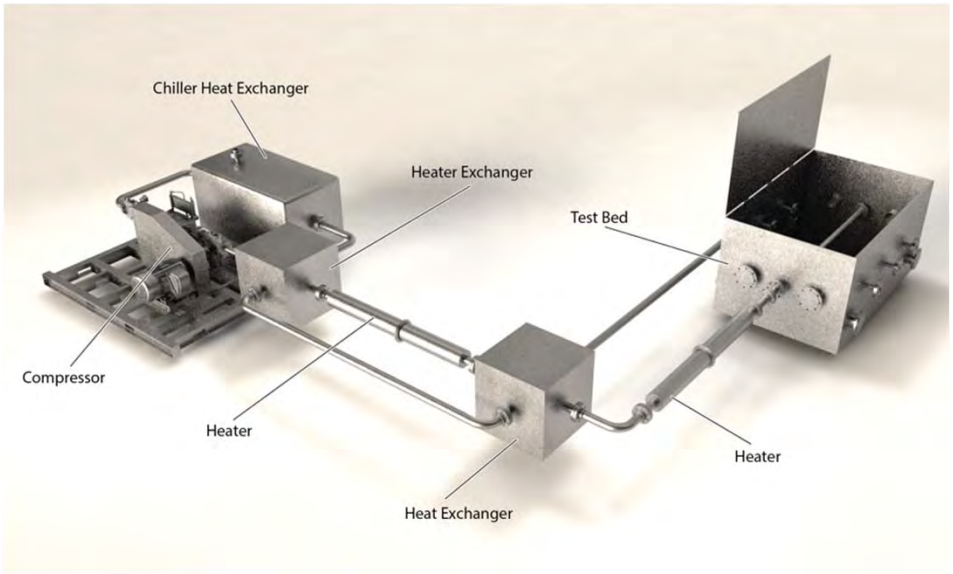
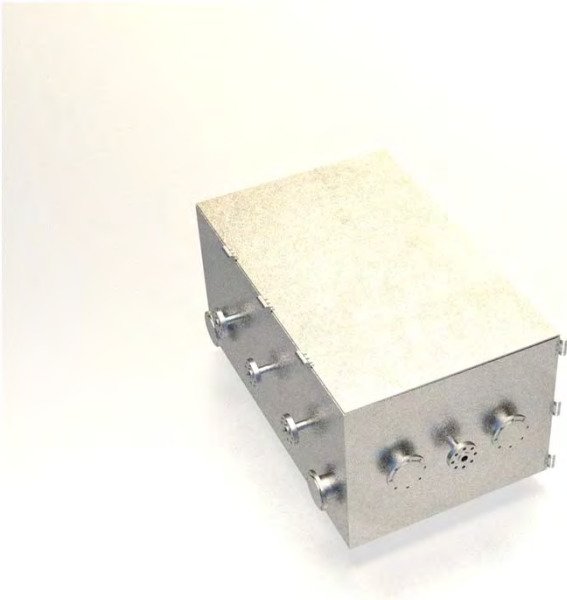
HElium Component Testing Out-of-pile Research Facility

Operating Conditions	
Pressure	4 - 8MPa
Temperature	Up to 800 C
Mass Flow	0.01 – 0.15 kg/s
Reynold's Number Range	12800 - 412560





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