



Technology Maturation for Microreactor Program Review

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Technical Area Lead

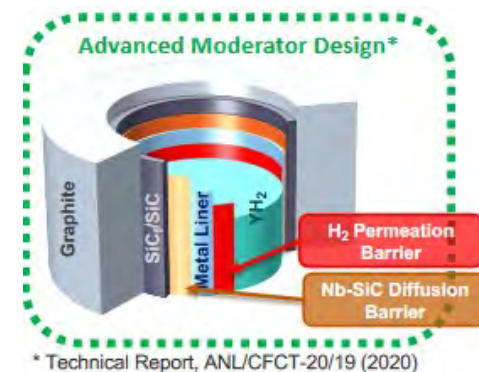
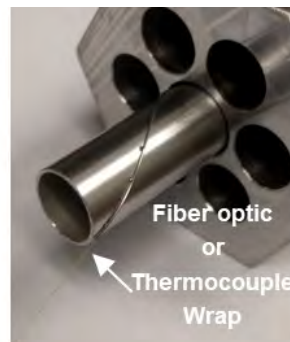
March 6, 2024

Outline

- Overview.....Holly Trelue (LANL)
- High Temperature Moderator Material
 - High Temperature Moderator Containment..Sumit Bhattacharya/Latif Yacout (ANL)
 - Advanced Moderator Material Handbook and Post Irradiation Examination of Yttrium Hydride (YH_x)Aditya Shivprasad (LANL)/Chase Taylor (INL)
- Instrumentation and Sensors
 - Microreactor Automated Control System.....Tony Crawford (INL)
 - Acoustic Sensors.....Paul Geimer (LANL)
- Heat Transfer/Graphite Test Article and Heat Pipe.....Katrina Sweetland (LANL)
- Structural Material
 - PM-HIP code caseTate Patterson (INL)
 - Refractory Metals.....John Carpenter (LANL)
- Wrap-Up.....Holly Trelue (LANL)
- NEUP – Mini-core Heat Pipe Facility.....Victor Petrov (UMICH)
- NEUP – Cost Reduction of Advanced Integration Heat Exchanger Technology for Micro-Reactor..... Curtis Foster/Greg Nellis (WISC)
- NEUP – Development of Hydrogen Transport Models for High Temperature Metal Hydride Moderators..... Jeff King (CSU)
- NEUP – Evaluation of Semi-Autonomous Passive Control Systems for HTGR Type Special Purpose Reactors..... Brendan Kochunas
- NEUP – Demonstrating Autonomous Control, Remote Operation, and Human Factors for Microreactors..... Stylianos Chatzidakis
- NEUP – Deciphering Irradiation Effects of YH_x through In-situ Evaluation and Micromechanics for Microreactor Applications..... Eric Lang (UNM)
- NEUP – Transforming Microreactor Economics Through Hydride Moderator Enabled Neutron Economy..... Jason Trelewicz (Stonybrook)

Four control areas are currently supported

- High Temperature Moderator Material (carryover)
 - INL (Chase Taylor)
 - LANL (Adi Shivprasad)
 - ANL (Latif Yacout)
- Instrumentation and Sensors
 - ORNL (Chris Petrie)
 - INL (Troy Unruh)
 - LANL (Paul Geimer)
- Heat Transfer
 - LANL (Katrina Sweetland)
- Structural Material (carryover)
 - INL (Sam Sham/Tate Patterson)
 - LANL (John Carpenter)

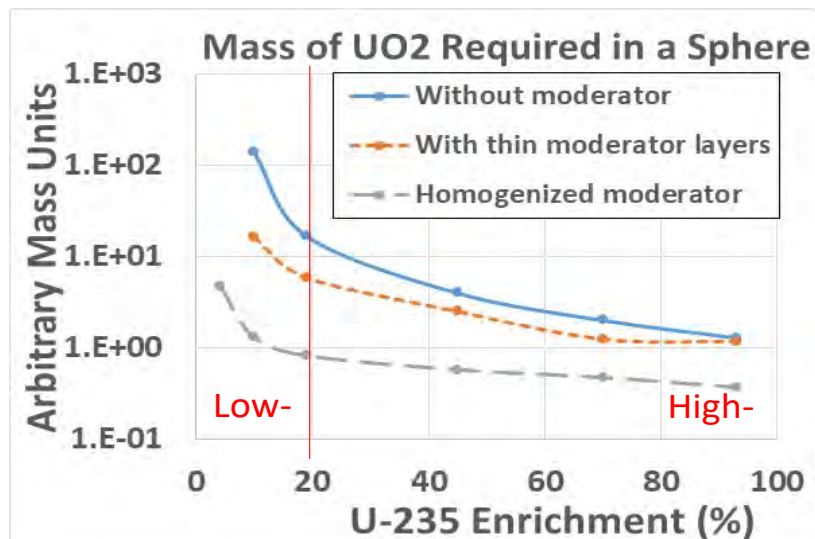


How Technology Maturation Meets Program Objectives

- Through cross-cutting research and development and technology demonstration support, achieve technological breakthroughs for key features of microreactors, examine:
 - Moderation to reduce required fuel mass
 - Instrumentation and sensors
 - Advanced heat transfer
- Meet critical R&D needs of existing developers that require national lab or university expertise or capabilities.
 - Develop and irradiate samples of moderating material
 - Build and test non-nuclear test articles
- Develop advanced technologies and concepts for next-generation microreactor applications and systems.
 - Design and fabricate state-of-the-art technology.
 - Understand performance of systems with instruments.
- Enable future microreactor applications
 - Coupling of the above components.

High Temperature Moderator Material

- Presence of moderator significantly decreases overall mass of fuel required in a microreactor by thermalizing neutrons and increasing probability of fission.
- Investigate materials performance, fabrication, and testing of moderators. FY24 work involves:
 - updating the advanced moderator material handbook with post irradiation examination data (LANL w/INL and ORNL support)
 - examining cladding and coating to contain the hydrogen over time and increasing temperature during microreactor operation (ANL w/INL support).



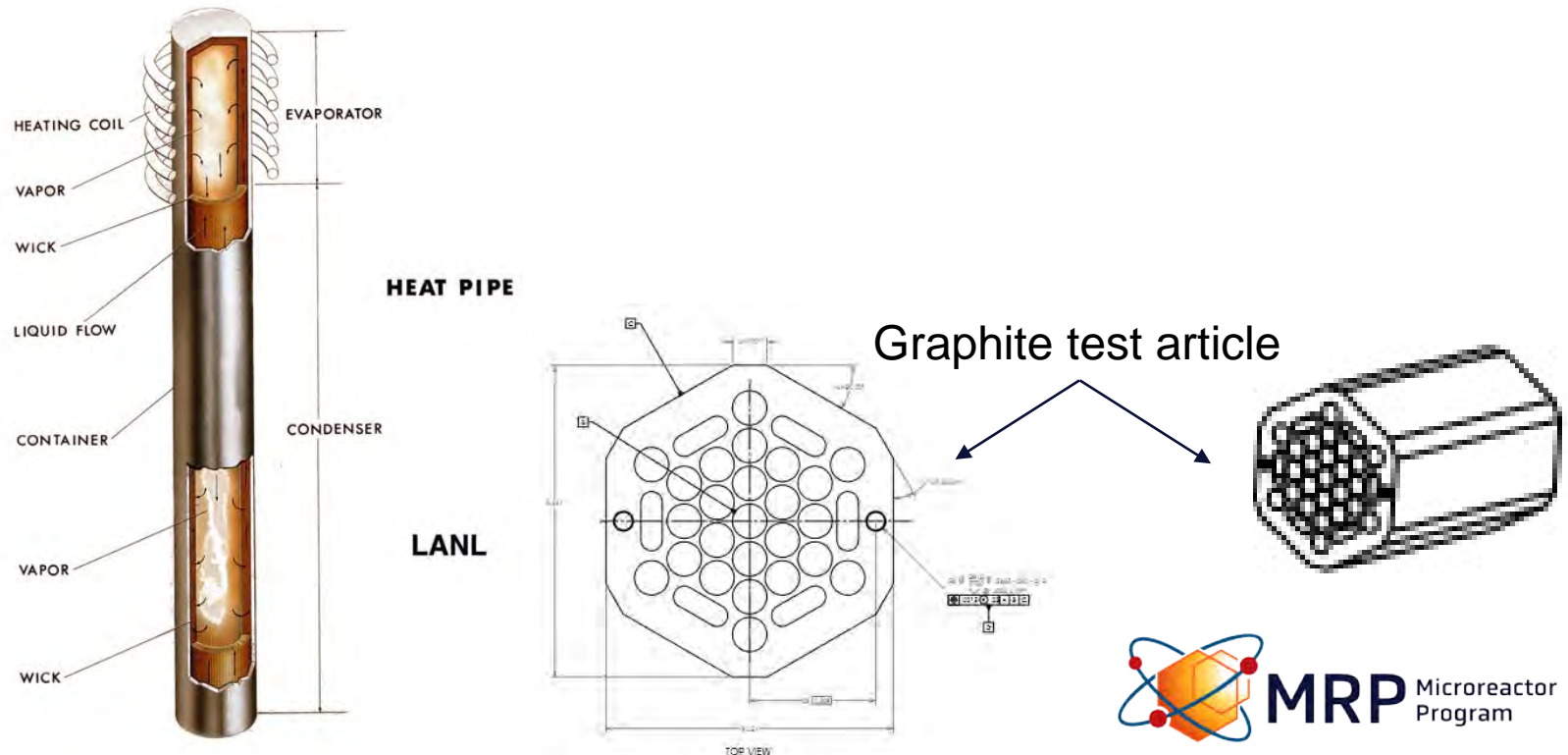
Instrumentation and Sensors

- Hardware and software is being developed as part of the microreactor automated control system (MACS) in conjunction with the MARVEL microreactor (INL).
- Ultimate goal: hardware-in-the-loop performance demo with software to move control drums with reactivity feedback of the system (ORNL).
- Development and testing of fiber optic sensors for determining temperatures, stress/strain, and acoustic measurements in a microreactor structural material (ORNL).
- Additional acoustic sensing techniques for detecting flaws in a solid structure of a core are being researched (LANL) :
 - Resonant ultrasound spectroscopy (RUS)
 - EGF (empirical Green function)
 - Digital Image Correlation (DIC).



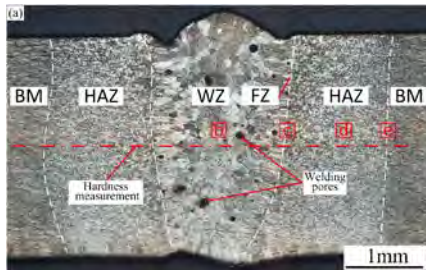
Heat Transfer: focus is heat pipes w/lower TRL than gas coolant

- Gas coolant or heat pipes can be used to remove heat from a microreactor and transfer thermal energy to a power conversion unit for electricity production.
- Both a graphite test article and single individual heat pipes are being fabricated.
 - Use of molybdenum tubes and sodium working fluid will produce high fidelity heat pipes.
 - Graphite article has ~13 heat pipes and other holes for heaters and maybe hydride moderator material, to be eventually tested at MAGNET.
- Report on horizontal and vertical heat pipe testing was produced at end of FY23.



Structural Material

- Materials are needed within microreactor core itself either as a core block, vessel, or surrounding structure
 - Ceramic moderating materials such as graphite can thermalize neutron energy spectrum and utilize high assay low enriched uranium (HALEU) while holding core together effectively.
 - Stainless steel is traditional material in a reactor core; new techniques such as powder metallurgy hot isostatic pressing (PM-HIP) can produce metallic components (INL).
- Refractory Metals
 - Scoping study in progress: examine Nb1Zr and/or molybdenum alloys such as Titanium-Zirconium-Molybdenum (TZM) for application as a core block (particularly in a faster neutron energy spectrum microreactor) and/or structural material in a system.
 - R&D for additive manufacture of TZM is underway (LANL).



Future Work and Conclusions

- The goal of Technology Maturation is to increase our knowledge about technology that could be used for microreactors through research and development and experimental testing.
- Details of particular microreactor designs are not explored, but skills and techniques gained will be passed on to industrial partners for their benefit in building systems.
- All control areas will expand with more potential work, and collaborations with partners (industry, university, other DOE programs) will continue.
- Feel free to contact me or other work package managers with ideas or questions: trellue@lanl.gov.