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I-Loop Briefing for Fuel Vendors

June 2023

Nate Oldham, Kendell R Horman

Changing the World's Energy Future

Idaho National Laboratory

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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Brian Durtschi

Nate Oldham

Michael Worrall

I-Loop Update for Fuel Vendor Update

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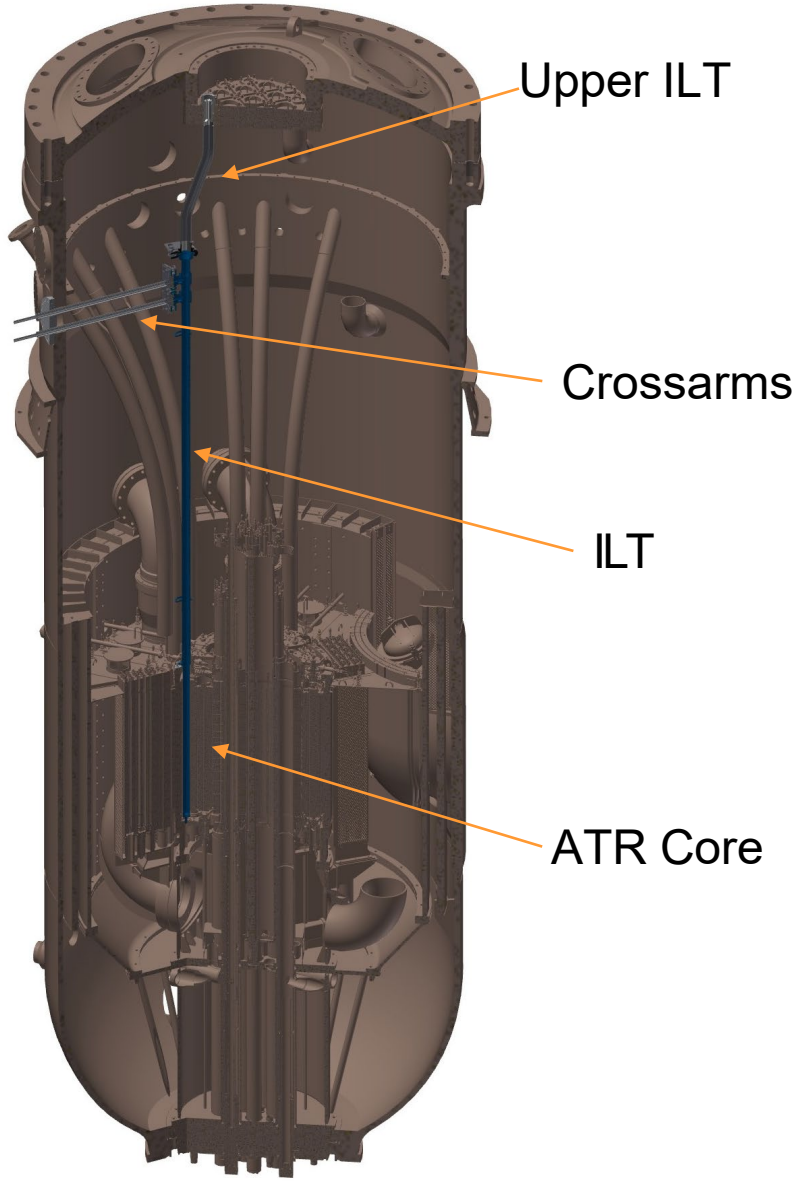
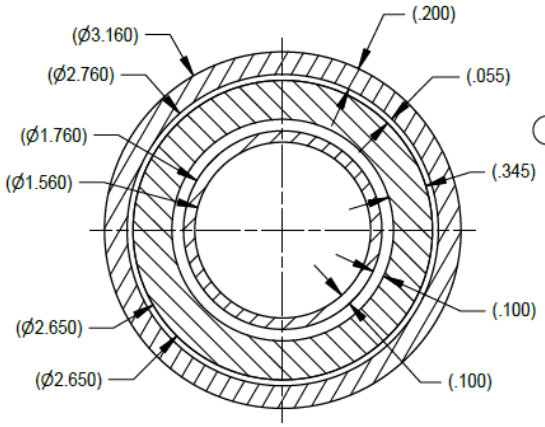
I-Loop Tube

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



ILT Flow



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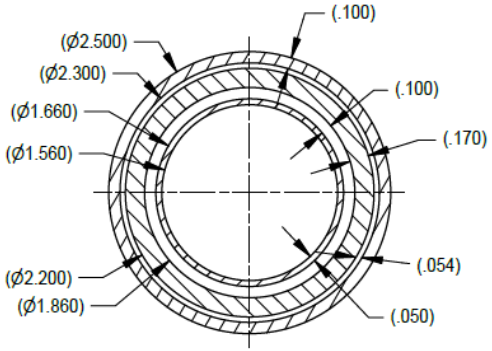

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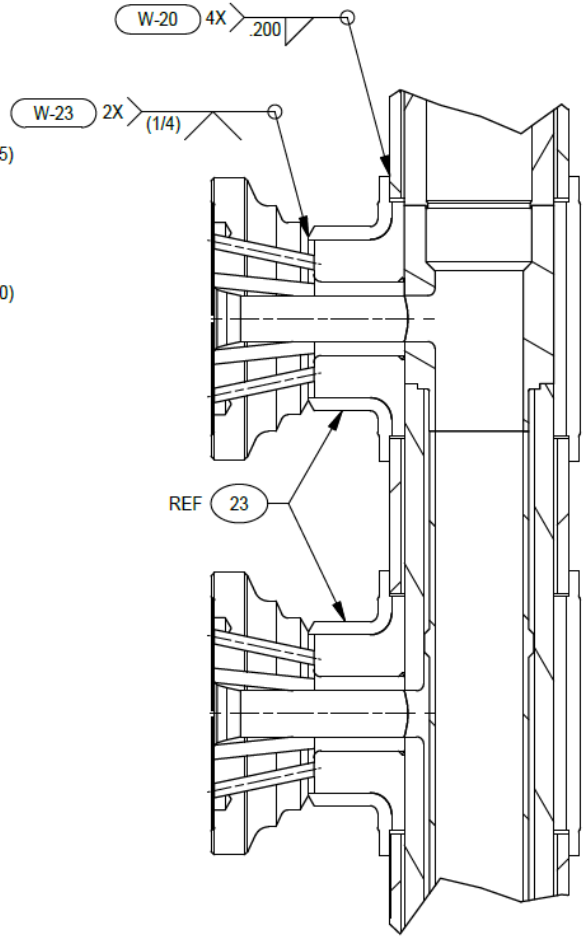
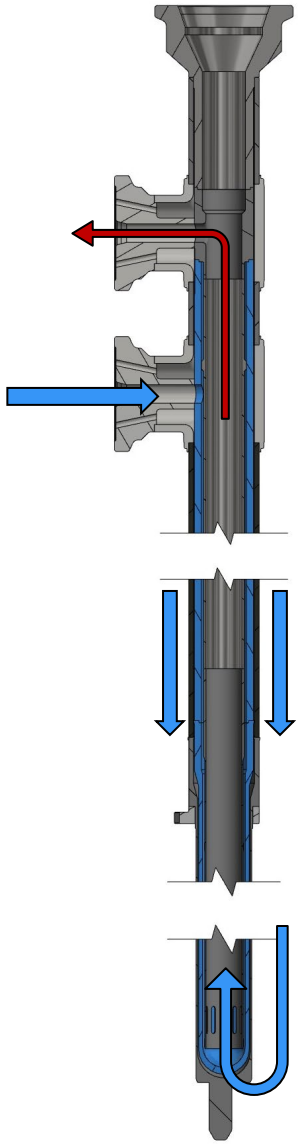
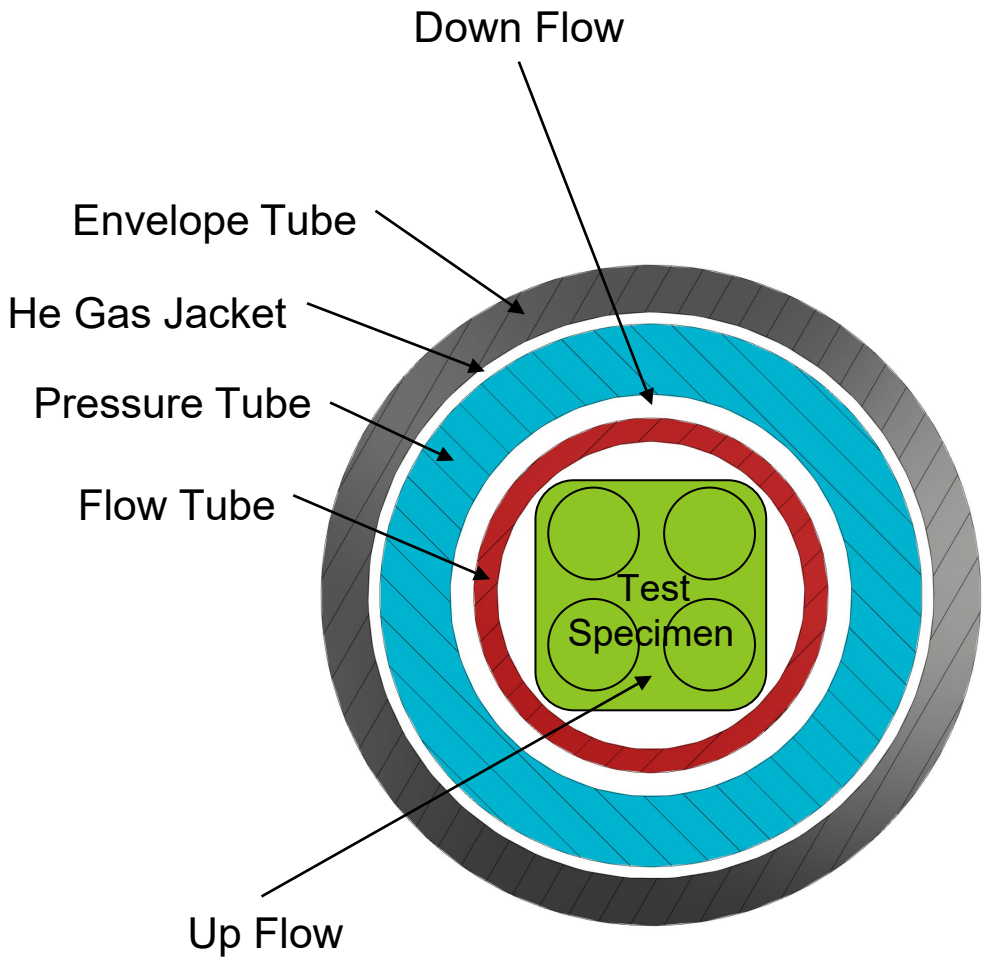


VIEW **C**
SCALE: 1/2





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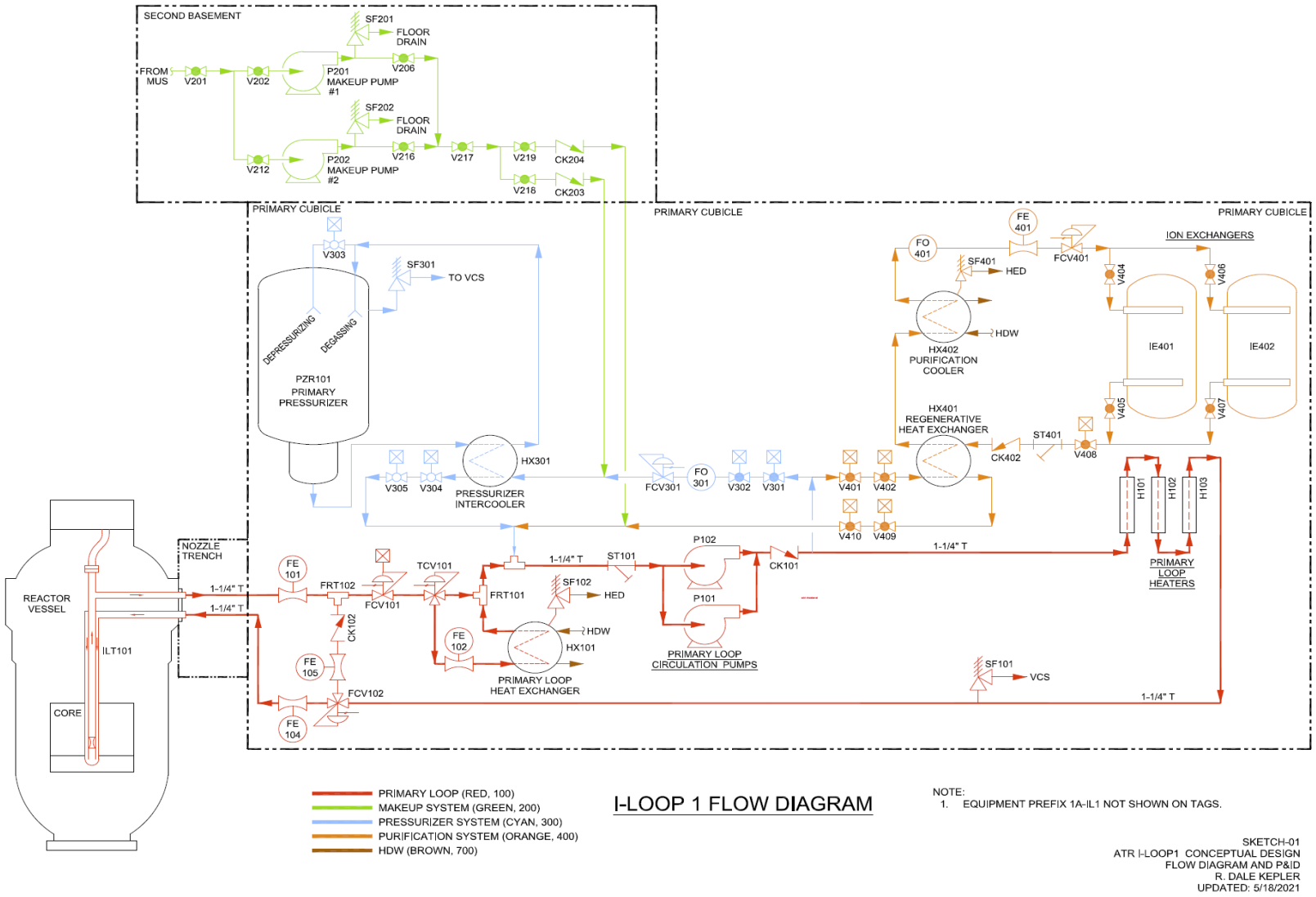
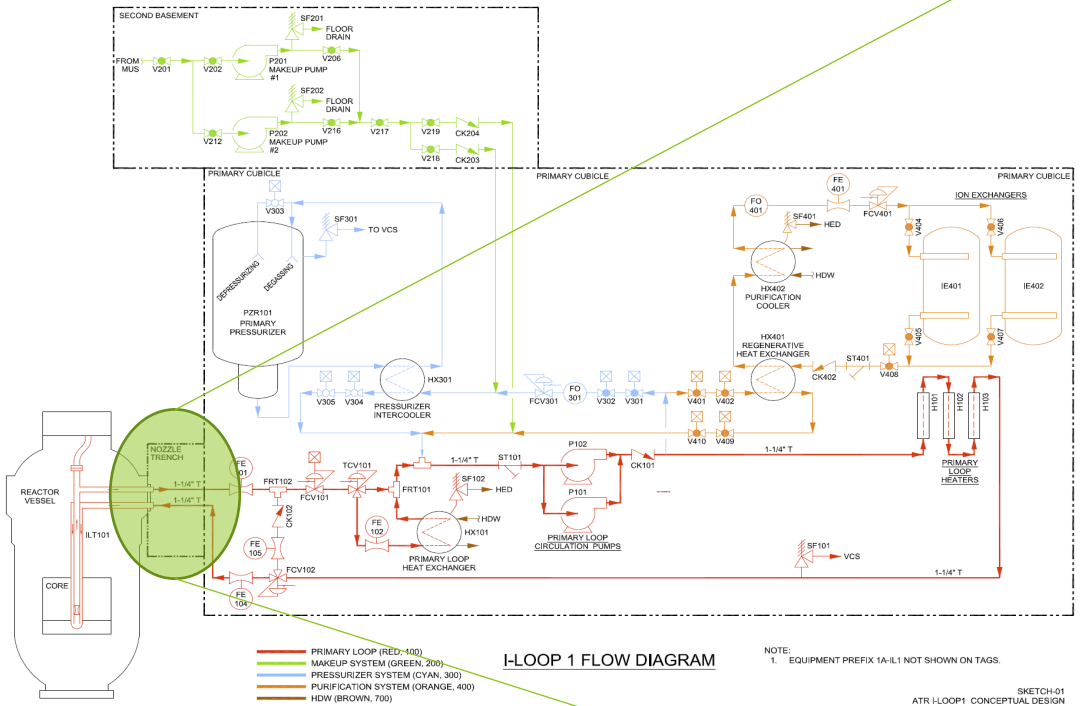
X-Core Equipment

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
    - 10-20 ppb Zinc
    - <100 Chloride (ppb)
    - <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

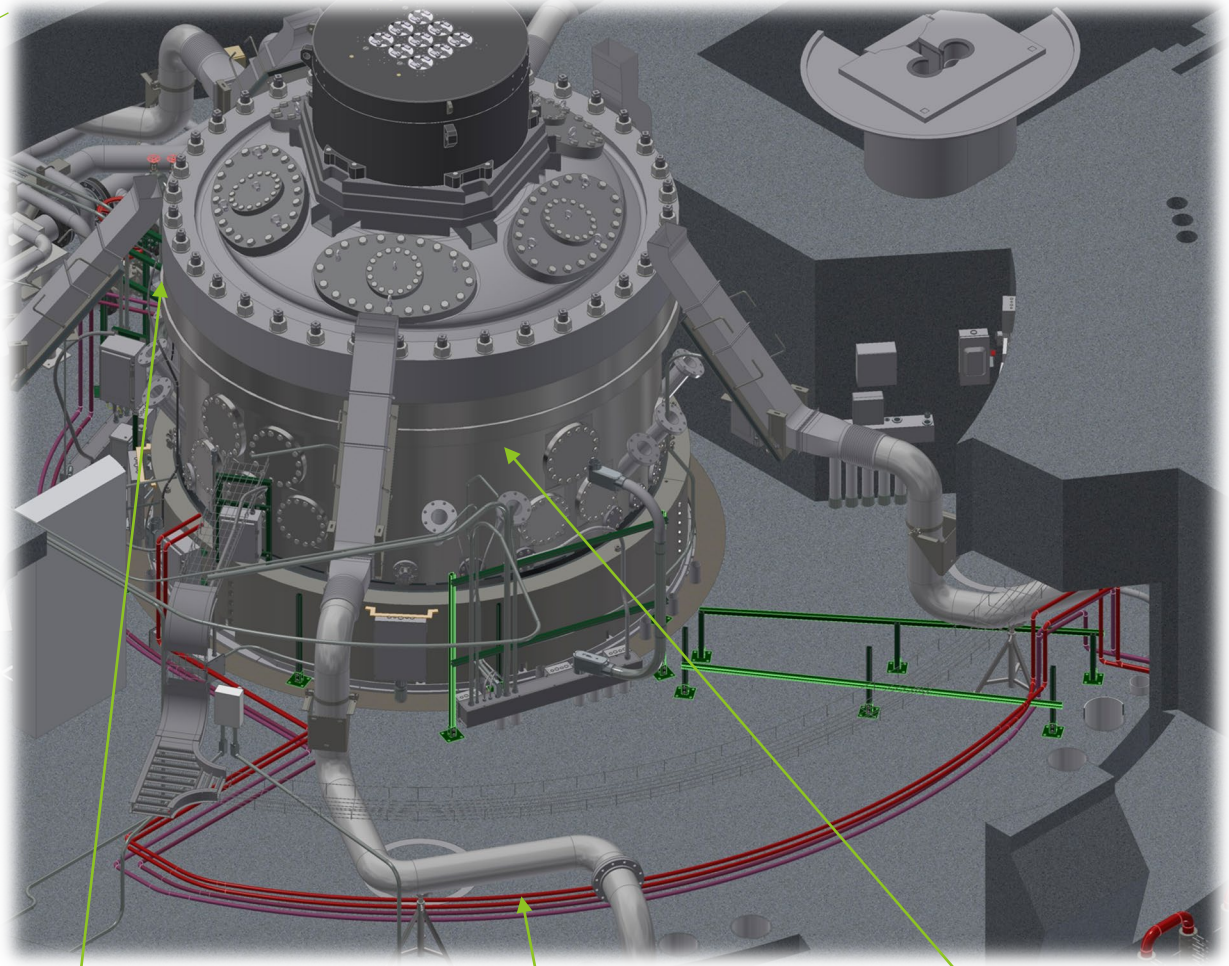


I-LOOP 1 FLOW DIAGRAM

NOTE:
1. EQUIPMENT PREFIX 1A-IL1 NOT SHOWN ON TAGS.

SKETCH-01
ATR I-LOOP1 CONCEPTUAL DESIGN
FLOW DIAGRAM AND P&ID
R. DALE KEPLER
UPDATED: 5/18/2021

Nozzle Trench

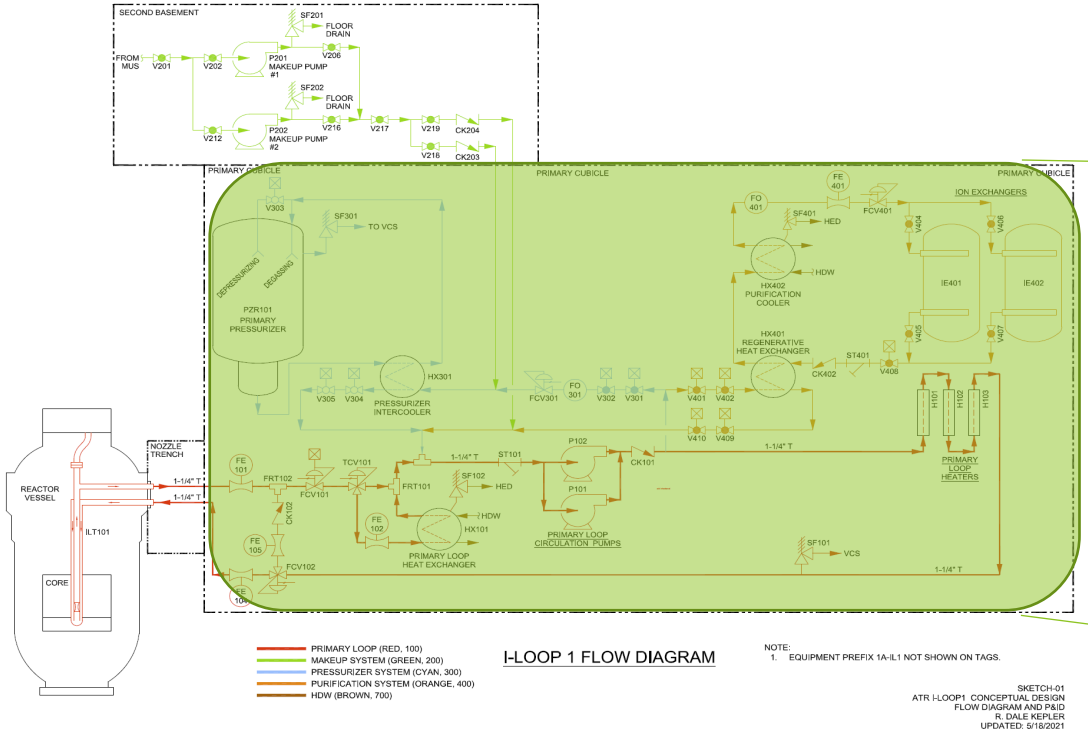


Vessel connections to I-Loop Tube

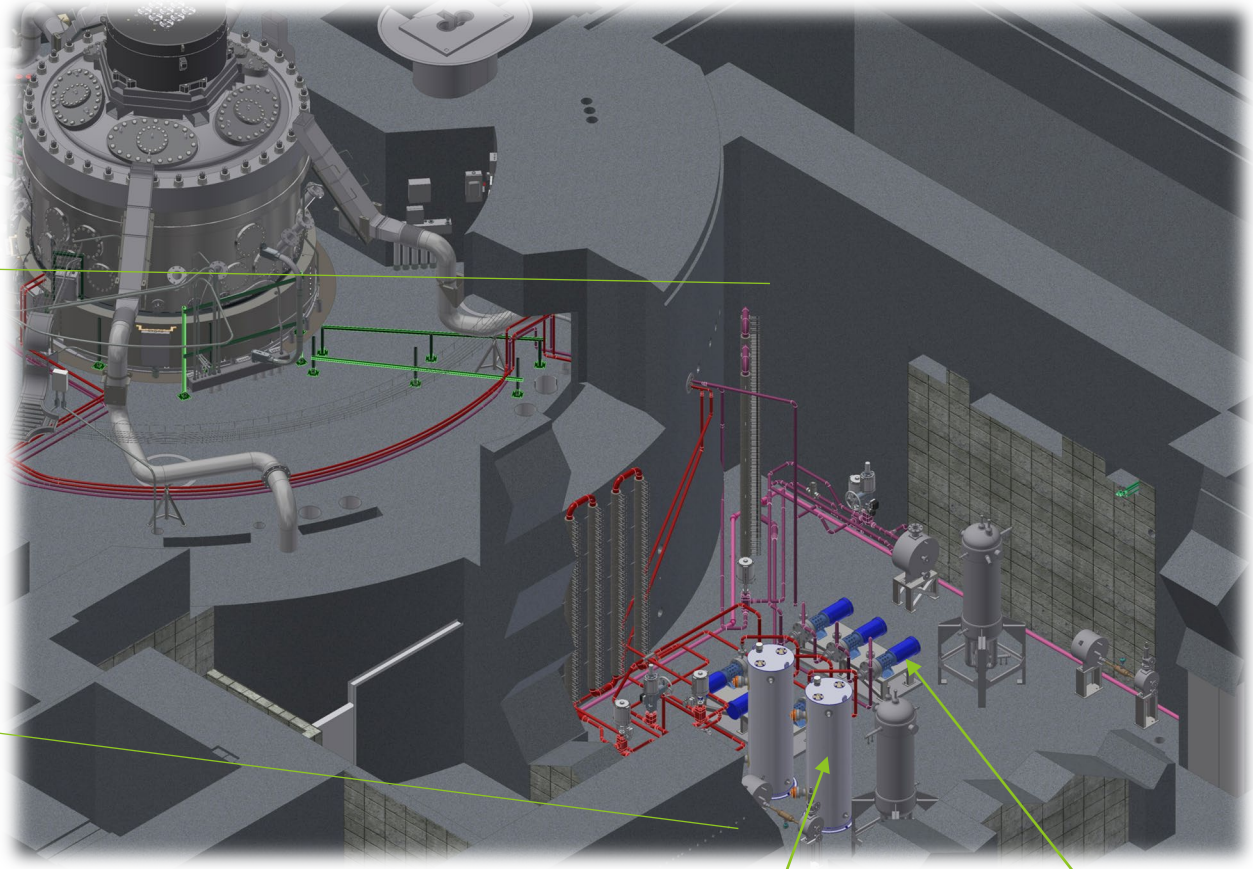
Piping to Cubicle

ATR Vessel

I-Loop Primary Cubicle



1A Cubicle



Ion Exchange Columns

Circulation Pumps

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

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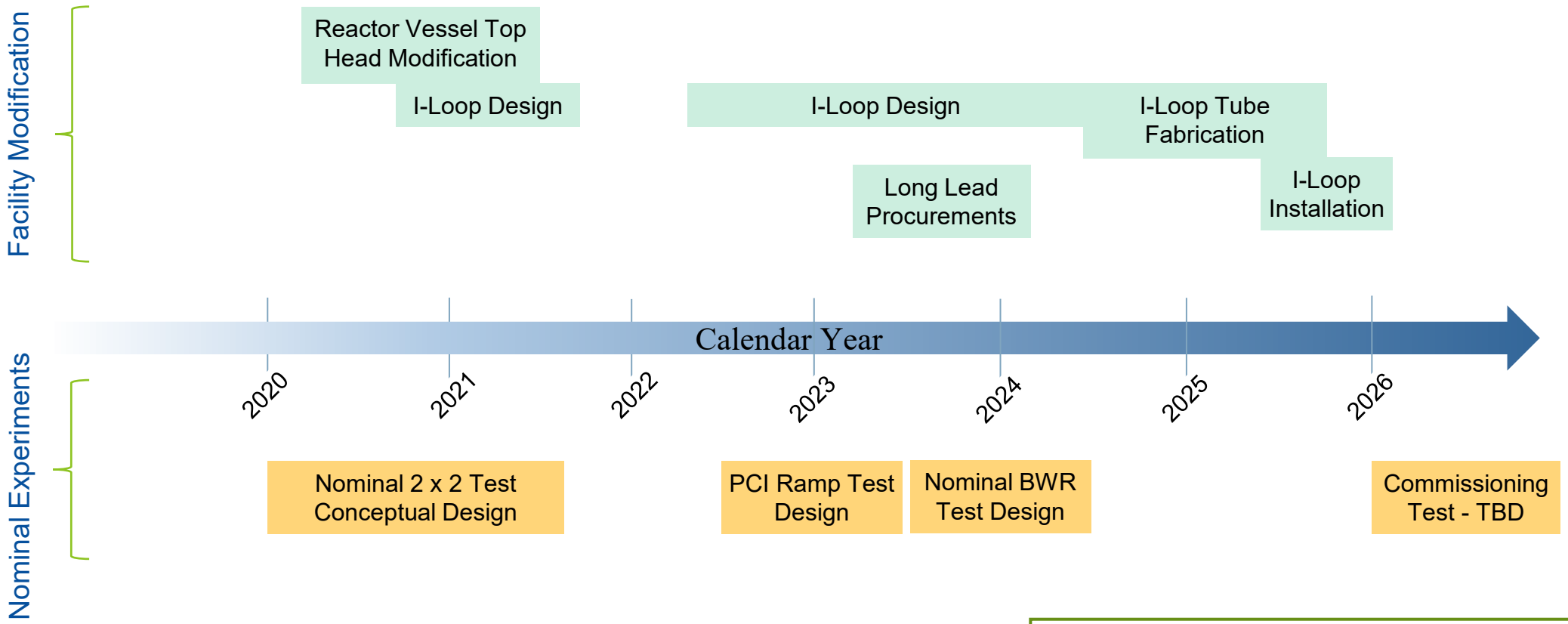
Schedule for I-Loop Deployment

I-Loop Project Schedule – for Two Loops



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

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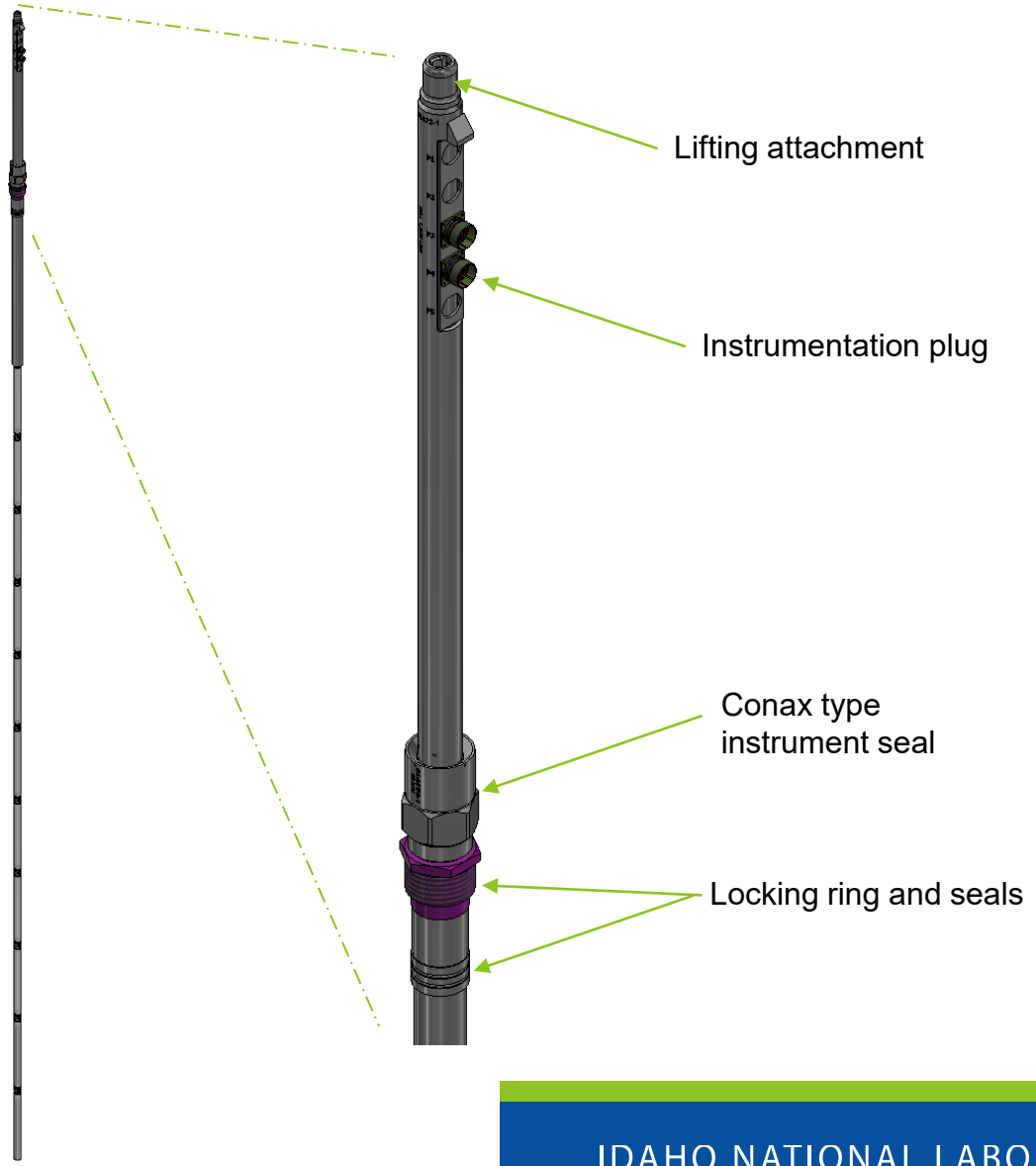
I-Loop PCI Ramp Test

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

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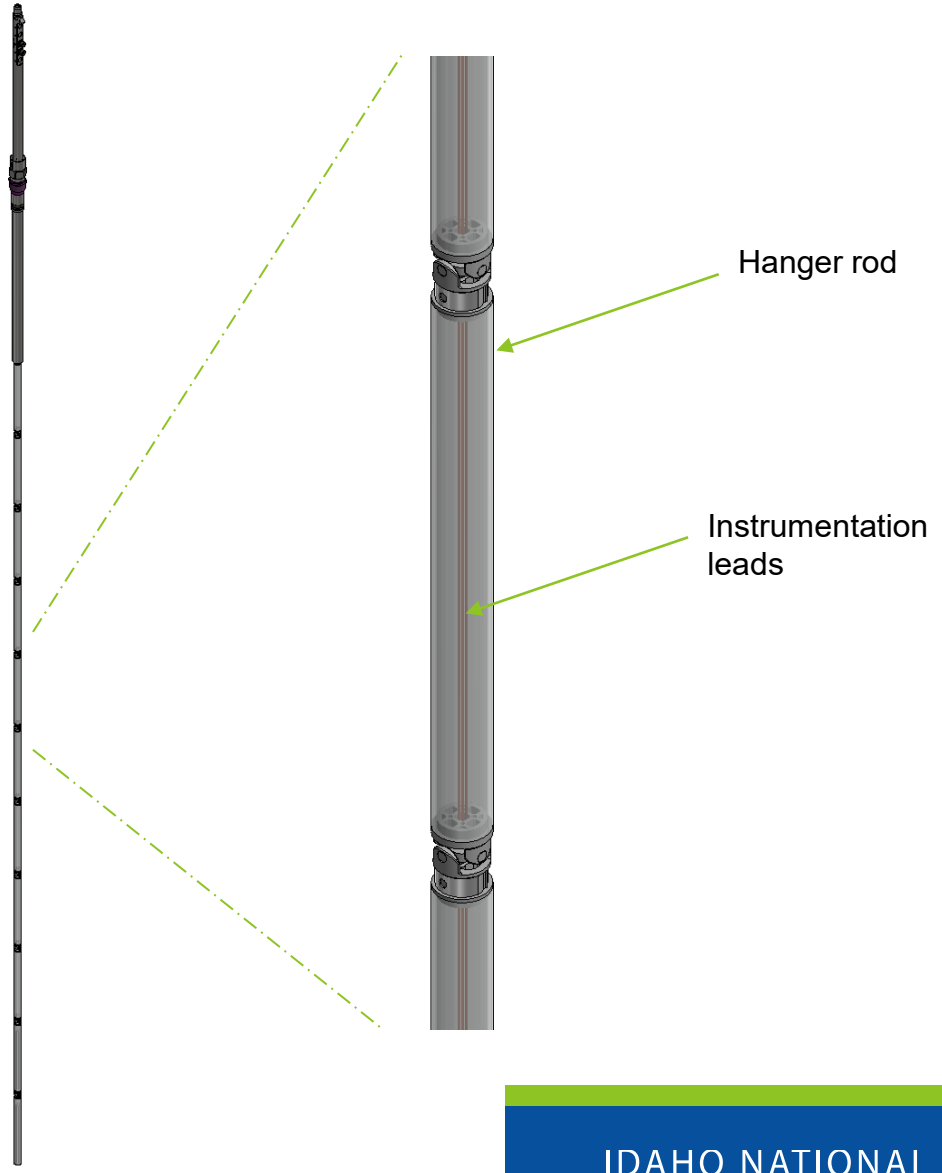
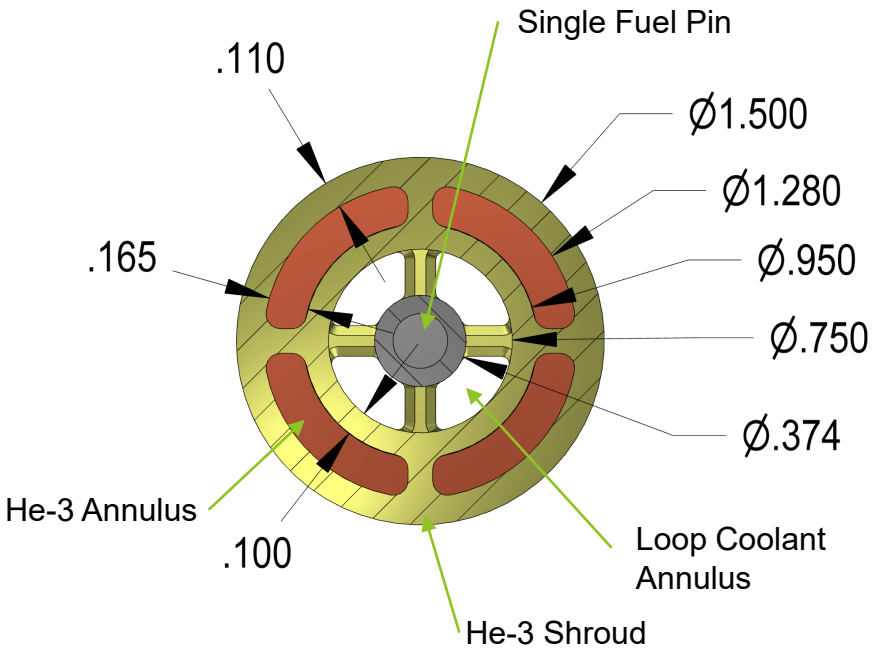
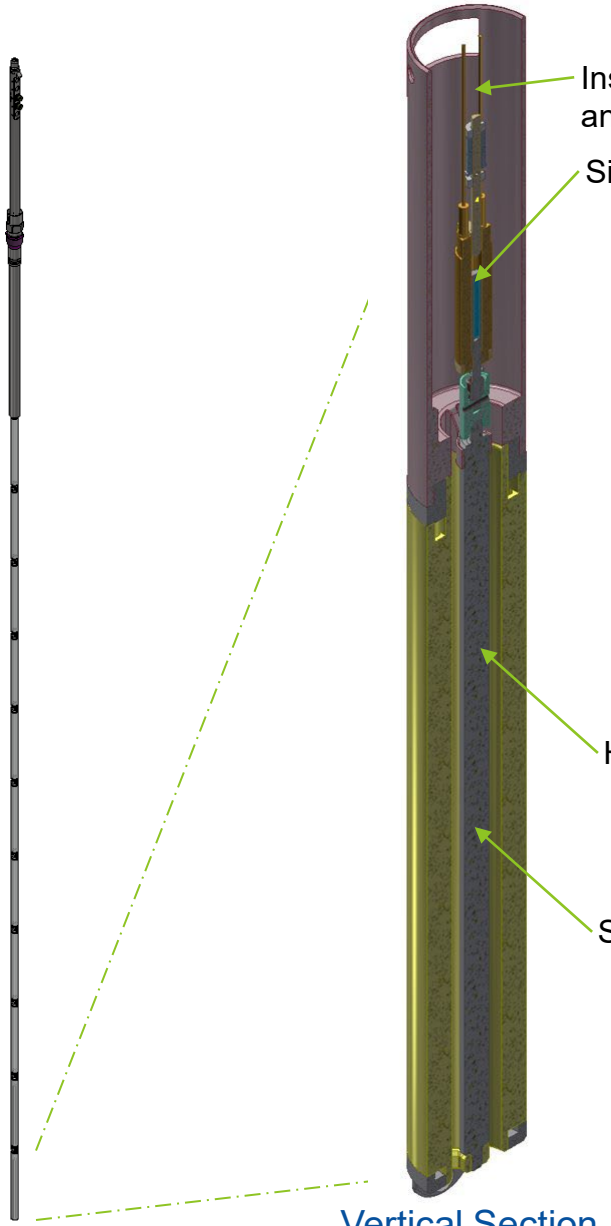


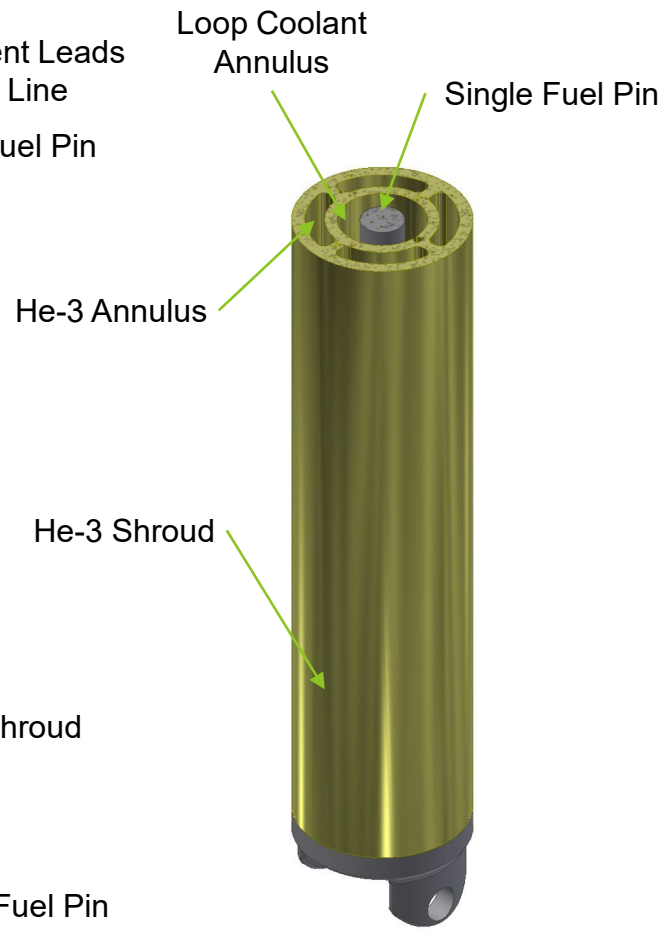
I-Loop PCI Ramp Test Experiment Design

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





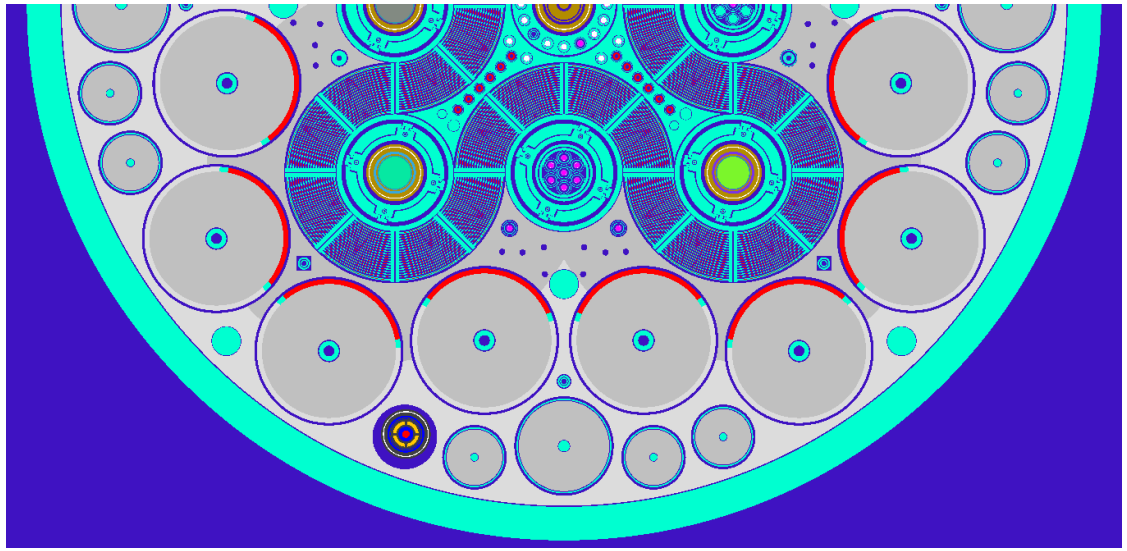
Vertical Section

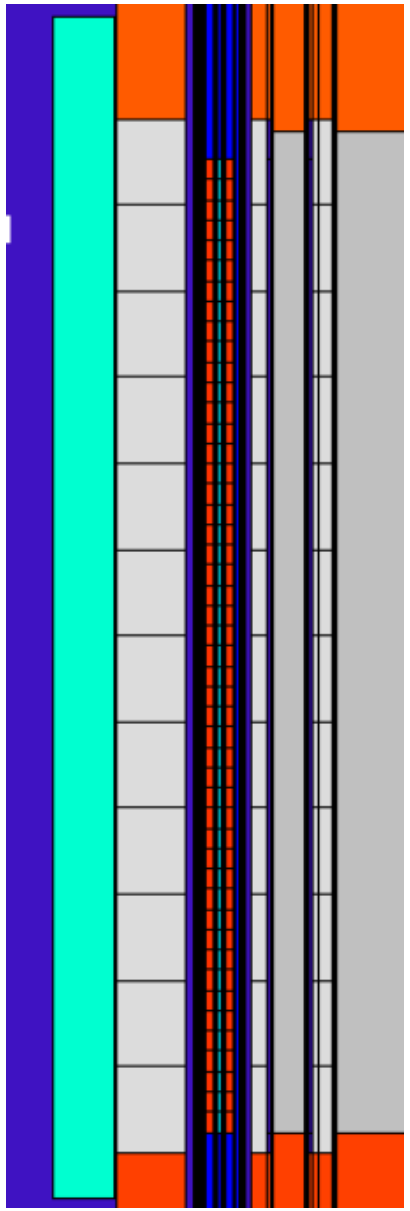


Horizontal Section

PCI Ramp Test – Neutronics Scoping

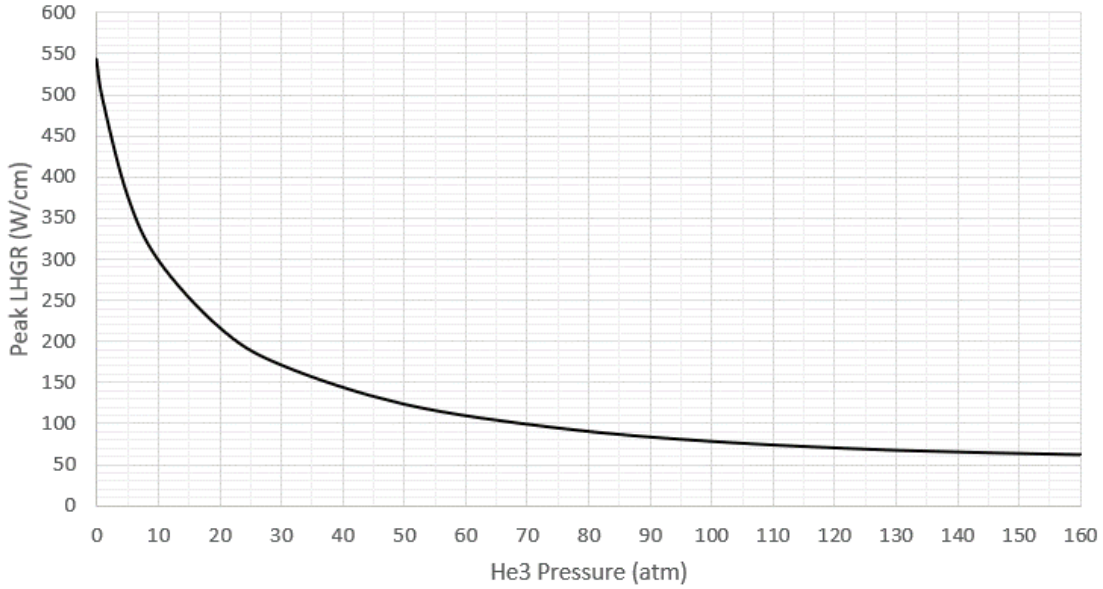
- Explicit 3D model using MC21 Monte Carlo code
- I-13 position in the ATR
- 1” axial segments from top to bottom of ATR core
- Fresh UO_2 fuel (4% enriched)

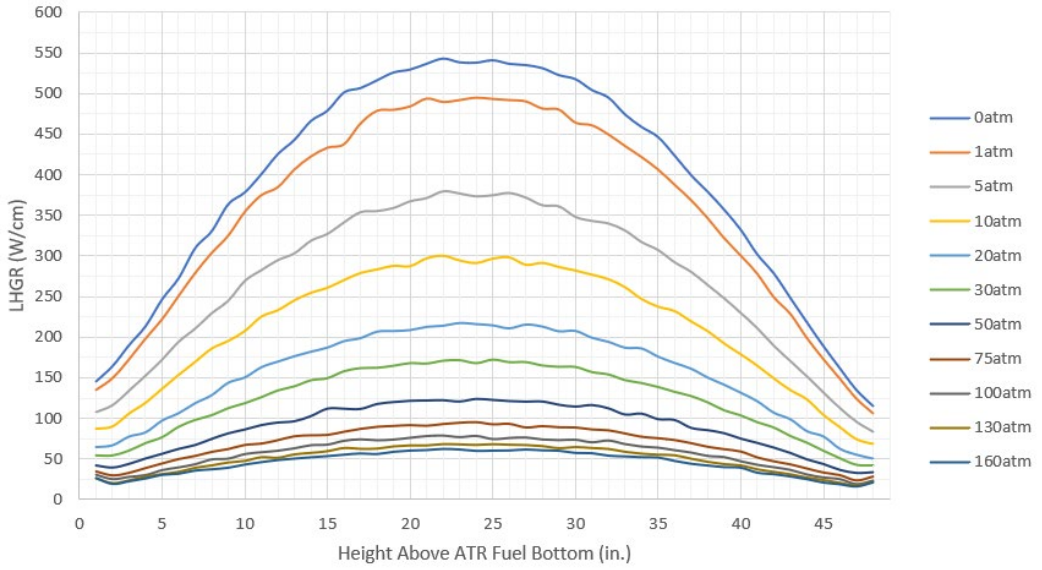




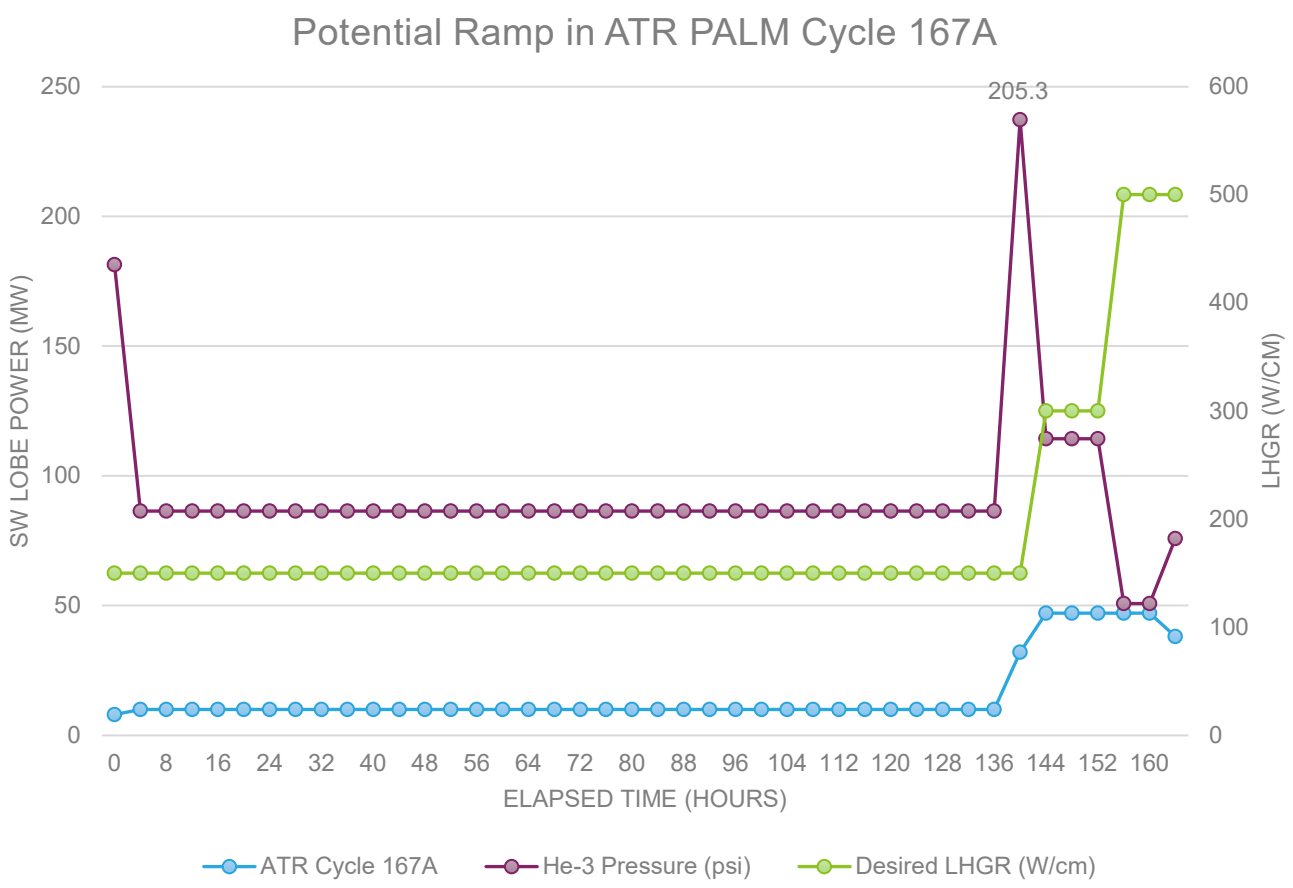
PCI Ramp Test – Neutronics Scoping

- 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



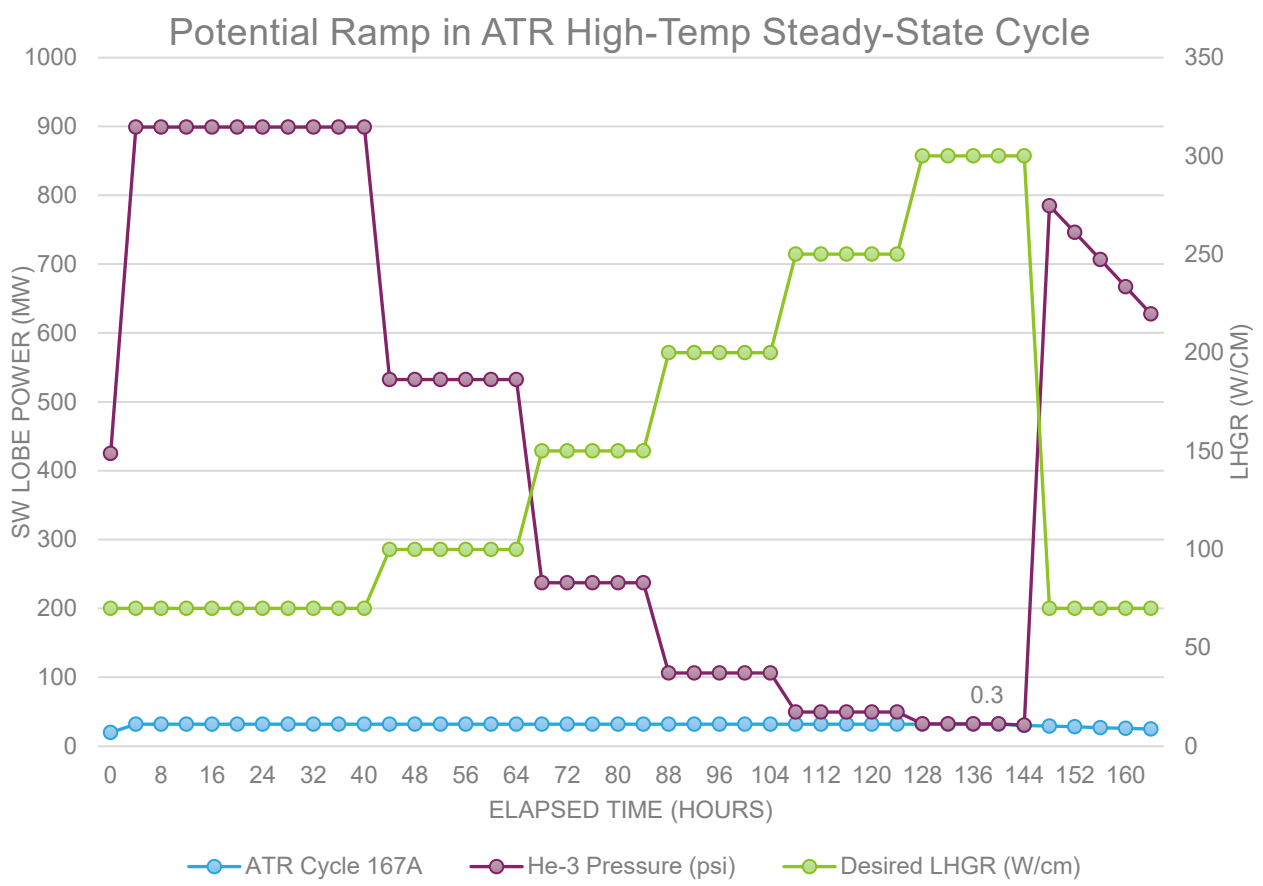


PCI Ramp Test – Proposed Ramp Cycle



- 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

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I-Loop BWR Experiment

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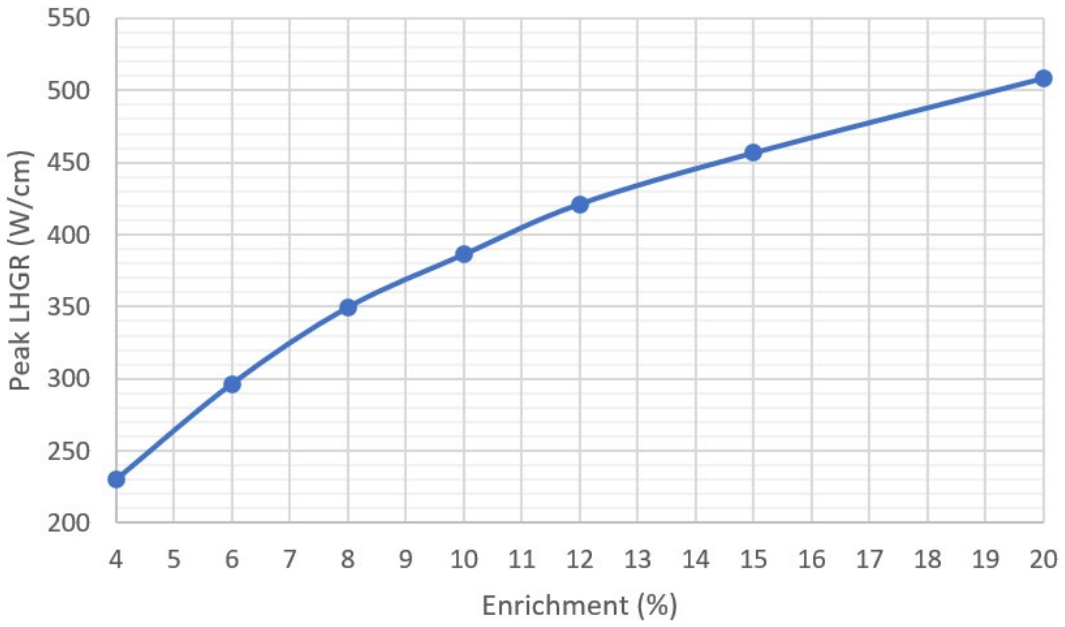
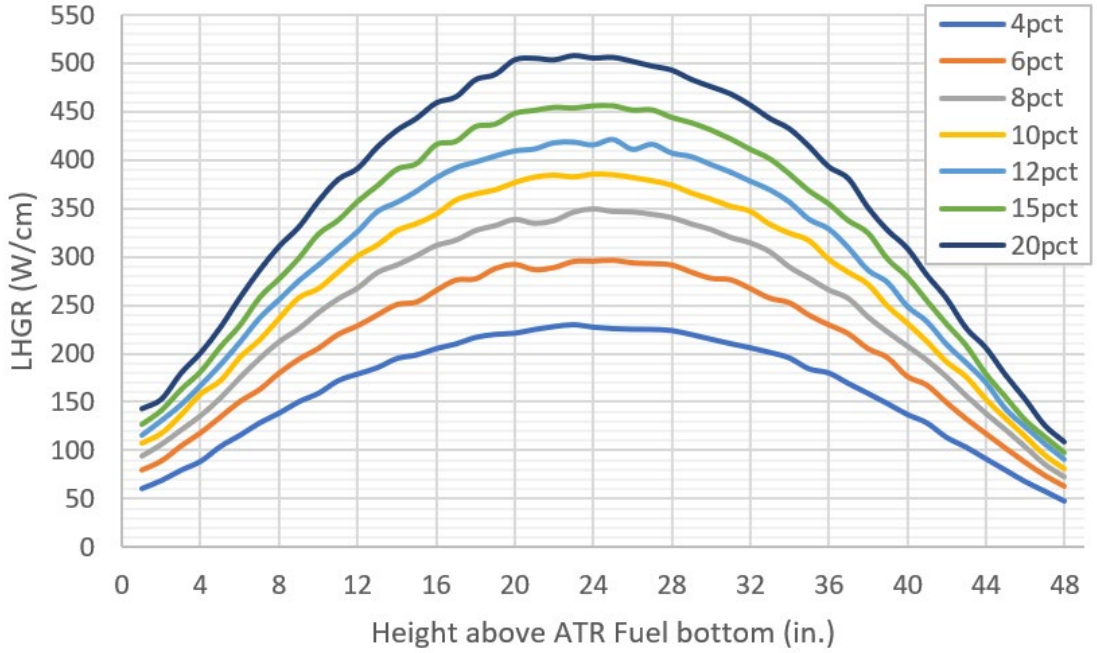
I-Loop BWR – Mechanical Design (BRIAN)

I-Loop BWR – Enrichment Sweep

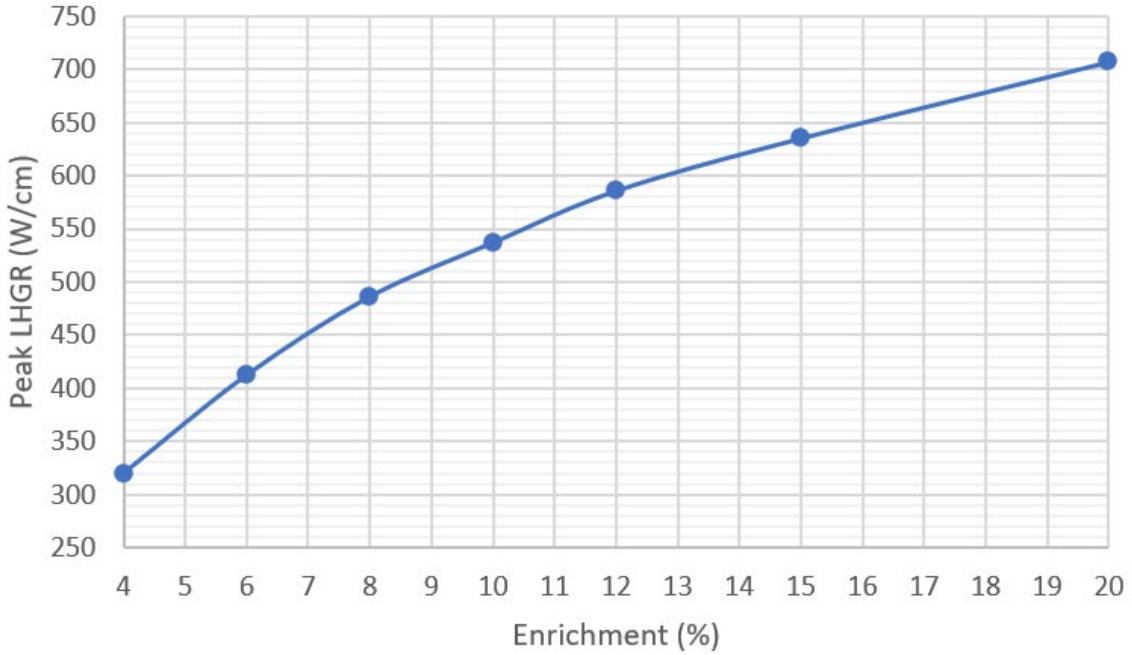
- Single pin, same as ramp test geometry (no boiling)
- Uranium enrichments range from 4-20% U235
- Data scaled to 23 MW lobe power (Standard ATR Cycle)

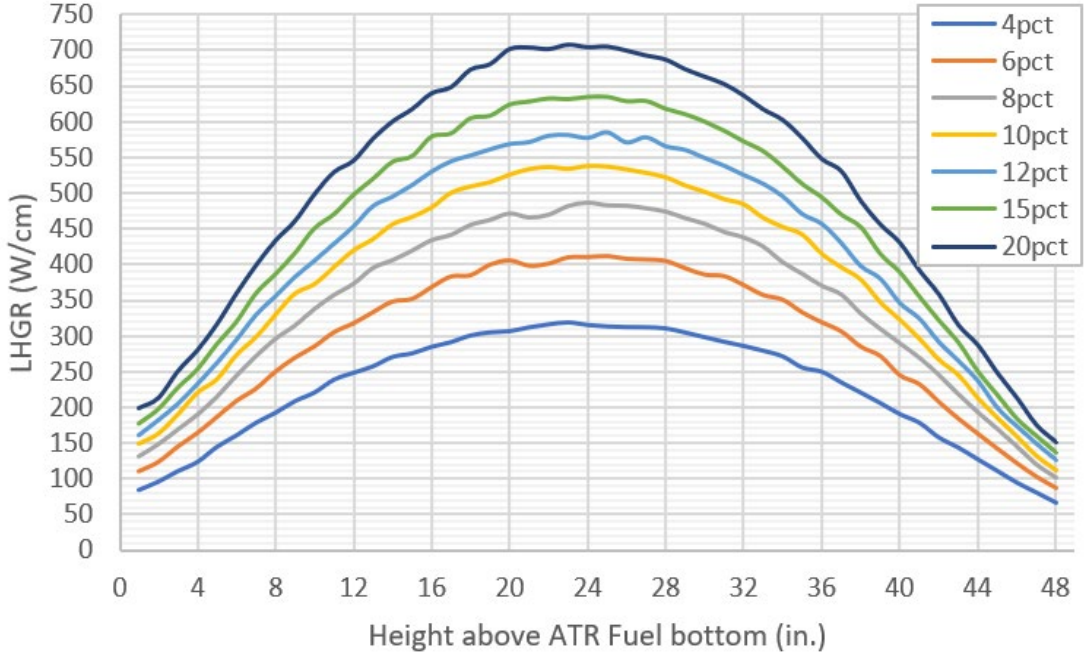




I-Loop BWR – Enrichment Sweep

- 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)





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