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Project: Cost Reduction of Advanced Heat Exchanger Technology for Microreactors
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Sponsor: U.S. Department of Energy

Background

Thermal Hydraulics Laboratory

- **Integrated heat pipe micro-reactors offer reliable and transportable, long-life power for a variety of applications such as: space power, remote communities, and emergency locations**
- **A critical component of these micro-reactors is the heat pipe interface heat exchanger (HPIHX) which interfaces with the condenser end of each heat pipe and the process fluid (primary heat exchanger, Figure 1)**
  - Development of design tools for the HPIHX will enable significant cost reduction over the entire application space
- **A report on the analysis of a 5 MW thermal heat pipe micro-reactor called for the research and development of a subscale engineering demonstration unit capable of resolving various issues related to the HPIHX [1]**
  - Issues included: transient/start up behavior, thermal performance, welding/joining techniques, and inspection challenges
- **The Westinghouse eVinci™ energy generator is a uranium fueled reactor with sodium filled heat pipes that transfers energy from the reactor to the HPIHX**
  - Sized to provide between 200 kW and 15 MW of electrical power
  - HPIHX nominal design is a shell-and-tube heat exchanger
- **A printed circuit heat exchanger (PCHE) has the potential to significantly reduce cost and improve reliability over alternative options**
  - High heat transfer coefficients and heat transfer area associated with microchannels will improve performance
  - Existing PCHE technology may reduce cost by using current manufacturing and assembly techniques

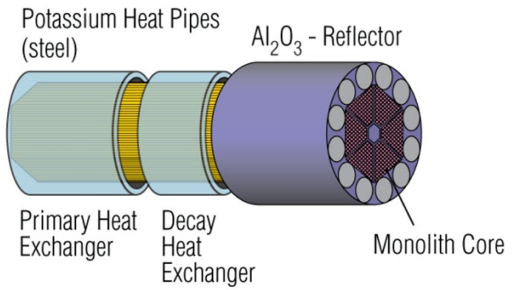

Figure 1: Special purpose reactor concept schematic [1]

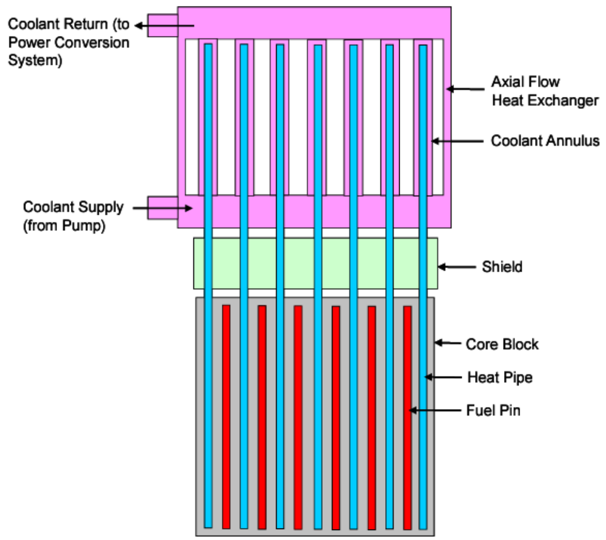

Figure 2: HPIHX and reactor interface cross-section [2]

U.S. Department of Energy

[1] Sterbentz, J.W., et al., Special Purpose Nuclear Reactor (5 MW) for Reliable Power at Remote Sites Assessment Report, INL/EXT-16-40741 Rev 1, April, (2017).
[2] McClure, P.R., D.I. Poston, V.R. Dasari, and R.S. Reid, "Design of Megawatt level heat pipe reactors," LA-UR-15- 28840, (2015).

Project Goals

Thermal Hydraulics Laboratory

- **Advance the integration heat exchanger technology design tools for a heat pipe micro-reactor**
  - Develop an optimal integration heat exchanger that is high performance, reliable, compact and can be customized to operate with various process fluids
  - Develop simulation and design processes that are useful across micro-reactor concepts and various end uses
- **Use the Westinghouse eVinci™ micro-reactor and end use to effectively understand operating parameters, performance requirements, and cost considerations while remaining relevant to current industrial work**
  - Use boundary conditions provided by a micro-reactor/end-use model similar to the Westinghouse eVinci™ micro-reactor to create a sophisticated component model of a PCHE and annular flow heat exchanger
  - Design integration heat exchanger that considers performance, cost, safety, and manufacturability
- **Procure two PCHE HPIHX test units in order to validate the design process and demonstrate the technology**
  - One test unit will be optimized for a low-density gas working fluid such as N2 and demonstrated using the Microreactor Agile Non-Nuclear Experimental Test Bed (MAGNET) facility at Idaho National Laboratory (INL)
  - Second test unit will be optimized for a sCO2 cycle and tested using the sCO2 facility at UW-Madison
- **Help code-qualify the PCHE technology for nuclear applications leveraging standardization, manufacturing and assembly results**
  - Data for ASME Boiler Pressure Vessel code

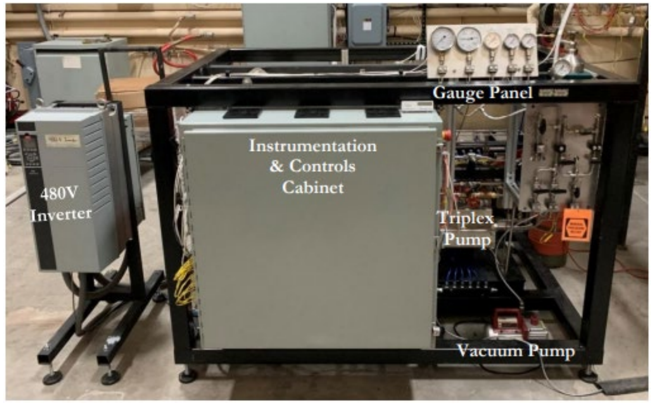

Figure 3: Wisconsin portable sCO2 loop [3]

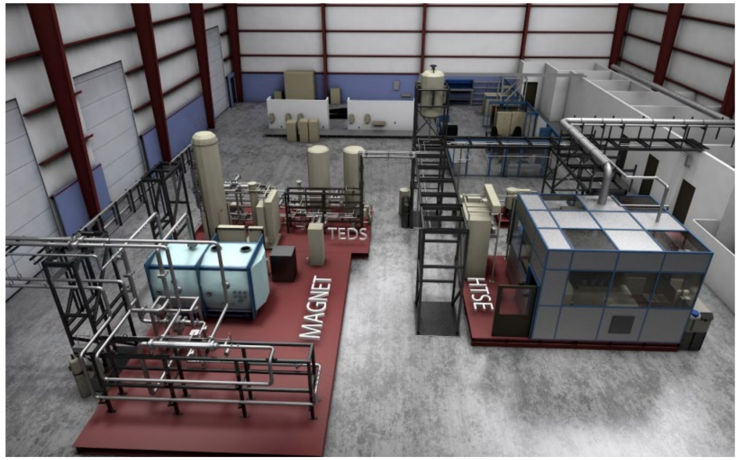

Figure 4: Rendering of INL's integrated energy laboratory housing the MAGNET facility [4]

[3] Aakre, S.R., "Thermal and Hydraulic Behavior of High-Temperature Fluids in Diffusion-Bonded Heat Exchangers." PhD diss., The University of Wisconsin-Madison, 2021.
[4] Morton, T.J., Integrated Energy Systems Experimental Systems Development, INL/MIS-20-59847D, September (2020).

INL NEUP Nuclear Energy University Program U.S. Department of Energy Westinghouse