

9/22/2026

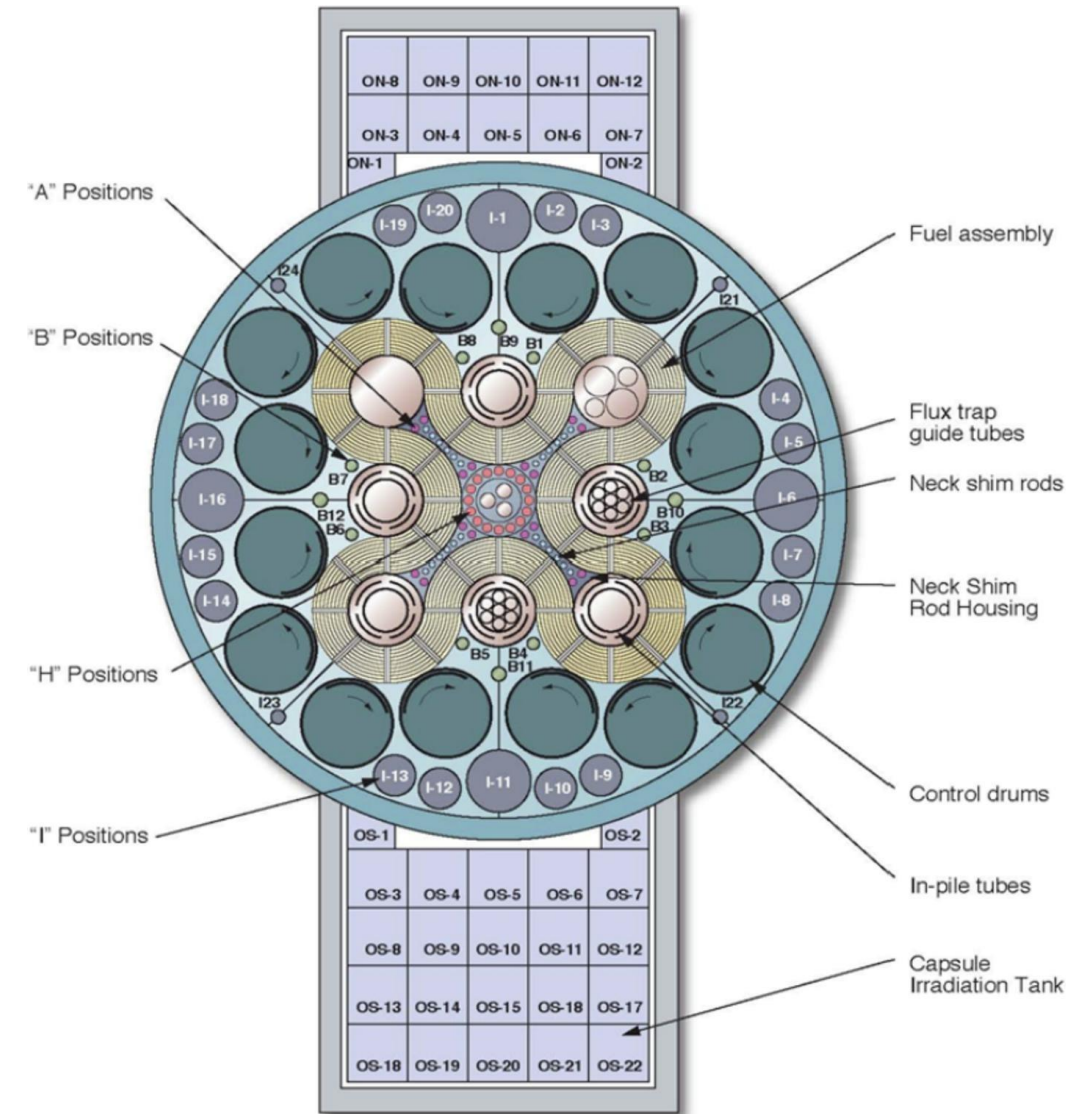
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Engineer



Zirconium-Based Alloy In-Pile Tubes in the Advanced Test Reactor

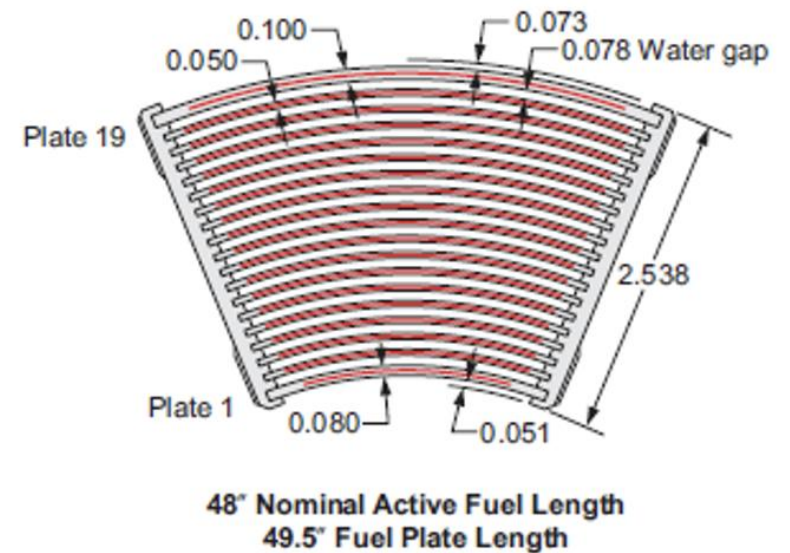
The Advanced Test Reactor

- 250 MW_{th} Water-Cooled, Beryllium Moderated Thermal Neutron Reactor
- 40 HEU Uranium Aluminide Fuel Elements in a Serpentine Arrangement – 9 Flux Traps
- Currently 6 Flux Traps Configured with In-Pile Tubes (IPTs)
 - NW, N, SE, SW, W, and C
- 76 Additional Irradiation Locations in Reflector and Neck Shim Housing Assembly
- Can Operate with 2 or 3 Primary Coolant Pumps (PCPs)
 - 3 PCPs reach 54,000 gpm
 - Flow velocity of ~ 47 fps through fuel elements
 - Coolant Temperature Increase of 45 °F in 83 milliseconds



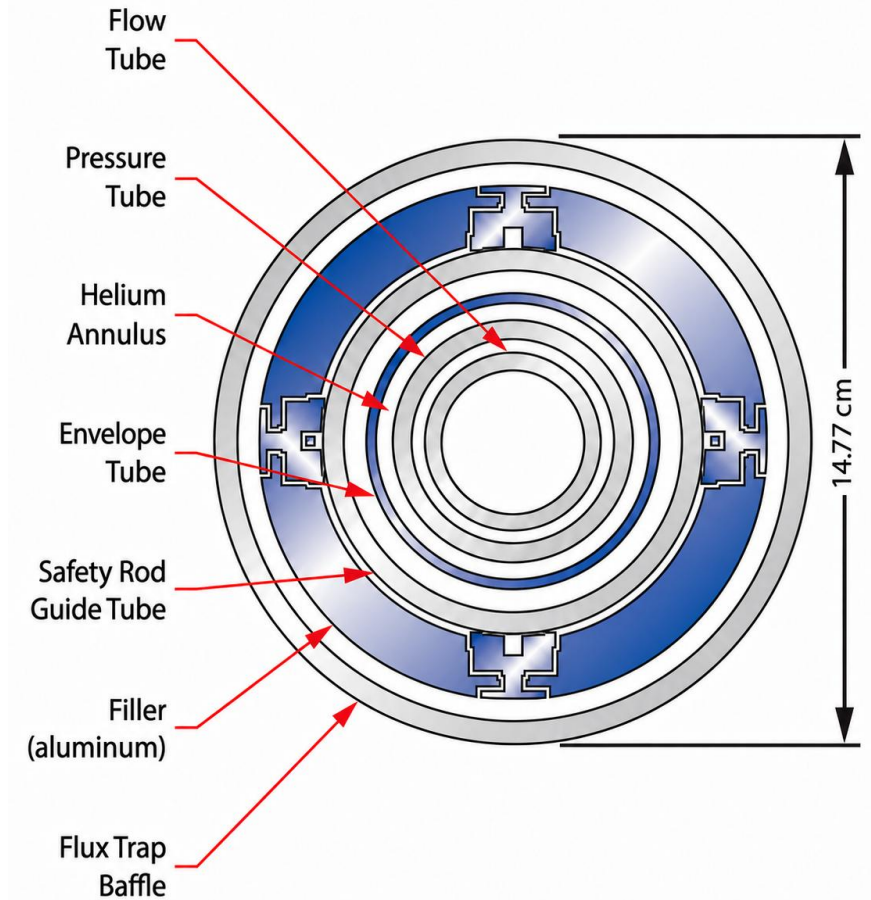
Operating Structure

- At 250 MW_{th} most fissionable experiments would overheat/melt at those fission powers
 - Typically operates at total core power of 110 MW, with highest lobe powers at 25MW for 60 days at power
 - Also operate high-power cycles, with maximum lobe powers of 60 MW for 7-14 days at power
 - High Temperature Steady State (HTSS) Operation starting in FY-27
 - 50 days at power with lobe powers of ~ 30 – 35 MW
 - Outages are 30 days, with one long outage (~90 days) per year
 - Normally target 200 days per year at full power
- During outages, experiments are replaced as well as all the fuel elements
 - Fuel elements can be re-used in multiple cycles (2-3)
 - The fission density SAR requirement of $2.3E21$ fissions/cm³ limits fuel element operating lifetime
 - At fission densities $> 2.3E21$ fissions/cm³, fuel swelling is no longer predictable and consistent
 - U-235 is depleted to the point maintaining full power for any appreciable length becomes impossible

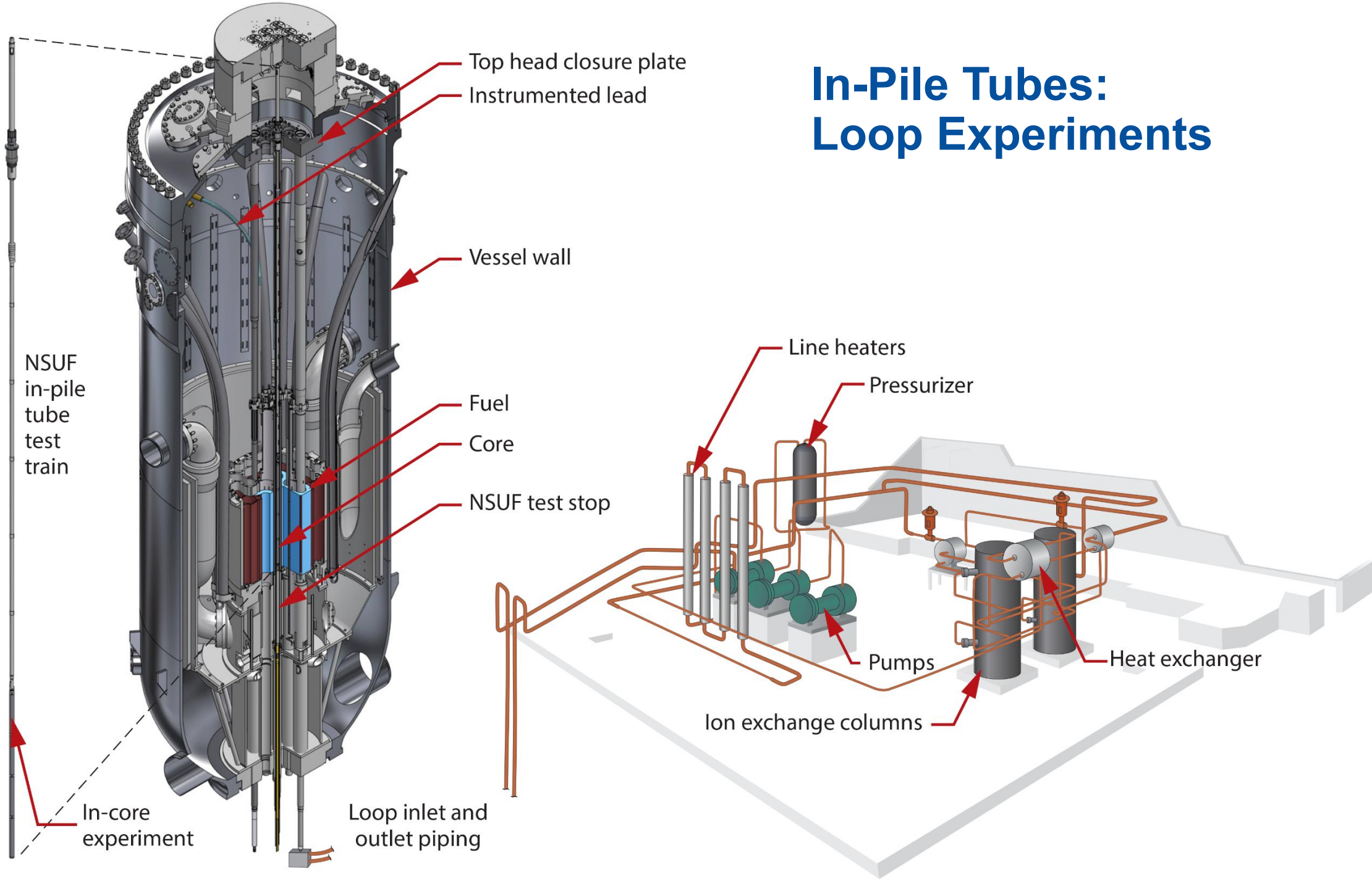


In-Pile Tubes (IPTs)

- Six flux traps configured with IPTs
 - An IPT is an extension of the pressure vessel boundary
 - Fabricated from SS348 Stainless Steel
 - Provides separation within the IPT from the reactor primary coolant system
 - Pressure, temperature and chemistry within the IPT can be and are independently controlled
 - IPTs are connected sub-pile to loop heat exchanger piping

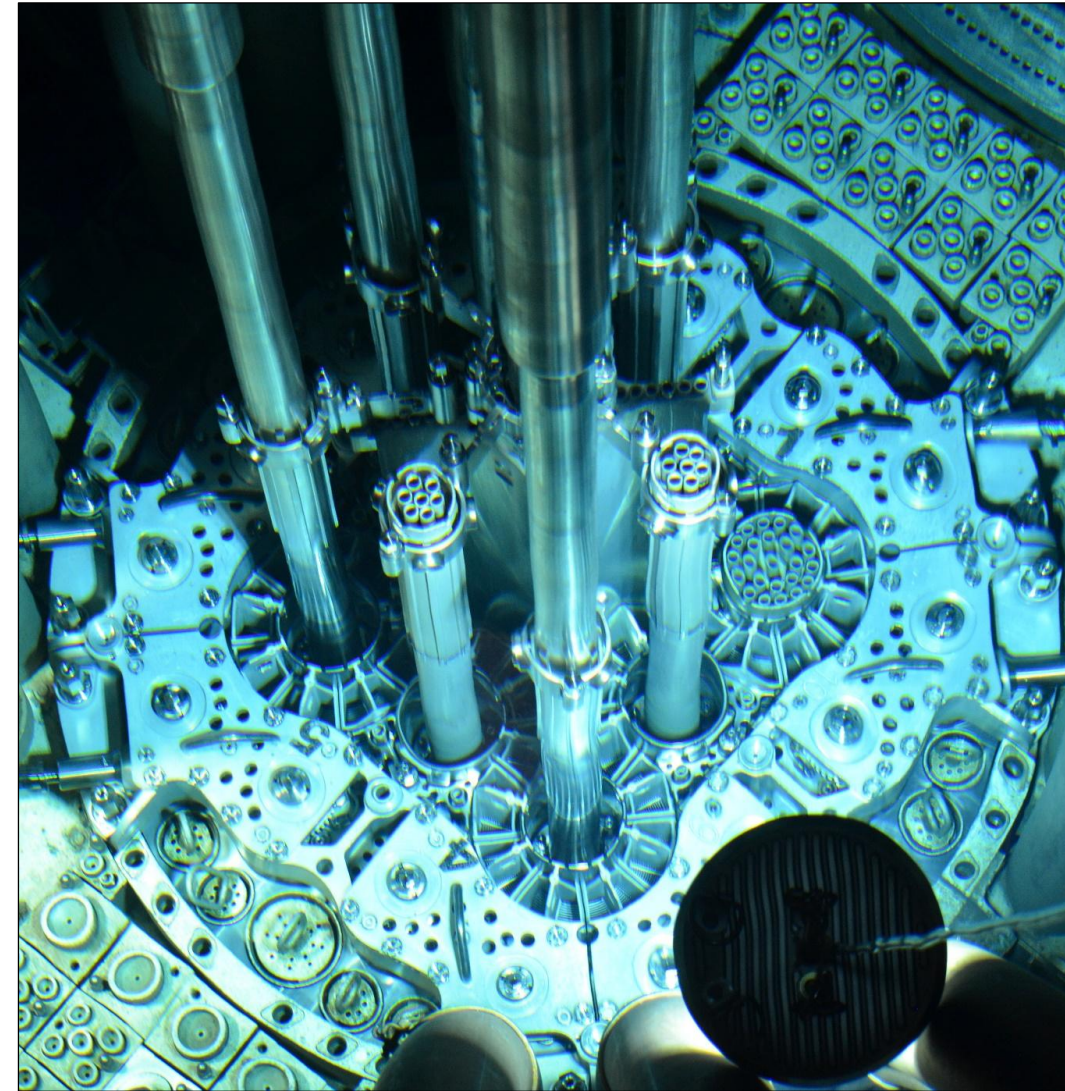


In-Pile Tubes: Loop Experiments



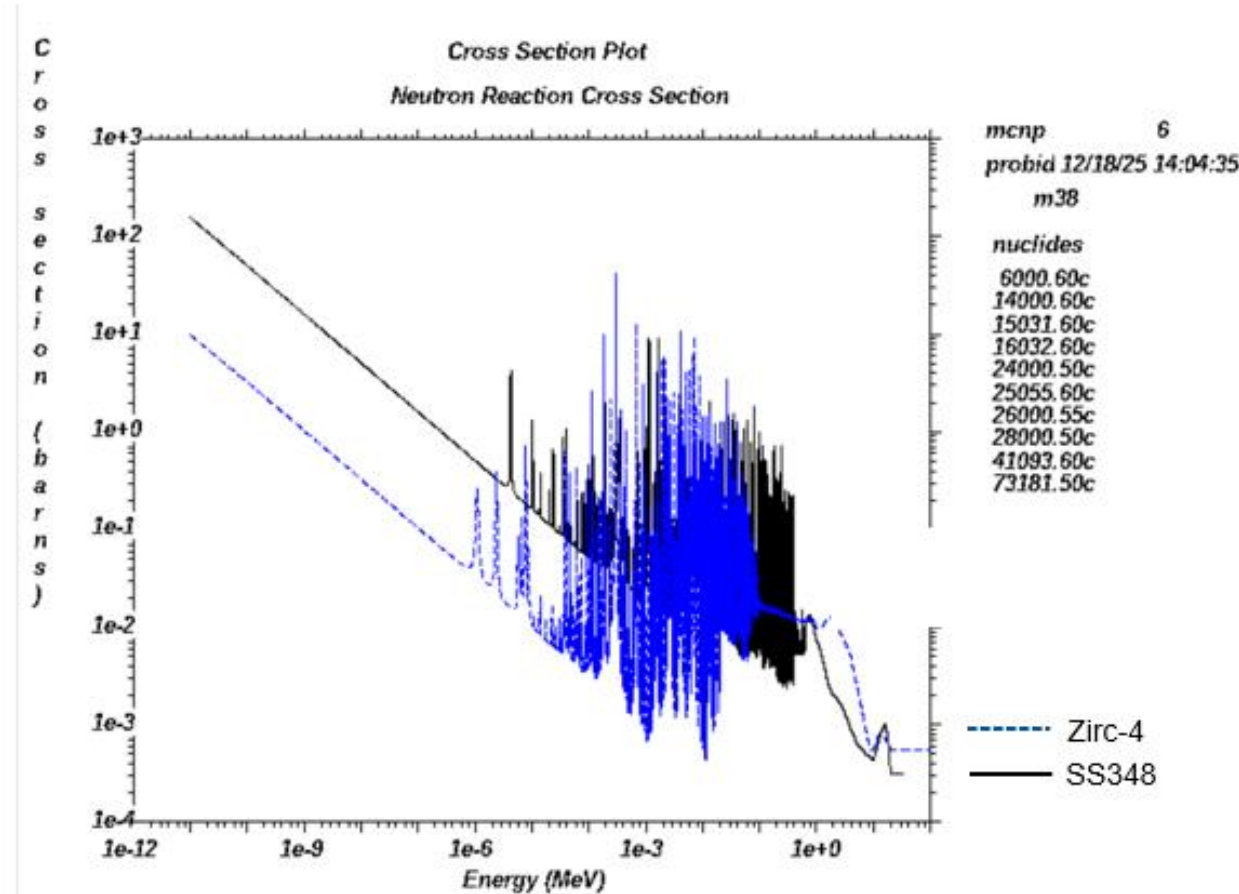
Power Demands

- Recent requests to operate lobes at > 60 MW
- Current SAR Maximum lobe power restricted ≤ 60 MW
 - These temperatures challenge the ATR Mark VII Fuel System
- How can we provide experimenters an environment equivalent to a 70 MW lobe, but at < 70 MW lobe powers?
 - This question led to a committee exploring numerous options, and all options were on the table
 - **One option is to use a more neutron transparent material for IPT hardware**



Zirconium Alloy IPTs

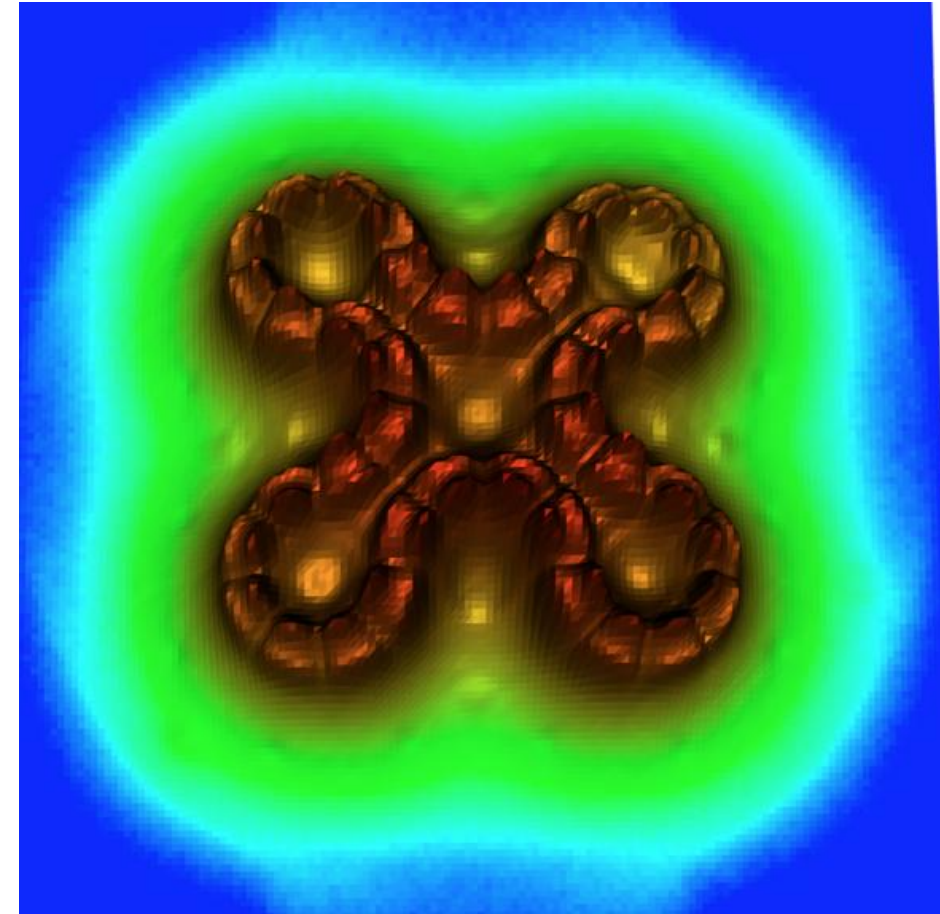
- It is no surprise that SS348 has a large neutron capture cross-section, but the component must qualify as an ASME pressure boundary
- INL researchers evaluated Zr2.5Nb IPT infrastructure in a large-I position
 - Determined an equivalence in material properties to SS348 for a pressure boundary exists
 - The biggest challenge is the sub-pile connections to the SS348 heat exchanger loop piping
 - There are mechanical fitting options, like Swagelok fittings



Zirconium Based Alloy IPTs in a Flux Trap

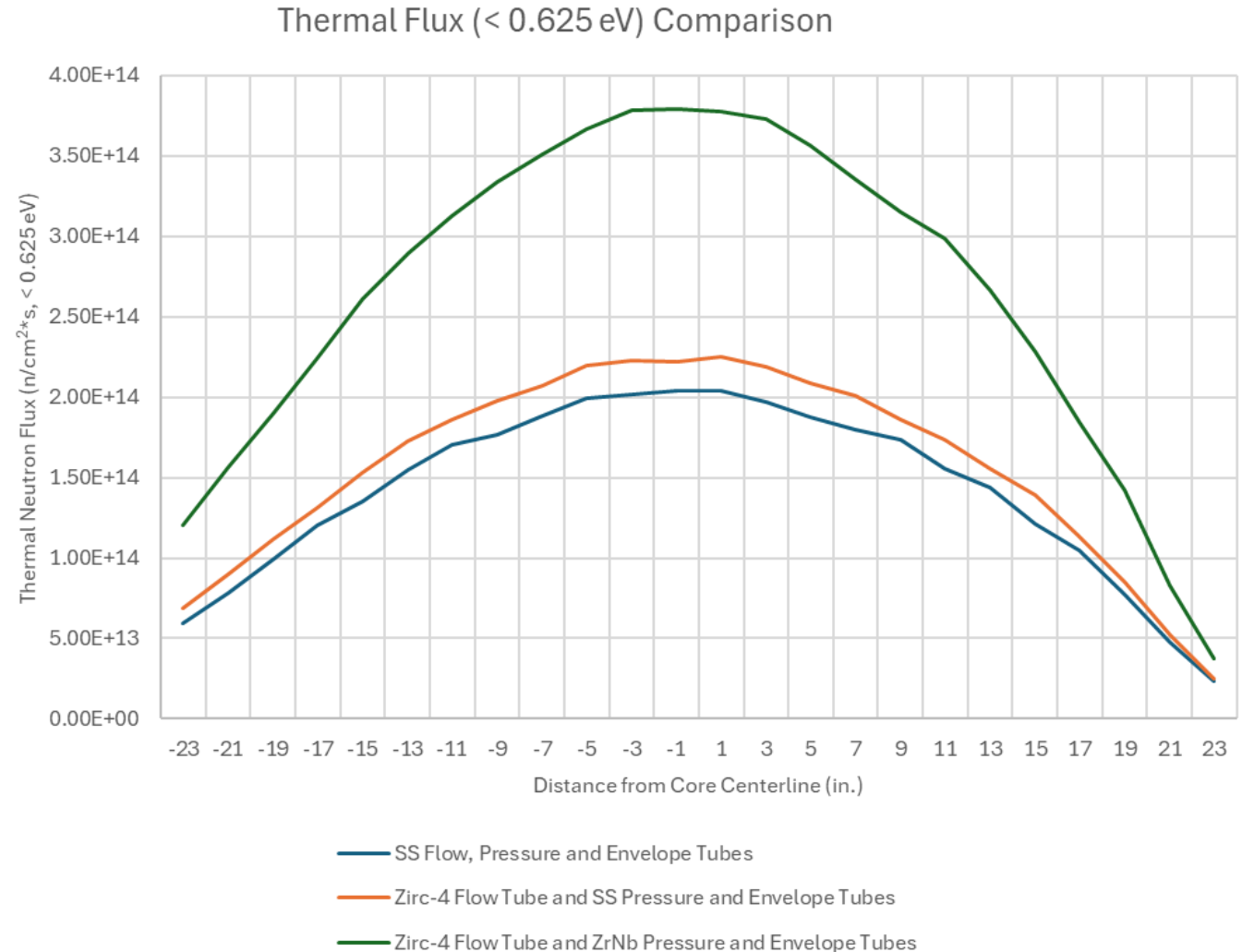
- What if we converted some, or all the SS348 IPT hardware to zirconium-based alloys?
 - This presentation provides the physics analysis evaluations for a zirconium-based alloy IPT
- ATR Cycle 175A Selected for Evaluation
 - 175A was a 60-day cycle with a nominal lobe power split of 24-20-22-23-23 (NW-NE-C-SW-SE)
- SE lobe was analyzed as the candidate
 - Axial homogenous, non-fissionable, transparent material modeled within the IPT to minimize perturbations caused from within the IPT
 - We wanted to strictly evaluate the change in IPT hardware
- Three Unique Core configurations analyzed
 1. Base Case – SS348 IPT
 2. A change of the flow tube only to Zircaloy-4
 3. A change of the flow tube to Zirc-4 and the pressure and

insulation tubes to Zr2.5Nb

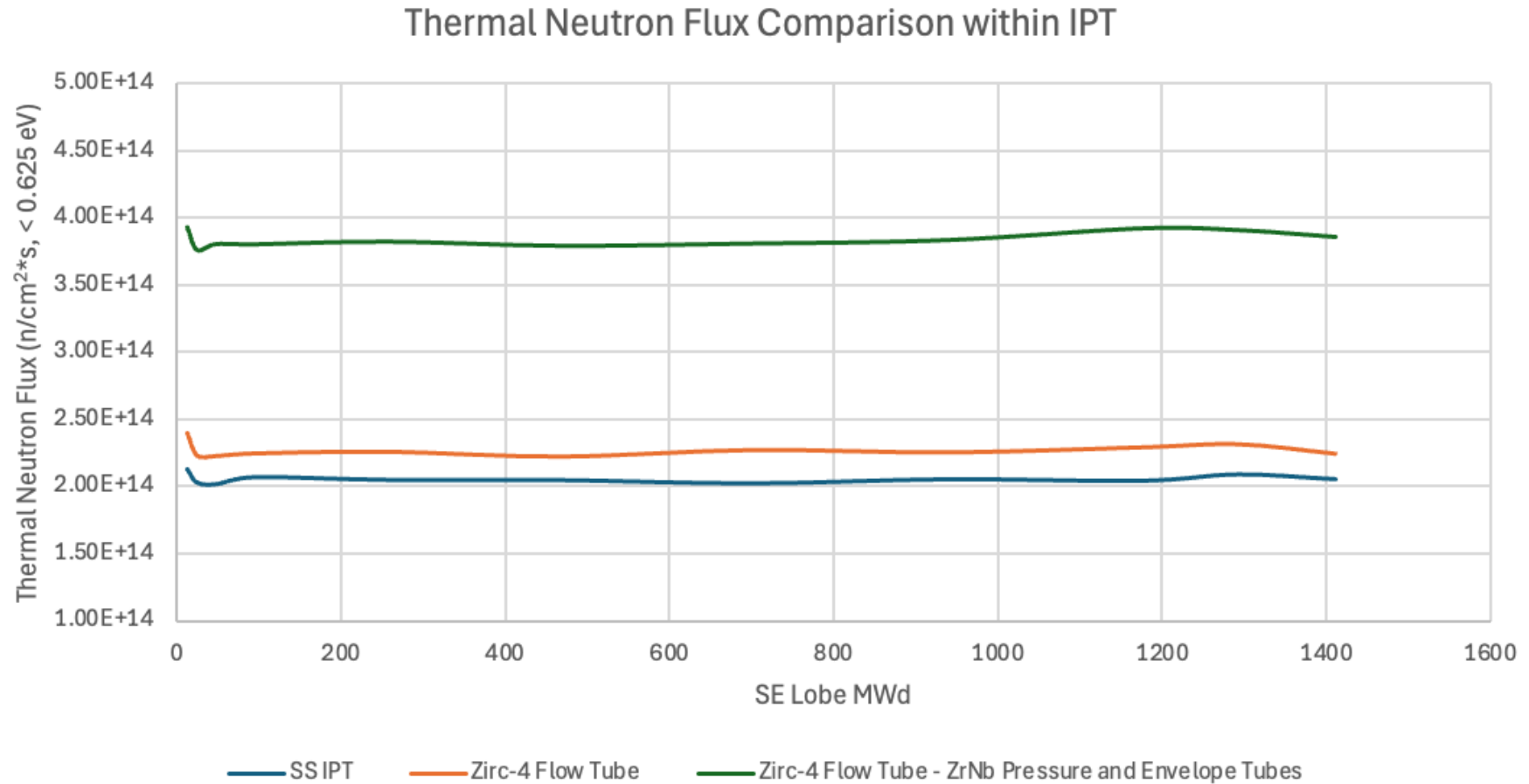


Thermal Flux Comparison

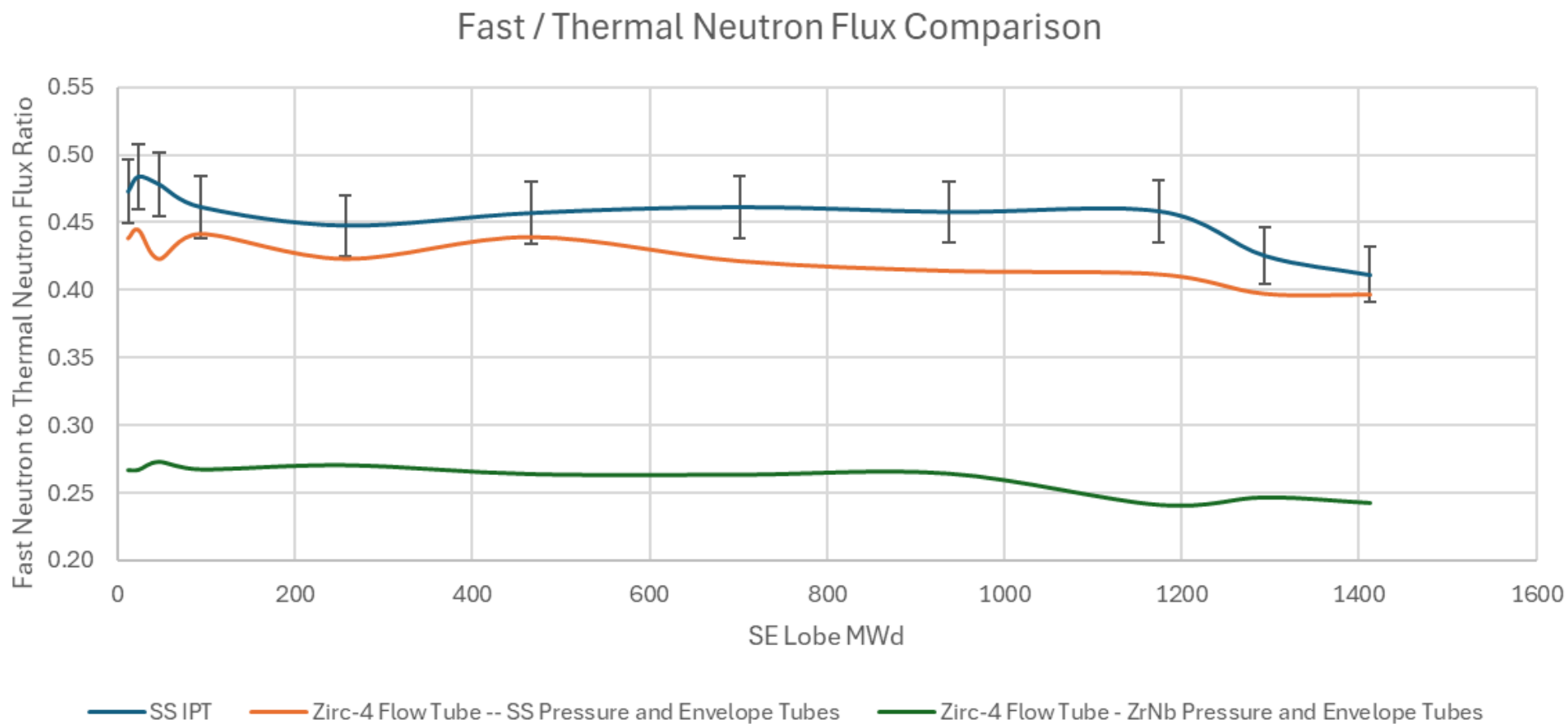
- Clearly more thermal neutrons getting to the center of the IPT
- Zirc-4 Flow Tube Change
 - 9-11% increase to incident thermal neutron flux
 - A lobe power of 64 MW would yield thermal flux seen at 70 MW
- Zirc-4 Flow Tube and Zr2.5Nb Pressure and Insulation Tubes
 - 86% increase to incident thermal neutron flux
 - Yields thermal fluxes of a 70 MW lobe at 38 MW



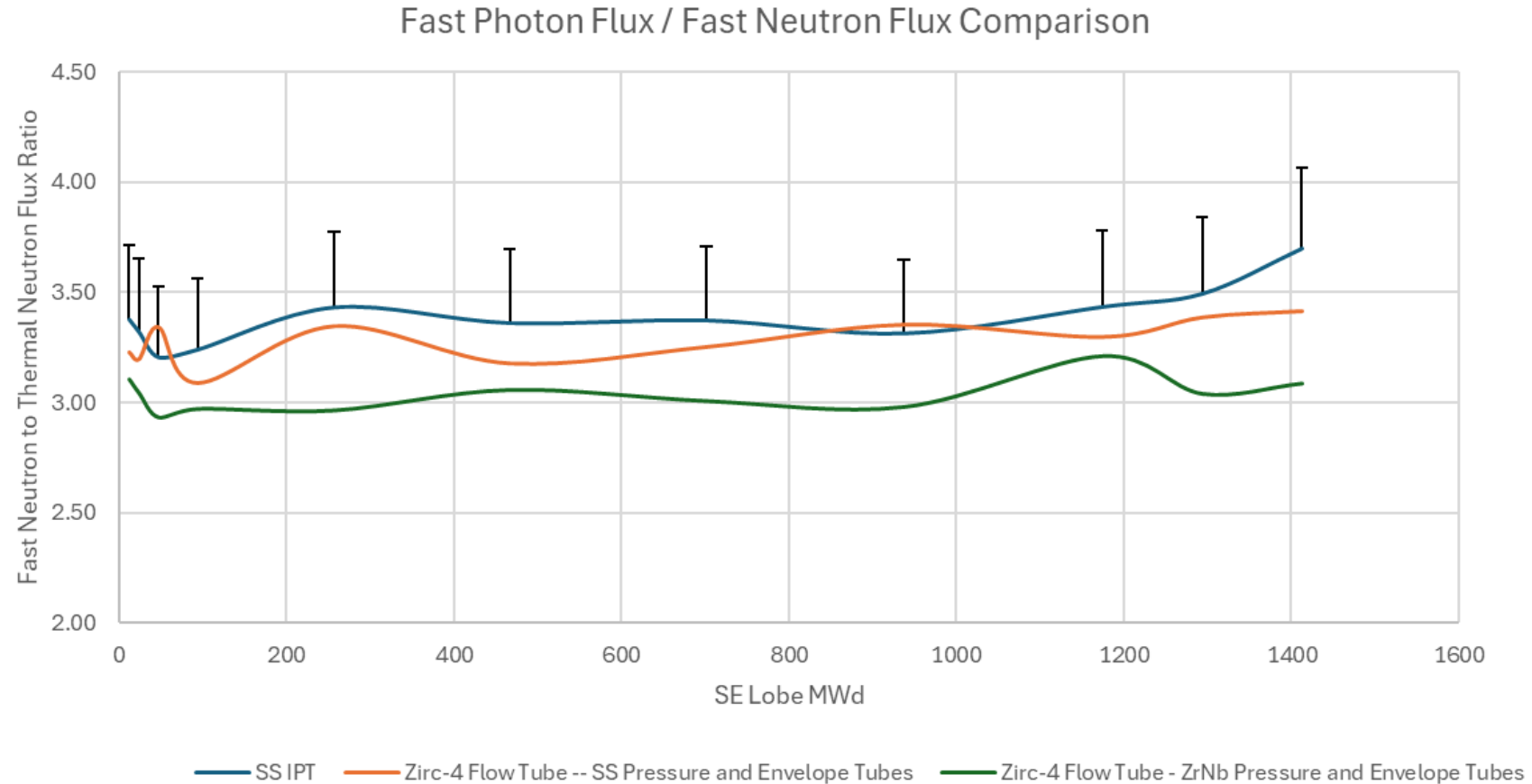
Thermal Flux Comparison over Cycle



Fast to Thermal Neutron Flux Comparison over Cycle

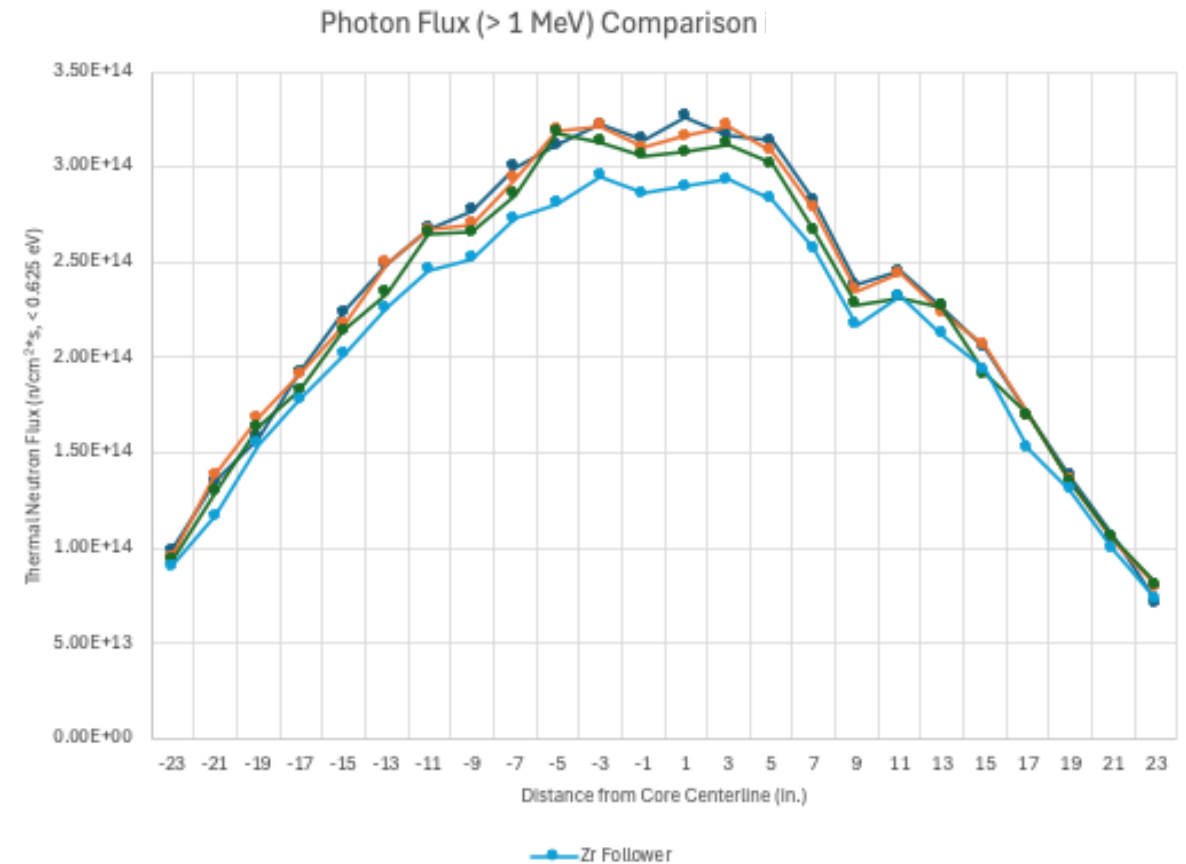
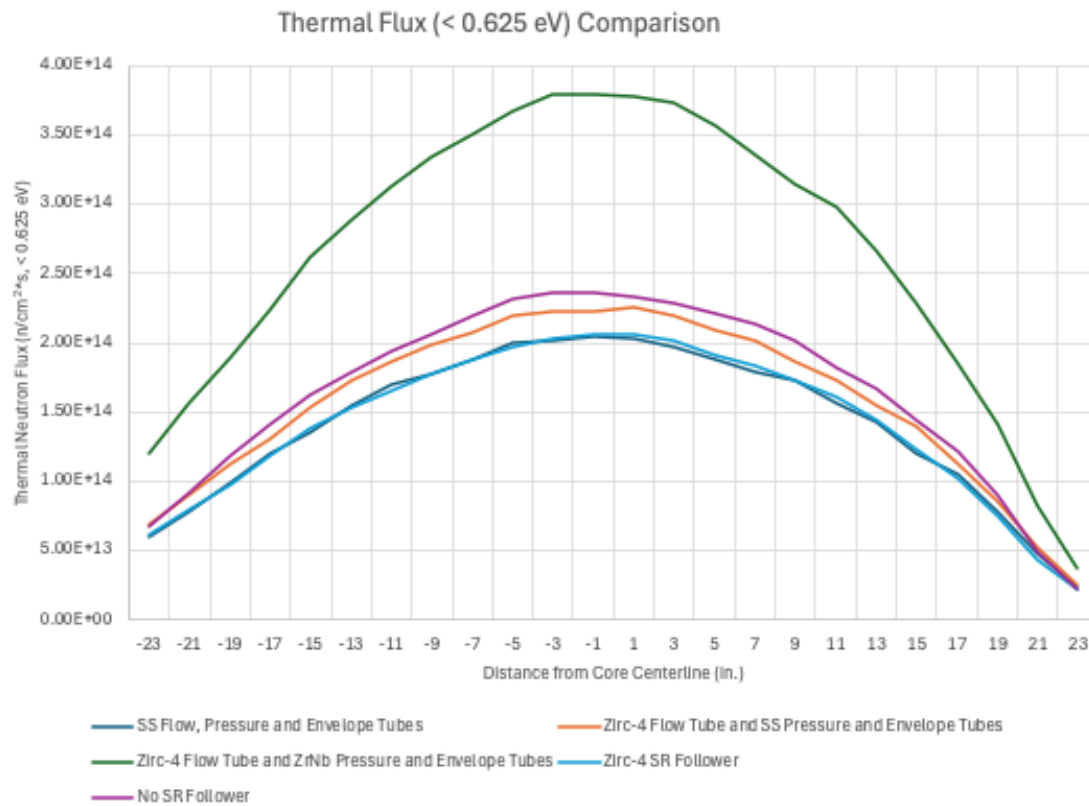


Fast Photon to Fast Neutron Flux Comparison over Cycle



Zirc-4 Safety Rod Follower

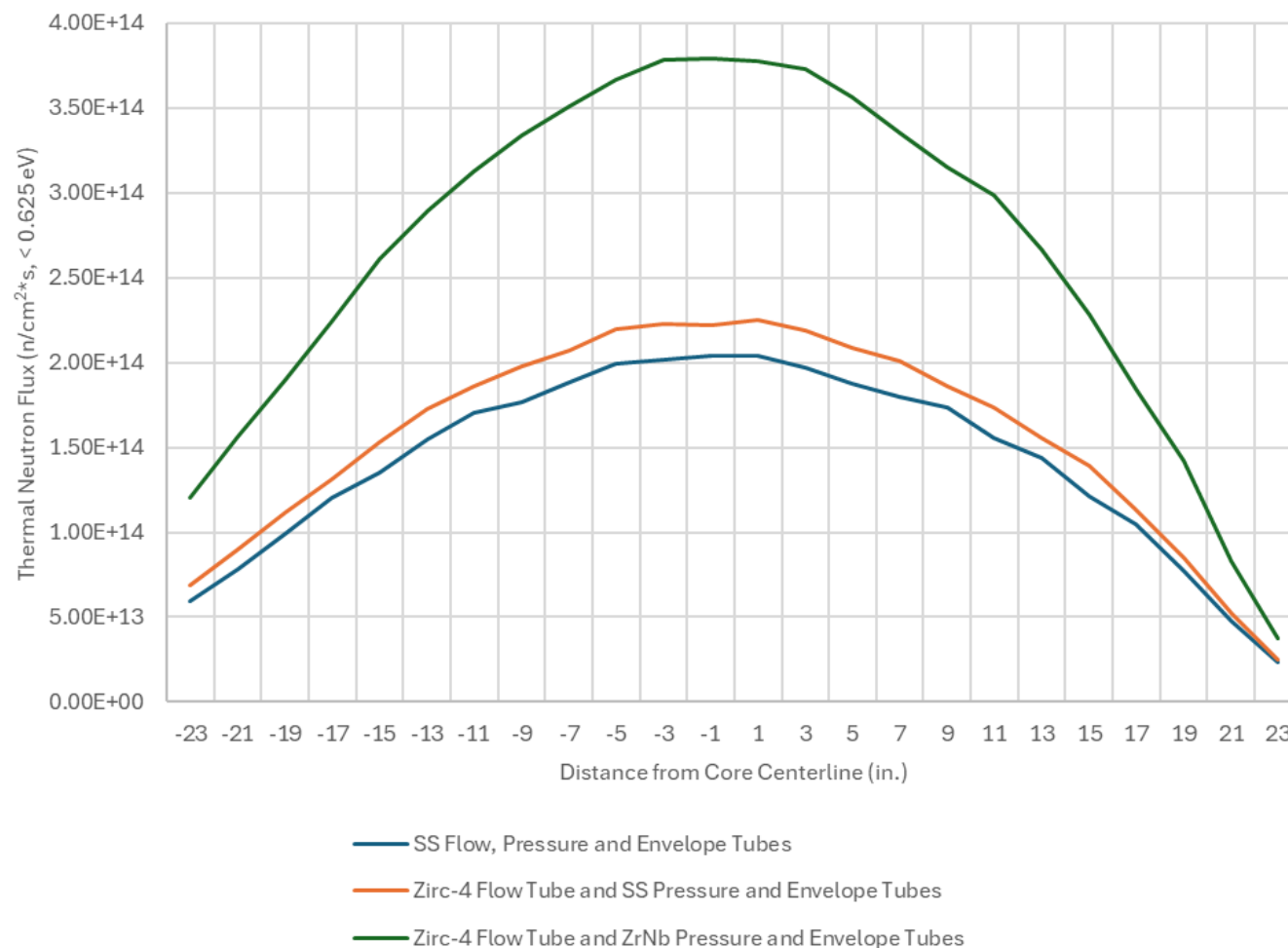
- These results are for a Zirc-4 safety rod follower and no follower – the rest of the IPT was modeled as SS348



Summary

- Changes to zirconium-based alloys provide significant neutronics benefits
- Joining the zirconium piping to the SS348 sub-pile piping remain the biggest challenge
 - How a full zirconium-based alloy IPT would challenge conclusions in the SAR needs explored
- A change of the flow tube only offers an 11% increase in incident thermal flux and is highly feasible
- A change of the flow tube and pressure and insulation tubes yields an increase of 86% in incident thermal flux – more challenging
- Removing the safety rod follower yields a 15% increase in thermal flux
 - A combination of a Zirc-4 flow tube and a reduction in cross-section of the safety rod follower will provide a significant benefit
 - There is a divergence from historical fast/thermal neutron flux and fast photon to fast neutron ratios
 - High-Z materials could shroud experiments to boost fast photons

Thermal Flux (< 0.625 eV) Comparison



Questions

