Technology Maturation for Microreactor Program Review

Holly Trellue,

Technical Area Lead

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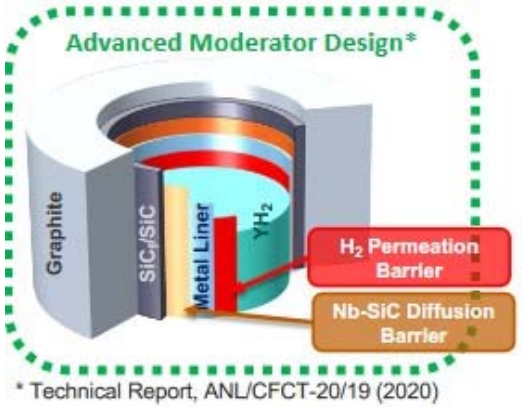
Outline

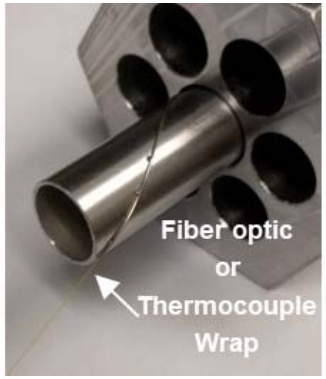
- Overview
- High Temperature Moderator Material
  - Hydrogen Permeation/Distribution……Adi Shivprasad (LANL)
  - Post Irradiation Examination of Yttrium Hydride (YH_x) …..…….Nedim Cinbiz (INL)
  - Coatings and Cladding for YH_x……..……....Sumit Bhattacharya (ANL)
- Instrumentation and Sensors
  - MACS/Acoustics……..…….…….....Chris Petrie (ORNL)
  - Acoustic Measurements……TJ Ulrich (LANL)
- Heat Transfer/37 Heat Pipe Test Article……..……Bob Reid (LANL)
- NEUP – Structural Integrity……Scott Thompson (KSU)
- Structural Material
  - PM-HIP code case ……..……..……..Tate Patterson (INL)
  - Additive Manufactured Molybdenum……..…John Carpenter (LANL)
- NEUP – Heat Pipe Failures……..……Victor Petrov (UMICH)
- NEUP – Heat Exchanger Technology……..…….….. Greg Nellis/Curtis Foster (WISC)
- NEUP – Hydrogen Transport in Moderator …….. Jeff King (CSU)
- Future Work/Wrap-Up

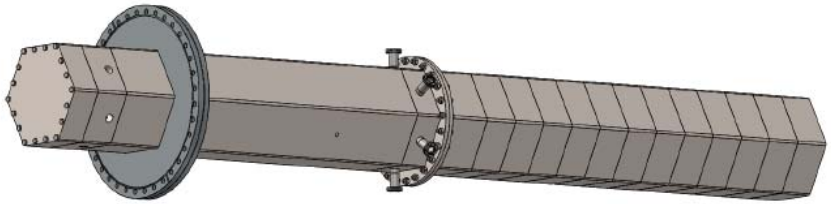
MRP Microreactor Program

Five control areas are currently supported

- High Temperature Moderator Material
  - INL (Chase Taylor)
  - LANL (Adi Shivprasad)
  - ANL (Latif Yacout)
- Instrumentation and Sensors
  - ORNL (Chris Petrie)
  - INL (Troy Unruh)
  - LANL (TJ Ulrich)
- Heat Transfer
  - LANL (Bob Reid)
- Structural Material
  - INL (Sam Sham/Tate Patterson)
  - LANL (John Carpenter)
- Fuels Scoping
  - LANL (Scarlett Widgeon Paisner)
  - INL (Nicolas Woolstenhulme)
  - ANL (Latif Yacout)







MRP Microreactor Program

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 and developing results for validating predictive performance

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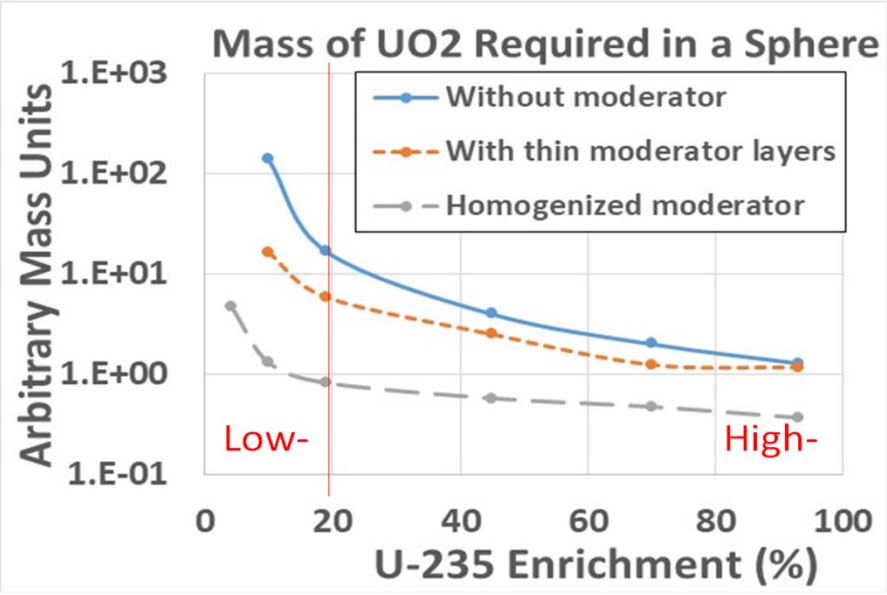
High Temperature Moderator Material

- 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. FY23 work involves:
  - Post irradiation examination of yttrium hydride material irradiated in the Advanced Test Reactor in FY21 (INL)
  - Updating the advanced moderator material handbook plus permeation and diffusion tests (LANL)
  - Examining cladding and coating to contain the hydrogen over time and increasing temperature during microreactor operation (ANL).



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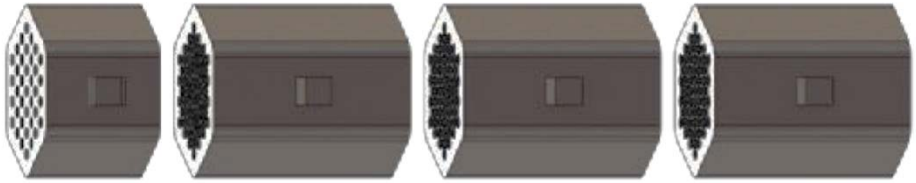
Instrumentation and Sensors

- Hardware and software is being developed as part of the microreactor automated control system (MACS) in conjunction with the MARVEL microreactor (INL).

Courtesy of Anthony Crawford, 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)
  - Empirical Green Function (EGF)
  - Digital Image Correlation (DIC).



Picture courtesy of Paul Geimer, LANL

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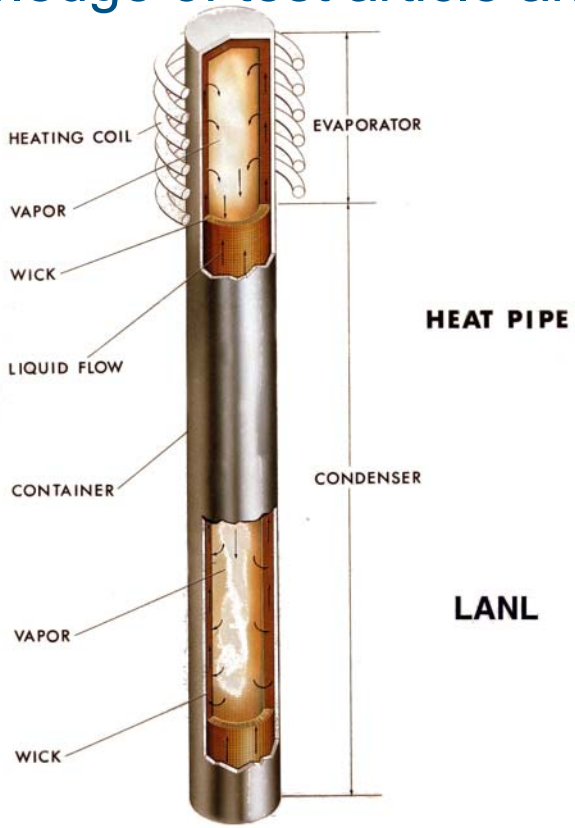
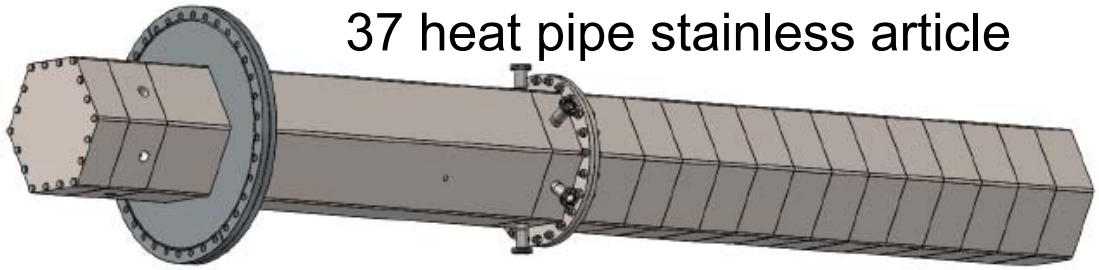
Heat Transfer: focus is heat pipes w/lower TRL than gas coolant

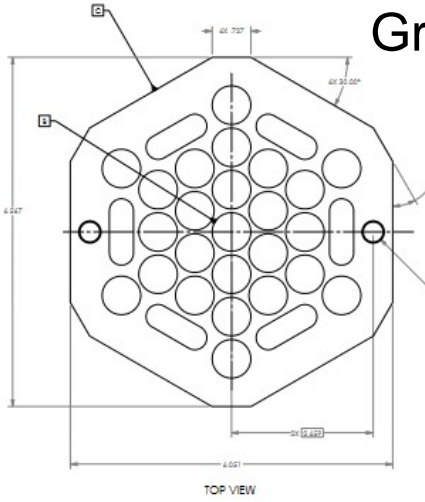
- Both a 37 heat pipe stainless steel test and a graphite test article are being fabricated.
  - 37 heat pipe test article is 2 m long: 1/2 with heaters and heat pipes filled with sodium and other 1/2 with heat pipes and a heat exchanger to produce thermal energy at nonnuclear MAGNET facility.
  - Graphite article has ~13 heat pipes and other holes for heaters and maybe hydride moderator material, to be eventually tested at MAGNET.
- Horizontal and vertical heat pipe tests are also underway, then transfer of knowledge of test article and heat pipe operation to industry.

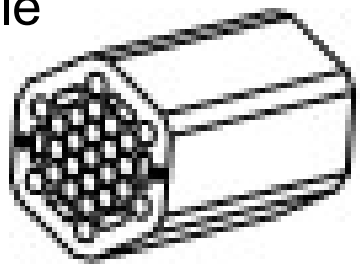


37 heat pipe stainless article



Graphite test article





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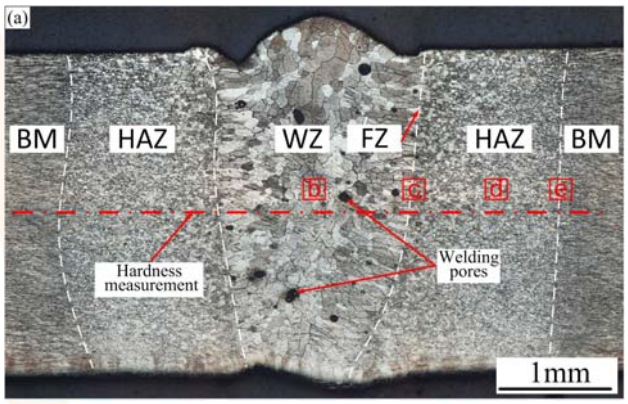
Structural Material

- 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).



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Technology Maturation Wrap-Up

Holly Trellue,

Technical Area Lead

Fuels Scoping Study

- Goal: Determine if appropriate R&D programs are in place for Microreactor fuels being proposed or if gaps exist
- Examples of features to be examined in fuels:
  - High fissile density,
  - Reliability,
  - Tolerate power/thermal cycles,
  - Withstand accident scenarios,
  - Economic to fabricate,
  - Fabrication development and performance testing.

Fuel types within study	Microreactor fuels being considered
TRISO particle fuel (LANL)	TRi-structural ISOtropic (TRISO)
Molten salt fuels (INL)	LEU w/ salt
UN (ANL)	UF_4
MOX fuels (ANL)	UZrH
UO_2–based fuels (LANL)	UO_2
Metallic fuels (INL)	Metallic

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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 five control areas will expand with more potential work, and collaborations will continue.
- Feel free to contact me or other work package managers with ideas or questions: trellue@lanl.gov.

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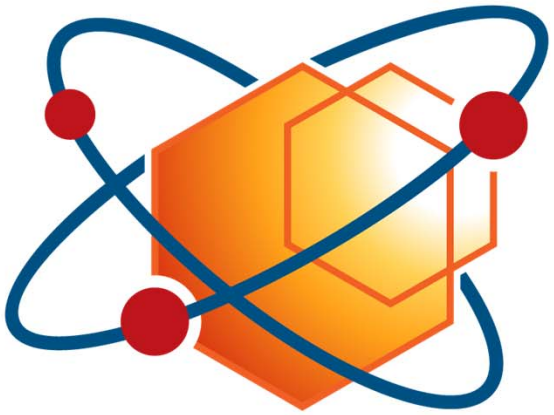

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