INL/CON-21-62362-Revision-0

OVERVIEW OF RECENT PU-238 PRODUCTION ACTIVITIES AT IDAHO NATIONAL LABORATORY

April 2021

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Changing the World's Energy Future

Idaho National Laboratory

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Introduction

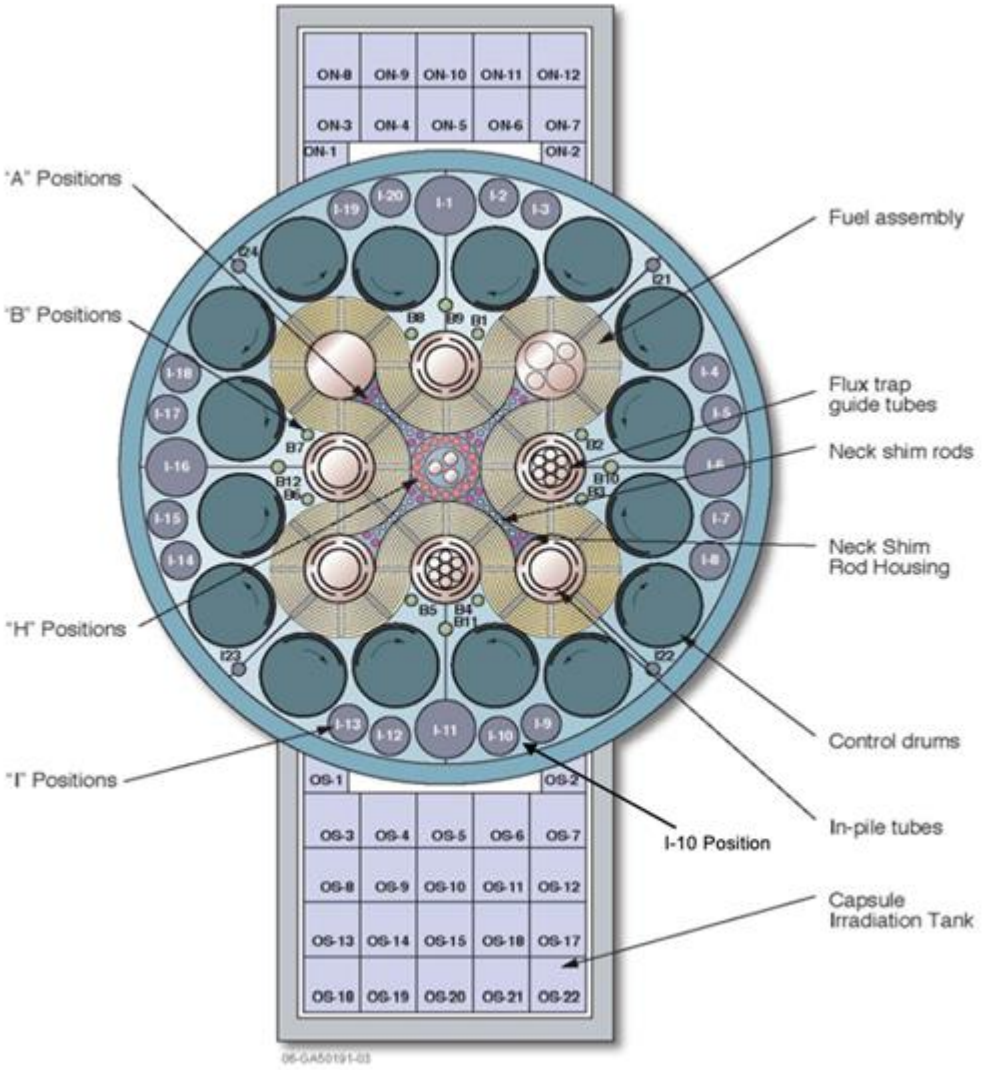
- The production of Radioisotope Power Systems (RPS) has been an ongoing endeavor for the U.S. Department of Energy (DOE) and its predecessor agencies for the past six decades.
- DOE has contracted the Idaho National Laboratory (INL) to provide RPS in support of National Aeronautics and Space Administration (NASA) missions
- INL is supporting the Department of Energy's efforts to restart Pu-238 production for use in future NASA missions that use Radioisotope Power Systems (RPS)
- Plutonium-238 Fuel Services (PFS) is a collaborative effort between Idaho National Laboratory (INL) and Oak Ridge National Laboratory (ORNL) to produce a constant rate of Pu-238 production
- INL has qualified targets originally designed for the High Flux Isotope Reactor for irradiation in the Advanced Test Reactor's (ATR) I-7 position and the South Flux Trap
- The process for qualifying targets containing Np-237 and irradiating in ATR is described in the following presentation

Overview

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

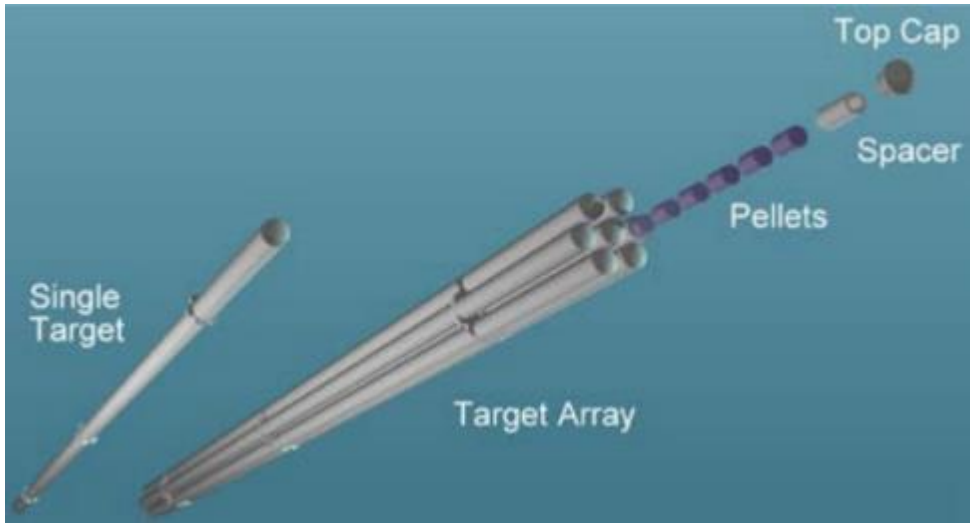
Overview of ATR Positions

- I-7 and South Flux Trap (SFT) are currently qualified for Pu-238 production with targets that are shorter than the core
  - Targets are about half the height of ATR's 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^2-s



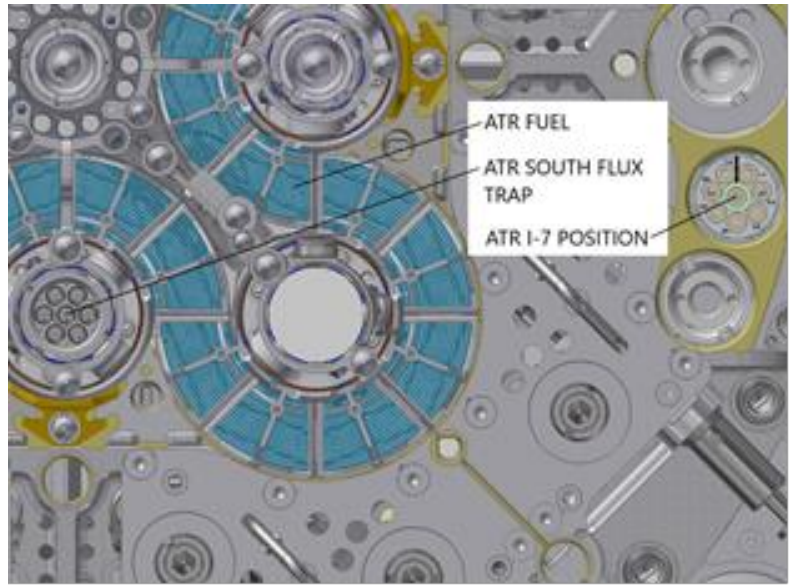
Target Design and Qualification

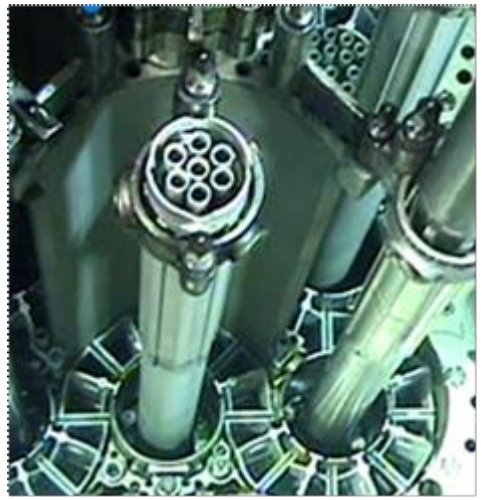
- Existing targets designed for Oak Ridge National Laboratory's (ORNL) High Flux Isotope Reactor (HFIR) were used
- Spacers were used to align the targets in the Advanced Test Reactor (ATR) core
- Analysis and lessons learned from the qualification process will inform future target design and position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



Design Support

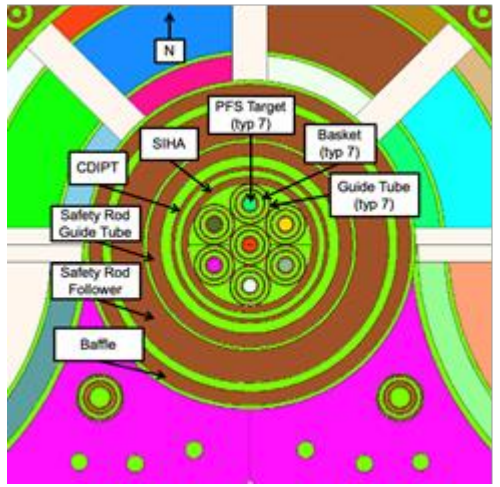
- Target Qualification required the design and fabrication of baskets, spacers, and specialized tools to handle and position the targets in ATR
- A Battelle Research Reactor cask was fabricated and payload licensing completed to enable shipment of irradiated targets containing Pu-238 for processing at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





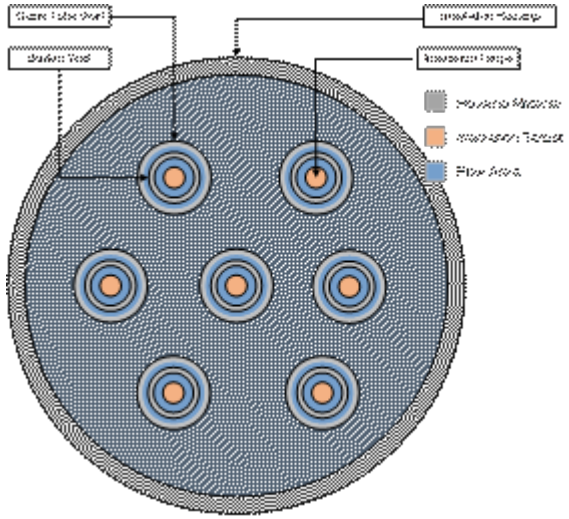
South Flux Trap Neutronics Qualification

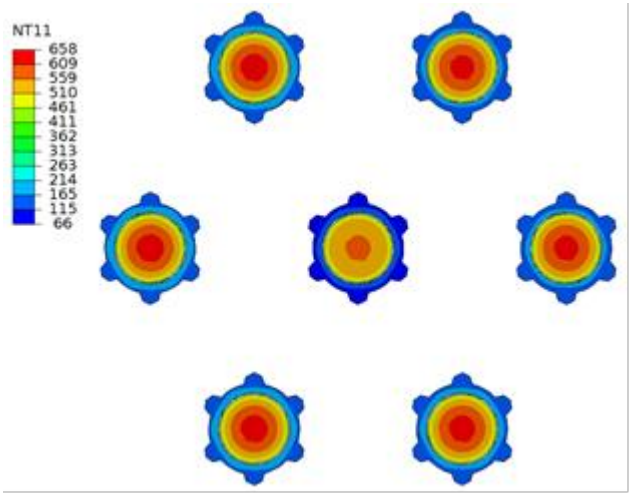
- A neutronics model was created to reflect CAD models developed by the design engineer
- ATR operational parameters were assumed to estimate irradiation induced heating and reactivity changes
  - ATR operational time and power levels vary by cycle
  - Parameters biased the analysis in a more conservative (safer) manner
- MCNP was used with ORIGEN to perform neutronics analysis
- 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



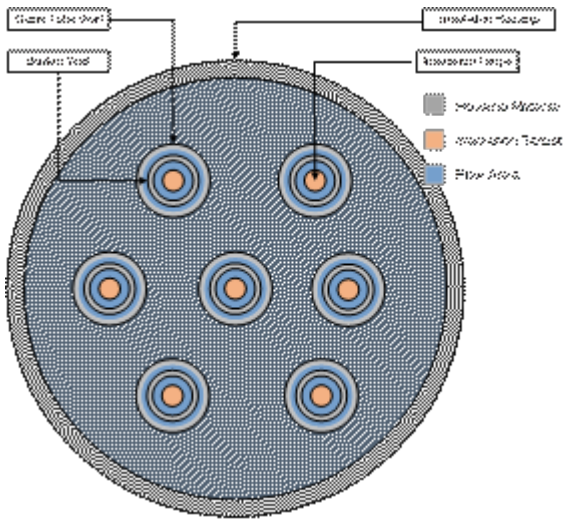
South Flux Trap Thermal Qualification

- 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

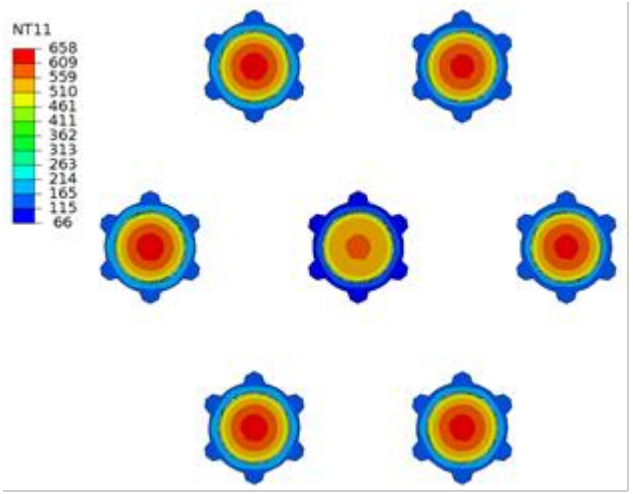




South Flux Trap Structural Qualification



- 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 targets 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
- Target reactivity and effect on axial flux profile was measured in ATRC
- 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
  - Verified to ensure it is property clocked and 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

Column Header	Positions in Target	# of Locations in ATR
NEFT	23	1
Inner A	1	8
H Position	1	14
B Position	1	8
South Flux Trap	7	1
East Flux Trap	7	1
I Position	1 to 7	23

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