INL/MIS-21-62920-Revision-0



I-Loop Briefing for Fuel Vendors

June 2023

Nate Oldham, Kendell R Horman

Changing the World's Energy Future

INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance, LLC

DISCLAIMER

This information was prepared as an account of work sponsored by an agency of the U.S. Government. Neither the U.S. Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness, of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. References herein to any specific commercial product, process, or service by trade name, trade mark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the U.S. Government or any agency thereof.

I-Loop Briefing for Fuel Vendors

Nate Oldham, Kendell R Horman

June 2023

Idaho National Laboratory Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the U.S. Department of Energy Under DOE Idaho Operations Office Contract DE-AC07-05ID14517

2023 June 06 Brian Durtschi Nate Oldham Michael Worrall

I-Loop Update for Fuel Vendor Update



Table of Contents

- I-Loop Tube Design
 - Total kW power
 - Features
- X-Core Equipment
 - Primary System
 - Makeup System
 - Chemistry
 - Purification System
 - Failed Fuel
- Schedule for I-Loop Deployment

- PCI Ramp Test Design
 - He-3 Mechanical
 - He-3 Neutronics
 - Proposed Ramps
- BWR Testing
 - Mechanical Design
 - Neutronics
 - Enrichment Sweep

June 6, 2023

Nate Oldham

I-Loop Tube



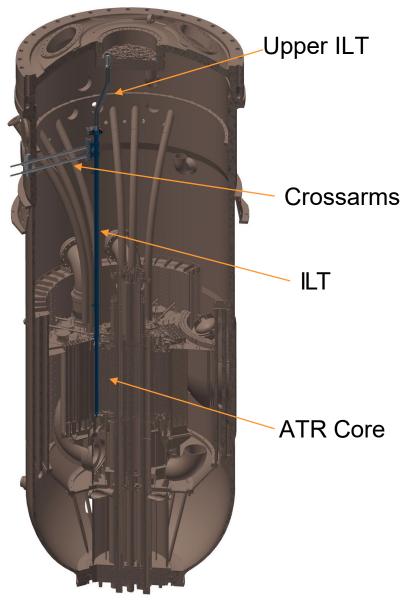
I-Loop Tube (ILT) Overview

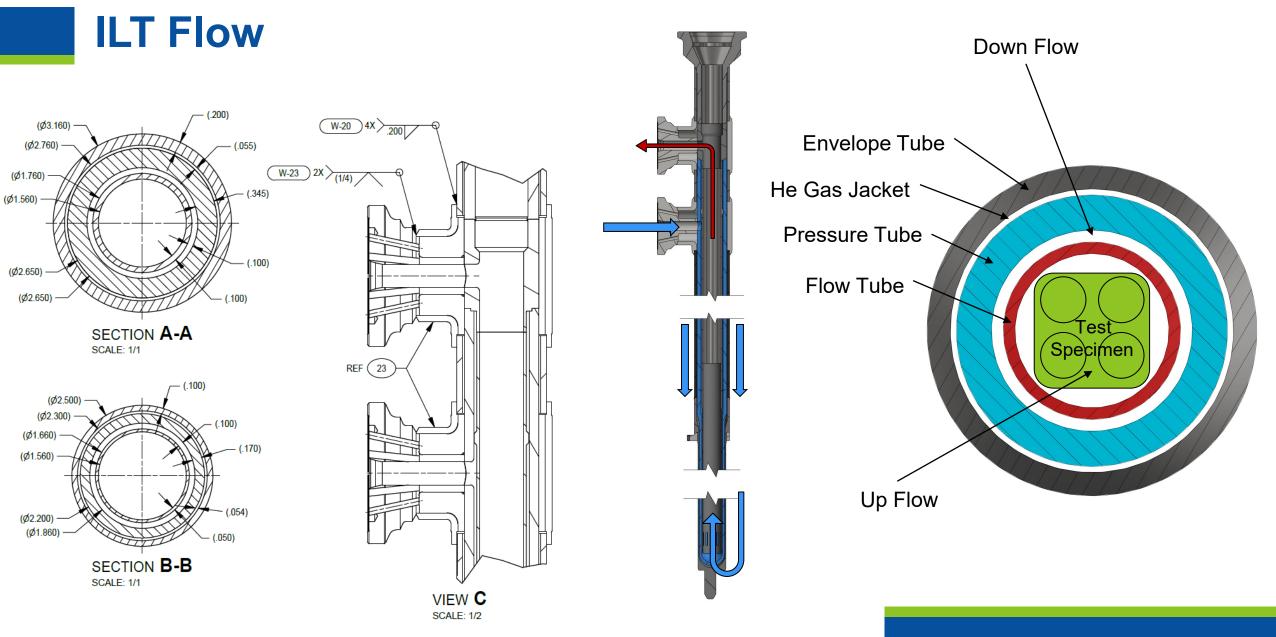
Quantity

- One BWR, capable of single pin or 2x2 array
- One PWR, capable of single pin or 2x2 array

• Functions

- Experiment housing
- Pressure boundary that separates the experiment fluid from ATR primary coolant
- Includes plumbing connections for experiment coolant
- Allows for experiment insertion/extraction from the reactor top via a shielded cask
- Designed for a maximum lobe power of 70 MW (ATR current maximum 50 MW)
- Designed for a maximum experiment nuclear heat of 100 kW
- Features
 - The ILT has 3 sections: ILT, Upper ILT, and the ILT crossarms
 - Cooling flow enters & exits through the crossarms
 - Approximately 8-inch offset from reactor closure penetration to the medium I-position (unique design fea
 - The in-core portion of the ILT is made from Zr-2.5%Nb for strength and neutron transparency





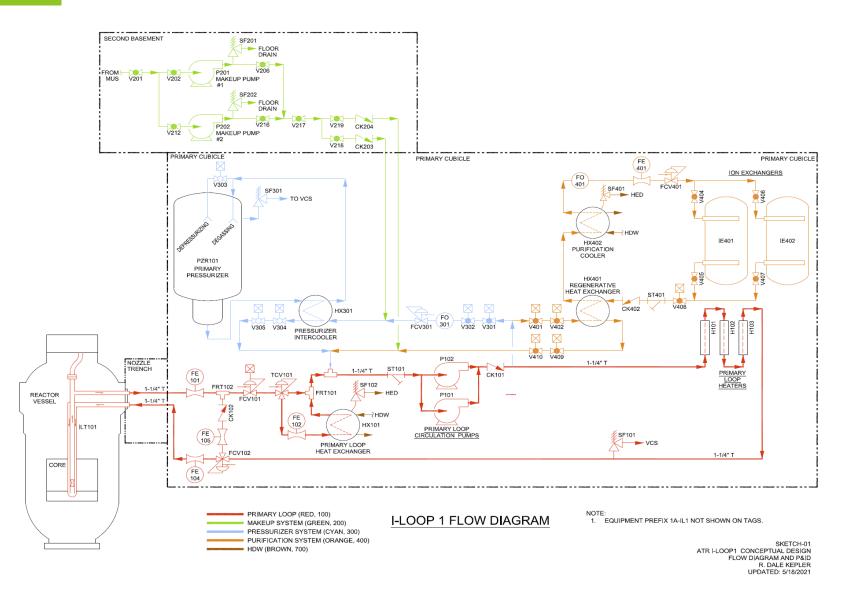
June 6, 2023

Nate Oldham

X-Core Equipment



I-Loop Flow Diagram



• Primary loop (in red)

- Operation of loop coolant at prototypic BWR conditions 250°C (482°F) to 288°C (550.4°F) 7.1 MPa (1,030 psig)
- Main equipment: circulation pumps, heat exchangers, control valves, heaters, etc.
- Makeup system (in green)
 - Chemistry addition
 - pH 5.6-8.6 @ 25°C (77°F)
 - excess Hydrogen inventory to control Oxygen
 - < 0.3 ppm Iron</p>
 - 10-20 ppb Zinc
 - <100 Chloride (ppb)</p>
 - <200 dissolved Oxygen (ppb)
- Purification system (in orange)
 - Cation/anion organic resin media
 - Capable of removing released materials from a failed fuel rod
- Pressurizer system (in cyan)

I-Loop Nozzle Trench

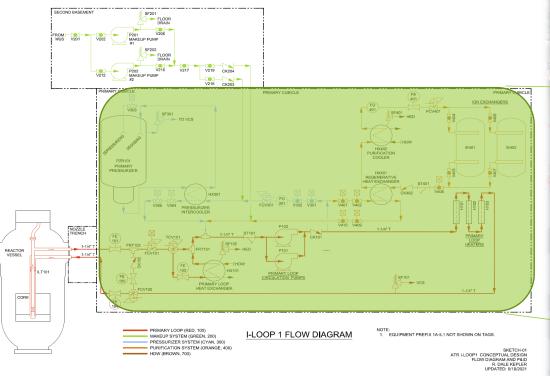
ECOND BASEMI V219 CK204 V218 CK203 TO VCS PZR10 PRIMARY PRESSURIZE REACTOR VESSEL PRIMARY LOOP CIRCULATION PUMP SF101 I-LOOP 1 FLOW DIAGRAM EQUIPMENT PREFIX 1A-IL1 NOT SHOWN ON TAGS. MAKEUP SYSTEM (GREEN, 200) PRESSURIZER SYSTEM (CYAN, 300) PURIFICATION SYSTEM (ORANGE, 400) SKETCH-01 ATR I-LOOP1 CONCEPTUAL DESIGN FLOW DIAGRAM AND P&ID R. DALE KEPLER UPDATED: 5/18/2021 HDW (BROWN, 700)

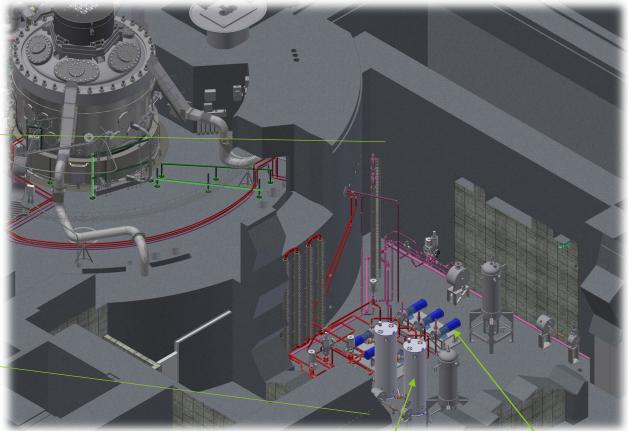
ATR Vessel Piping to Cubicle **Vessel connections** to I-Loop Tube

Nozzle Trench

1A Cubicle

I-Loop Primary Cubicle





- Shielded Wall Cubicle in ATR Basement
- BWR Loop
 - Red piping
- PWR Loop
 - Red piping

Ion Exchange Columns

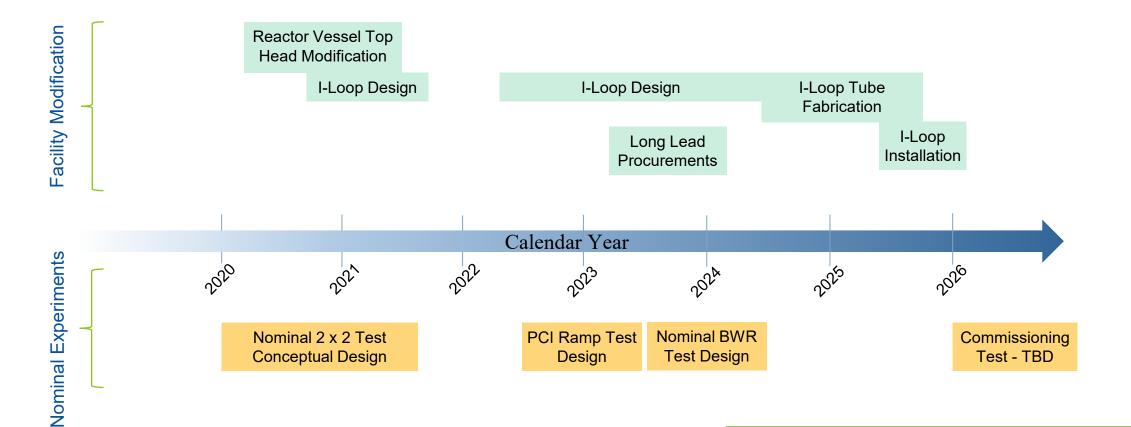
June 6, 2023

Nate Oldham

Schedule for I-Loop Deployment



I-Loop Project Schedule – for Two Loops



- Estimated completion date of March 2026
- Commissioning testing March 2026

June 6, 2023

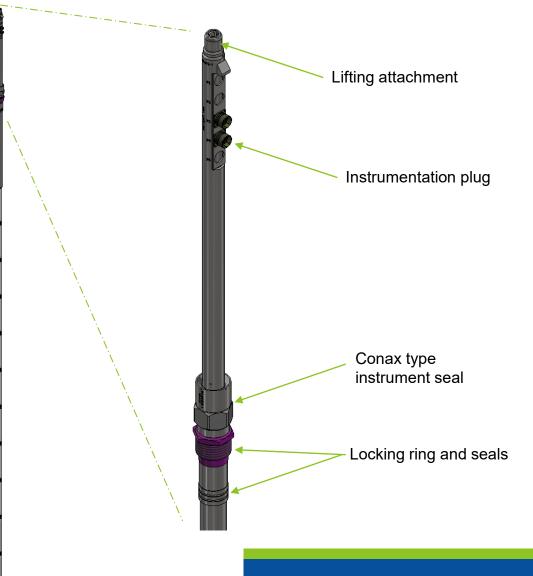
Nate Oldham and Michael Worrall

I-Loop PCI Ramp Test



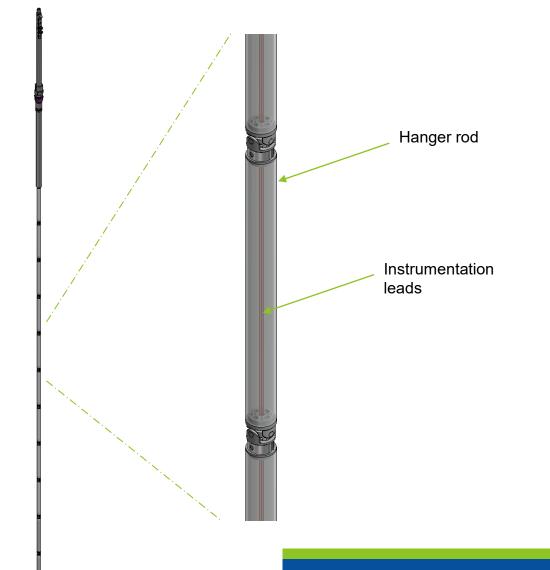
I-Loop Experiment Mechanical Design

- Experiment test train
 - Inserted into an I-Loop Tube
 - ~20 feet long
 - Lifting attachment
 - Instrumentation plug
 - Conax type instrument seal
 - Locking ring and seals to I-Loop Tube
 - Hanger rods housing leads
 - Fueled test sections



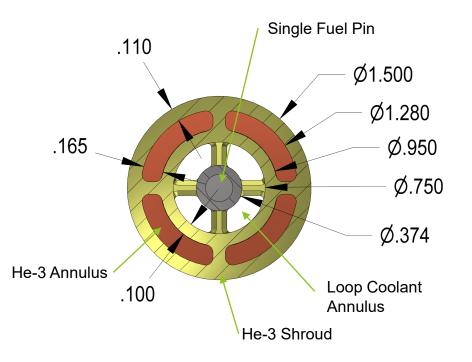
I-Loop Experiment Mechanical Design

- Experiment test train
 - ~20 feet long
 - Lifting attachment
 - Instrumentation plug
 - Conax type instrument seal
 - Locking ring and seals to I-Loop Tube
 - Hanger rods housing leads
 - Fueled test sections



I-Loop PCI Ramp Test Experiment Design

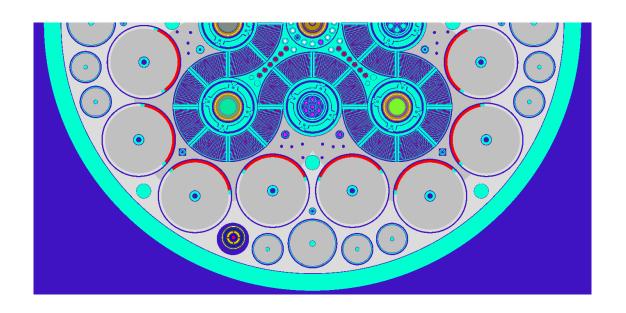
- Helium-3 Shroud
 - Wagon-wheel type annulus for Helium-3 neutron absorber
 - Pressurization from 0-1000 psig
 - LVDT for cladding elongation measurement



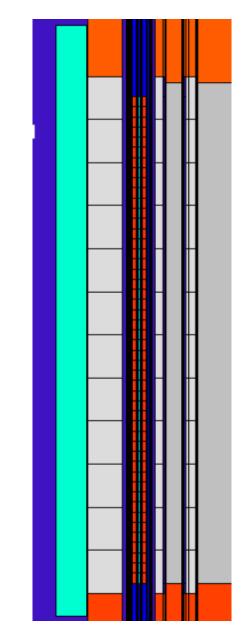


PCI Ramp Test – Neutronics Scoping

- Explicit 3D model using MC21 Monte Carlo code
- I-13 position in the ATR
- 1" axial segments from top to bottom of ATR core
- Fresh UO₂ fuel (4% enriched)

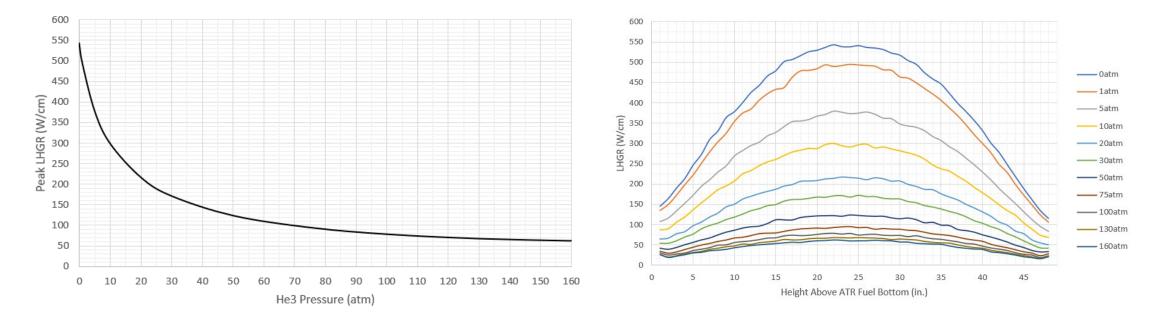




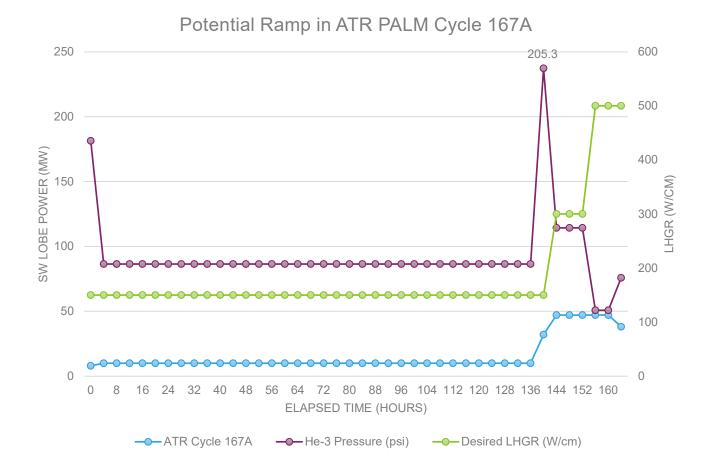


PCI Ramp Test – Neutronics Scoping

- Linear Heat Generation Rates (LHGRs) as a function of He-3 pressure
- Data scaled to 55 MW lobe power (ATR PALM cycle)
- Non-linear relation between He-3 pressure and LHGR will be challenging

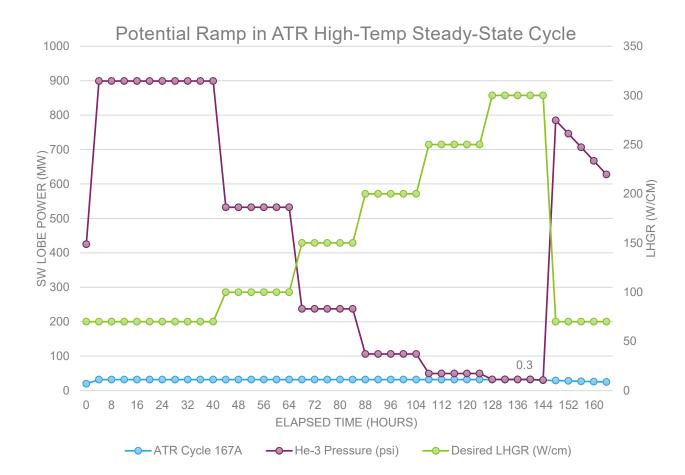


PCI Ramp Test – Proposed Ramp Cycle



- PALM Cycle
 - 7 day total cycle
 - ~5 day lobe power at 10 MW
 - ~2 day lobe power at 47 MW
- Fresh fuel, 4% enrichment
- ~550 W/cm max LHGR
 - Could be more with higher enrichment and/or booster element
 - Could be more with a higher PALM cycle

PCI Ramp Test – Proposed Ramp Cycle in ATR HTSS Cycle



- High Temperature Steady State Cycle (HTTS)
 - 32 MW (vs. 23 MW) lobe power
 - 40 day cycle (vs. 60 day)
- Fresh fuel, 4% enrichment
- ~300 W/cm max LHGR
 - Longer cycle than PALM cycle, but lower maximum LHGR
 - Could be more with higher enrichment and/or booster element

June 6, 2023

Brian Durtschi and Michael Worrall

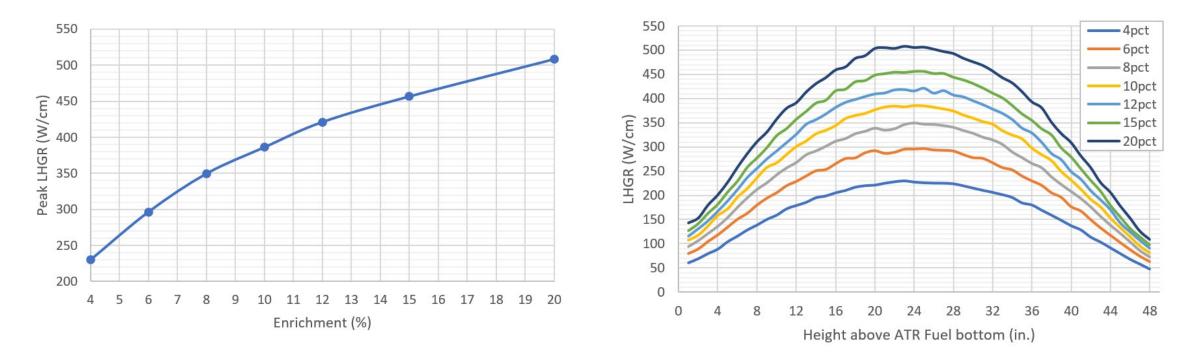
I-Loop BWR Experiment



I-Loop BWR – Mechanical Design (BRIAN)

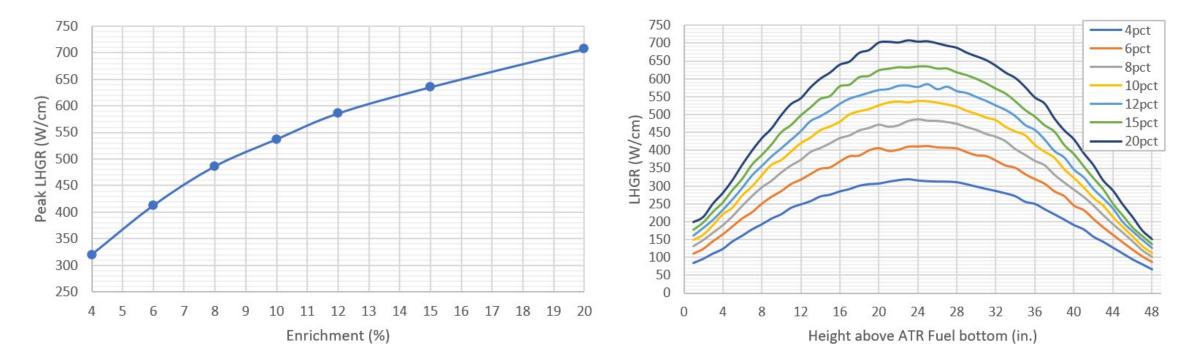
I-Loop BWR – Enrichment Sweep

- Single pin, same as ramp test geometry (no boiling)
- Uranium enrichments range from 4-20% U235
- Data scaled to 23 MW lobe power (Standard ATR Cycle)



I-Loop BWR – Enrichment Sweep

- Single pin, same as ramp test geometry (no boiling)
- Uranium enrichments range from 4-20% U235
- Data scaled to 32 MW lobe power (HTSS ATR Cycle, ~2027)



Idaho National Laboratory

WWW.INL.GOV