INL/MIS-24-78336-Revision-0

Pu-238 Production At Idaho National Laboratory

June 2024

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Changing the World's Energy Future

Idaho National Laboratory

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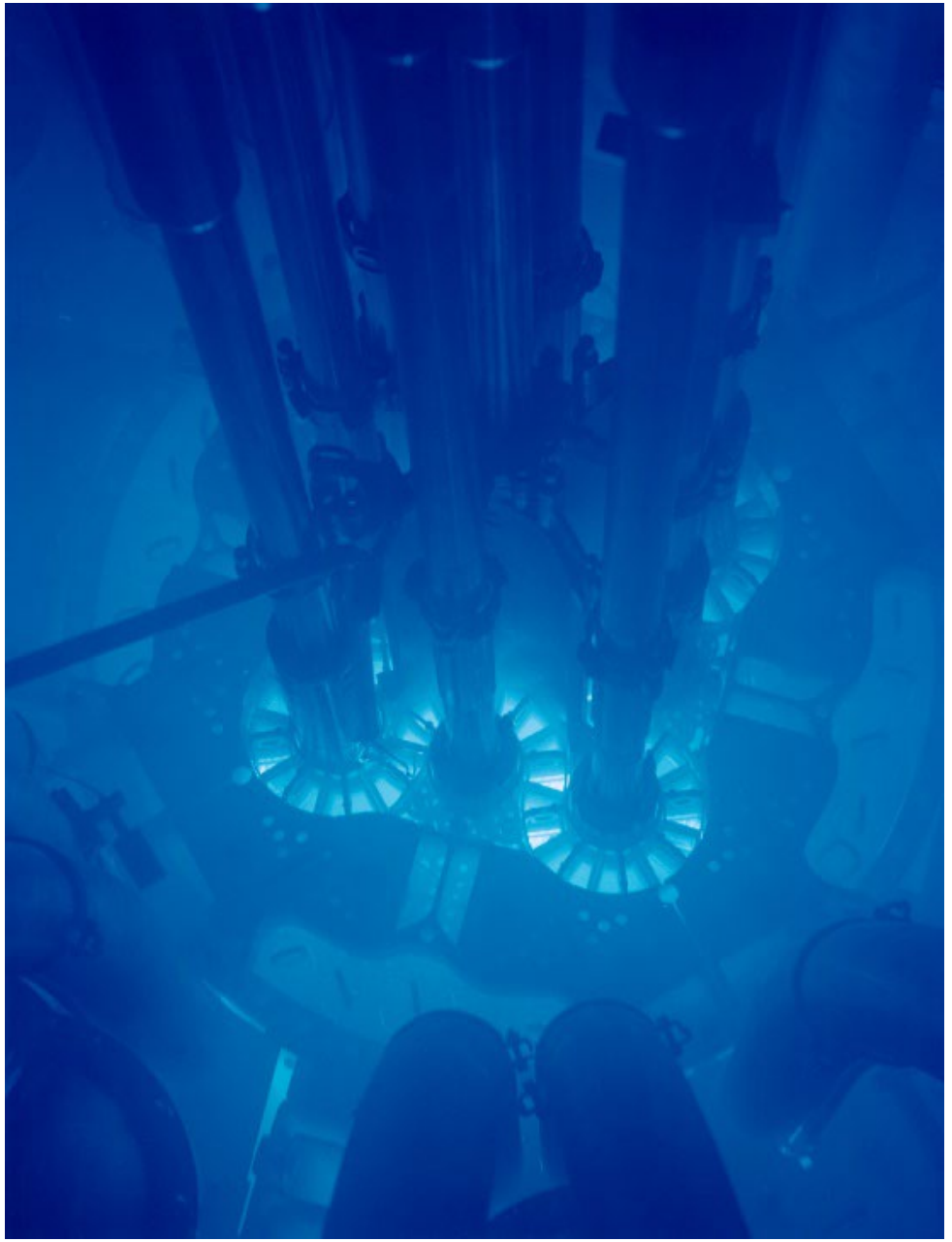
Pu-238 Production at Idaho National Laboratory

Overview

- Program Overview
- Recent Work
- Process Improvements
- Future Work

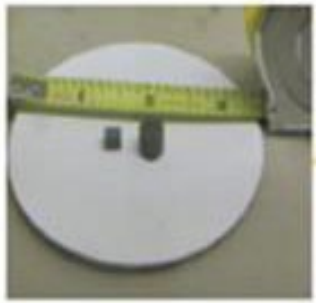


Pu-238 Production Background

- One goal of the Constant Rate Production (CRP) program is to produce at least 1.5 kg of Pu-238 heat source material every year for future NASA deep space missions
  - Production in the Advanced Test Reactor (ATR) at INL and the High Flux Isotope Reactor (HFIR) at ORNL.
- INL is currently working to qualify as many positions as possible so Pu-238 production will be a backup experiment in these positions
  - If other experiments are having difficulty qualifying and miss the insertion date, Pu-238 production will replace the experiment
  - Enables better utilization of the ATR core by ensuring that positions are fully utilized
- Pu-238 production targets irradiated in ATR are fabricated and supplied by ORNL
- INL has worked with ORNL to advance the target designs for improved production rates, handling, and fabricability
- The northeast flux trap (NEFT), south flux trap (SFT), east flux trap (EFT), inner-A and H positions have all been qualified for the insertion of the ATR GEN I target.

Pu-238 Oxide Fuel Life Cycle for RPS Program

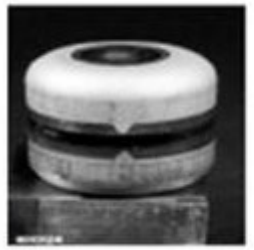
Pu-238 Isotope Production
- Oak Ridge National Laboratory
- Idaho National Laboratory

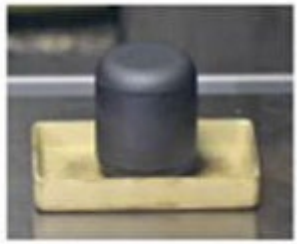


Neptunium Target

Fuel Clad Manufacturing
- Oak Ridge National Laboratory
- Los Alamos National Laboratory

Iridium Alloy Clad Vent Set





Pu-238 Ceramic Fuel Pellet

Fueling/Testing/Delivery
- Idaho National Laboratory

Launch Support
- Idaho National Laboratory

RPS Testing

Fuel Clads

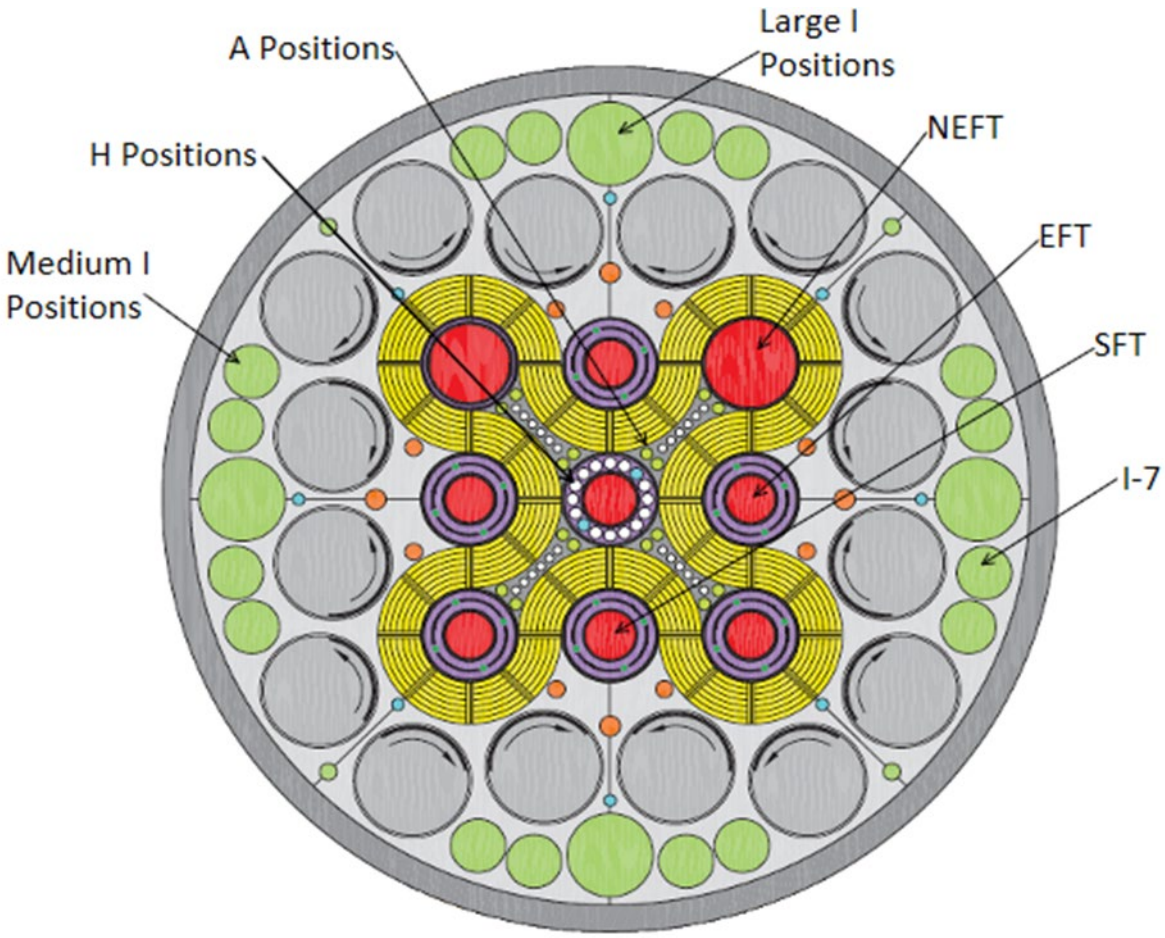
INL Pu-238 Production Life Cycle

1. INL packages and transfers Np-237 to Oak Ridge National Lab (ORNL)
2. ORNL fabricates targets and inserts Np-237 pellets. Then ORNL ships a portion of the completed targets to the Idaho National Lab (INL) for irradiation and keeps some to be irradiated in the High Flux Isotope Reactor (HFIR).
3. Targets are irradiated in INL's Advanced Test Reactor (ATR) and HFIR to convert Np-237 to Pu-238. All targets are processed at ORNL.
4. ORNL processes the targets and ships the Pu-238 to Los Alamos National Lab (LANL)
5. LANL fabricates Pu-238 into iridium clad pellets and ships them to INL to fuel radioisotope thermoelectric generators (RTG).
6. INL fuels the RTG and performs acceptance testing. Then the RTG is shipped to support the identified launch window at Kennedy Space Center.

**ORNL also irradiates the same design of targets in HFIR. Targets from both facilities are processed at ORNL and sent to LANL.*

Recent Pu-238 Production Activities

- All of the ATR inner core is qualified for ATR Gen 1 production target with 20% Np concentration
  - Allows 2 targets stacked on top of each other per irradiation position
- Completed qualification of a 30% Np concentration target in the ATR inner core
  - Increases production ~25% to 35% per target
  - Allows a running change at ORNL to move to higher performing target
- Current activities
  - Qualification for reduced loading in flux traps
    - Provides flexibility in the event of target supply disruptions from ORNL
  - Qualification of medium and large I positions
    - ~2 year irradiation campaign (~six cycles of 60 day length) with high assay material



Recent Pu-238 Production Quantities

Number of Targets By Position

	CY2021	CY2023		Projected CY2024		
Position	169A	171A	171B	173A	173B	173C
Inner A		2				
H		2	2			
SFT	7	7	1			
NEFT		46	46	46	46	46
Totals by Cycle	7	57	49	46	46	46
Yearly Total	7	106		138		

Grams of Pu-238 by Position

	CY2021	CY2023		Projected CY2024		
Position	169A	171A	171B	173A	173B	173C
Inner A		6				
H		6	6			
SFT	30	30	4			
NEFT		144	144	144	144	144
Totals by Cycle	30	186	154	144	144	144
Yearly Total	30	340		432		
Yearly Total Pu238 Heat Source	38	429		545		

Target Progression

HFIR GEN II

- Initial irradiation in I-7
- Final Irradiation in the SFT
- 33.5” Long
- Single target per position centered around core centerline

ATR GEN I 20 vol-% Np

- Initial irradiation in the NEFT
- Qualified for insertion into the NEFT, SFT, Inner A, and H positions
- 28.7” Long
- Two targets per positions
- Utilizes full height of ATR Core

ATR GEN I 30 vol-% Np

- Same Target Body and pellet stack as the ATR GEN I Target
- Qualified for insertion into the NEFT, SFT, Inner A, and H positions
- Qualified up to 35 vol-% Np to simplify fabrication requirements

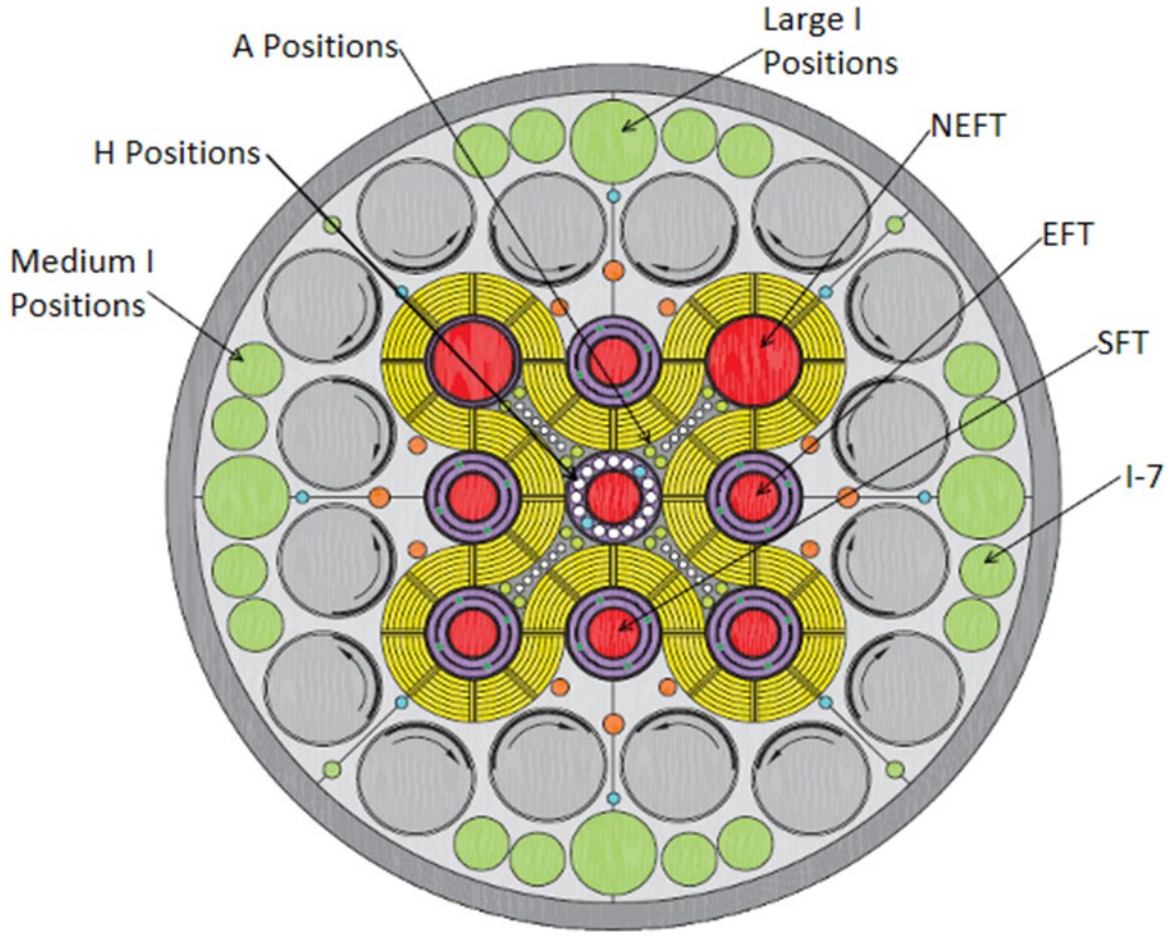
HFIR GEN II Target

ATR GEN I Target

Production Increases from Improved Target Design

Position	HFIR GEN II Average Production	ATR GEN I 20 vol-% Peak Production	ATR GEN I 30 vol-% Peak Production
EFT			5.67 grams
SFT	4.21 grams	4.67 grams	6.04 grams
NEFT		3.48 grams	5.65 grams
H		3.41 grams	4.40 grams
Inner-A		3.66 grams	4.80 grams

*All values are grams of Pu-238 per single target irradiated for 60 days in ATR

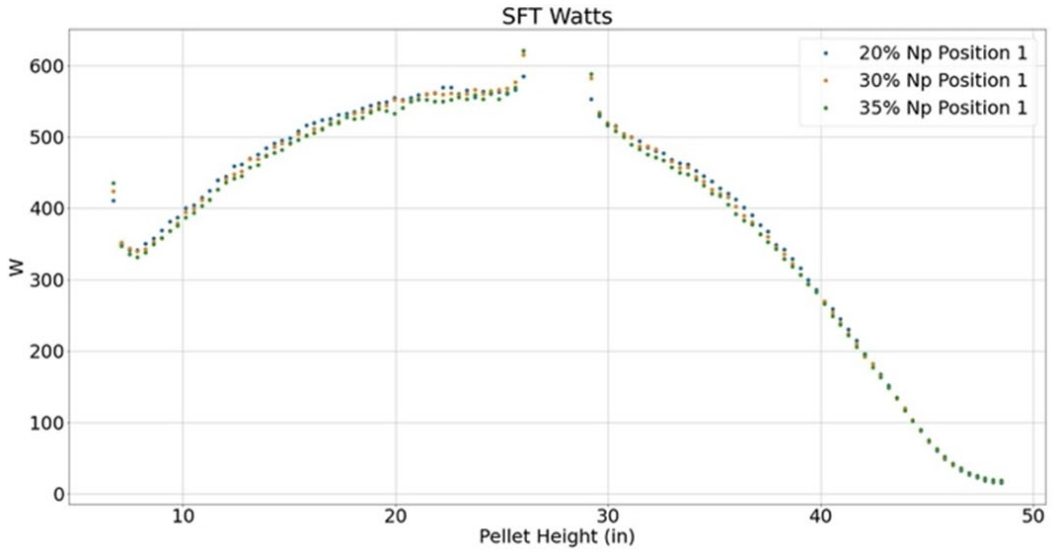


Evolutionary improvements in target design enables a 30% to 60% increase in production while using no additional irradiation positions

Neutronics Analysis 30% Np Qualification

- The table below gives averages for production values at 60-days for a single target with 30 vol-% Np.
- The production rates and Np conversion parameters are for each of the individual positions. Each position is scaled to its respective bounding lobe power – 22 MW in the NE, 25 MW for the inner-A and H positions, 25.7 MW in the S, and 23.7 in the E.
- Over a 60-day cycle, the NEFT has a maximum total production of 202 g Pu-238, the SFT has a maximum total production of 71.6 g Pu-238, and the EFT has a maximum total production of 67.4 g Pu-238.

Position	Avg. Pu-238 (g)	Avg. Assay (%)	Lobe Power (MW)	Number of Positions
EFT	4.82	89.5	23.7	7
SFT	5.11	88.9	25.7	7
NEFT	4.39	90.9	22	23
H	4.15	93.3	25	14
Inner-A	3.90	93.7	25	8



Shipping Improvements

Modified shipping containers to increase loading up to 5 targets rather than 1 per 85 gallon drum

Changed shipping carriers to ensure a firm delivery date, simplifying offload to the ATR canal

Interim storage cart was designed and built to allow target delivery when the ATR canal is unavailable

Future Work

- Complete qualification of medium and large I positions
- Collaborate with ORNL for a clean sheet target design to increase production rates, improve fabricability, and decrease fabrication costs
- Complete design and build of a transfer cask for ORNL to unload a BRR cask at the REDC facility

Acknowledgments

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