High temperature moderator material

March 3, 2022

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Objective

- 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. FY22 work involved yttrium hydride (YH_x).
- High temperature moderator work in FY22 focused on two main technical activities:
  - Post irradiation examination of YH_x irradiated in the Advanced Test Reactor (ATR).
  - Neutron imaging measurements at the Los Alamos Neutron Science Center (LANSCE) to determine hydrogen diffusion with temperature.

Yttrium hydride microreactor moderators

March 3, 2022

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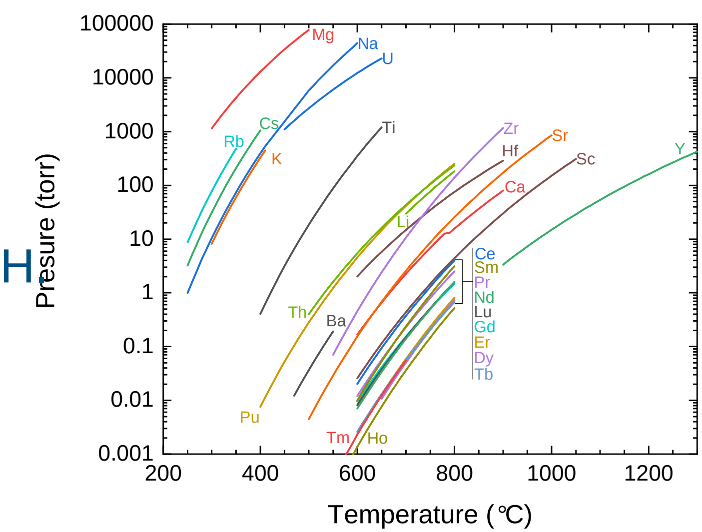
Introduction

- Advanced neutron moderators are required for microreactors due to the:
  - Lower fuel enrichment of HALEU (<20%) instead of high enriched uranium.
  - Compact size.
  - High efficiency/high temperature requirements.
- Hydrogen is the best moderator as it has a low Z number.
  - Metal hydrides have exceptionally high hydrogen density.
  - Yttrium hydride YH has the highest temperature stability of metal hydrides.
- Legacy experiments proved that YH can be an extremely effective moderator, but no quantitative post-irradiation data exists for YH.

Hydride	Attainable hydrogen density	
	10^{22}atoms H/cm^3	g H/cm^3
TiH_2	9.1	0.152
ZrH_2	7.3	0.122
LiH	5.8	0.095
YH_2	5.8	0.097
ThH_2	4.9	0.082
H_2O	6.6	0.110
$ThZr_2H_7$	7.7	0.129
$ThTi_2H_6$	8.8	0.147



Objective

- Obtain the properties of irradiated YH.

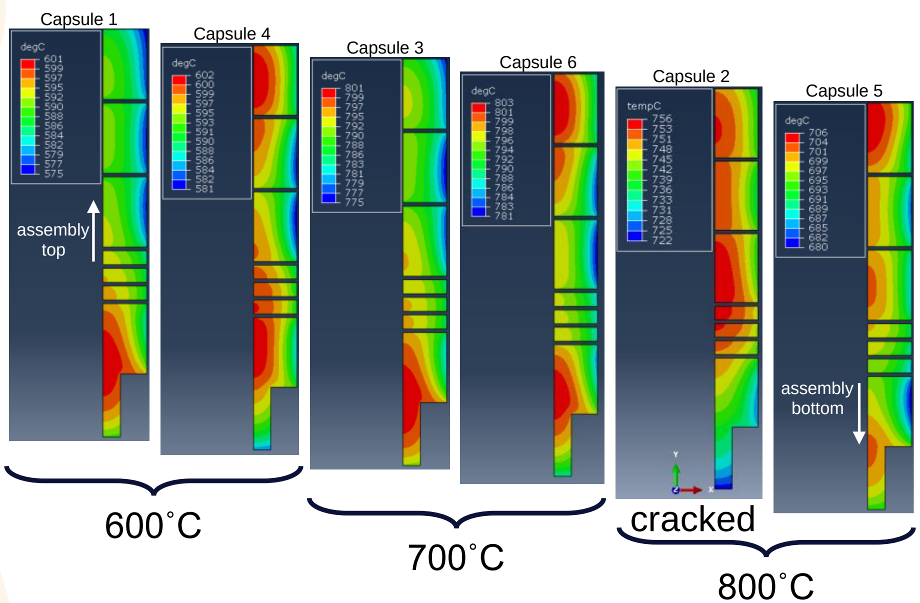
X. Hu et al., Journal of Nuclear Materials 539 (2020) 152335
C.N. Taylor, Journal of Nuclear Materials 558 (2022) 153396

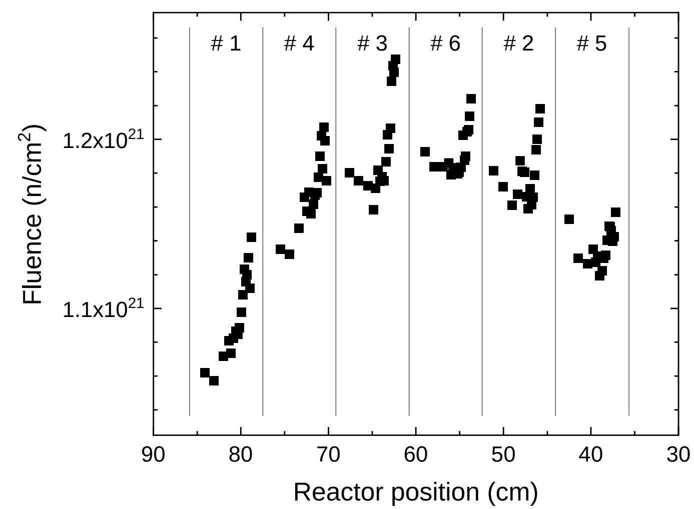
MRP Microreactor Program

Summary of project progress

(…since February 2021)

- February 19, 2021 – Advanced Test Reactor (ATR) irradiation of yttrium hydride samples commenced
- April 19, 2021 – ATR irradiation completed.





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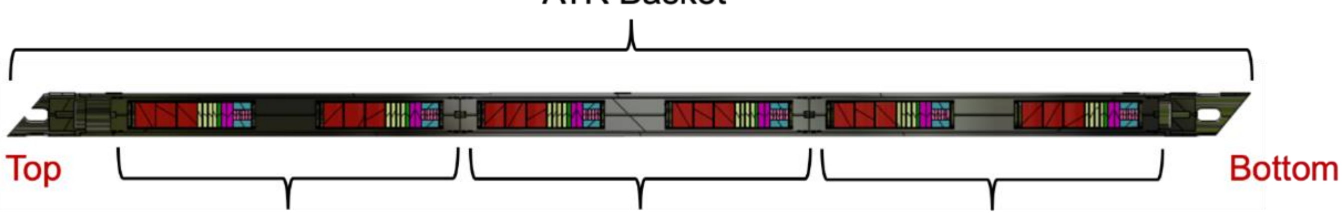

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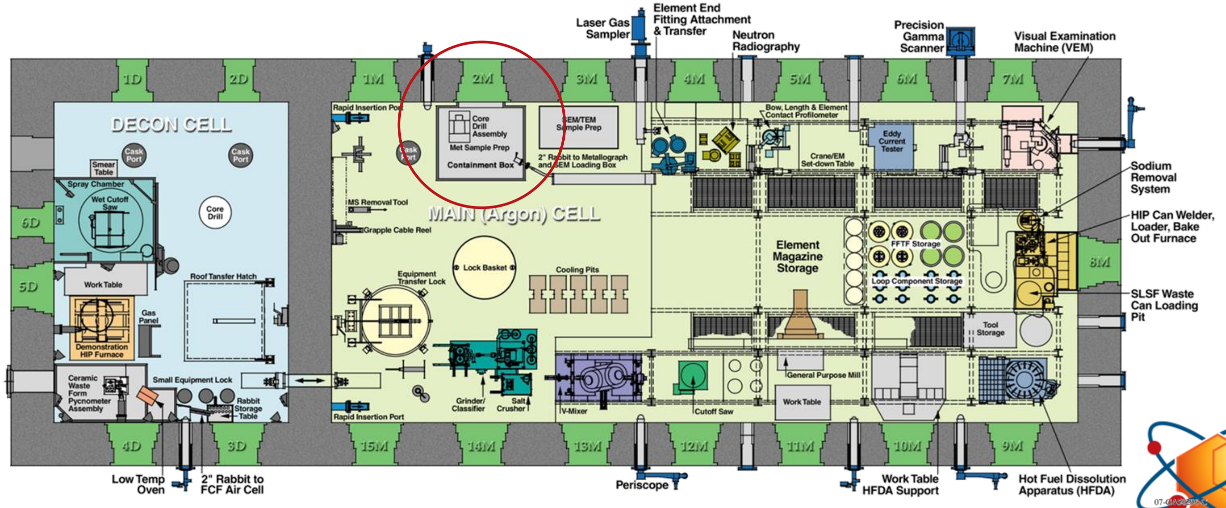

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- October 6, 2021 – Irradiation assembly disassembled.
- November 8, 2021 – First batch of samples (19) transferred from HFEF to the Analytical Research Laboratory for extended PIE.
- January 31, 2022 – Moving the samples from the contaminated KGTs to the clean KGTs.
- February 16, 2022 – Gamma spectroscopy results on radioactive constituents.

MRP Microreactor Program

Milestones

- M3 (11/30/2021): Transfer LANL capsules from HFEF to analytical laboratory
  - Complete
- M4 (2/28/2021): Disassembly of the LANL capsules
  - Complete
- M2 (8/30/2022): Complete at least half of post irradiation examination activities for YH irradiated in ATR.
  - Higher than expected radiation and contamination levels are introducing significant delays.
  - Path forward to completion identified.

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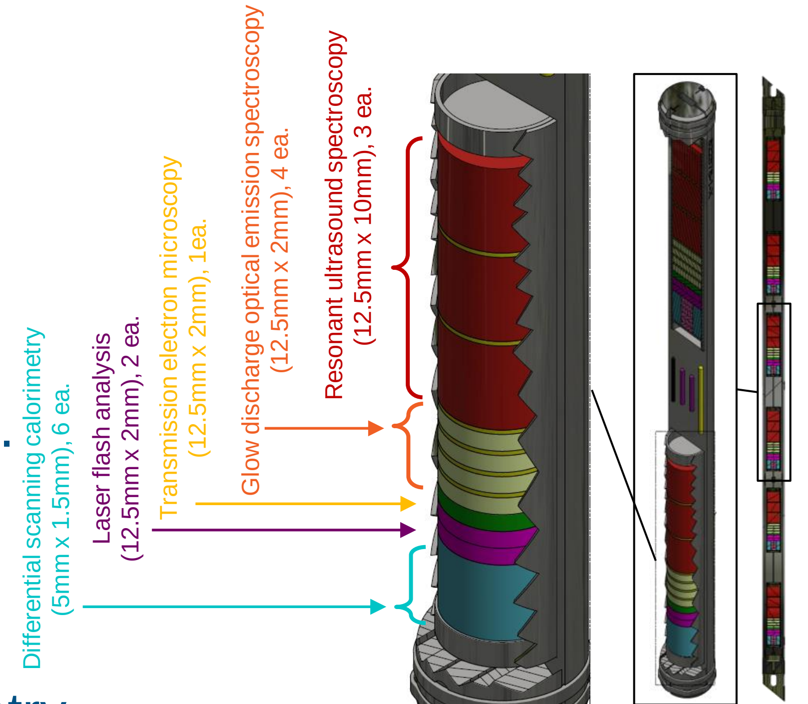
Future work

- Continue PIE activities
  - Non-destructive examination:
    - Optical
    - Dimensional
    - Volumetric
    - Mass characterization.
    - Fluence wire characterization.
  - Begin thermal characterization:
    - Hydrogen analysis
    - Thermal diffusivity
    - Differential scanning calorimetry



- FY23 PIE will include:
  - SEM, TEM, nanoindentaion, XRD, elastic properties, GD-OES.
  - Continue thermal characterization (including thermal expansion).
  - PIE on TZM foils.

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