

22 September 2026

Paul Gilbreath
Neutronics Analyst

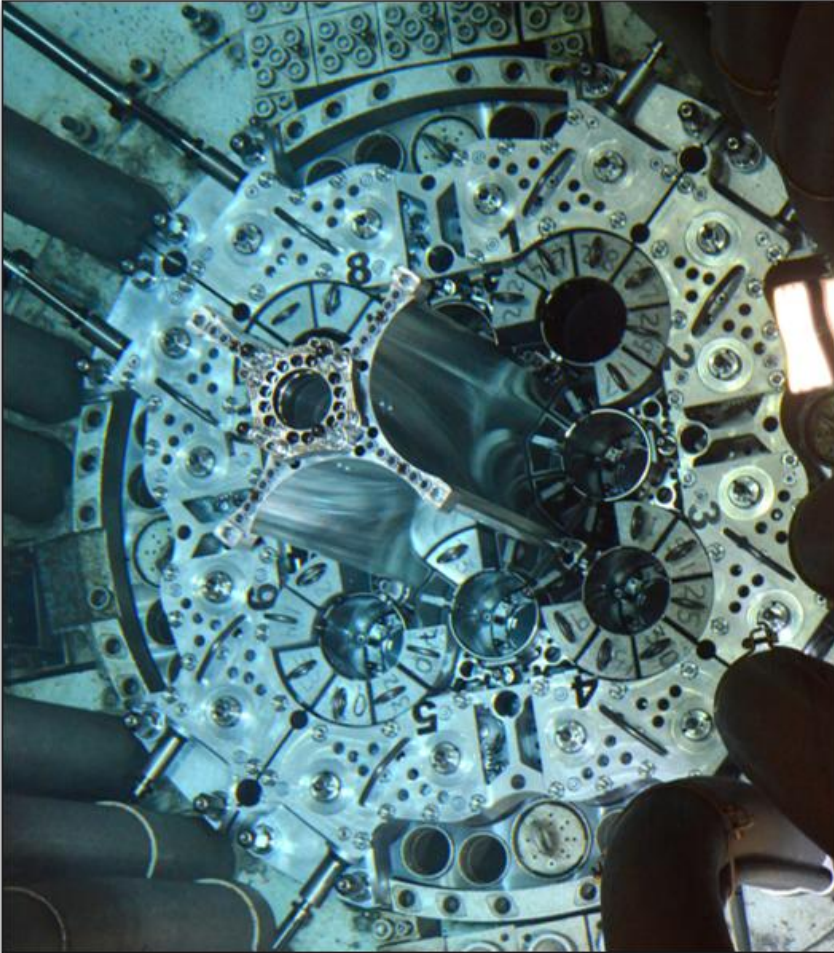
As-Run neutronic analysis of U-10Mo monolithic fuel plate experiments in the Advanced Test Reactor

Battelle Energy Alliance manages INL for the
U.S. Department of Energy's Office of Nuclear Energy



Idaho National Laboratory

As-Run neutronic analysis of U-10Mo monolithic fuel plate experiments in the Advanced Test Reactor



ATR core

Outline:

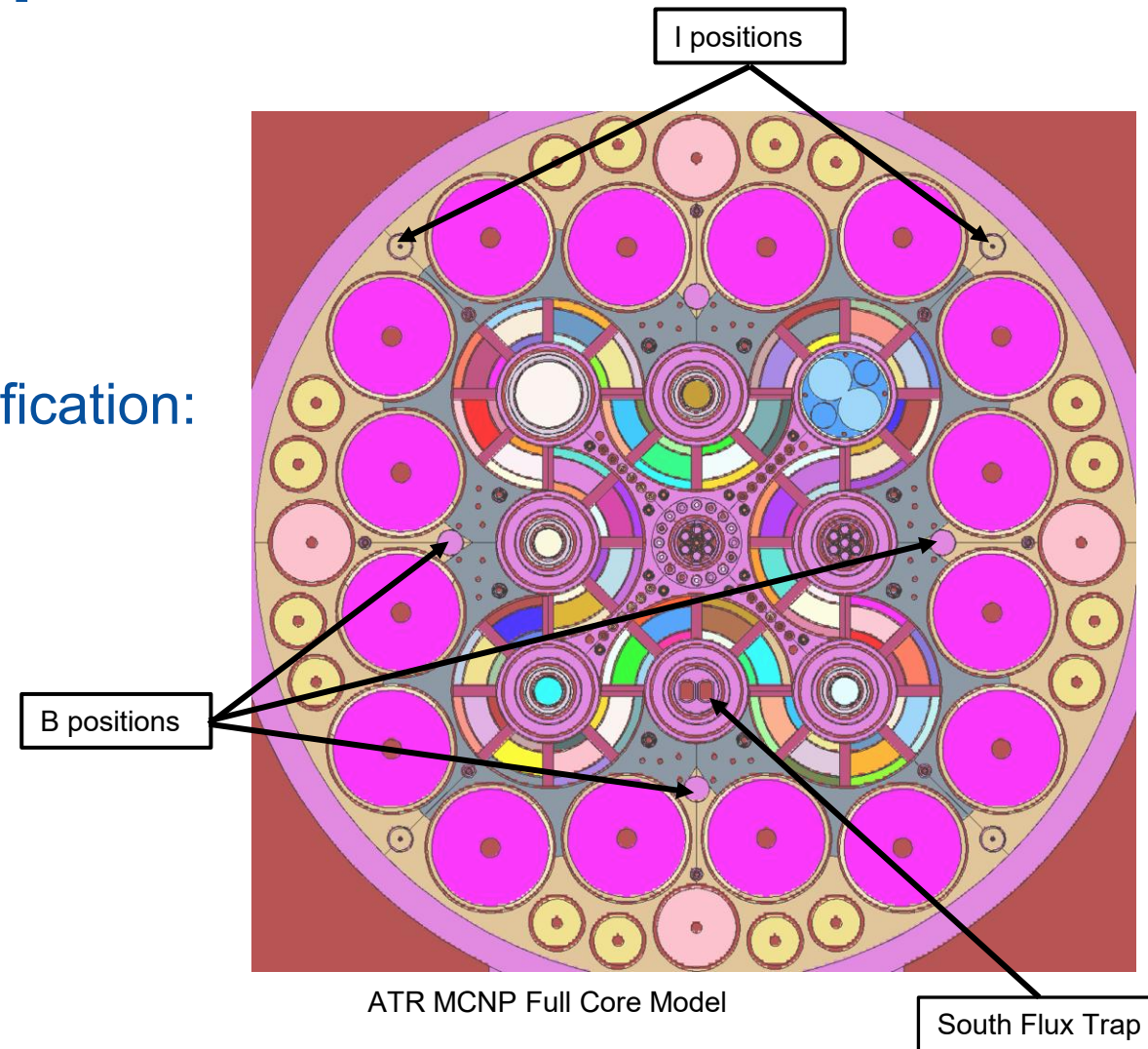
- Background
- Experiment Description
- Model Description
- As-Run Methods
- Results
- Validation of Results
- Acknowledgements

Background

- The U.S. Department of Energy (DOE) Office of Materials Management and Minimization needs to convert the five U.S. High Performance Research Reactors (HPRR) from highly enriched uranium to low enriched uranium (LEU).
- Reactors regulated by the Nuclear Regulatory Commission (NRC):
 - Massachusetts Institute of Technology Reactor (MITR)
 - University of Missouri's Research Reactor (MURR)
 - National Bureau of Standards Reactor (NBSR)
- Reactors regulated by DOE:
 - High Flux Isotope Reactor
 - Advanced Test Reactor (ATR)
- Second mini-plate experiment (MP-2) will focus on NRC reactors with small consideration of ATR low power requirements.

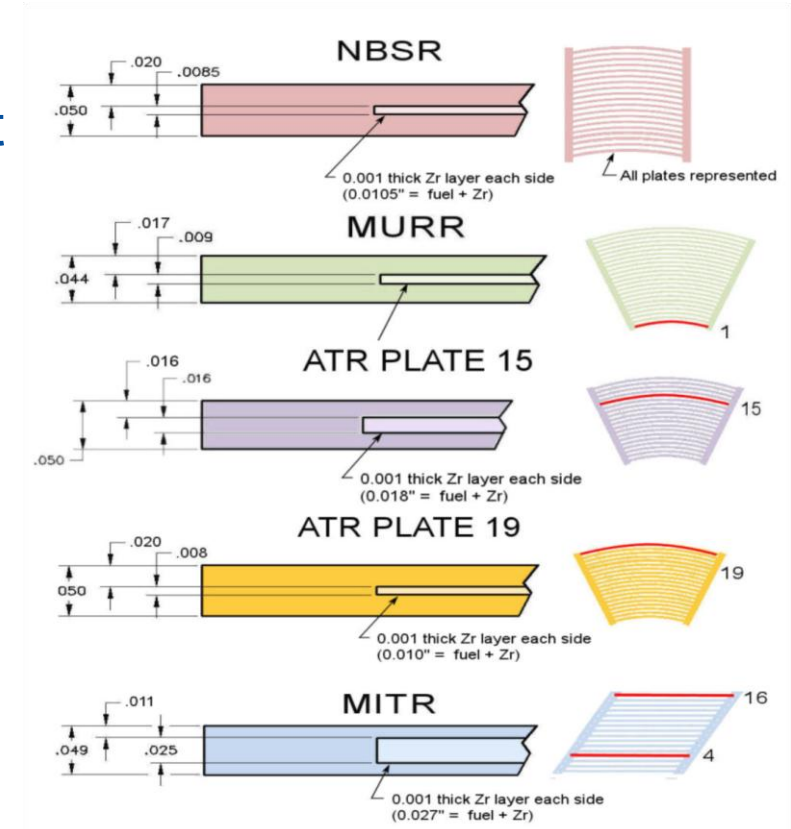
MP-2 Experiment Description

- Goal: qualify the LEU fuel meets irradiation performance requirements for NRC reactors
- ATR the chosen reactor to support fuel qualification:
 - Can support many irradiation conditions
- MP-2 experiment positions in the ATR:
 - ‘I’ positions (I-21, I-24)
 - ‘B’ positions (B-10, B-11, B-12)
 - South Flux Trap
- 8 ATR cycles: 171A through 175C



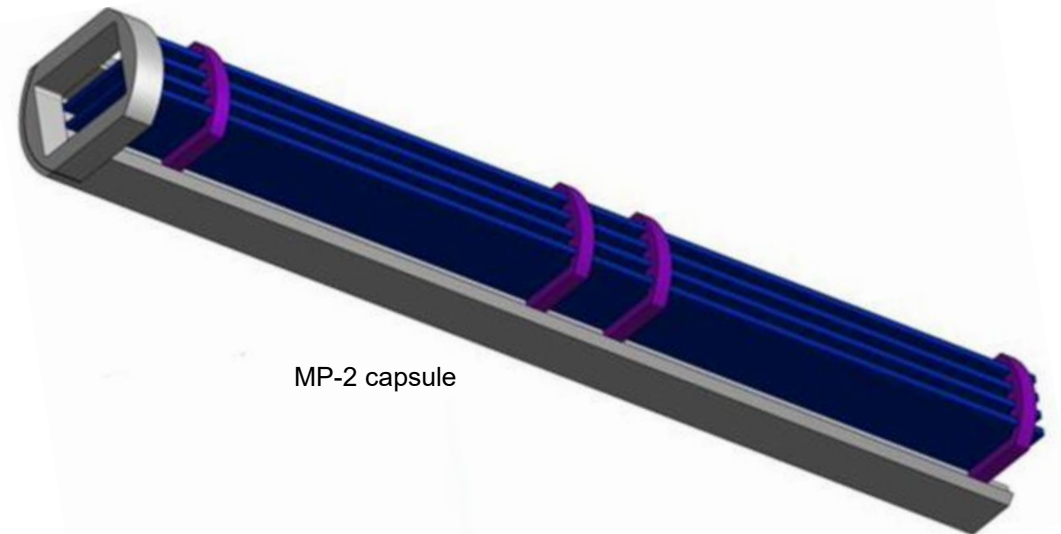
MP-2 Experiment Description

- Fuel qualities:
 - U-10Mo monolithic fuel with 19.75% U-235 enrichment
 - Plate-type with aluminum cladding
 - Zirconium interlayer
 - Fuel region: 1.905 cm × 8.255 cm × thickness
 - Fully clad plate: 2.540 cm × 10.147 cm × thickness



MP-2 Experiment Description

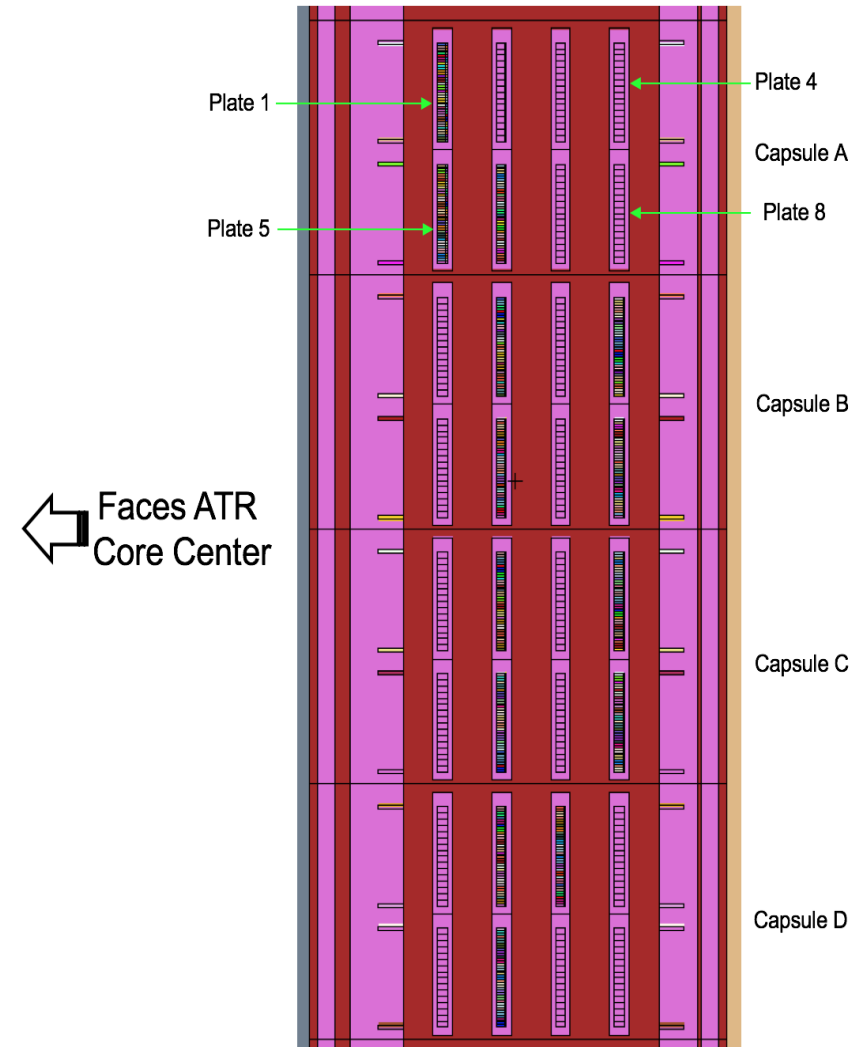
- Single test train in B and I positions and two test trains in the South Flux Trap
 - Test train contains four capsules
 - Capsule contains two rows of four plates
- Hafnium rings suppress corner peaking (except NBSR plates)
- Irradiation conditions per plate type:
 - Three power conditions
 - Peak targets for fission density and power density
 - Conditions evaluated on representative reactor's safety basis fuel node



MP-2 capsule

MP-2 Model Description

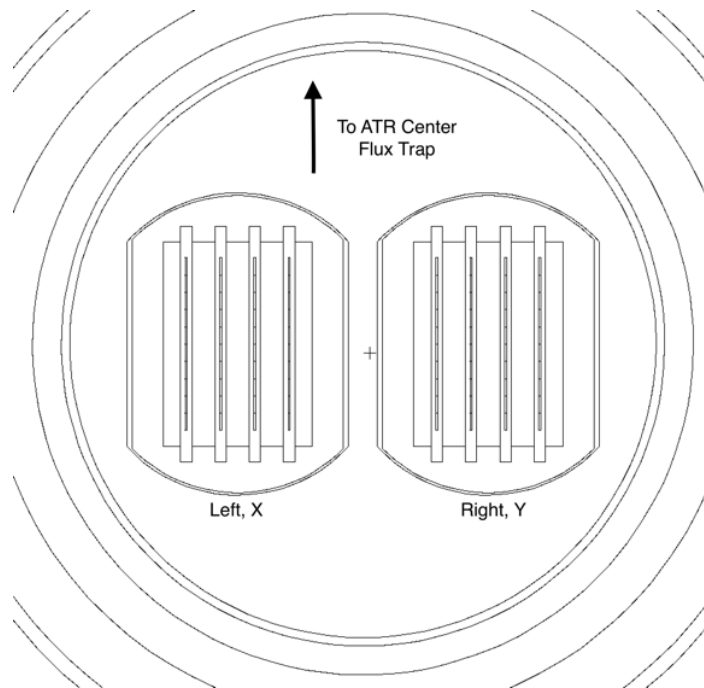
- Goal: demonstrate programmatic requirements were met
- Three-dimensional Monte Carlo N-Particle (MCNP6.3) model based on current program drawings
 - Utilizes an ATR full-core model
 - ENDF/B-VIII and JENDL-3.2 cross-section libraries
- Depletion using SCALE6.2
 - ATR-specific library
 - Experiment-specific MCNP-generated cross-sections



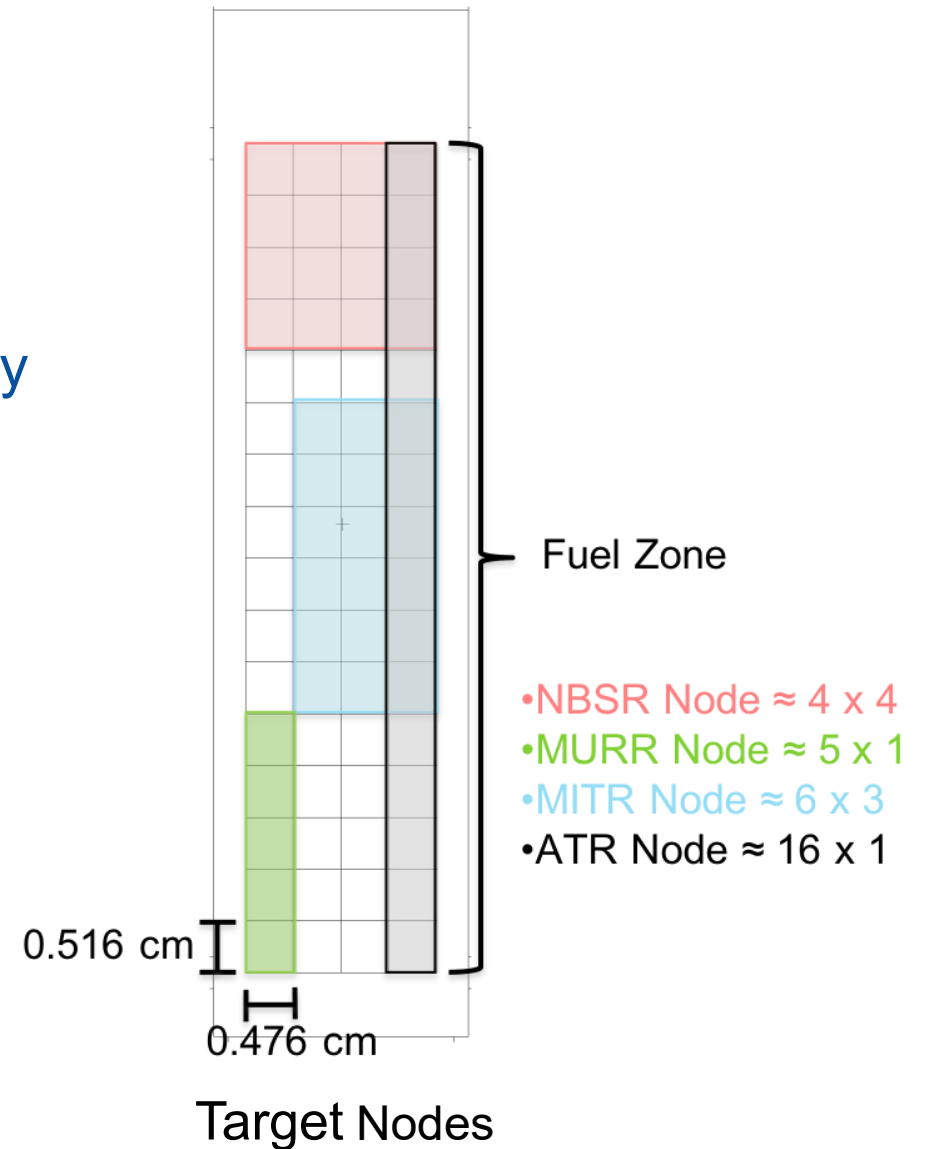
MP-2 B-11 test train axial cross section
*not to scale

MP-2 Model Description

- 4 × 16 mesh for each fueled plate
 - More accurately track burnup and fission density
 - Aids specific reactor node analysis
 - Averaged anywhere on plate

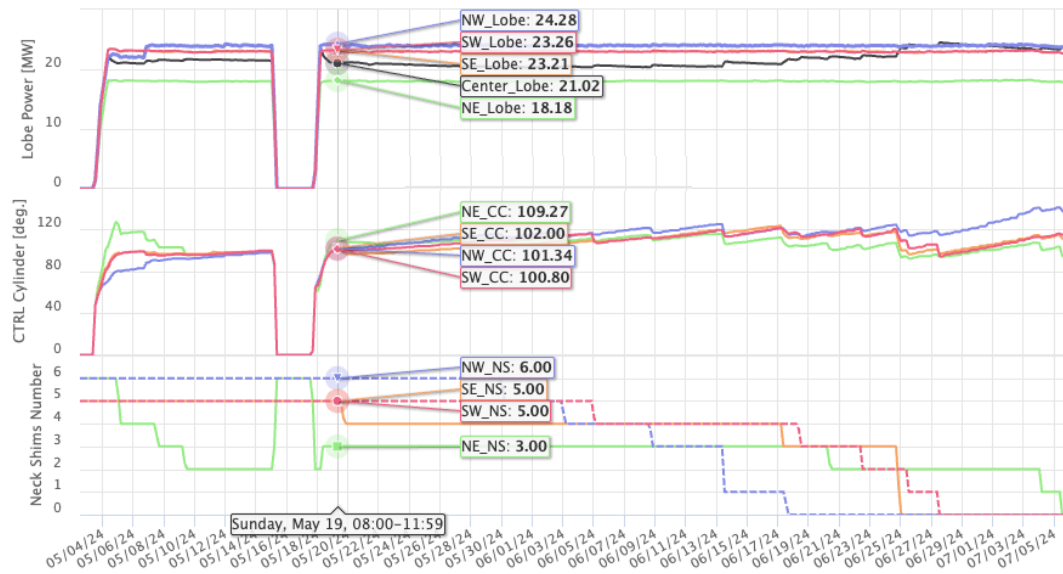


MCNP model of MP-2 in SFT



MP-2 As-Run Methods

- ATR fuel element loading
- ATR Surveillance and Data Acquisition System
 - As-run power history and control history
 - Hourly data used to refine depletion timesteps



Reactor data for Cycle 173A-1

POWER HISTORY -- LOBES

-----N-16 Unconstrained (MW)----- -----N-16 Constrained (MW)-----

Time	Date	NW	NE	C	SW	SE	NW	NE	C	SW	SE
1459	07-25-19	19.58	16.73	24.32	25.05	24.89	* 19.01	16.11	23.92	24.38	24.27
1659	07-25-19	19.58	16.68	24.07	25.58	25.34	* 18.84	15.86	23.54	24.70	24.53
1459	07-26-19	20.99	17.71	23.43	26.04	26.04	* 20.20	16.84	22.86	25.11	25.18
1459	07-28-19	21.12	17.96	23.12	26.20	26.17	* 20.05	16.79	22.36	24.94	25.01
1559	07-30-19	20.99	18.10	23.53	27.17	25.99	* 19.95	16.96	22.80	25.95	24.86
1459	08-04-19	20.96	17.92	23.52	27.09	26.21	* 19.87	16.74	22.75	25.82	25.04
2359	08-13-19	21.02	17.85	23.52	26.93	27.04	* 20.07	16.81	22.85	25.81	26.01
1459	08-14-19	21.00	17.98	23.46	27.12	27.13	* 19.93	16.81	22.70	25.86	25.96
1459	08-24-19	20.85	17.94	22.62	27.14	27.06	* 19.86	16.86	21.92	25.99	25.99
1459	09-03-19	20.97	18.02	22.60	27.21	27.10	* 20.01	16.98	21.92	26.10	26.07
0859	09-06-19	20.74	17.97	22.36	26.72	26.79	* 19.74	16.87	21.65	25.55	25.71

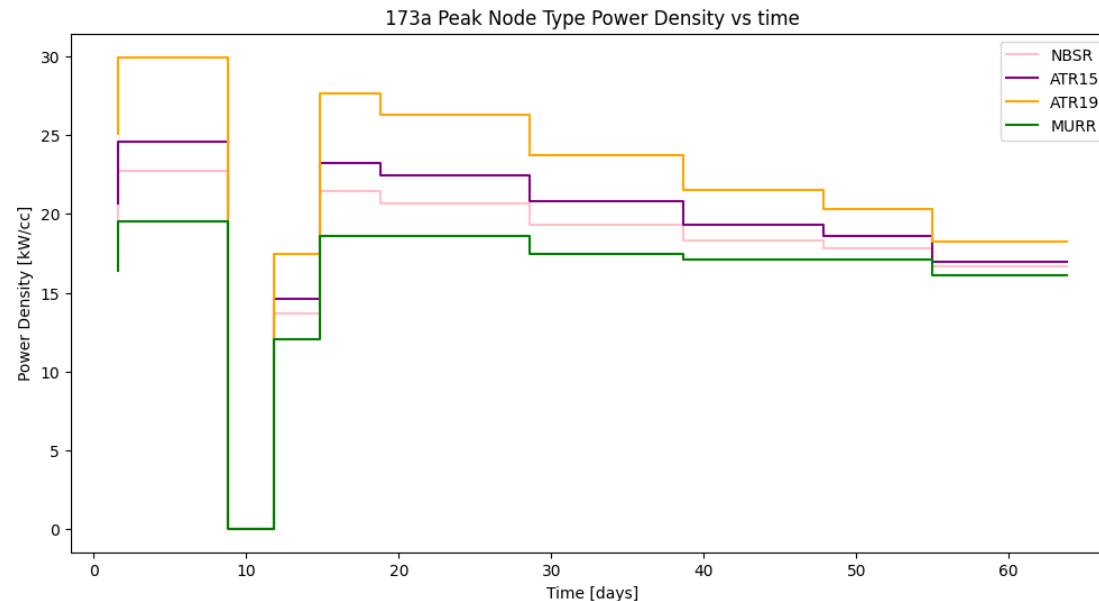
REACTOR CONTROL HISTORY

		Outer Shims (deg)					Reg Rods-		Neck Shims-----			
		NW	SW	NE	SE	(in)			NW	NE	SW	SE
Time	Date	N1-2	W3-4	W1-2	S3-4	N3-4	E1-2	E3-4	S1-2	RR-1	RR-2	
1459	07-25-19	81.8	81.4	55.8	55.6	40.2	40.1	54.9	55.2	25.6	47.8	IIIII IIIII IIIII IIIII
1659	07-25-19	85.5	86.0	60.4	60.3	42.7	42.8	59.8	59.9	24.1	47.8	IIIII IIIII IIIII IIIII
1459	07-26-19	113.5	113.1	75.1	75.0	59.9	59.9	76.0	76.2	29.1	47.8	IIIOOO IIIII IIIII IIIII
1459	07-28-19	117.4	117.3	78.0	78.0	62.8	62.7	78.5	78.6	26.0	47.8	IIIOOO IIIII IIIII IIIII
1559	07-30-19	106.6	106.3	79.7	80.0	60.2	60.3	75.5	75.4	25.4	47.8	IIIOOO IIIII IIIII IIIII
1459	08-04-19	102.9	102.9	78.5	78.5	60.3	60.3	75.1	75.1	26.4	47.8	IOOOOO IIIII IIIII IIIII
2359	08-13-19	101.5	101.2	76.8	76.7	64.0	63.5	76.9	76.8	22.8	47.8	OOOOOO IIIII IIIII IIIII
1459	08-14-19	101.7	101.9	77.5	77.4	65.0	65.0	77.2	77.2	25.0	47.8	OOOOOO IIIII IIIII IIIII
1459	08-24-19	107.4	107.0	79.8	79.9	73.7	73.7	79.0	79.0	20.8	47.8	OOOOOO IIIII IIIIO IIIIO
1459	09-03-19	111.1	111.0	80.0	80.2	79.6	79.3	79.3	79.4	23.1	47.8	OOOOOO IIIII IIOOO IIOOO
0859	09-06-19	112.3	112.4	80.2	80.3	82.6	82.7	80.1	80.4	47.8	28.8	OOOOOO IIIII IIOOO IIOOO

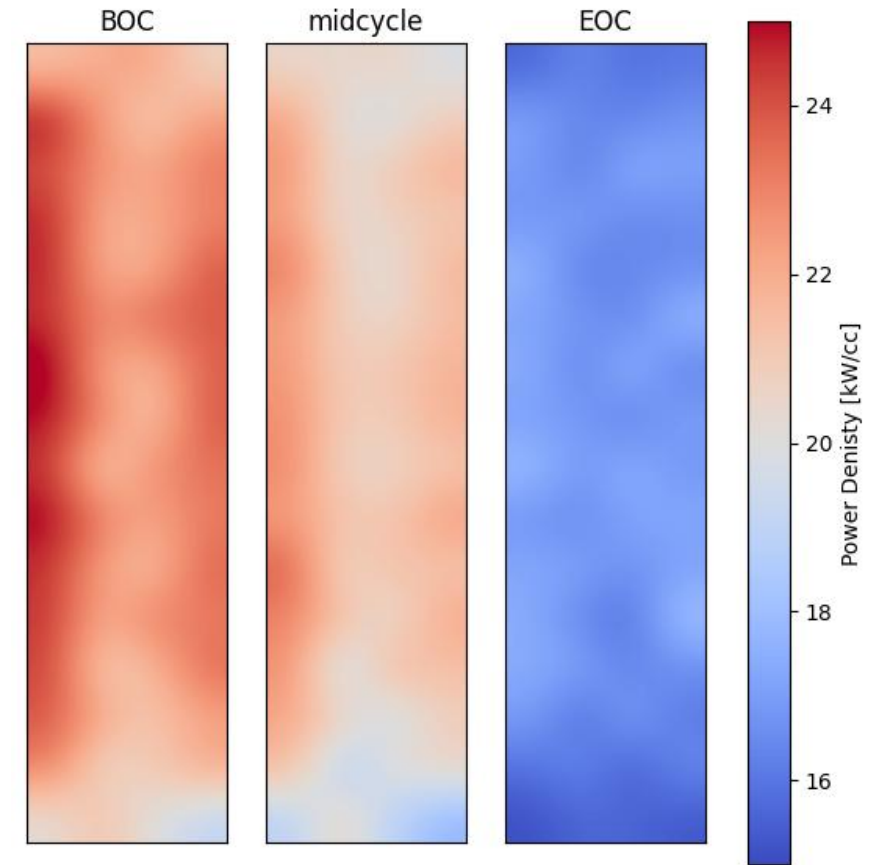
Example ASUDAS data for Cycle 166A-1

MP-2 As-Run Methods

- Use MCNP and ORIGEN to calculate:
 - Beginning of Life (BOL) peak power density
 - End of life (EOL) peak fission density
 - Neutron flux
 - %U-235 depletion
 - Fissions Per Initial Heavy Metal Atom



XB1 plate in Cycle 173A



An MP-2 Plate Power Density throughout a cycle

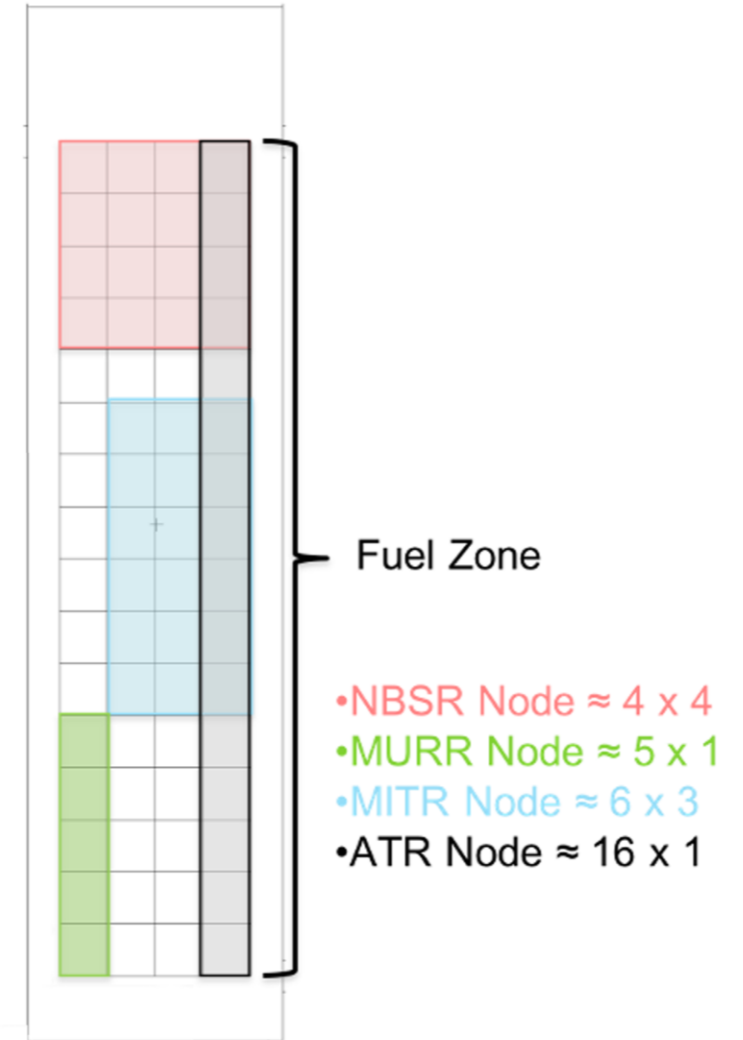
MP-2 Results

%U-235 Burnup

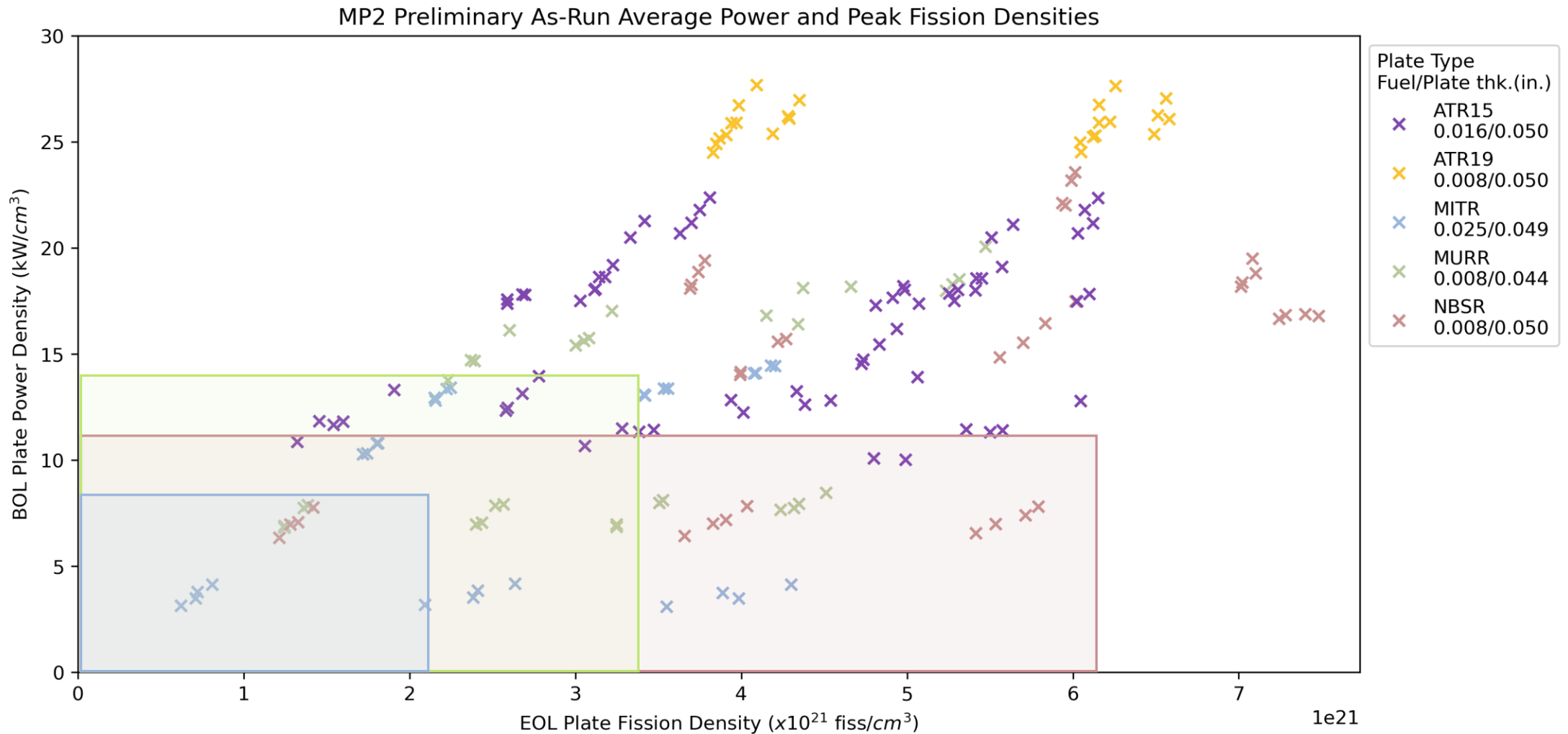
Plate location	173A_EOC			173B_EOC			173C_EOC		
	Plate Avg	4x16 Max	Node Max	Plate Avg	4x16 Max	Node Max	Plate Avg	4x16 Max	Node Max
YA1	47.10	55.51	50.84	76.86	84.09	80.49	89.99	94.24	92.32
YA2	45.89	54.85	49.68	76.08	83.78	79.85	89.62	94.18	92.06
YA3	46.29	55.45	50.17	76.50	84.10	80.27	89.85	94.23	92.26
YA4	48.25	56.05	51.92	78.07	84.54	81.46	90.65	94.46	92.79

%FIMA

Plate location	173A_EOC			173B_EOC			173C_EOC		
	Plate Avg	4x16 Max	Node Max	Plate Avg	4x16 Max	Node Max	Plate Avg	4x16 Max	Node Max
YA1	8.13	9.63	8.80	13.75	15.23	14.48	16.65	17.78	17.24
YA2	7.91	9.49	8.58	13.55	15.06	14.30	16.48	17.60	17.08
YA3	7.98	9.60	8.67	13.62	15.16	14.37	16.52	17.67	17.13
YA4	8.34	9.74	9.00	14.01	15.34	14.71	16.85	17.84	17.41

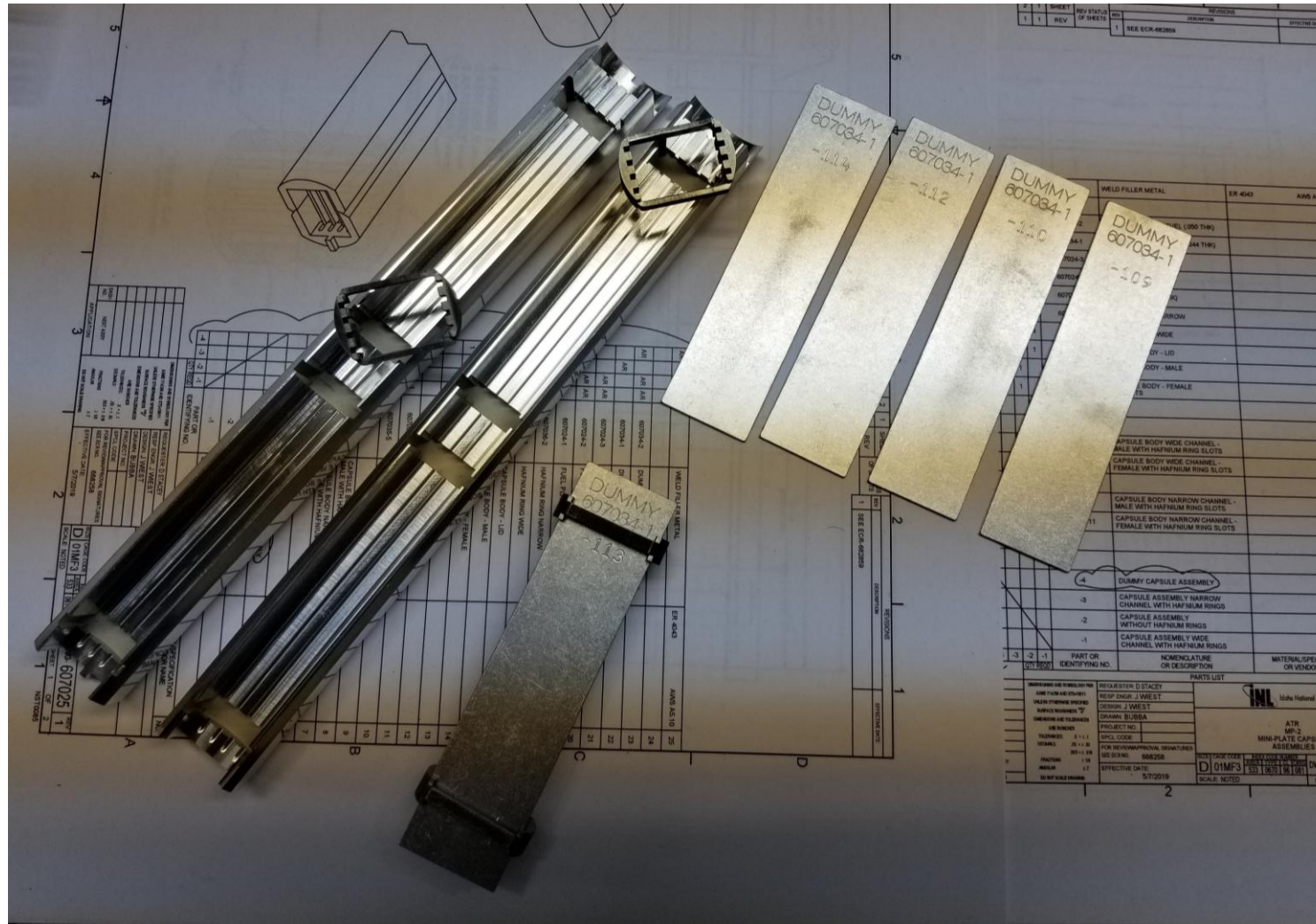


MP-2 Results



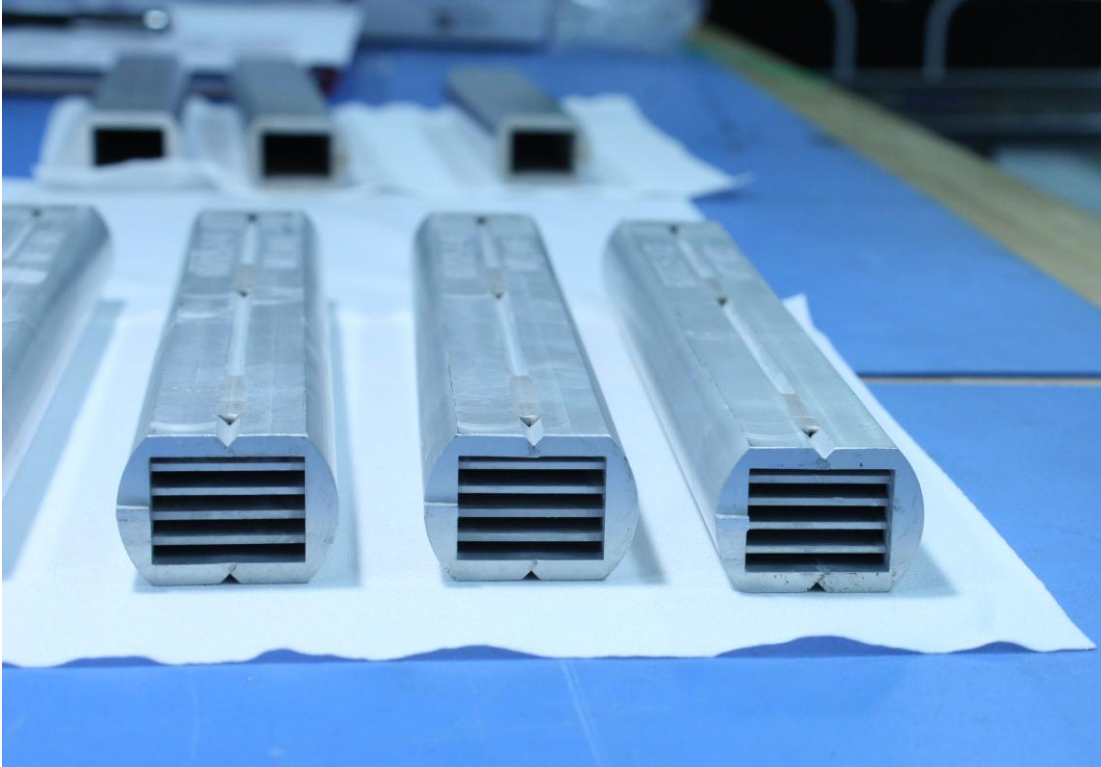
NOTE: ATR15/19 plates in MP-2 only account for the fuel type's low power irradiation target. The box for PD extends beyond the y-axis bounds.

MP-2 Irradiation



An unwelded MP-2 capsule with hafnium rings and dummy plates.

MP-2 Irradiation



MP-2 capsules and irradiation hardware

MP-2 Irradiation



ATR operators working with the MP-2 South Flux Trap experiment.

MP-2 Irradiation



MP-2 is installed into the South Flux Trap of the ATR.

Current work: MP-2 Validation of Results

- Power density
 - Impossible without actively instrumented experiment
- Fission density
 - EOL isotopics via destructive examination
 - Expectations from the previous MP-1 experiment:
 - MP-1 Post Irradiation Examination Report
 - Multi-channel inductively coupled plasma mass spectrometry
 - Report stated generally within 5% burnup

Acknowledgements

- US HPRR Fuel Qualification Pillar at INL
 - National Technical Lead:
 - Pillar Lead:
 - Experiment Manager:
 - Principle Investigator:
- Neutronics Contributors:

Jeff Giglio

Tracy Kunz

Margaret Marshall

Margaret Marshall

Dong Choe



Idaho National Laboratory

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.

WWW.INL.GOV