September 16, 2021
Joshua Fishler
Thermal/Thermal Systems Analyst

Overview of the Plutonium Fuel Services (PFS) Irradiation Experiment in the Advanced Test Reactor (ATR)

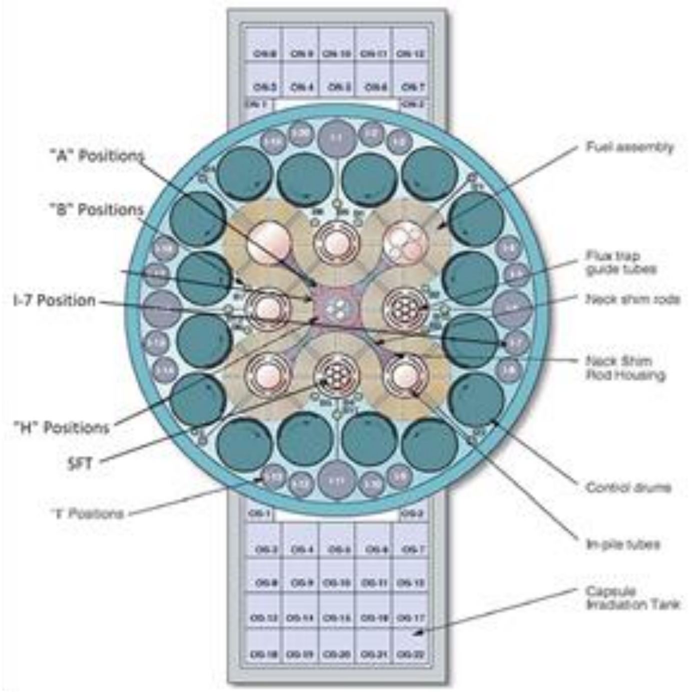
Idaho National Laboratory

Overview

- ATR Positions
- ATR Irradiation Qualification Process
  - Design
  - Neutronics
  - Thermal
  - Structural
  - ATR Critical Facility
- Operations
- Future Work

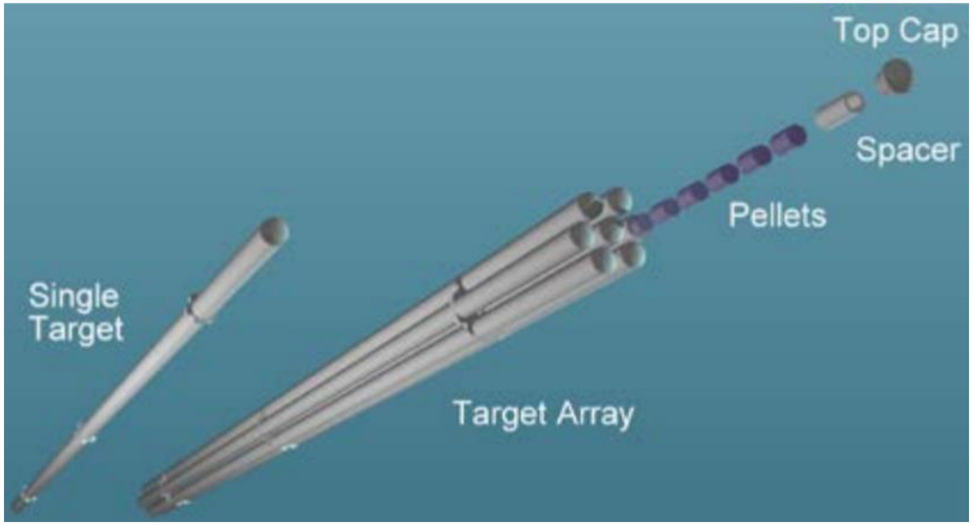
Overview of ATR Positions

- I-7 and South Flux Trap (SFT) are currently qualified for Pu-238 production
  - Targets are shorter than length of the core
  - Aligned at center to maximize Pu-238 yield
- I positions are in outer periphery of core
  - Thermal flux of 1 to 9 x 10E12 n/cm^2-s
  - Lower flux compared to other positions negatively impacts production rate
- Flux Traps are located in each cloverleaf
  - Thermal flux ~ 4 to 5 x 10E14 n/Cm



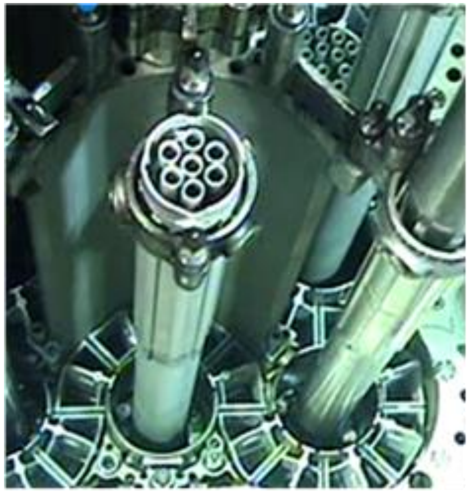
Target Design and Qualification

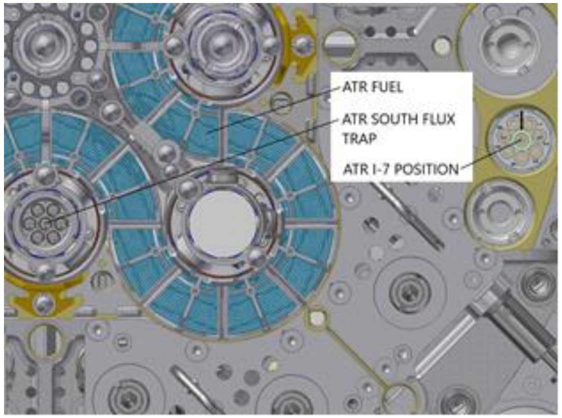
- Existing targets designed for Oak Ridge National Laboratory’s (ORNL) High Flux Isotope Reactor (HFIR) were used
- Spacers were used to align the targets in the Advanced Test Reactor (ATR) core
- Analysis and lessons learned from the qualification process will inform future target design and position qualifications



Design Support

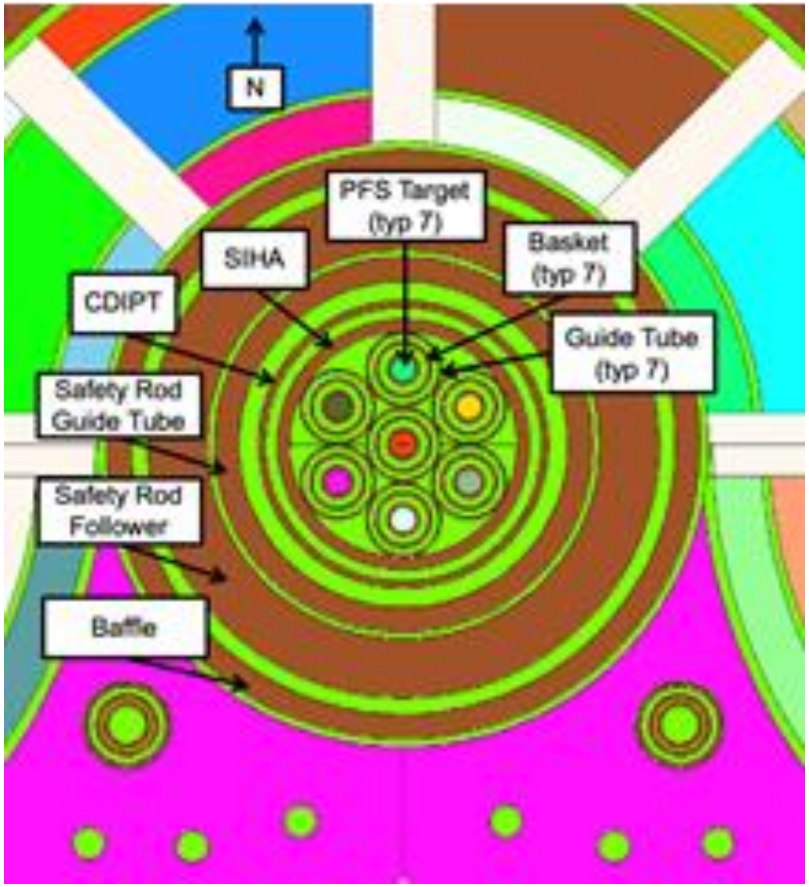
- Target Qualification required the design and fabrication of baskets, spacers, and specialized tools to handle and position the targets in ATR
- A Battelle Research Reactor cask was fabricated and payload licensing completed to enable shipment of irradiated targets containing Pu-238 for processing at ORNL
- Prior work on qualifying the I-7 position was leveraged for qualifying the South Flux Trap





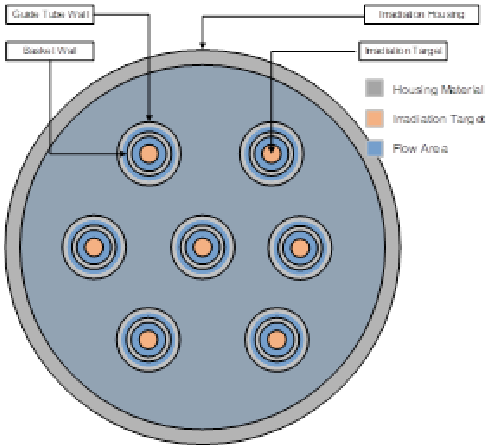
South Flux Trap Neutronics Qualification

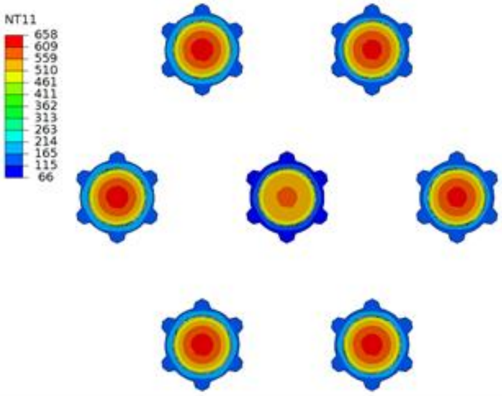
- Neutronics model is created to reflect CAD models developed by the design engineer
- ATR operational parameters are assumed to estimate irradiation induced heating and reactivity changes
  - ATR operational time and power levels vary by cycle
  - Parameters bias the analysis in a more conservative (safer) manner
- MCNP is used to perform neutronics analysis
- ORIGEN is used for cross section data
- Baseline requirement of 60 day cycle was used for qualification
- ~30 grams of Pu-238 will be produced in the South Flux Trap
  - Approximately 2 times the amount produced in the I-7 position in 1/5 the time



South Flux Trap Thermal Qualification

- Thermal qualification was dependent on neutronics qualification
  - Several iterations were needed
  - Goal was to prevent capsule failure from overheating and calculate a minimum post-irradiation cooling time
- Finite volume methodology tool RELAP5-3D and finite element tool ABAQUS used to simulate thermal and hydraulic behavior
  - Models heating rates that included operational lobe power, instrument measurement error, and outer ship rotation
  - Normal operating and accident scenarios covered

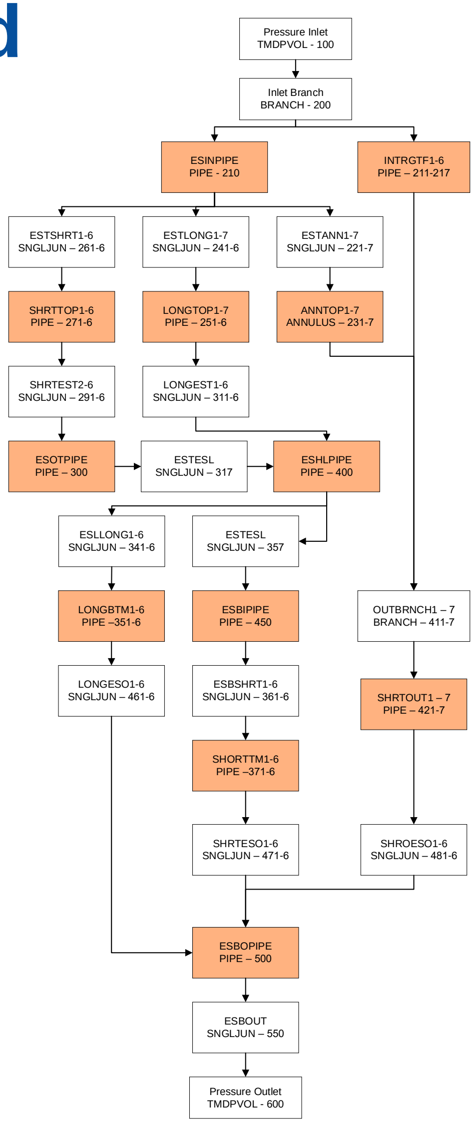




RELAP Models Developed and Schematic

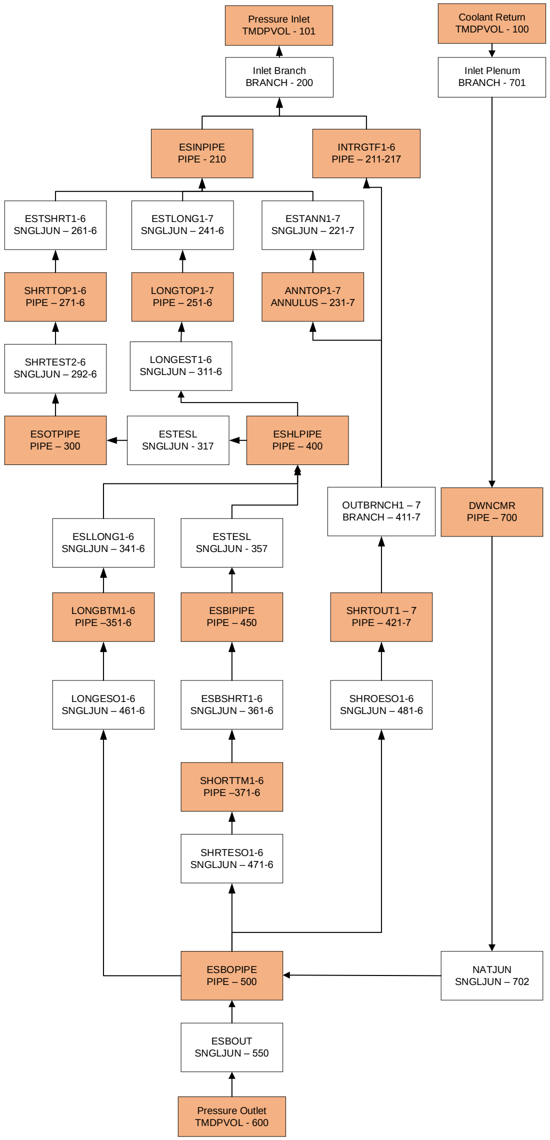
Based on analysis guidelines, the following RELAP5-3D models were constructed:

1. Nominal flow rates (initialize FEA analysis),
2. LOCA analysis (FIR, DNBR),
3. Free convection.



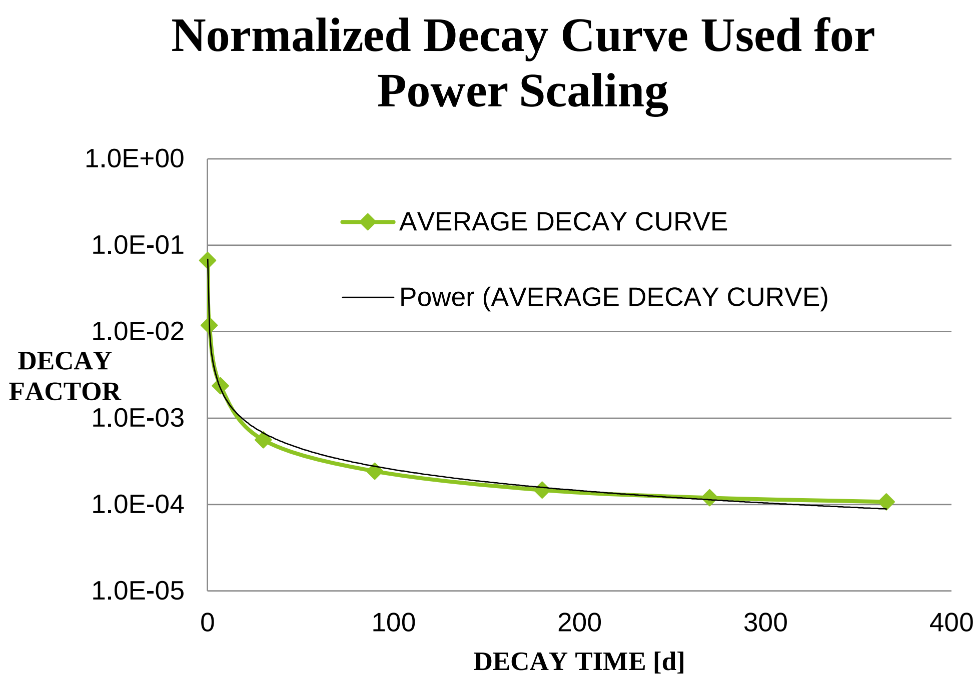
Natural Convection Model Schematics

The natural convection model schematic features its own feed volume, downcomer pipe, to represent a free convection loop.

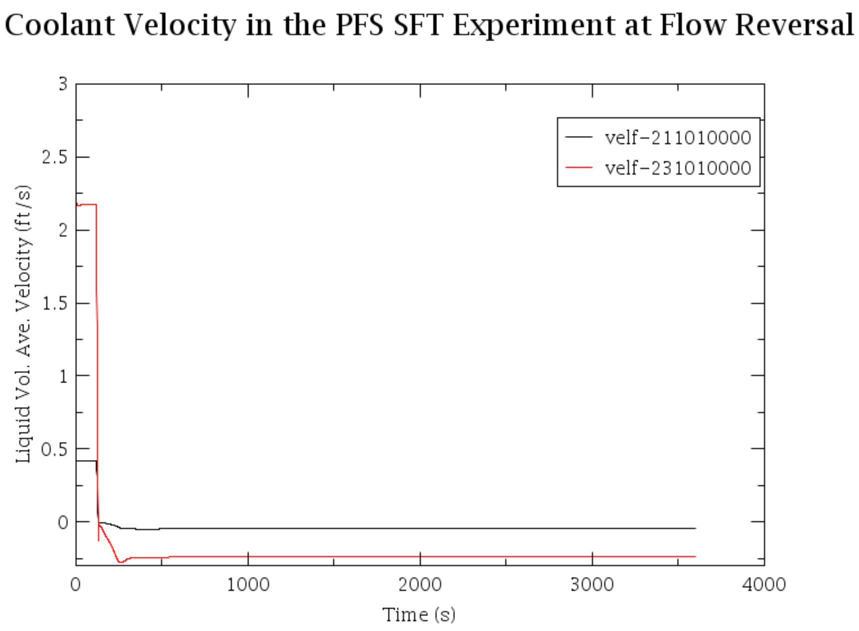


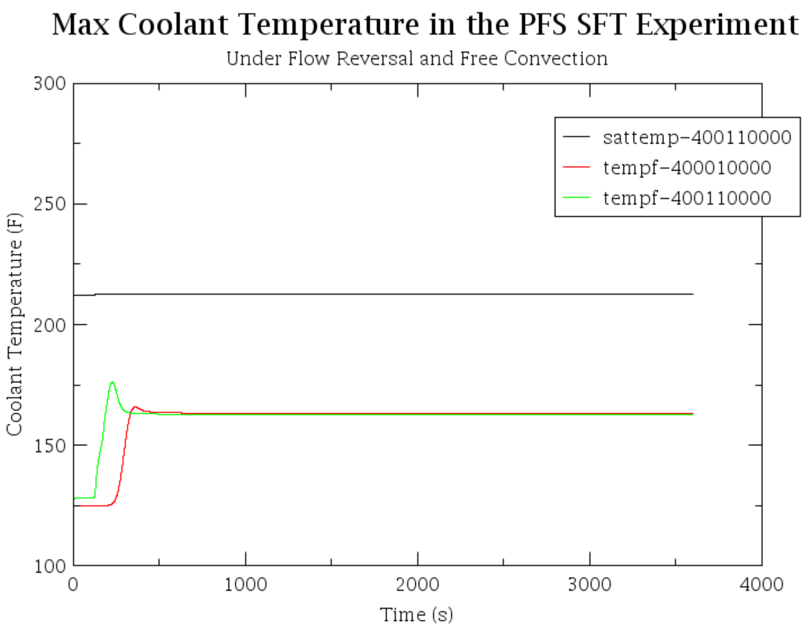
Decay Heat

Due to the unique isotopics of this experiment, a unique decay power curve was developed with input from neutronics and implemented in the RELAP model.



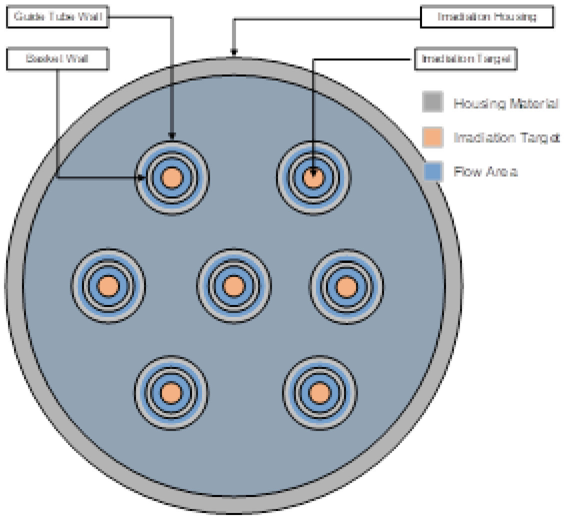
Natural Convection Results

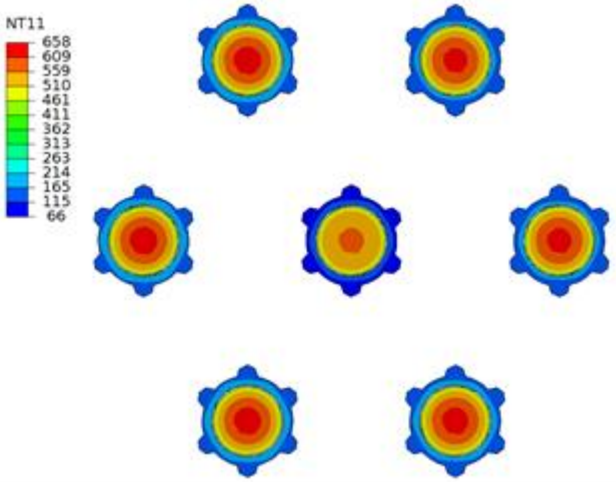




South Flux Trap Structural

- Structural analysis evaluated target and associated hardware stress and strain under various potential loading scenarios
  - Internal pressure within the target due to fission gas production
  - External pressures
  - External pressure differential along the length of the target
  - Pressure and skin friction drag forces from coolant flow
  - Flow induced loads and vibrations
  - Handling loading
- ASME B&PV Code used because it is a nationally accepted design and analysis approach





Advanced Test Reactor – Critical (ATRC)

- Initial irradiation testing was performed on NpO2 sensors in the ATRC
- ATRC is a low power copy of ATR which runs at 600 W rather than 110 MW
- 20 minute run was used to benchmark analysis
- A target assembly of 7 targes was irradiated at low power in ATRC to determine reactivity worth
- Flux wires were used in ATRC to determine the flux profile

ATRC Operations

- Targets shipped from ONRL were unloaded at INL’s ATR Complex
- An ATRC run was performed
- Targets from the ATRC run were reconfigured after testing to prepare for insertion into ATR
- Targets assembled under water by ATR Canal Operations
- Target assembly was inserted into the South Flux Trap
  - Inventoried to sure it is property seated into the chopped dummy in-pile tube

Future Work

- The INL team is currently working to qualify several ATR core positions with an updated target design
  - New design will have a full length of the ATR core
  - Two targets will be stacked on top of each other to simplify Pu-238 processing at ORNL hot cells
- Currently plan on qualifying
  - North East Flux Trap (NEFT)
  - Inner A
  - H Position
  - South Flux Trap (SFT)
  - East Flux Trap (EFT)
- Qualification of multiple positions enables ATR to meet production goals for Pu-238

Acknowledgments

This work was funded through DOE & NASA Interagency Agreement # NNH19OB05A and DOE contract DE-AC05-00OR22725.

Questions?