INL/EXT-11-24282

RERTR-6 Irradiation Summary Report

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Prepared for the
U.S. Department of Energy
Office of National Nuclear Security Administration
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

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INL/EXT-11-24282
Revision 0

December 2011

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SUMMARY

The Reduced Enrichment for Research and Test Reactor (RERTR) experiment RERTR-6 was designed to evaluate several modified fuel designs that were proposed to address the possibility of breakaway swelling due to porosity within the (U. Mo) Al interaction product observed in the full-size plate tests performed in Russia and France[1].

The following report summarizes the life of the RERTR-6 experiment through end of irradiation, including as-run neutronic analyses, thermal analyses and hydraulic testing results.

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TABLES

ACRONYMS

Al	aluminum
ATR	Advanced Test Reactor
EFPD	effective full power days
FSW	friction stir weld
GTRI	Global Threat Reduction Initiative
L2AR	local-to-average ratio
LEU	low enriched uranium
MCNP	Monte Carlo N-Particle
Mo	molybdenum
RERTR	Reduced Enrichment Research and Test Reactor
Si	silicon
Ti	titanium
U	uranium
U-Mo	uranium-molybdenum
Zr	zirconium

RERTR-6 Irradiation Summary Report

1. EXPERIMENT SUMMARY

In support of the Global Threat Reduction Initiative (GTRI) Fuel Development (FD) program (historically known as Reduced Enrichment for Research and Test Reactors (RERTR)), the RERTR-6 experiment was designed to evaluate several modified fuel designs that were proposed to address the possibility of breakaway swelling due to porosity within the (U. Mo) Al interaction product observed in the full-size plate tests performed in Russia and France[1].

The RERTR-6 test assembly holds 4 capsules, designated as A, B, C and D, with A at the top of the assembly and D at the bottom. Each capsule has 2 levels, with 4 plate positions per level, for a total of 8 plate positions per capsule and 32 plate positions per assembly. Within each capsule the 8 plate positions are azimuthally designated as 1 through 4 in the upper level and 5 through 8 in the lower level. The loading diagram for the RERTR-6 experiment matrix is shown in Table 1.

Table 1. RERTR-6 experiment matrix loading diagram.[1]

RERTR-6 Experiment Matrix				
Capsule	**Column 1**	**Column 2**	**Column 3**	**Column 4**
A Top	A1 BLANK	A2 R1R010 U-7Mo Roll Al-6061	A3 BLANK	A4 L2F020 U-10Mo FSW 0.020” Foil
A Bottom	A5 R5R010 U-7Mo Roll Al-0.2Si	A6 L1F090 U-10Mo FSW 0.010” Foil	A7 BLANK	A8 N1F090 U-7Mo FSW 0.010” Foil
B Top	B1 R1R020 U-7Mo Roll Al-6061	B2 R2R020 U-7Mo Roll Al-2.0Si	B3 V0R020 U-10Mo Roll Al	B4 N1F010 U-7Mo FSW 0.010” Foil
B Bottom	B5 R3R030 U-7Mo Roll Al-4043	B6 N1F040 U-7Mo FSW 0.010” Foil	B7 L1F140 U-10Mo FSW 0.010” Foil	B8 V1R020 U-10Mo Roll Al-6061
C Top	C1 V0R010 U-10Mo Roll Al	C2 R3R010 U-7Mo Roll Al-4043	C3 R2R010 U-7Mo Roll Al-2.0Si	C4 N1F030 U-7Mo FSW 0.010” Foil
C Bottom	C5 R5R020 U-7Mo Roll Al-0.2Si	C6 N1F060 U-7Mo Roll Al-2.0Si	C7 V5R030 U-10Mo Roll Al-0.2Si	C8 BLANK
D Top	D1 L1F100 U-10Mo FSW 0.010” Foil	D2 R2R030 U-7Mo Roll Al-2.0Si	D3 V1R010 U-10Mo Roll Al-6061	D4 BLANK
D Bottom	D5 R1R030 U-7Mo Roll Al-6061	D6 BLANK	D7 L2F030 U-10Mo FSW 0.020” Foil	D8 V5R020 U-10Mo Roll Al-0.2Si

2. CONSTITUENT MASSES AND DENSITIES

The constituent masses and densities for the plates in the RERTR-6 experiment were obtained from the as-built plate summary sheets. Table 2 summarizes the constituent masses and densities for the plates in the RERTR-6 experiment.

Table 2. Constituent masses and densities for RERTR-6 plates[2].

Fuel Plate ID	Fuel Plate #	Fuel Constituent Masses				Constituent Densities			
		Total-U (g)	U-235 (g)	Mo (g)	Matrix (g)	Total-U (g/cc)	U-235 (g/cc)	Mo (g/cc)	Matrix (g/cc)
A1	Blank	--	--	--	--	--	--	--	--
A2	R1R010	6.152	1.169	0.398	1.370	7.071	1.344	0.457	1.575
A3	Blank	--	--	--	--	--	--	--	--
A4	L2F020	12.160	2.400	1.470	--	15.200	3.000	1.838	--
A5	R5R010	6.134	1.165	0.396	1.430	6.816	1.294	0.440	1.589
A6	L1F090	6.820	1.340	0.760	--	15.156	2.978	1.689	--
A7	Blank	--	--	--	--	--	--	--	--
A8	N1F090	6.490	1.280	0.480	--	16.225	3.200	1.200	--
B1	R1R020	6.124	1.167	0.506	1.380	7.039	1.341	0.582	1.586
B2	R2R020	5.944	1.153	0.586	1.420	6.679	1.296	0.658	1.596
B3	V0R020	6.062	1.164	0.748	1.310	7.304	1.402	0.901	1.578
B4	N1F010	6.650	1.310	0.500	--	16.220	3.195	1.220	--
B5	R3R030	6.143	1.167	0.397	1.410	6.981	1.326	0.451	1.602
B6	N1F040	6.950	1.370	0.520	--	16.163	3.186	1.209	--
B7	L1F040	5.990	1.180	0.670	--	15.359	3.026	1.718	--
B8	V1R020	6.055	1.162	0.745	1.410	6.654	1.277	0.819	1.549
C1	V0R010	6.058	1.163	0.742	1.320	7.044	1.352	0.863	1.535
C2	R3R010	6.145	1.168	0.395	1.410	7.229	1.374	0.465	1.659
C3	R2R010	5.960	1.156	0.580	1.420	6.697	1.299	0.652	1.596
C4	N1F030	6.910	1.360	0.520	--	16.452	3.238	1.238	--
C5	R5R020	6.135	1.166	0.395	1.420	7.766	1.476	0.500	1.797
C6	N1F060	6.740	1.330	0.500	--	16.439	3.244	1.220	--
C7	V5R030	6.072	1.165	0.748	1.330	6.900	1.324	0.850	1.511
C8	Blank	--	--	--	--	--	--	--	--
D1	L1F100	6.250	1.230	0.670	--	15.244	3.000	1.634	--
D2	R2R030	5.951	1.155	0.579	1.420	6.687	1.298	0.651	1.596
D3	V1R010	6.143	1.600	0.647	1.370	6.902	1.798	0.727	1.539
D4	Blank	--	--	--	--	--	--	--	--
D5	R1R030	6.139	1.166	0.391	1.380	7.056	1.340	0.449	1.586
D6	Blank	--	--	--	--	--	--	--	--
D7	L2F030	11.850	2.340	1.430	--	15.192	3.000	1.833	--
D8	V5R020	6.050	1.161	0.740	1.320	6.954	1.334	0.851	1.517

3. EXPERIMENT HARDWARE

The experiment hardware configuration used for the RERTR-6 experiment is listed in Table 3.

Table 3. RERTR-6 irradiation hardware drawing list.

Drawing Number	Revision	Drawing Title
DWG-630223	1	RERTR ATR Large B-Position Irradiation Experiment Assembly
DWG-630233	0	ATR Large B-Position Basket
DWG-630231	1	ATR Top Spacer Assembly
DWG-630225	1	ATR Upper Spacer Assembly
DWG-630229	0	ATR Bottom Spacer Assembly
DWG-630227	1	ATR Large B-Position Fuel Capsule Assembly
DWG-630237	1	Fuel Capsule
DWG-630239	0	Capsule Cap
DWG-749209	1	Fuel Plate, 0.010 Monolithic
DWG-630245	1	Fuel Plate, 0.020 Monolithic
DWG-630238	1	Fuel Plate, Dispersion

The RERTR miniplate irradiation assembly, (see Figure 1) shows the main components of the test assembly, which include the bottom spacer, upper and top spacers, experiment capsules and basket. The bottom spacer elevates the experiment capsules to the correct location in the core. The upper and top spacers allow the operators to assure that the experiment is seated fully into the basket. All spacers are similar to the capsule design except the spacers do not have the grooves for the plates. The capsules hold the fuel plates; a capsule cap is welded onto the top of the capsule to keep the plates from sliding out during handling and irradiation. The fuel plate drawings for monolithic and dispersion plates (DWG-749209, DWG-630245 and DWG-630238, respectively) and RERTR miniplate capsule assembly are shown in Figure 2, Figure 3, Figure 4 and Figure 5, respectively. Each capsule has a notch at the top and a groove at the bottom which allow the capsules to stack and align properly into the core. The basket holds the test assembly in the reactor during irradiation, the notches on the outer wall allow for bypass coolant flow to cool the outer wall. The basket has two guide bars on the inside wall to guide the assembly into the baskets.

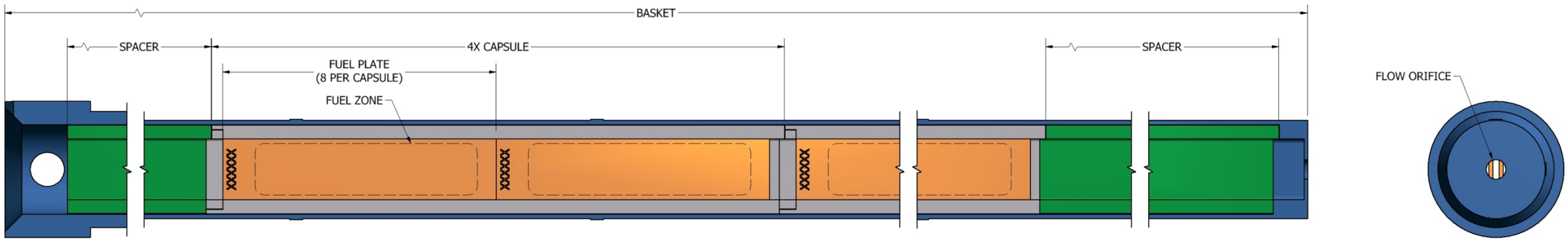

Figure 1 RERTR-6 miniplate irradiation Assembly.

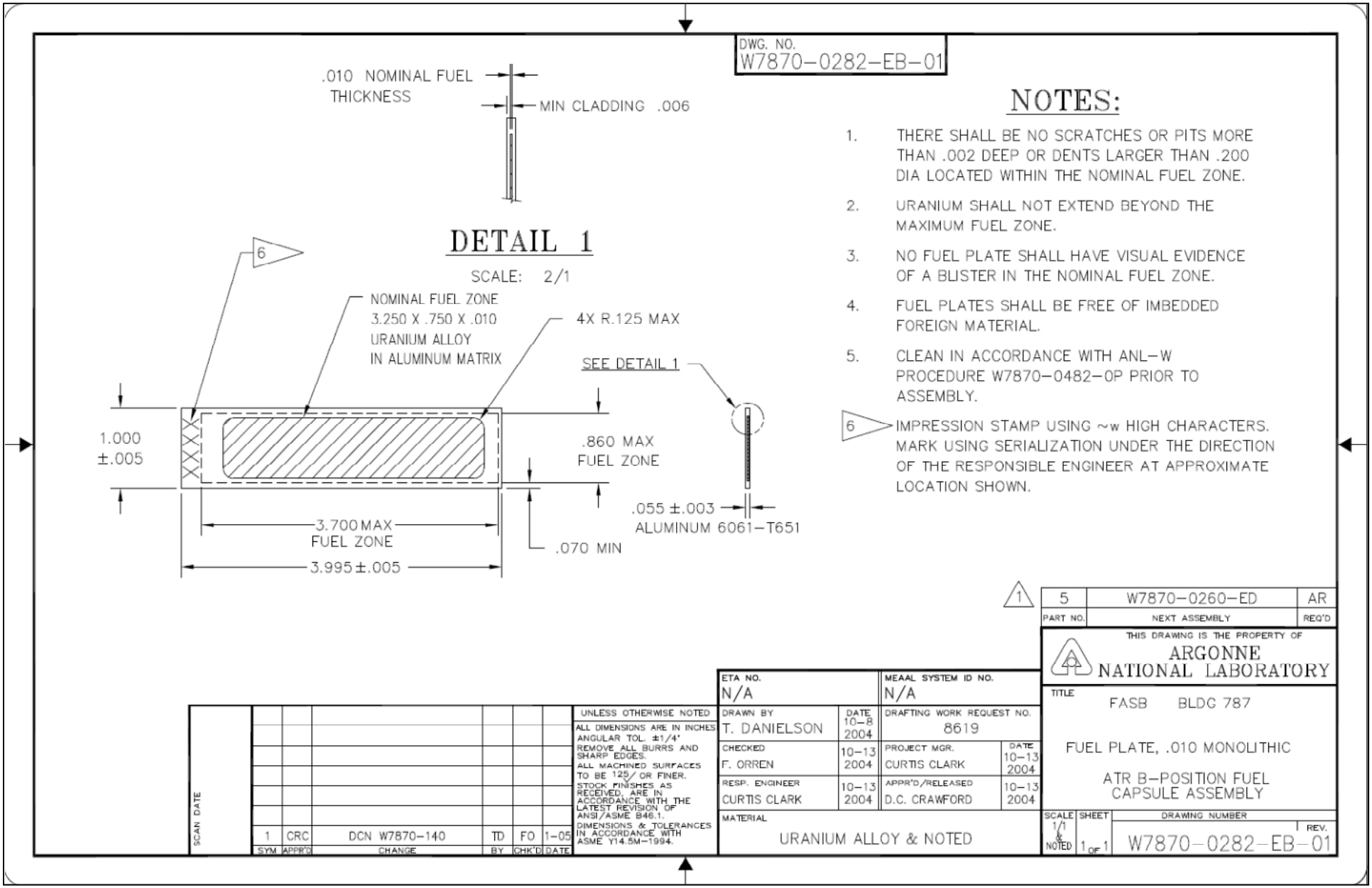

Figure 2. DWG-749209 Rev1 (W7870-0282-EB-01): RERTR-6 0.010 monolithic fuel miniplate.

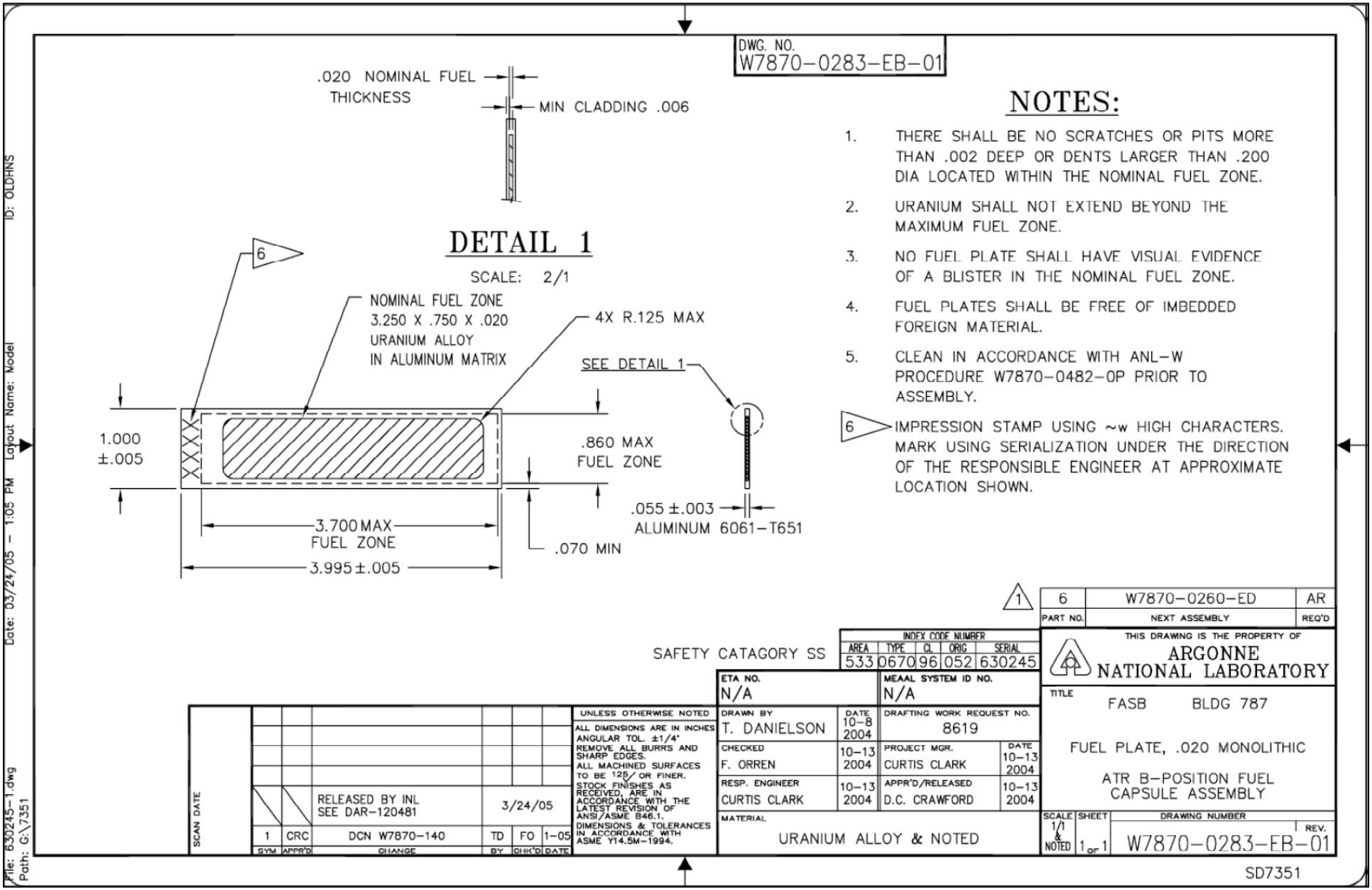

Figure 3. DWG-630245 Rev1: RERTR 0.020 Monolithic fuel miniplate.

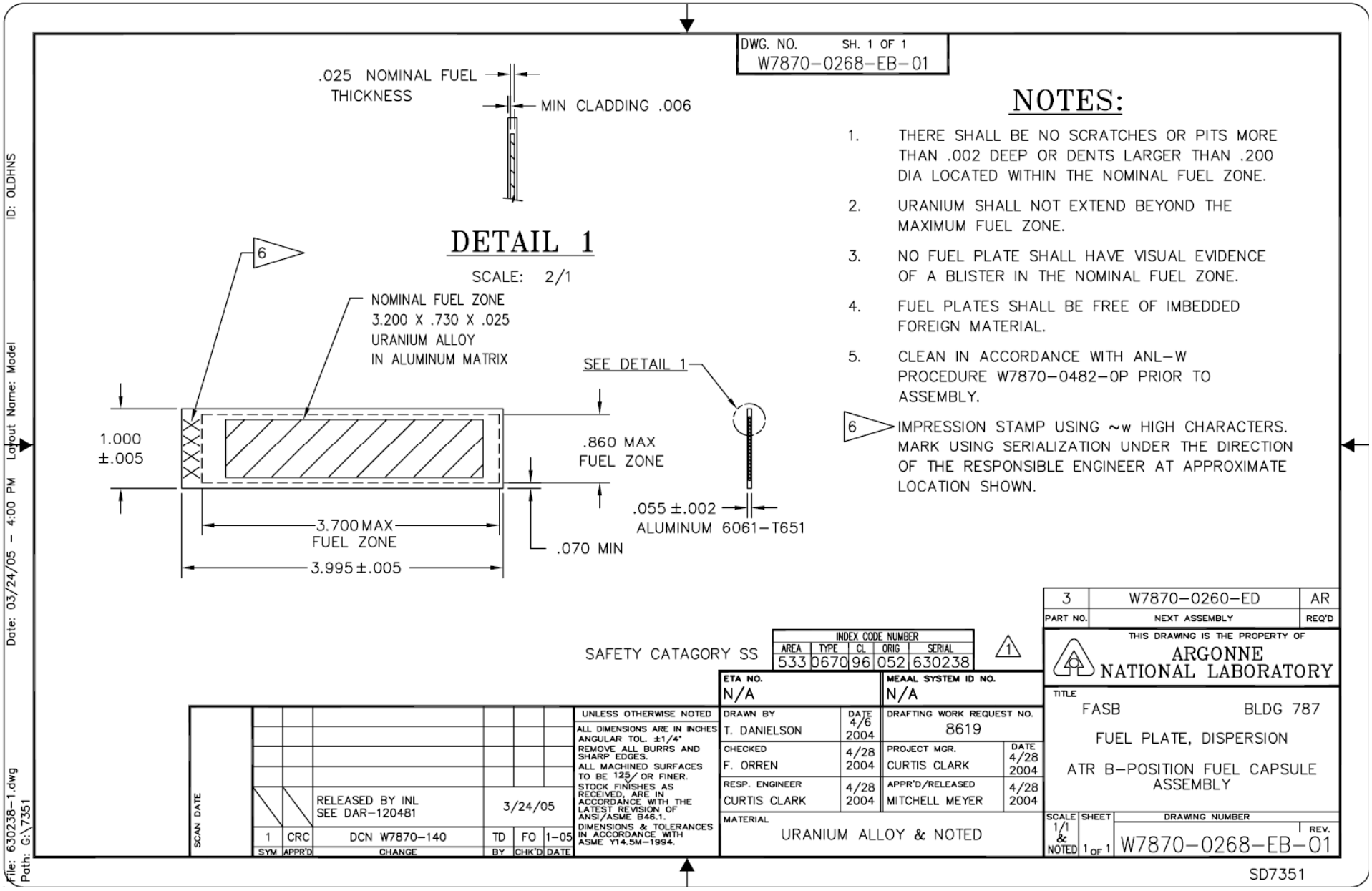

Figure 4. DWG-630238 Rev1: RERTR dispersion fuel miniplate.

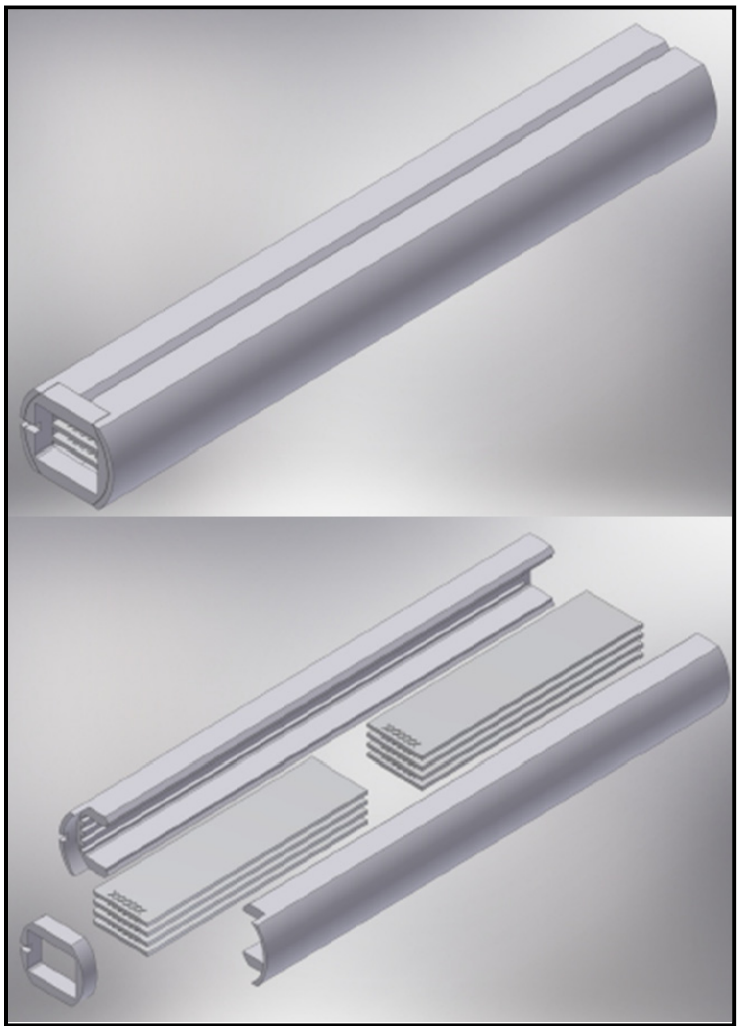

Figure 5. RERTR capsule assembly.

4. IRRADIATION HISTORY

The RERTR-6 test assembly was irradiated in Cycles 134B, 135B and 135C in the large-B position B-12. The power of position B-12 in the core is represented by the west lobe power which is the average of the NW, C, and SW lobe powers, W = (NW + C + SW)/3. Cycle 134B ran for 46.5 EFPDs with the west lobe power at 22.03 MW (total core power of 109.1 MW), Cycle 135B ran for 48 EFPDs with the west lobe power at 22 MW (total core power 109.0 MW). Cycle 135C ran for 40.6 EFPDs with the west lobe power at 22 MW (Total core power of 109.0 MW). This information is tabulated in Table 4.

Table 4. Irradiation history for the RERTR-6 experiment.

ATR CYCLE	RERTR-6 Capsules Irradiated	Dates Irradiated	Cycle EFPDs	West Lobe Source Power (MW)	Total Core Power (MW)
134B	A,B,C,D	04/15/2005 – 06/05/2005	46.5	22.03	109.1
135B	A,B,C,D	07/25/2005 – 09/17/2005	48.0	22.0	109.0
135C	A,B,C,D	09/26/2005 – 11/05/2005	40.6	22.0	109.0

5. AS-RUN NUCLEAR ANALYSIS

5.1 Neutronics

The as-run calculations were performed using the irradiation history in Table 4 and the Monte Carlo N-Particle (MCNP) code. The calculated as-run fission heat rates and as-run U-235 burnup results for the fueled miniplates reported have an uncertainty band (1σ) of 2.5%.[3] The time intervals used to calculate average plate power and burnup for the plates in RERTR-6 are shown in Table 5. The RERTR-6 average plate power and burnup for cycle 134B, 135B and 135C are shown in Table 6 through Table 14. The plots of the power and burnup as a function of the ATR Cycle time interval are in Appendix A.

Table 5. RERTR-6 Cycle breakdown.

Time Interval	134B (days)	135B (days)	135C (days)
01	1.00E-4	1.00E-4	1.00E-4
02	11	12	12
03	24.89	13.5	20
04	10.61	22.5	8.6
05	1.00E-3	1.00E-3	1.00E-3
EFPDs	46.5	48.0	40.6
Cumulative	46.5	94.5	135.1

Table 6. RERTR-6 average plate power and burnup for MOC1 134B (11 EFPD).

Plate Location	Plate ID	Fission Heat Rate (W/g)	Fission Power Density (W/cc)	Surface Heat Flux* (W/cm^2)	U-235 Burnup (%)	Fission Density (fissions/cc)
A1	Blank	--	--	--	--	--
A2	R1R010	400.75	3317.01	105.32	4.05%	1.081E+20
A3	Blank	--	--	--	--	--
A4	L2F020	400.52	6873.32	174.58	3.35%	2.239E+20
A5	R5R010	444.31	3696.66	117.37	4.52%	1.205E+20
A6	L1F090	522.77	9978.11	126.72	4.39%	3.251E+20
A7	Blank	--	--	--	--	--
A8	N1F090	569.67	9998.28	126.98	4.60%	3.258E+20
B1	R1R020	473.67	3965.09	125.89	4.83%	1.292E+20
B2	R2R020	441.56	3668.92	116.49	4.50%	1.195E+20
B3	V0R020	518.90	3693.01	117.25	4.53%	1.203E+20
B4	N1F010	585.45	10540.44	133.86	4.71%	3.434E+20
B5	R3R030	485.94	4037.68	128.20	4.93%	1.316E+20
B6	N1F040	548.57	10319.15	131.05	4.50%	3.362E+20
B7	L1F040	544.83	9316.25	118.32	4.58%	2.977E+20
B8	V1R020	470.01	4032.69	128.04	4.92%	1.314E+20
C1	V0R010	567.94	4036.35	128.15	4.95%	1.315E+20
C2	R3R010	455.91	3787.70	120.26	4.61%	1.234E+20
C3	R2R010	449.83	3742.59	118.83	4.62%	1.219E+20
C4	N1F030	596.04	11151.31	141.62	4.81%	3.633E+20
C5	R5R020	495.02	4114.11	130.62	5.00%	1.340E+20
C6	N1F060	584.26	10651.64	135.28	4.78%	3.471E+20
C7	V5R030	487.82	4156.23	131.96	5.07%	1.354E+20
C8	Blank	--	--	--	--	--
D1	L1F100	562.77	9805.70	124.53	4.72%	3.195E+20
D2	R2R030	446.39	3708.61	117.75	4.56%	1.208E+20
D3	V1R010	454.66	3878.25	123.13	4.76%	1.264E+20
D4	Blank	--	--	--	--	--
D5	R1R030	414.98	3431.47	108.95	4.17%	1.118E+20
D6	Blank	--	--	--	--	--
D7	L2F030	398.96	6670.61	169.43	3.35%	2.173E+20
D8	V5R020	381.44	3233.47	102.66	3.99%	1.054E+20

*Calculated using nominal fuel meat thickness (0.0635 cm for dispersion, 0.0254 cm for thin monolithic and 0.0508 cm for thick monolithic).

Table 7. RERTR-6 average plate power and burnup for MOC2 134B (35.89 EFPD).

Plate Location	Plate ID	Fission Heat Rate (W/g)	Fission Power Density (W/cc)	Surface Heat Flux* (W/cm^2)	U-235 Burnup (%)	Fission Density (fissions/cc)
A1	Blank	--	--	--	--	--
A2	R1R010	385.11	3173.31	100.75	12.58%	3.463E+20
A3	Blank	--	--	--	--	--
A4	L2F020	386.30	6598.39	167.60	10.58%	7.190E+20
A5	R5R010	426.10	3526.40	111.96	13.95%	3.852E+20
A6	L1F090	501.19	9507.07	120.74	13.58%	1.039E+21
A7	Blank	--	--	--	--	--
A8	N1F090	546.46	9528.08	121.01	14.22%	1.041E+21
B1	R1R020	452.78	3770.30	119.71	14.85%	4.123E+20
B2	R2R020	422.66	3494.13	110.94	13.96%	3.818E+20
B3	V0R020	497.74	3521.51	111.81	13.96%	3.847E+20
B4	N1F010	560.23	10018.59	127.24	14.62%	1.095E+21
B5	R3R030	465.45	3845.55	122.10	15.14%	4.202E+20
B6	N1F040	526.45	9839.35	124.96	13.77%	1.075E+21
B7	L1F040	521.36	8687.94	110.34	14.08%	9.501E+20
B8	V1R020	448.40	3826.65	121.50	15.14%	4.187E+20
C1	V0R010	542.89	3832.26	121.67	15.19%	4.192E+20
C2	R3R010	434.28	3589.76	113.97	14.20%	3.929E+20
C3	R2R010	429.57	3554.69	112.86	14.18%	3.888E+20
C4	N1F030	569.85	10587.81	134.47	14.89%	1.158E+21
C5	R5R020	472.05	3900.08	123.83	15.38%	4.268E+20
C6	N1F060	558.62	10114.93	128.46	14.60%	1.107E+21
C7	V5R030	465.75	3945.37	125.27	15.55%	4.316E+20
C8	Blank	--	--	--	--	--
D1	L1F100	538.80	9326.63	118.45	14.51%	1.020E+21
D2	R2R030	426.10	3522.14	111.83	14.06%	3.852E+20
D3	V1R010	434.78	3688.78	117.12	14.65%	4.033E+20
D4	Blank	--	--	--	--	--
D5	R1R030	398.05	3275.16	103.99	12.98%	3.577E+20
D6	Blank	--	--	--	--	--
D7	L2F030	384.35	6396.35	162.47	10.54%	6.973E+20
D8	V5R020	364.88	3078.86	97.75	12.32%	3.365E+20

*Calculated using nominal fuel meat thickness (0.0635 cm for dispersion, 0.0254 cm for thin monolithic and 0.0508 cm for thick monolithic).

Table 8. RERTR-6 average plate power and burnup for EOC 134B (46.5 EFPD).

Plate Location	Plate ID	Fission Heat Rate (W/g)	Fission Power Density (W/cc)	Surface Heat Flux* (W/cm^2)	U-235 Burnup (%)	Fission Density (fissions/cc)
A1	Blank	--	--	--	--	--
A2	R1R010	366.20	2988.19	94.88	16.03%	4.279E+20
A3	Blank	--	--	--	--	--
A4	L2F020	373.17	6311.80	160.32	13.54%	8.914E+20
A5	R5R010	403.65	3304.68	104.92	17.90%	4.754E+20
A6	L1F090	478.04	8953.21	113.71	17.35%	1.284E+21
A7	Blank	--	--	--	--	--
A8	N1F090	519.49	8932.11	113.44	18.17%	1.285E+21
B1	R1R020	428.86	3530.38	112.09	18.95%	5.087E+20
B2	R2R020	403.42	3298.70	104.73	17.84%	4.719E+20
B3	V0R020	475.81	3324.01	105.54	17.81%	4.755E+20
B4	N1F010	532.44	9385.85	119.20	18.60%	1.351E+21
B5	R3R030	439.00	3584.44	113.81	19.30%	5.181E+20
B6	N1F040	504.70	9307.68	118.21	17.58%	1.329E+21
B7	L1F040	499.73	8218.06	104.37	17.96%	1.175E+21
B8	V1R020	423.83	3576.28	113.55	19.29%	5.163E+20
C1	V0R010	514.99	3585.88	113.85	19.30%	5.171E+20
C2	R3R010	416.29	3403.17	108.05	18.11%	4.858E+20
C3	R2R010	410.14	3358.23	106.62	18.12%	4.805E+20
C4	N1F030	541.30	9912.29	125.89	18.94%	1.428E+21
C5	R5R020	444.05	3625.22	115.10	19.55%	5.258E+20
C6	N1F060	533.58	9525.47	120.97	18.60%	1.367E+21
C7	V5R030	440.61	3688.79	117.12	19.81%	5.323E+20
C8	Blank	--	--	--	--	--
D1	L1F100	512.89	8757.08	111.21	18.46%	1.259E+21
D2	R2R030	407.43	3331.96	105.79	17.98%	4.762E+20
D3	V1R010	411.17	3449.72	109.53	18.67%	4.975E+20
D4	Blank	--	--	--	--	--
D5	R1R030	378.15	3080.41	97.80	16.53%	4.418E+20
D6	Blank	--	--	--	--	--
D7	L2F030	374.34	6168.75	156.69	13.57%	8.658E+20
D8	V5R020	349.13	2918.73	92.67	15.73%	4.162E+20

*Calculated using nominal fuel meat thickness (0.0635 cm for dispersion, 0.0254 cm for thin monolithic and 0.0508 cm for thick monolithic).

Table 9. RERTR-6 average plate power and burnup for MOC1 135B (12 EFPD, 58.5 EFPD cumulative).

Plate Location	Plate ID	Fission Heat Rate (W/g)	Fission Power Density (W/cc)	Surface Heat Flux* (W/cm^2)	U-235 Burnup (%)	Fission Density (fissions/cc)
A1	Blank	--	--	--	--	--
A2	R1R010	354.72	2882.10	91.51	19.76%	5.332E+20
A3	Blank	--	--	--		--
A4	L2F020	364.00	6130.85	155.72	16.81%	1.115E+21
A5	R5R010	390.15	3180.50	100.98	21.90%	5.917E+20
A6	L1F090	464.00	8643.86	109.78	21.40%	1.600E+21
A7	Blank	--	--	--		--
A8	N1F090	501.16	8566.83	108.80	22.32%	1.598E+21
B1	R1R020	412.70	3380.84	107.34	23.34%	6.323E+20
B2	R2R020	391.03	3183.77	101.08	22.02%	5.884E+20
B3	V0R020	462.04	3211.18	101.95	21.98%	5.929E+20
B4	N1F010	514.11	9009.78	114.42	22.96%	1.681E+21
B5	R3R030	422.95	3436.47	109.11	23.72%	6.438E+20
B6	N1F040	489.93	8984.83	114.11	21.73%	1.657E+21
B7	L1F040	485.01	7931.37	100.73	22.21%	1.464E+21
B8	V1R020	409.21	3436.14	109.10	23.75%	6.420E+20
C1	V0R010	496.52	3437.41	109.14	23.76%	6.428E+20
C2	R3R010	402.49	3274.66	103.97	22.36%	6.055E+20
C3	R2R010	397.04	3235.48	102.73	22.35%	5.988E+20
C4	N1F030	523.07	9520.92	120.92	22.34%	1.777E+21
C5	R5R020	427.73	3474.45	110.31	24.03%	6.529E+20
C6	N1F060	515.58	9148.97	116.19	22.87%	1.701E+21
C7	V5R030	424.93	3539.67	112.38	24.40%	6.618E+20
C8	Blank	--	--	--	--	--
D1	L1F100	496.93	8436.88	107.15	22.78%	1.568E+21
D2	R2R030	394.65	3212.45	102.00	22.18%	5.937E+20
D3	V1R010	396.63	3313.05	105.19	22.96%	6.187E+20
D4	Blank	--	--	--	--	--
D5	R1R030	365.70	2966.19	94.18	20.41%	5.502E+20
D6	Blank	--	--	--	--	--
D7	L2F030	365.56	5998.48	152.36	16.84%	1.085E+21
D8	V5R020	338.40	2818.53	89.49	19.43%	5.192E+20

*Calculated using nominal fuel meat thickness (0.0635 cm for dispersion, 0.0254 cm for thin monolithic and 0.0508 cm for thick monolithic).

Table 10. RERTR-6 average plate power and burnup for MOC2 135B (25.5 EFPD, 72 EFPD cumulative).

Plate Location	Plate ID	Fission Heat Rate (W/g)	Fission Power Density (W/cc)	Surface Heat Flux* (W/cm^2)	U-235 Burnup (%)	Fission Density (fissions/cc)
A1	Blank	--	--	--	--	--
A2	R1R010	346.20	2800.07	88.90	23.85%	6.482E+20
A3	Blank	--	--	--	--	--
A4	L2F020	357.93	6000.70	152.42	20.39%	1.362E+21
A5	R5R010	379.40	3077.31	97.70	26.39%	7.181E+20
A6	L1F090	452.78	8386.39	106.51	25.78%	1.944E+21
A7	Blank	--	--	--	--	--
A8	N1F090	48.65	8300.70	105.42	26.84%	1.940E+21
B1	R1R020	399.97	3259.36	103.48	28.01%	7.663E+20
B2	R2R020	380.90	3085.67	97.97	26.55%	7.153E+20
B3	V0R020	452.17	3124.04	99.19	26.54%	7.213E+20
B4	N1F010	499.83	8701.54	110.51	27.59%	2.039E+21
B5	R3R030	411.15	3322.91	105.50	28.52%	7.804E+20
B6	N1F040	479.29	8734.58	110.93	26.23%	2.016E+21
B7	L1F040	473.72	7698.73	97.77	26.79%	1.781E+21
B8	V1R020	387.38	3319.71	105.40	28.58%	7.785E+20
C1	V0R010	482.89	3322.28	105.48	28.55%	7.793E+20
C2	R3R010	392.93	3180.38	100.98	26.97%	7.362E+20
C3	R2R010	387.31	3140.31	99.70	26.94%	7.278E+20
C4	N1F030	509.40	9210.97	116.98	28.07%	2.155E+21
C5	R5R020	415.30	3355.21	106.53	28.87%	7.908E+20
C6	N1F060	503.26	8872.47	112.68	27.58%	2.066E+21
C7	V5R030	412.61	3418.89	108.55	29.30%	8.024E+20
C8	Blank	--	--	--	--	--
D1	L1F100	483.50	8156.65	103.59	27.40%	1.903E+21
D2	R2R030	384.31	3112.91	98.83	26.74%	7.216E+20
D3	V1R010	385.61	3204.80	101.75	27.62%	7.504E+20
D4	Blank	--	--	--	--	--
D5	R1R030	356.43	2877.10	91.35	24.61%	6.684E+20
D6	Blank	--	--	--	--	--
D7	L2F030	359.61	5873.51	149.19	20.39%	1.326E+21
D8	V5R020	333.63	2766.46	87.84	23.42%	6.315E+20

*Calculated using nominal fuel meat thickness (0.0635 cm for dispersion, 0.0254 cm for thin monolithic and 0.0508 cm for thick monolithic).

Table 11. RERTR-6 average plate power and burnup for EOC 135B (48 EFPD, 94.5 EFPD cumulative).

Plate Location	Plate ID	Fission Heat Rate (W/g)	Fission Power Density (W/cc)	Surface Heat Flux* (W/cm^2)	U-235 Burnup (%)	Fission Density (fissions/cc)
A1	Blank	--	--	--	--	--
A2	R1R010	337.16	2714.14	86.17	30.24%	8.379E+20
A3	Blank	--	--	--	--	--
A4	L2F020	351.70	5865.30	148.98	26.05%	1.772E+21
A5	R5R010	367.77	2966.80	94.20	33.34%	9.256E+20
A6	L1F090	439.70	8091.80	102.77	32.69%	2.510E+21
A7	Blank	--	--	--	--	--
A8	N1F090	473.47	7987.44	101.44	33.95%	2.498E+21
B1	R1R020	387.29	3138.60	99.65	35.34%	9.858E+20
B2	R2R020	371.59	2993.90	95.06	33.65%	9.250E+20
B3	V0R020	440.82	3025.79	96.07	33.63%	9.329E+20
B4	N1F010	485.55	8393.70	106.60	34.84%	2.626E+21
B5	R3R030	397.95	3197.53	101.52	35.95%	1.004E+21
B6	N1F040	467.87	8468.45	107.55	33.25%	2.609E+21
B7	L1F040	461.50	7449.53	94.61	33.96%	2.302E+21
B8	V1R020	383.71	3187.48	101.20	36.06%	1.002E+21
C1	V0R010	466.72	3189.10	101.25	36.00%	1.002E+21
C2	R3R010	381.78	3072.95	97.57	34.17%	9.511E+20
C3	R2R010	376.09	3032.79	96.29	34.11%	9.399E+20
C4	N1F030	493.11	8852.31	112.42	35.41%	2.774E+21
C5	R5R020	402.23	3230.71	102.58	36.37%	1.017E+21
C6	N1F060	488.80	8555.96	108.66	34.84%	2.665E+21
C7	V5R030	389.05	3279.14	104.11	36.93%	1.032E+21
C8	Blank	--	--	--	--	--
D1	L1F100	468.14	7843.65	99.61	34.62%	2.452E+21
D2	R2R030	373.62	3009.88	95.56	33.88%	9.322E+20
D3	V1R010	373.86	3090.33	98.12	34.90%	9.665E+20
D4	Blank	--	--	--	--	--
D5	R1R030	346.02	2779.58	88.25	31.18%	8.628E+20
D6	Blank	--	--	--	--	--
D7	L2F030	353.71	5747.79	145.99	26.12%	1.728E+21
D8	V5R020	321.23	2650.79	84.16	29.75%	8.168E+20

*Calculated using nominal fuel meat thickness (0.0635 cm for dispersion, 0.0254 cm for thin monolithic and 0.0508 cm for thick monolithic).

Table 12. RERTR-6 average plate power and burnup for MOC1 135C (12 EFPD, 106.5 EFPD cumulative).

Plate Location	Plate ID	Fission Heat Rate (W/g)	Fission Power Density (W/cc)	Surface Heat Flux* (W/cm^2)	U-235 Burnup (%)	Fission Density (fissions/cc)
A1	Blank	--	--	--	--	--
A2	R1R010	320.41	2559.11	81.25	33.49%	9.293E+20
A3	Blank	--	--	--	--	--
A4	L2F020	338.82	5604.76	142.36	28.97%	1.972E+21
A5	R5R010	347.42	2779.01	88.23	36.87%	1.025E+21
A6	L1F090	418.52	7622.09	96.80	36.20%	2.783E+21
A7	Blank	--	--	--	--	--
A8	N1F090	446.95	7456.91	94.70	37.51%	2.764E+21
B1	R1R020	365.31	2933.44	93.14	39.02%	1.091E+21
B2	R2R020	352.90	2818.97	89.50	37.27%	1.026E+21
B3	V0R020	419.70	2851.44	90.53	37.26%	1.035E+21
B4	N1F010	458.24	7833.15	99.48	38.50%	2.906E+21
B5	R3R030	373.65	2974.25	94.43	39.69%	1.110E+21
B6	N1F040	447.24	8007.83	101.70	36.85%	2.895E+21
B7	L1F040	438.23	6998.97	88.89	37.60%	2.552E+21
B8	V1R020	359.24	2957.26	93.89	39.76%	1.107E+21
C1	V0R010	441.19	2981.56	94.66	39.72%	1.109E+21
C2	R3R010	362.35	2891.19	91.80	37.78%	1.054E+21
C3	R2R010	357.37	2856.10	90.68	37.73%	1.042E+21
C4	N1F030	466.68	8281.24	105.17	39.11%	3.070E+21
C5	R5R020	377.73	3005.60	95.43	40..15%	1.124E+21
C6	N1F060	464.60	8040.83	102.12	38.53%	2.952E+21
C7	V5R030	372.42	3039.32	96.50	40.75%	1.140E+21
C8	Blank	--	--	--	--	--
D1	L1F100	441.75	7321.12	92.98	38.26%	2.713E+21
D2	R2R030	352.26	2813.15	89.32	37.50%	1.033E+21
D3	V1R010	352.32	2886.21	91.64	38.54%	1.070E+21
D4	Blank	--	--	--	--	--
D5	R1R030	328.40	2616.03	83.06	34.48%	9.563E+20
D6	Blank	--	--	--	--	--
D7	L2F030	342.73	5523.09	140.29	29.08%	1.926E+21
D8	V5R020	306.99	2514.25	79.83	32.97%	9.066E+20

*Calculated using nominal fuel meat thickness (0.0635 cm for dispersion, 0.0254 cm for thin monolithic and 0.0508 cm for thick monolithic).

Table 13. RERTR-6 average plate power and burnup for MOC2 135C (32 EFPD, 126.5 EFPD cumulative).

Plate Location	Plate ID	Fission Heat Rate (W/g)	Fission Power Density (W/cc)	Surface Heat Flux* (W/cm^2)	U-235 Burnup (%)	Fission Density (fissions/cc)
A1	Blank	--	--	--	--	--
A2	R1R010	311.65	2478.55	78.69	38.63%	1.077E+21
A3	Blank	--	--	--	--	--
A4	L2F020	331.88	5466.40	138.85	33.63%	2.298E+21
A5	R5R010	337.21	2685.54	85.27	42.39%	1.185E+21
A6	L1F090	406.46	7363.84	93.52	41.69%	3.221E+21
A7	Blank	--	--	--	--	--
A8	N1F090	432.90	7180.95	91.20	43.09%	3.192E+21
B1	R1R020	353.18	2822.97	89.63	44.75%	1.259E+21
B2	R2R020	341.56	2715.74	86.22	42.91%	1.188E+21
B3	V0R020	407.67	2754.63	87.46	42.94%	1.199E+21
B4	N1F010	444.15	7547.89	95.86	44.22%	3.355E+21
B5	R3R030	632.15	2869.31	91.10	45.52%	1.281E+21
B6	N1F040	436.68	7774.21	98.73	42.52%	3.358E+21
B7	L1F040	426.21	6769.49	85.97	43.31%	2.955E+21
B8	V1R020	347.05	2844.07	90.30	45.58%	1.276E+21
C1	V0R010	427.46	2872.96	91.22	45.57%	1.280E+21
C2	R3R010	353.02	2803.68	89.02	43.51%	1.221E+21
C3	R2R010	347.51	2765.48	87.80	43.44%	1.206E+21
C4	N1F030	452.21	7877.44	100.04	44.90%	3.545E+21
C5	R5R020	365.19	2871.94	91.18	46.01%	1.296E+21
C6	N1F060	451.54	7768.75	98.66	44.33%	3.414E+21
C7	V5R030	360.02	2924.08	92.84	46.71%	1.314E+21
C8	Blank	--	--	--	--	--
D1	L1F100	429.94	7084.98	89.98	43.96%	3.135E+21
D2	R2R030	342.15	2719.75	86.35	43.16%	1.195E+21
D3	V1R010	340.47	2777.55	88.19	44.24%	1.235E+21
D4	Blank	--	--	--	--	--
D5	R1R030	319.46	2534.92	80.48	39.76%	1.107E+21
D6	Blank	--	--	--	--	--
D7	L2F030	335.70	5386.31	136.81	33.81%	2.247E+21
D8	V5R020	298.24	2433.64	77.27	38.05%	1.052E+21

*Calculated using nominal fuel meat thickness (0.0635 cm for dispersion, 0.0254 cm for thin monolithic and 0.0508 cm for thick monolithic).

Table 14. RERTR-6 average plate power and burnup for EOC 135C (40.6 EFPD, 135.1 EFPD cumulative).

Plate Location	Plate ID	Fission Heat Rate (W/g)	Fission Power Density (W/cc)	Surface Heat Flux* (W/cm^2)	U-235 Burnup (%)	Fission Density (fissions/cc)
A1	Blank	--	--	--	--	--
A2	R1R010	297.37	2349.52	74.60	40.74%	1.147E+21
A3	Blank	--	--	--	--	--
A4	L2F020	321.42	5256.50	133.52	35.59%	2.454E+21
A5	R5R010	320.48	2534.36	80.47	44.63%	1.260E+21
A6	L1F090	387.36	6958.15	88.37	43.96%	3.428E+21
A7	Blank	--	--	--	--	--
A8	N1F090	410.61	6750.02	85.73	45.37%	3.393E+21
B1	R1R020	333.70	2647.91	84.07	47.09%	1.337E+21
B2	R2R020	325.40	2569.03	81.57	45.27%	1.264E+21
B3	V0R020	389.54	2609.92	82.86	45.28%	1.276E+21
B4	N1F010	420.29	7078.42	89.90	46.57%	3.566E+21
B5	R3R030	341.97	2689.25	85.38	47.89%	1.361E+21
B6	N1F040	417.74	7369.35	93.59	44.86%	3.577E+21
B7	L1F040	405.54	6384.01	81.08	45.66%	3.145E+21
B8	V1R020	327.93	2668.04	84.71	47.96%	1.356E+21
C1	V0R010	404.29	2693.38	85.51	47.98%	1.360E+21
C2	R3R010	336.12	2649.97	84.14	45.87%	1.300E+21
C3	R2R010	331.97	2621.90	83.25	45.80%	1.285E+21
C4	N1F030	428.59	7490.04	95.12	47.27%	3.768E+21
C5	R5R020	344.19	2705.33	85.89	48.41%	1.377E+21
C6	N1F060	427.94	7292.95	92.62	46.69%	3.631E+21
C7	V5R030	337.92	2724.65	86.51	49.12%	1.395E+21
C8	Blank	--	--	--	--	--
D1	L1F100	407.51	6656.27	84.53	46.29%	3.333E+21
D2	R2R030	324.95	2565.48	81.45	45.49%	1.271E+21
D3	V1R010	322.05	2608.61	82.82	46.59%	1.313E+21
D4	Blank	--	--	--	--	--
D5	R1R030	303.45	2391.49	75.93	41.91%	1.178E+21
D6	Blank	--	--	--	--	--
D7	L2F030	326.00	5193.51	131.92	35.79%	2.401E+21
D8	V5R020	285.68	2316.29	73.54	40.17%	1.120E+21

*Calculated using nominal fuel meat thickness (0.0635 cm for dispersion, 0.0254 cm for thin monolithic and 0.0508 cm for thick monolithic).

5.2 Gradients

The MCNP-calculated power gradients[4] in the transverse directions are represented by the thermal neutron flux and fission rate local-2-average ratios (L2ARs) as a function of position. Figure 6 and Figure 7 depict the power gradient in the transverse direction for the RERTR-6 experiment.

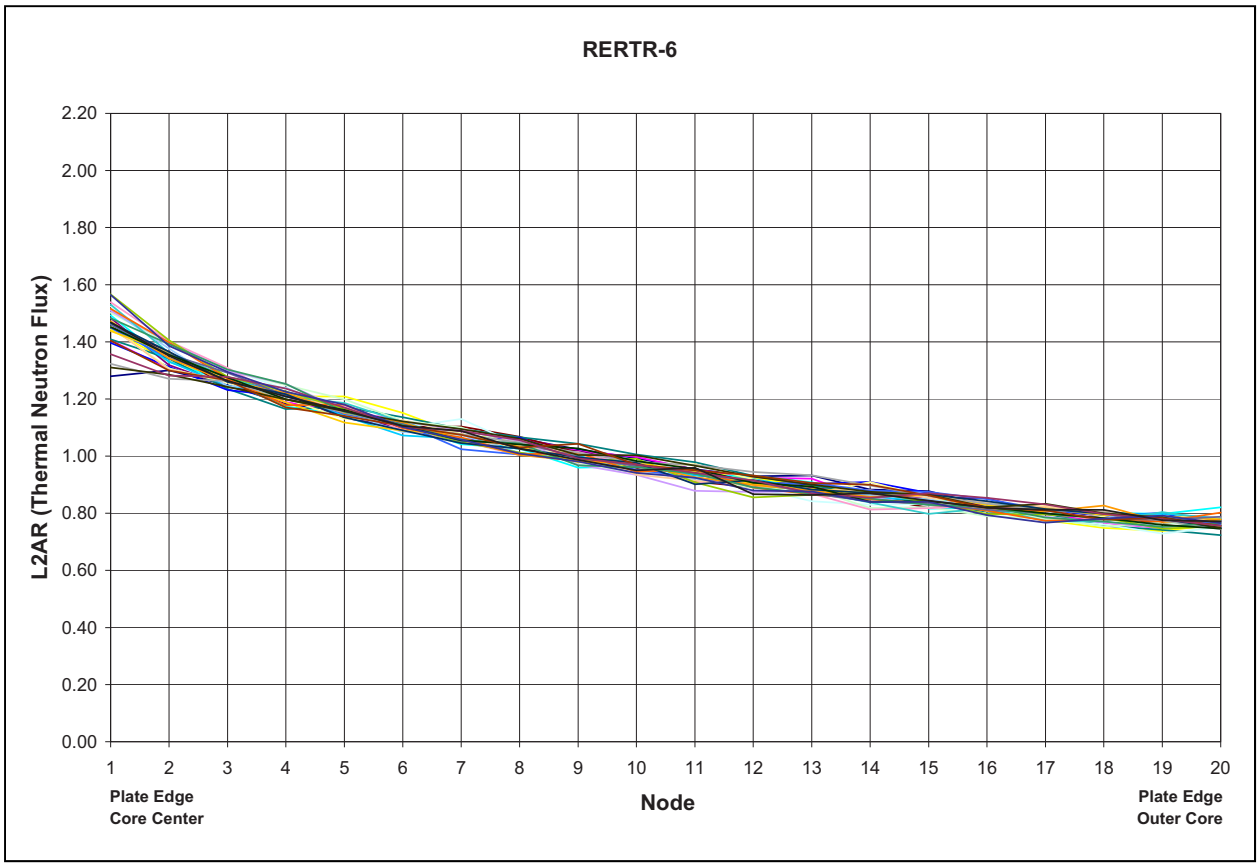

Figure 6. RERTR-6 fuel miniplates thermal neutron flux L2ARs in transverse direction.[4]

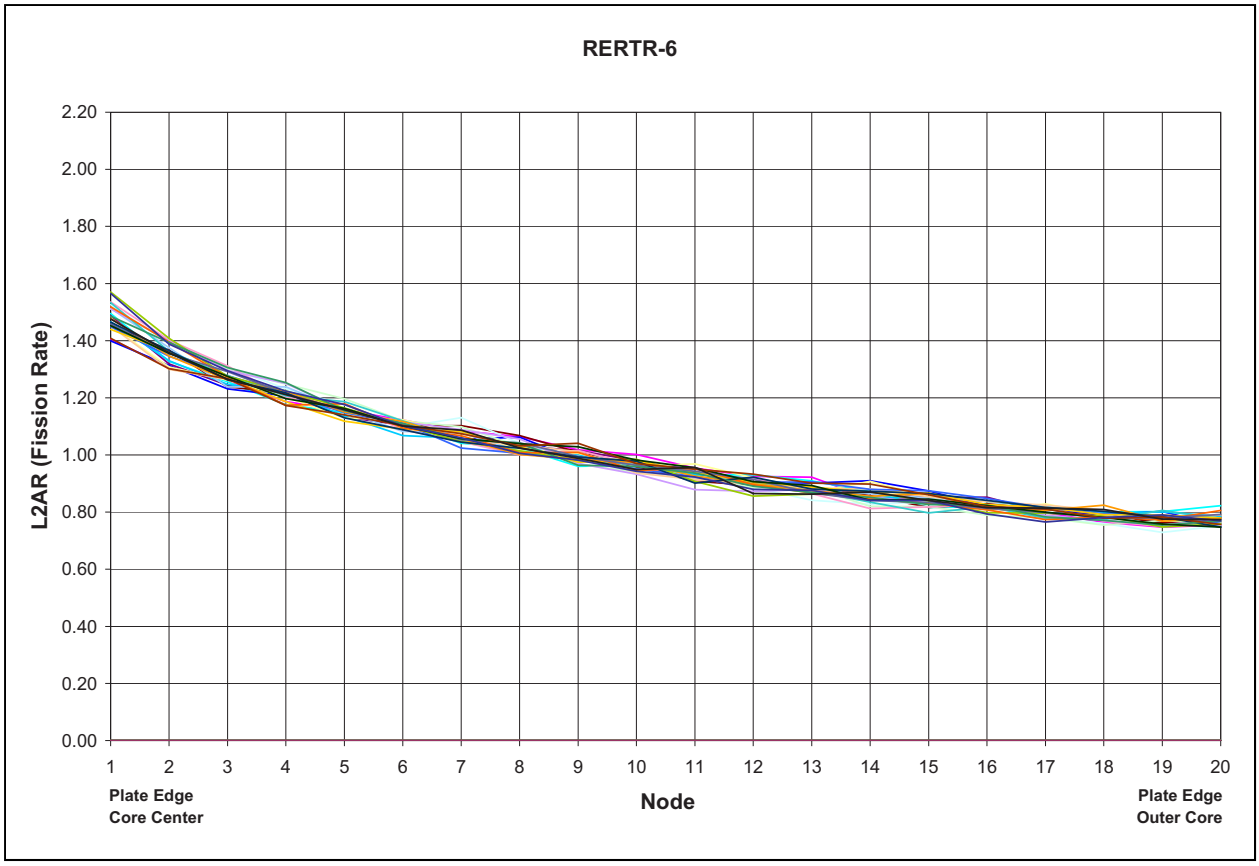

Figure 7. RERTR-6 fuel miniplates fission rate L2ARs in transverse direction.[4]

6. HYDRAULIC TESTING

A fully assembled irradiation test vehicle (with simulated fuel plates) was used for testing. The test vehicle was fabricated such that the orifice plates could be easily changed. The hydraulic resistance of the RERTR Large B-Position irradiation test vehicle with various orifice plate sizes were calculated, the results are shown in Table 15.

Table 15. Loss coefficients for the RERTR irradiation test vehicle components.[5]

Orifice Dia. (mm)	K/A^2 ($1/m^4$)	ATR Coolant Flow Rate (cm^3/sec)
10	5.3041×10^8	1252
9	8.2181×10^8	1046
8	1.6961×10^9	757
7.32	2.9022×10^9	588
7	3.0058×10^9	579
6	4.0784×10^9	500
5	101743×10^{10}	298
Bypass	2.7958×10^8	--
Vehicle	1.4161×10^8	2727

The orifice used in the RERTR-6 experiment was 7.32 mm in diameter. Based off of the experimental data shown in Table 15, the ATR coolant flow rate through the test vehicle was 588 cm^3/sec.

7. AS-RUN THERMAL ANALYSIS

The thermal as-run analysis was performed using the as-built geometry, MCNP-calculated surface heat flux (W/cm^2) and nominal coolant channel flow rate. ABAQUS[6] was used to calculate the coolant channel temperatures and plate surface temperatures.

The heat transfer correlation used to calculate these temperatures was calculated from the Colburn equation (equation 5-50c from Reference 7):

$$Nu = \frac{hD}{k} = 0.023 Re^{0.8} Pr^{0.3}$$

Where Nu is the Nusselt number, h is the heat transfer coefficient, D is the hydraulic diameter, k is the thermal conductivity, Re is the Reynolds number and Pr is the Prandlt number.

7.1 Coolant Temperature as a Function of Location

The coolant temperature was analyzed at the five flow channels in the test assembly, with Channel 1 at the right of the assembly. For each cycle, the coolant temperature was plotted as a function of location along the test assembly with 0 inches being at the top of the assembly. These plots are shown in Figure 8 through Figure 16.

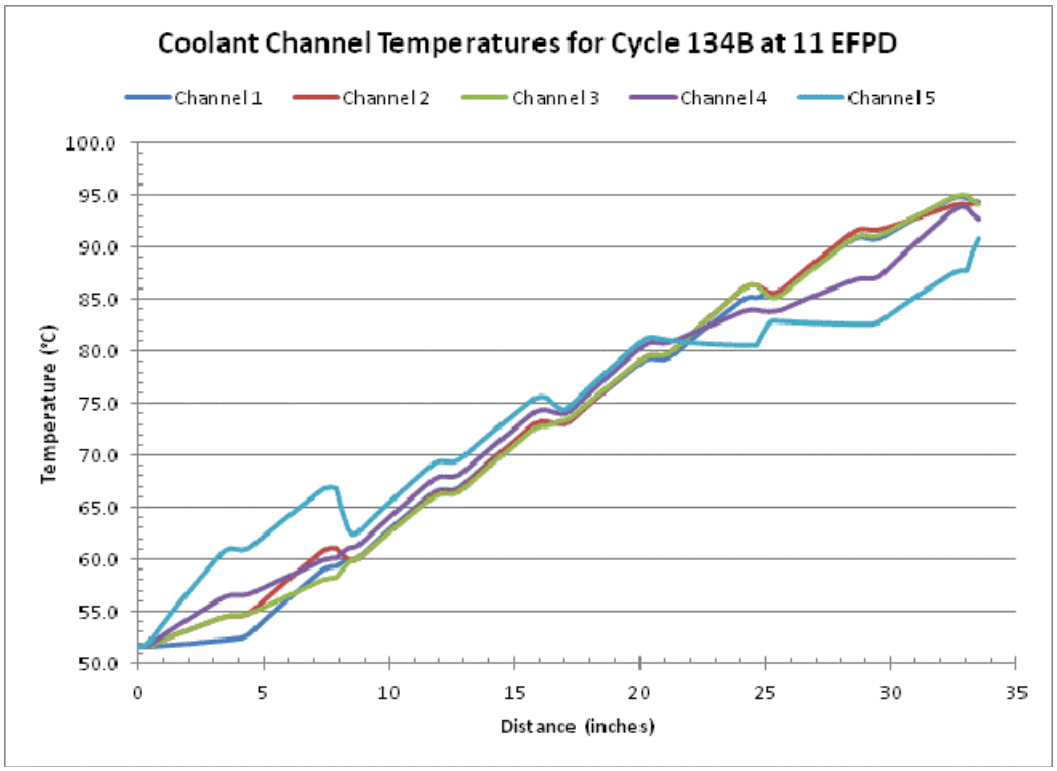

Figure 8. RERTR-6 experiment coolant temperature as a function of location along the test assembly for Cycle 134B at 11 EFPD.

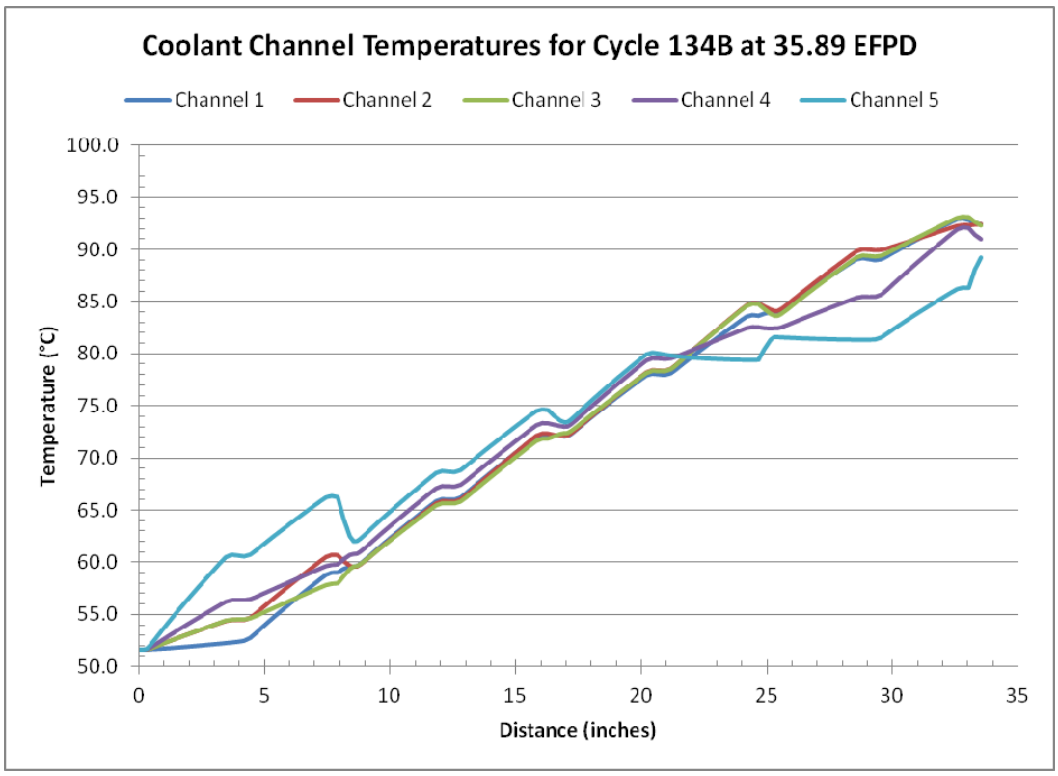

Figure 9. RERTR-6 experiment coolant temperature as a function of location along the test assembly for Cycle 134B at 35.89 EFPD.

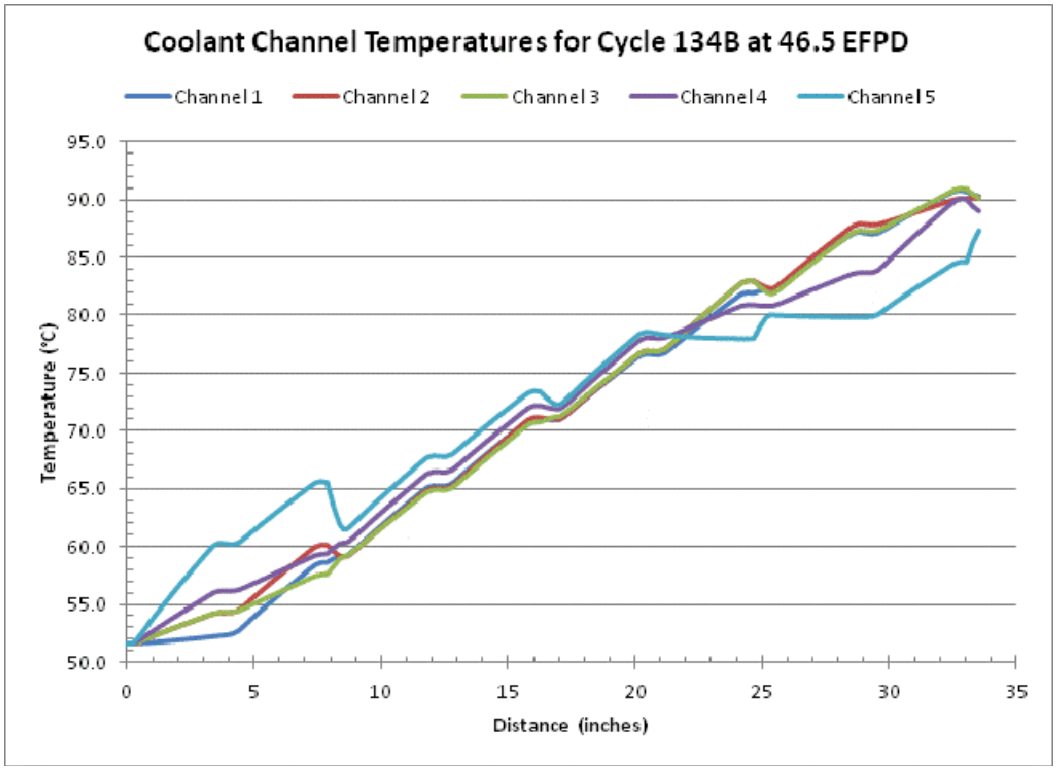

Figure 10. RERTR-6 experiment coolant temperature as a function of location along the test assembly for Cycle 134B at 46.5 EFPD.

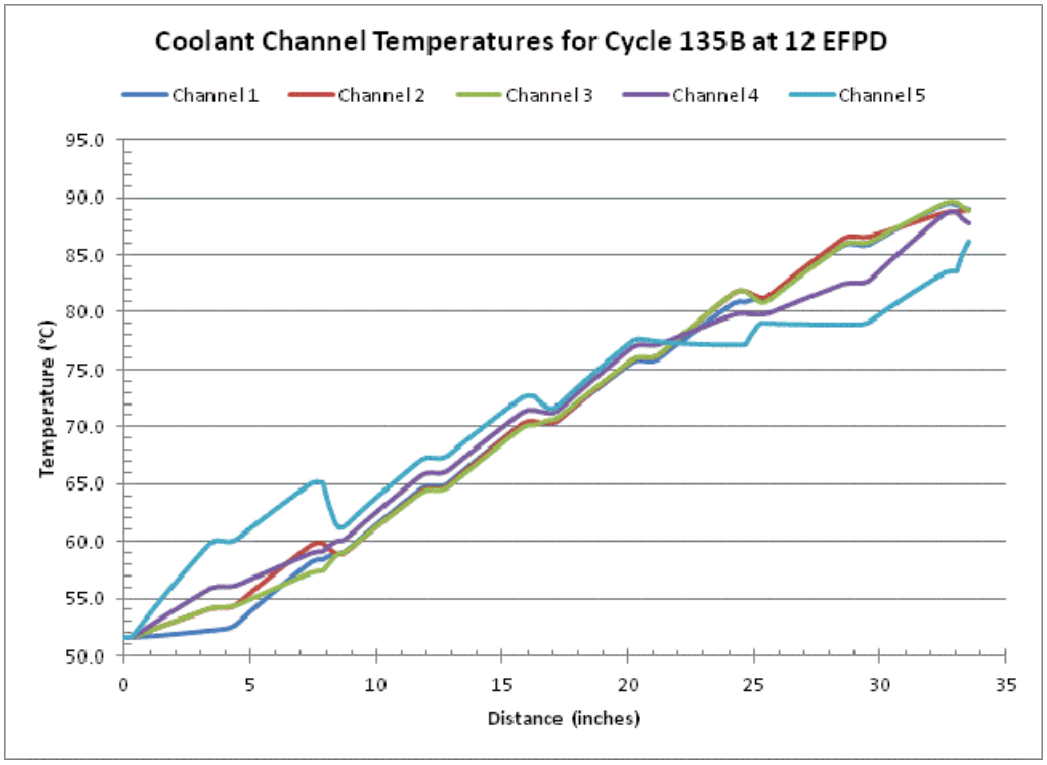

Figure 11. RERTR-6 experiment coolant temperature as a function of location along the test assembly for Cycle 135B at 12 EFPD.

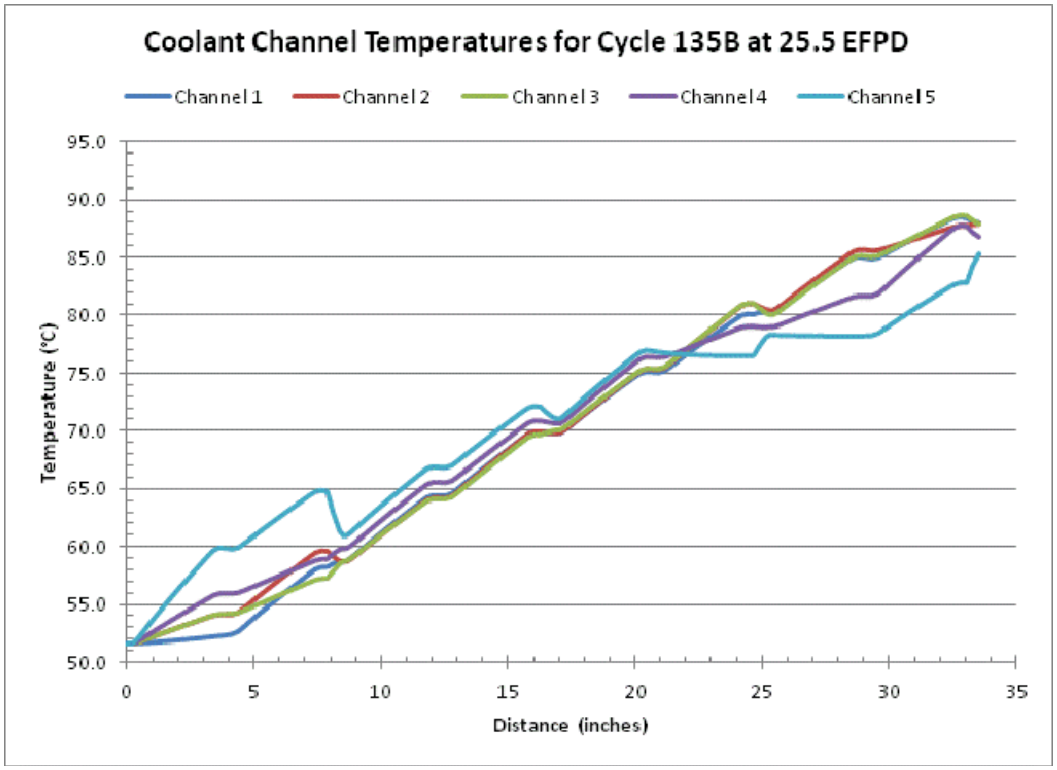

Figure 12. RERTR-6 experiment coolant temperature as a function of location along the test assembly for Cycle 135B at 25.5 EFPD.

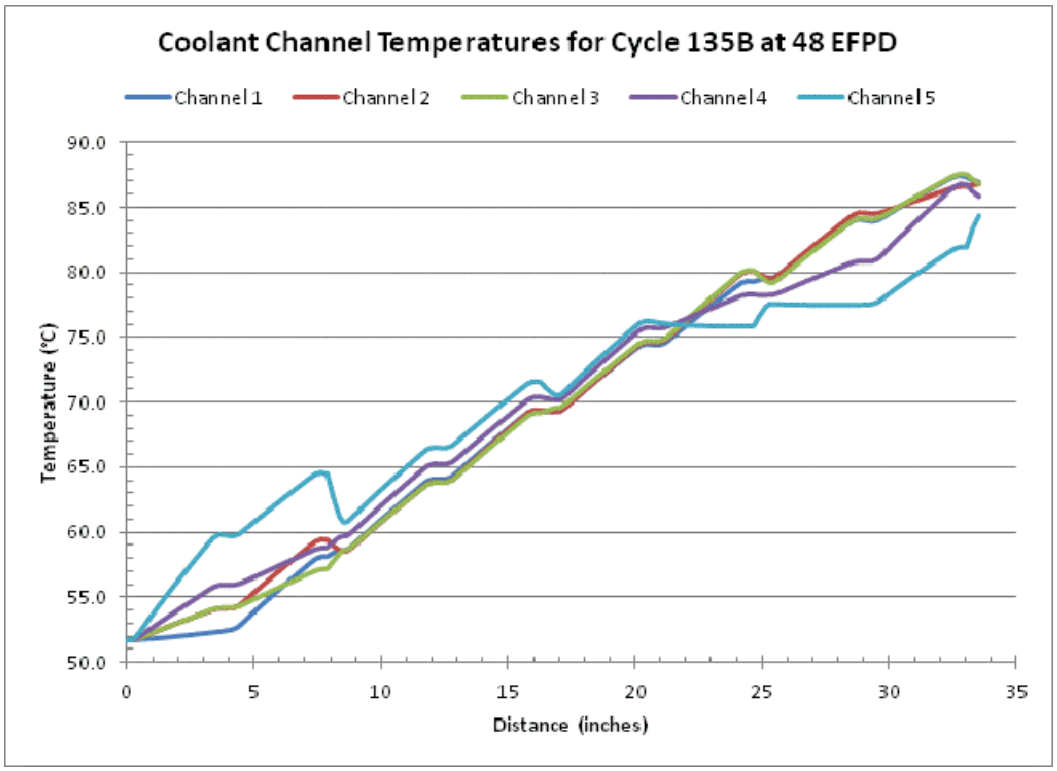

Figure 13. RERTR-6 experiment coolant temperature as a function of location along the test assembly for Cycle 135B at 48 EFPD.

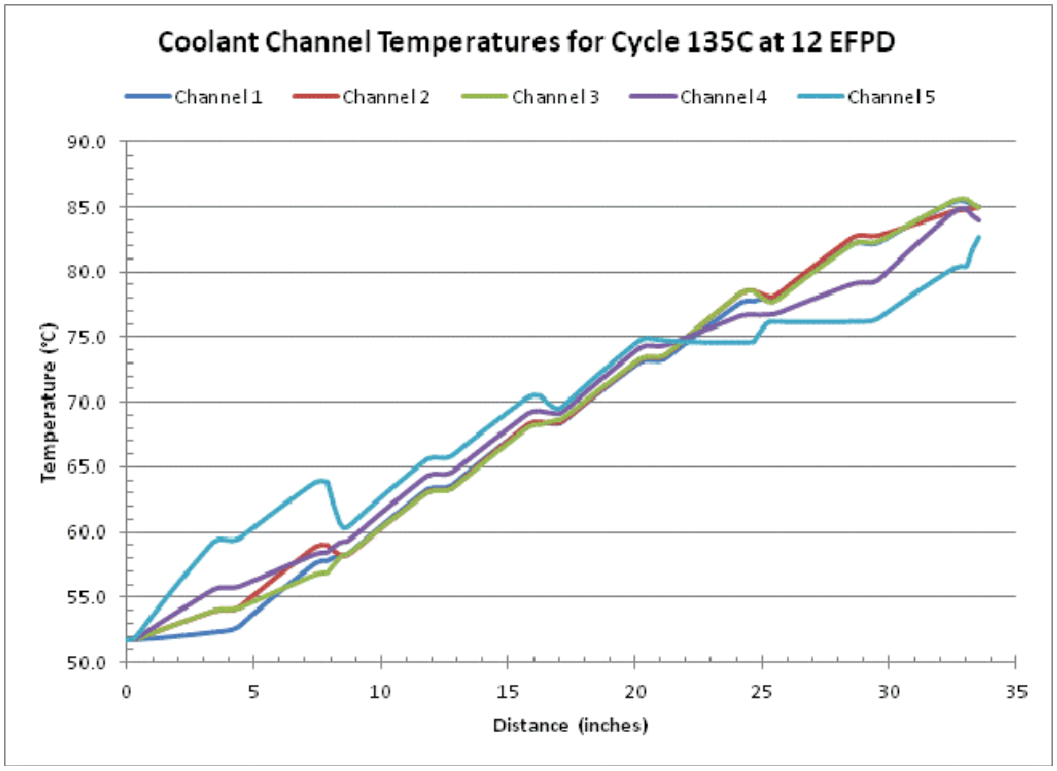

Figure 14. RERTR-6 experiment coolant temperature as a function of location along the test assembly for Cycle 135C at 12 EFPD.

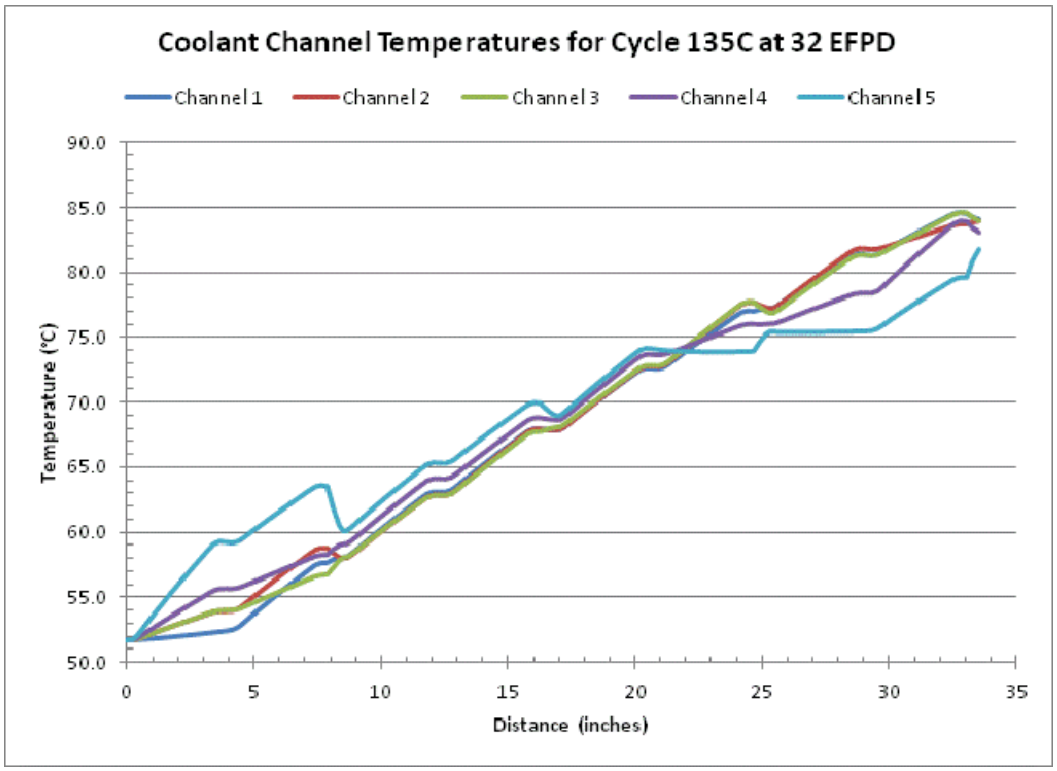

Figure 15. RERTR-6 experiment coolant temperature as a function of location along the test assembly for Cycle 135C at 32 EFPD.

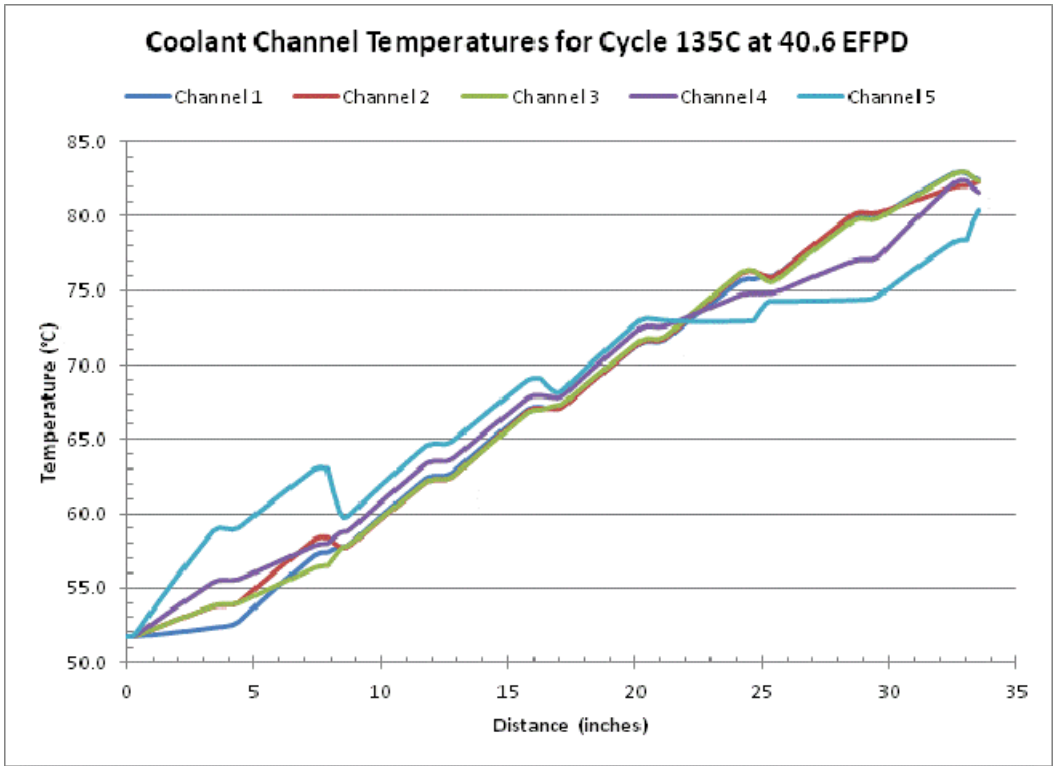

Figure 16. RERTR-6 experiment coolant temperature as a function of location along the test assembly for Cycle 135C at 40.6 EFPD.

7.2 Plate Surface Temperature

The maximum, minimum, and average plate temperatures for each cycle at end of cycle are provided in Table 16 through Table 18.

Table 16. Plate surface temperatures for Cycle 134B (46.5 EFPD).

Plate Location	Plate ID	Maximum Temp (°C)	Minimum Temp (°C)	Average Temp (°C)
A1	Blank	--	--	--
A2	R1R010	73.14	51.76	62.42
A3	Blank	--	--	--
A4	L2F020	90.39	51.73	70.52
A5	R5R010	79.84	51.70	69.61
A6	L1F090	80.89	52.92	70.16
A7	Blank	--	--	--
A8	N1F090	86.38	55.76	73.71
B1	R1R020	86.44	59.17	74.99
B2	R2R020	83.68	59.24	73.71
B3	V0R020	84.85	59.62	74.38
B4	N1F010	89.73	60.79	77.37
B5	R3R030	91.79	63.60	80.74
B6	N1F040	91.13	63.41	80.61
B7	L1F040	89.68	63.96	79.75
B8	V1R020	93.69	65.25	82.33
C1	V0R010	96.81	68.36	86.06
C2	R3R010	94.74	71.02	85.24
C3	R2R010	95.38	71.37	85.54
C4	N1F030	100.40	71.87	88.56
C5	R5R020	101.81	75.41	91.52
C6	N1F060	102.15	75.69	92.05
C7	V5R030	101.37	76.00	91.43
C8	Blank	--	--	--
D1	L1F100	105.89	76.70	95.92
D2	R2R030	104.29	81.67	95.14
D3	V1R010	104.06	80.85	94.09
D4	Blank	--	--	--
D5	R1R030	106.91	85.73	98.39
D6	Blank	--	--	--
D7	L2F030	114.50	83.11	102.82
D8	V5R020	103.87	79.96	93.92

Table 17. Plate surface temperatures for Cycle 135B (48.0 EFPD).

Plate Location	Plate ID	Maximum Temp (°C)	Minimum Temp (°C)	Average Temp (°C)
A1	Blank	--	--	--
A2	R1R010	71.36	51.77	61.53
A3	Blank	--	--	--
A4	L2F020	88.04	51.74	69.34
A5	R5R010	77.36	51.77	68.02
A6	L1F090	78.40	52.85	68.58
A7	Blank	--	--	--
A8	N1F090	83.40	55.56	71.82
B1	R1R020	83.23	58.57	72.84
B2	R2R020	81.05	58.61	71.90
B3	V0R020	82.22	58.99	72.56
B4	N1F010	86.38	60.10	75.15
B5	R3R030	88.10	62.56	78.12
B6	N1F040	87.83	62.41	78.24
B7	L1F040	86.47	62.94	77.43
B8	V1R020	89.90	64.15	79.62
C1	V0R010	92.66	67.19	82.93
C2	R3R010	91.05	69.35	82.34
C3	R2R010	91.63	69.69	82.64
C4	N1F030	96.07	70.16	85.29
C5	R5R020	97.30	73.34	87.92
C6	N1F060	97.70	73.56	88.47
C7	V5R030	96.82	73.89	87.83
C8	Blank	--	--	--
D1	L1F100	101.12	74.81	91.99
D2	R2R030	99.73	79.00	91.34
D3	V1R010	99.40	78.29	90.34
D4	Blank	--	--	--
D5	R1R030	102.22	82.73	94.34
D6	Blank	--	--	--
D7	L2F030	109.94	80.31	98.92
D8	V5R020	99.57	77.61	90.44

Table 18. Plate surface temperatures for Cycle 135C (40.6 EFPD).

Plate Location	Plate ID	Maximum Temp (°C)	Minimum Temp (°C)	Average Temp (°C)
A1	Blank	--	--	--
A2	R1R010	68.95	51.78	60.32
A3	Blank	--	--	--
A4	L2F020	84.77	51.75	67.72
A5	R5R010	74.12	51.87	65.94
A6	L1F090	75.07	52.75	66.46
A7	Blank	--	--	--
A8	N1F090	79.37	55.28	69.29
B1	R1R020	79.08	57.79	70.07
B2	R2R020	77.40	57.80	69.39
B3	V0R020	78.55	58.15	70.05
B4	N1F010	81.92	59.19	72.15
B5	R3R030	83.31	61.24	74.67
B6	N1F040	83.55	61.07	75.10
B7	L1F040	82.12	61.58	74.25
B8	V1R020	84.79	62.68	75.98
C1	V0R010	87.30	65.70	78.90
C2	R3R010	86.18	67.16	78.56
C3	R2R010	86.70	67.46	78.84
C4	N1F030	90.34	67.90	80.98
C5	R5R020	91.26	70.67	83.15
C6	N1F060	91.78	70.81	83.75
C7	V5R030	90.64	71.14	82.97
C8	Blank	--	--	--
D1	L1F100	94.82	72.38	86.83
D2	R2R030	93.56	75.51	86.24
D3	V1R010	93.14	74.93	85.32
D4	Blank	--	--	--
D5	R1R030	96.06	78.83	89.03
D6	Blank	--	--	--
D7	L2F030	103.85	76.63	93.74
D8	V5R020	93.97	74.52	85.90

8. REFERENCES

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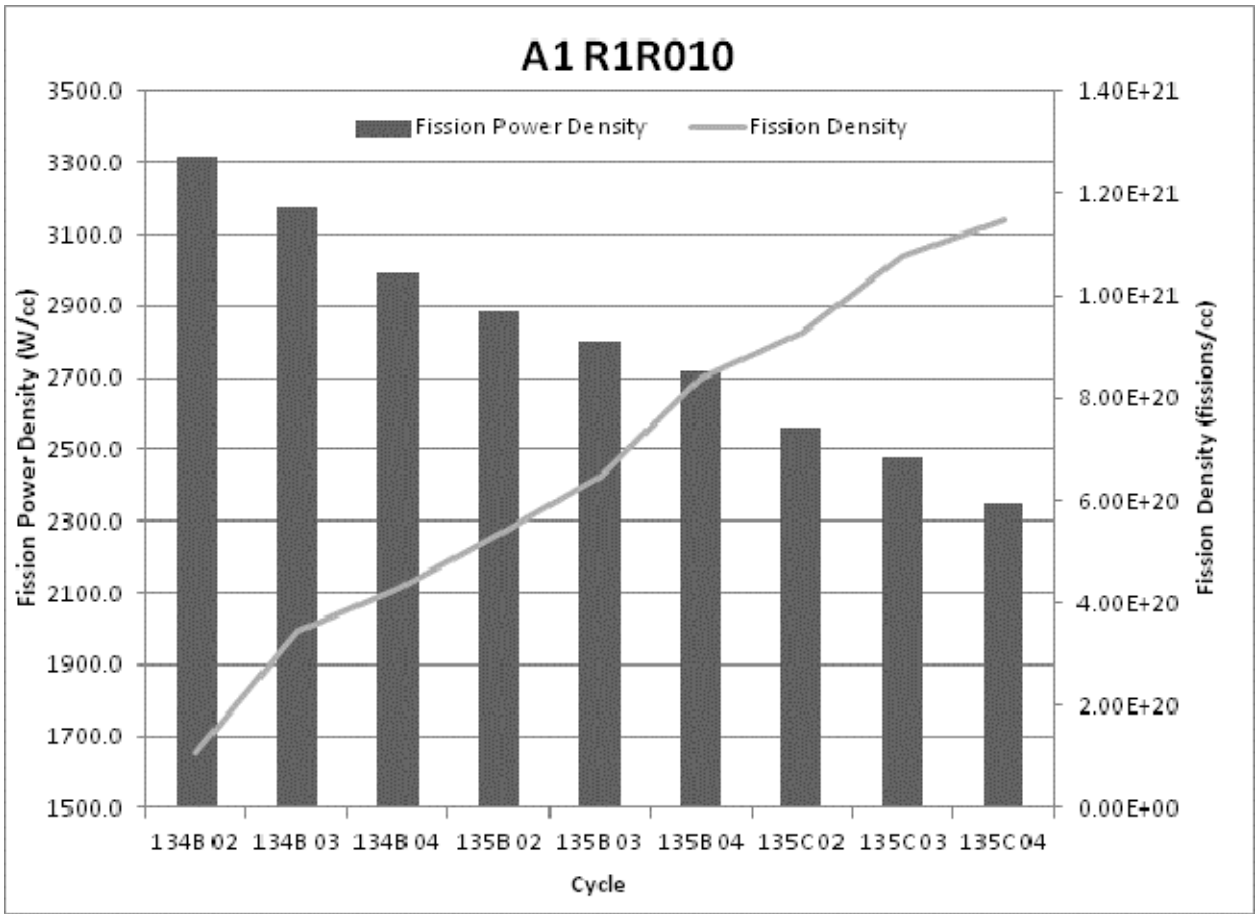
3. M. A. Lillo, G. S. Chang,“RERTR-6 As-Run Physics Re-Analysis Based on Corrected As-Built Data,” EDF-6856 Rev 1, January 2007.
4. M. A. Lillo to M. R. Finlay, “MCNP-Calculated Gradients Across RERTR-6 and RERTR-7A Miniplates Irradiated in ATR,” Interoffice Memorandum, January 2007. (See appendix B)
5. Wachs, D. M., 2007, “RERTR Large B Position Irradiation Vehicle Flow Test,” EDF-8292, July 2007.
6. P. E. Murray, “Validation of ABAQUS Standard 6.7-3 Heat Transfer,” ECAR-131, January 2008.
7. R. H. Perry, D. W. Green, “Perry’s Chemical Engineer’s Handbook,” 7th Edition, McGraw-Hill, 1997.

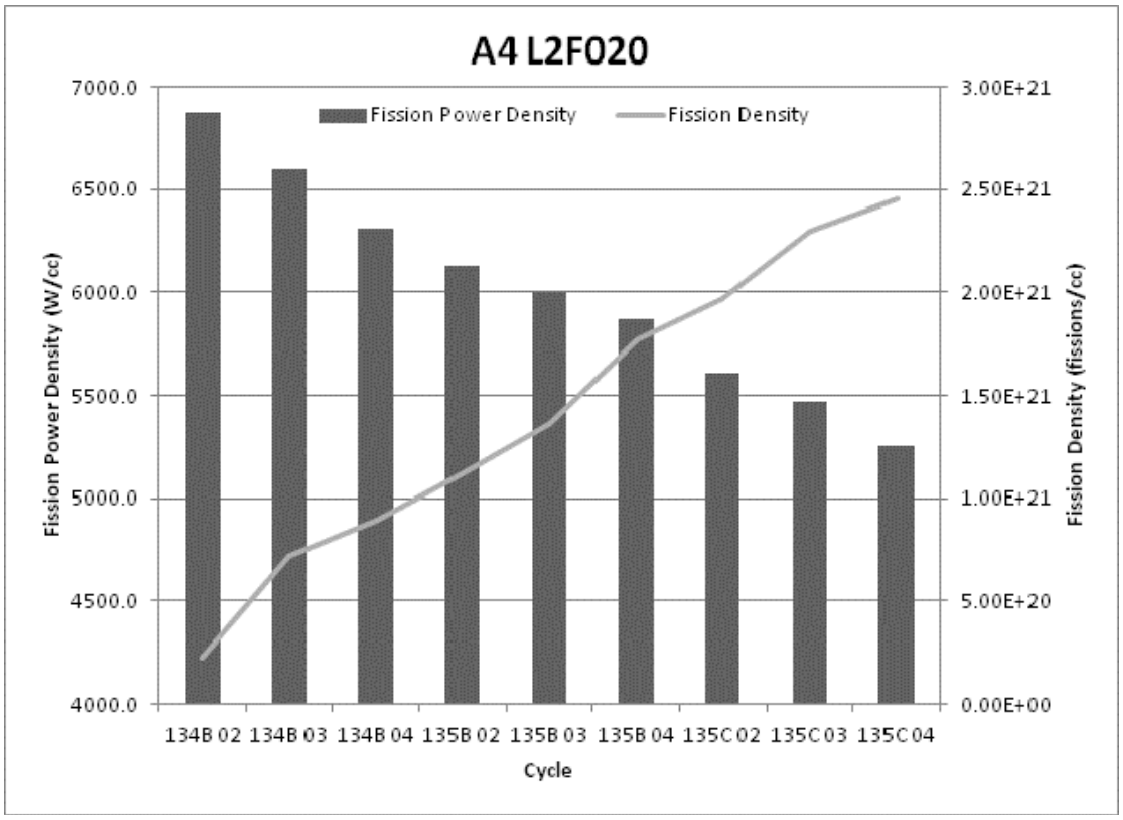
Appendix A

Individual Plate Power and Burnup Plots

Appendix A
Individual Plate Power and Burnup Plots

A-1. RERTR-6

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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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5000.0
4500.0
4000.0
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2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
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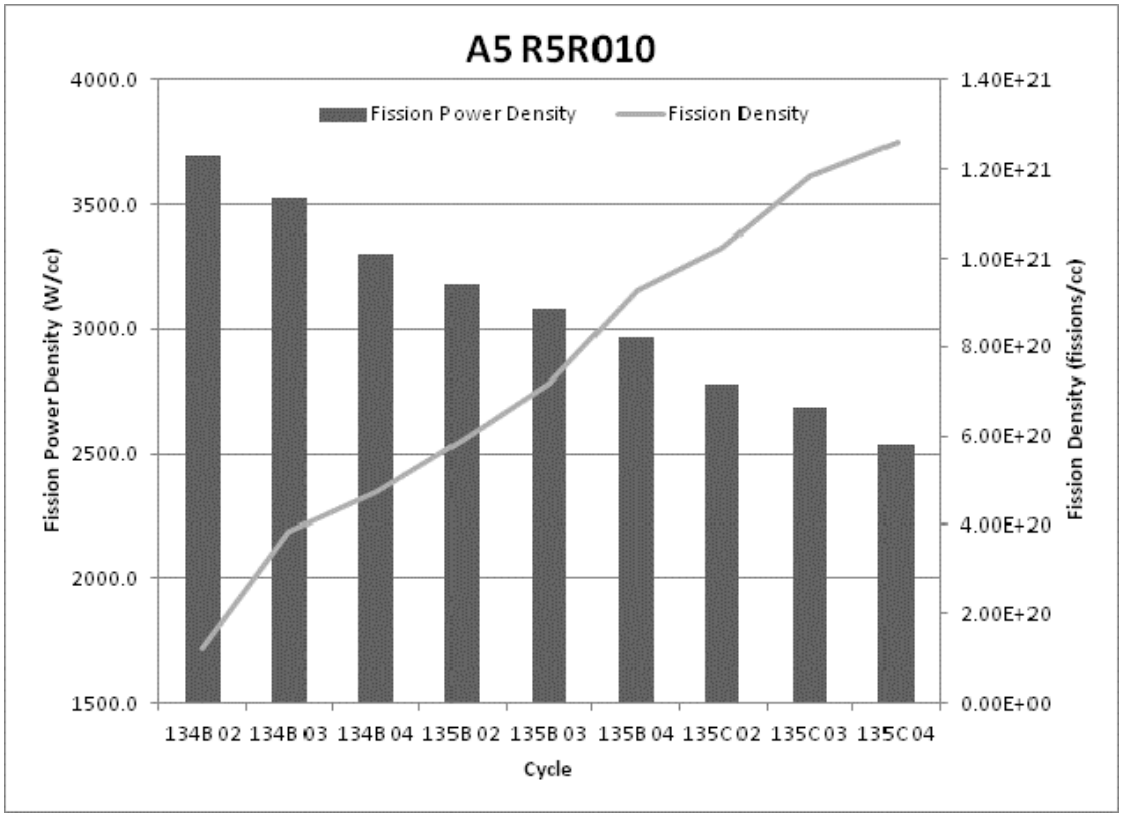
Cycle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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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1500.0
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1.20E+21
1.00E+21
8.00E+20
6.00E+20
4.00E+20
2.00E+20
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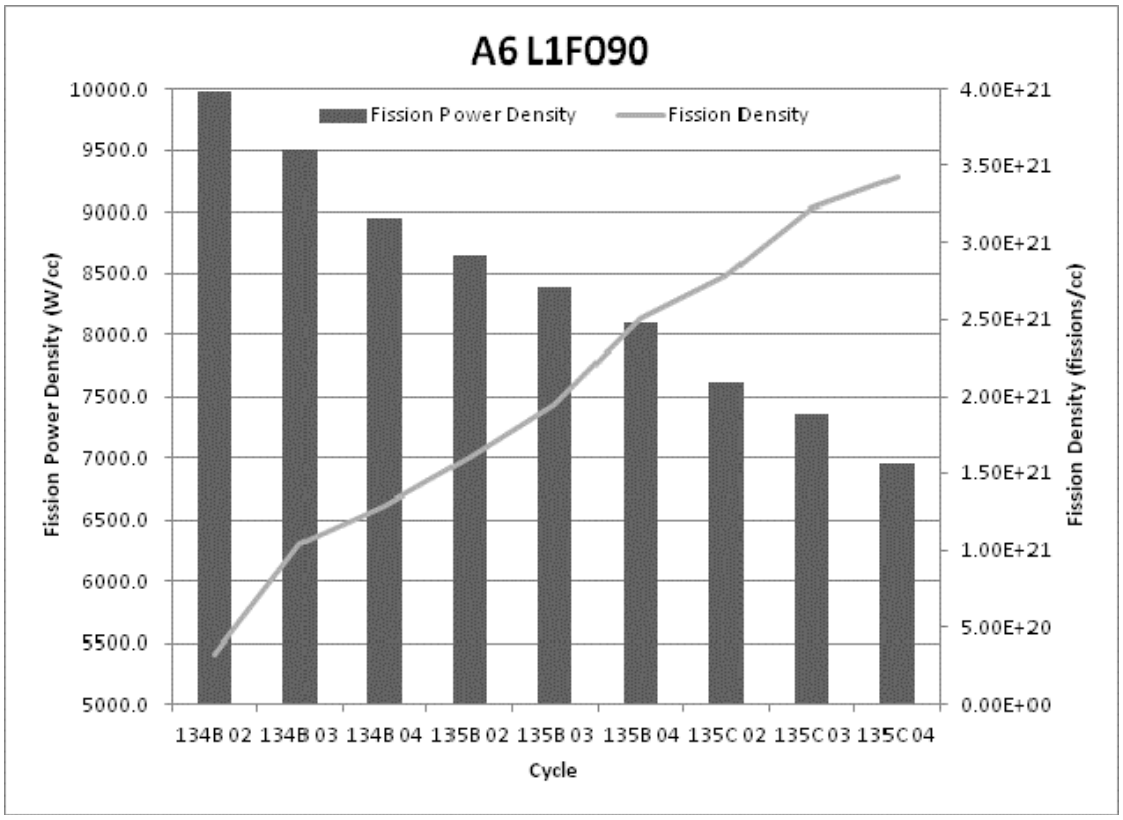
Cycle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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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9000.0
8500.0
8000.0
7500.0
7000.0
6500.0
6000.0
5500.0
5000.0
4.00E+21
3.50E+21
3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
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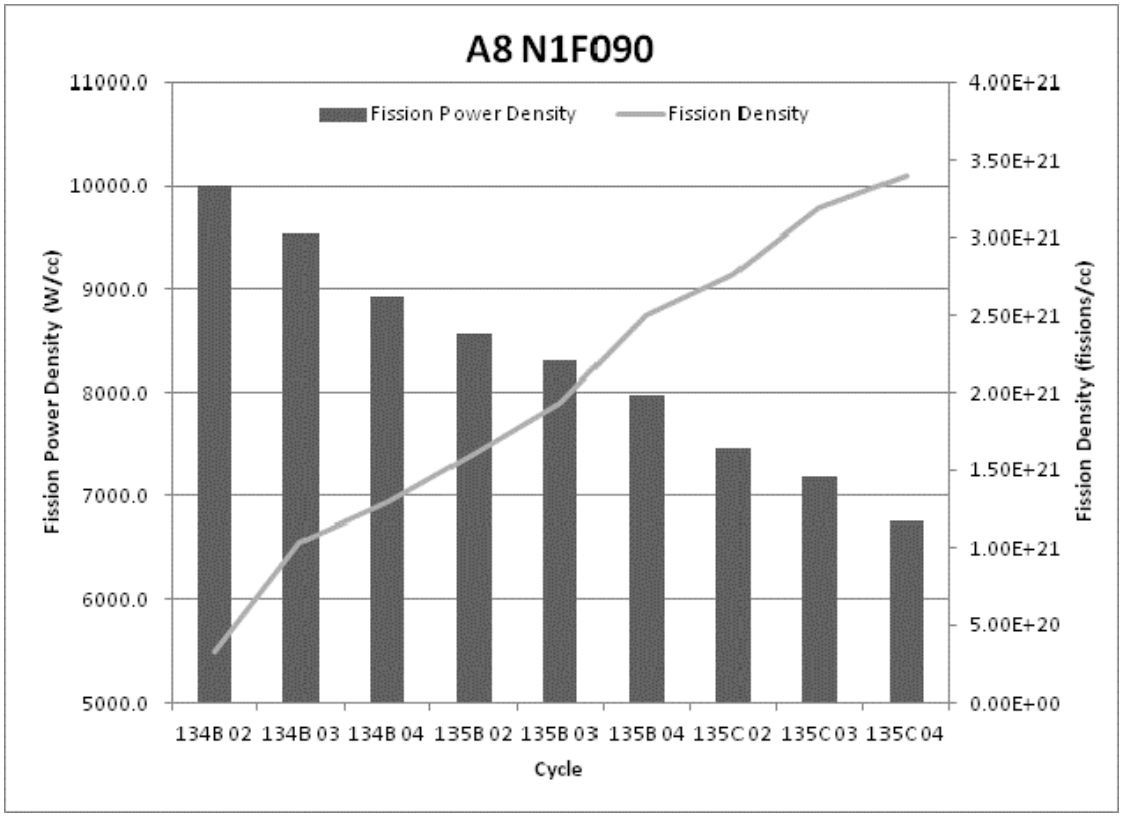
Cycle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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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3.50E+21
3.00E+21
2.50E+21
2.00E+21
1.50E+21
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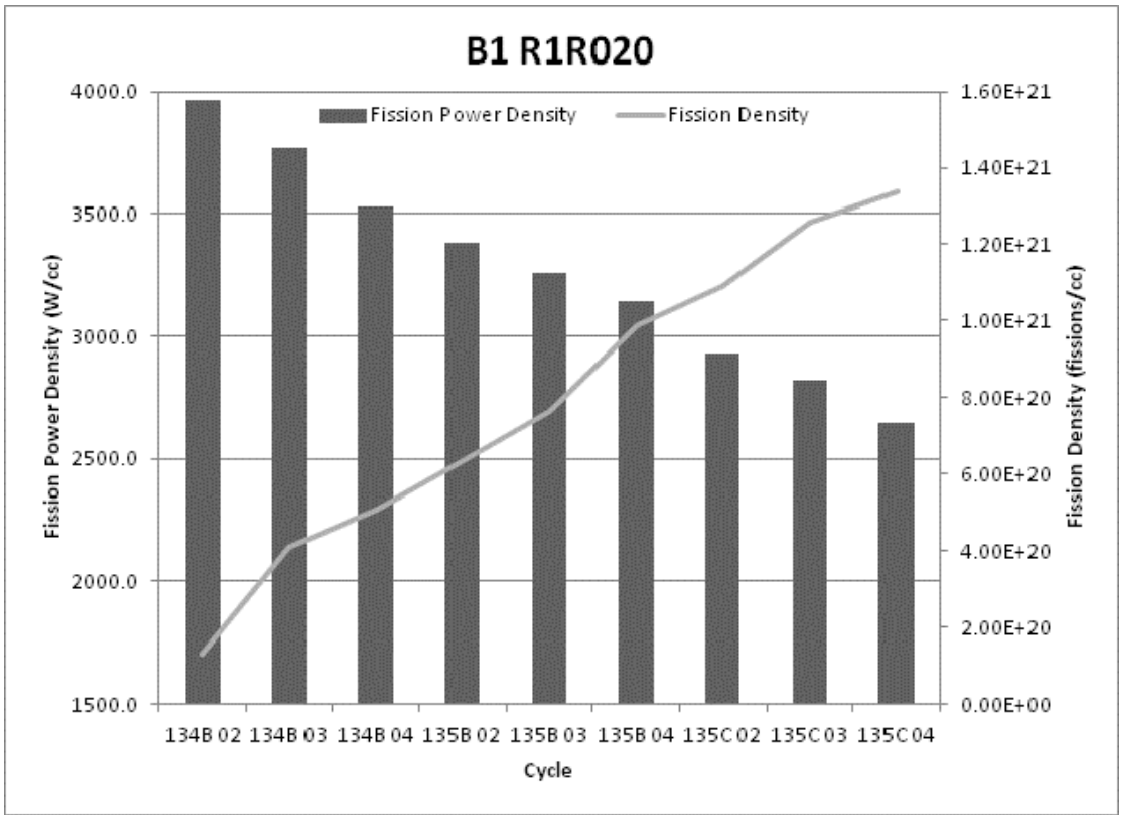
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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3000.0
2500.0
2000.0
1500.0
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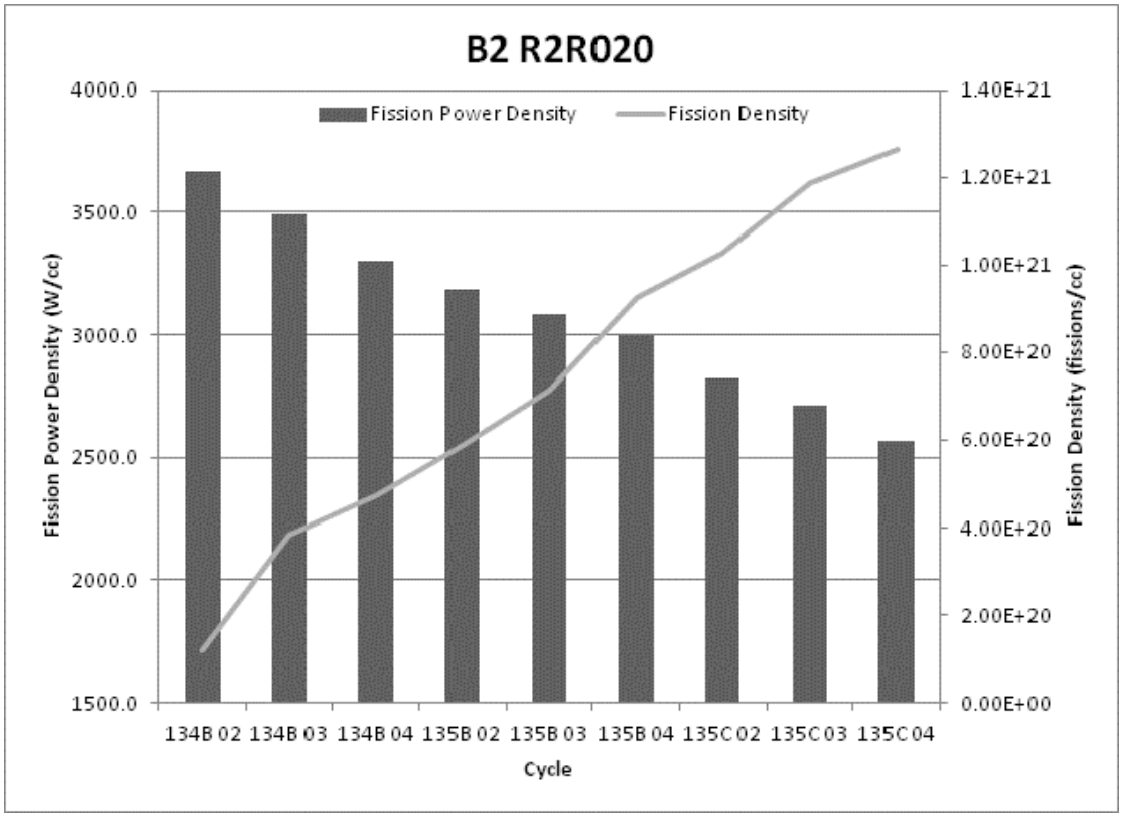
1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
4.00E+20
2.00E+20
0.00E+00
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle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Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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1500.0
1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
4.00E+20
2.00E+20
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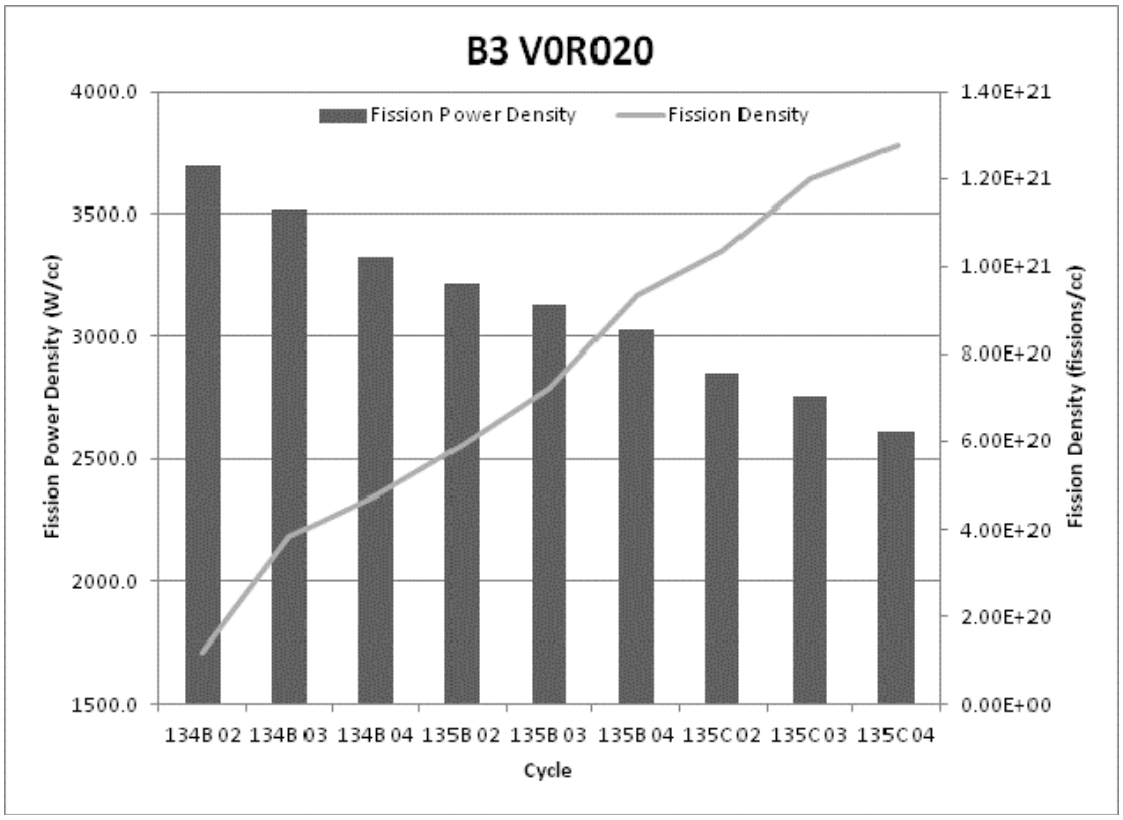
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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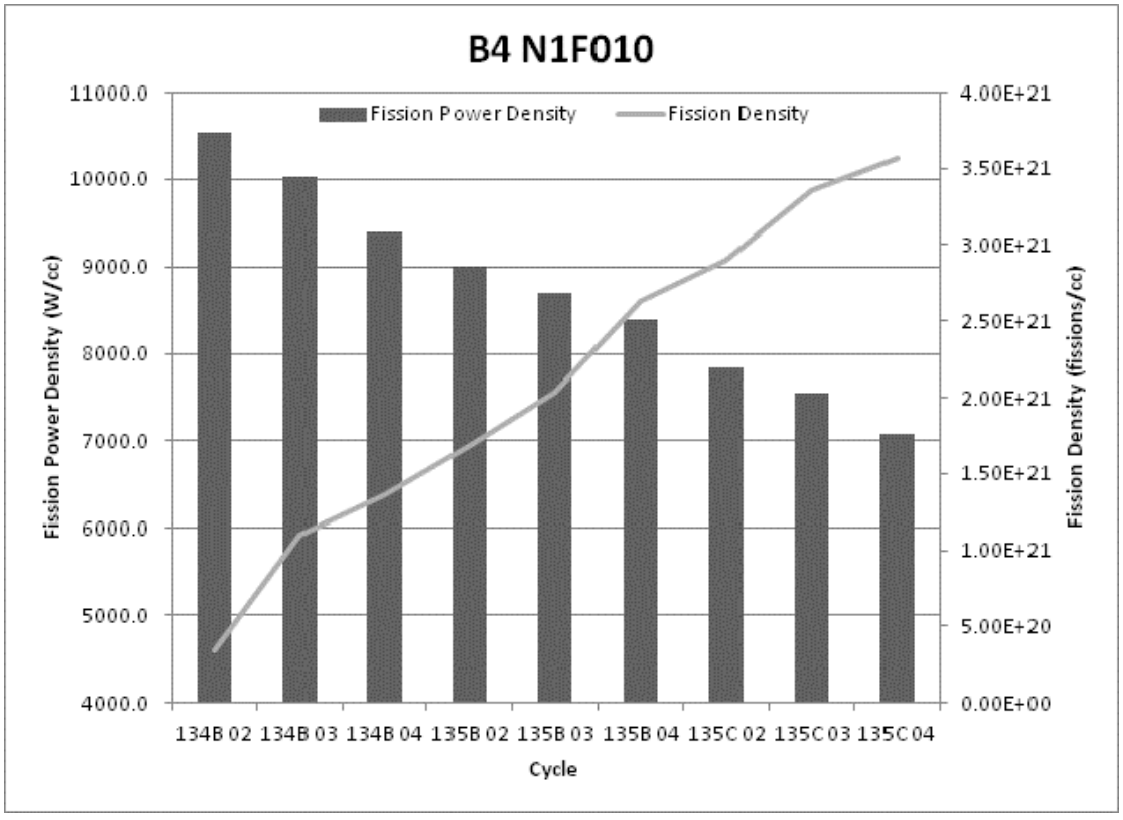
2500.0
2000.0
1500.0
1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
4.00E+20
2.00E+20
0.00E+00
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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8000.0
7000.0
6000.0
5000.0
4000.0
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3.50E+21
3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
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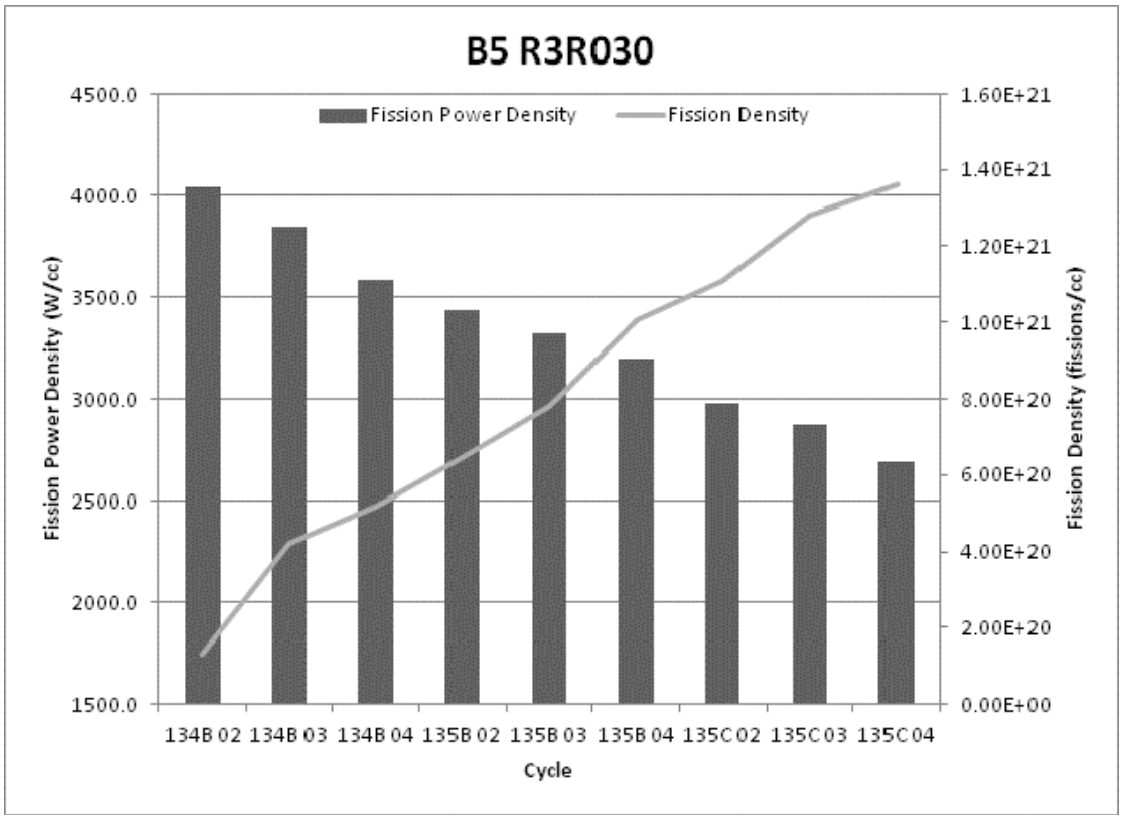
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
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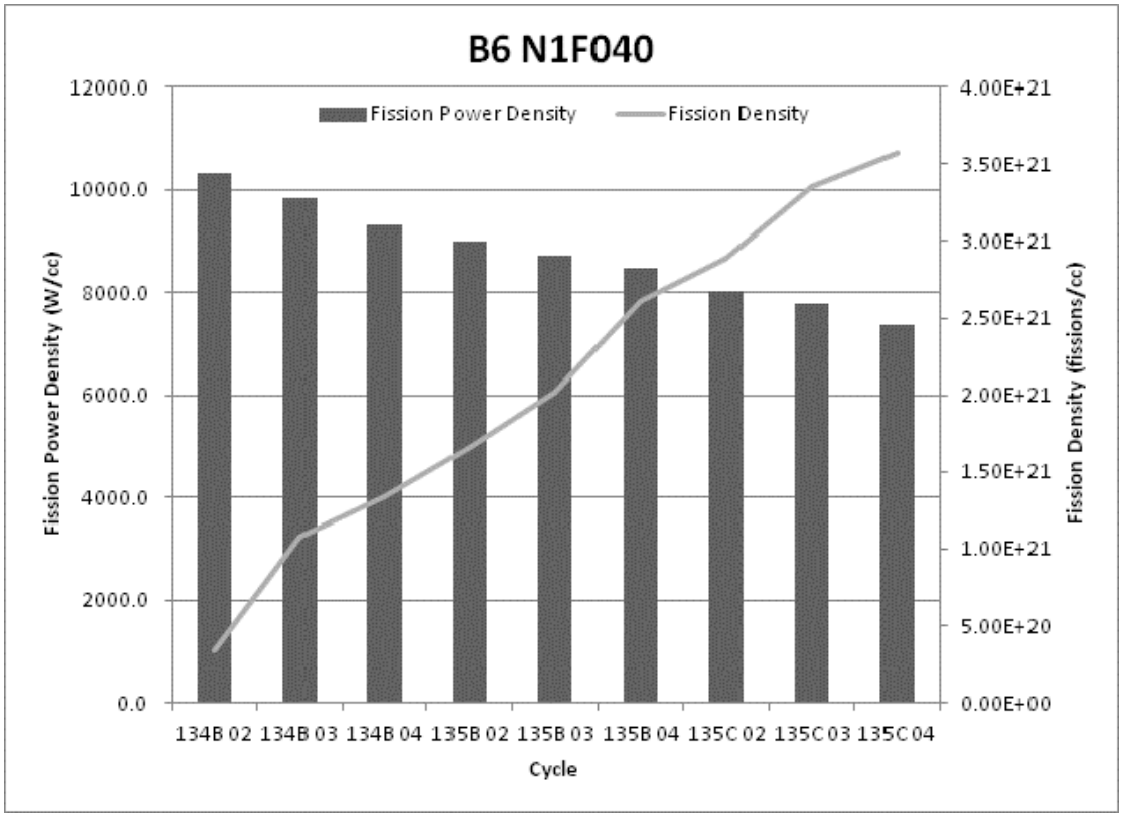
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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4000.0
2000.0
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4.00E+21
3.50E+21
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2.00E+21
1.50E+21
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5.00E+20
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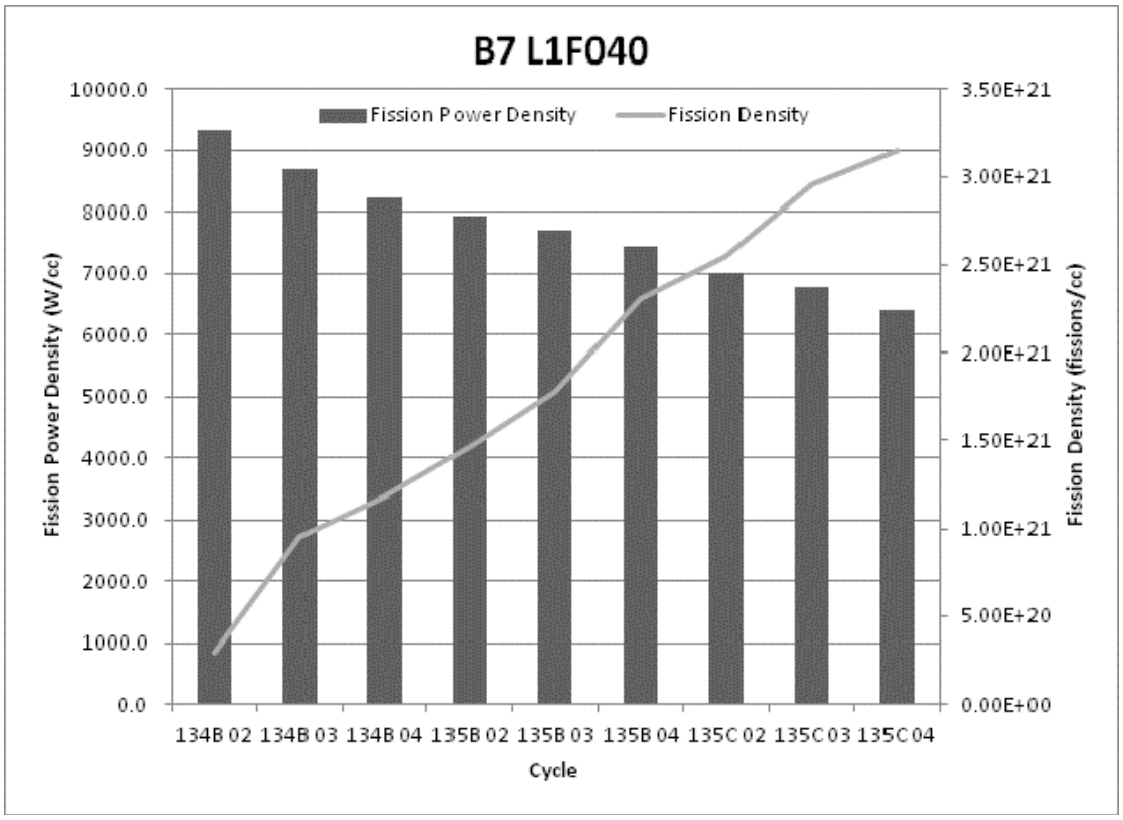
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle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Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
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3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
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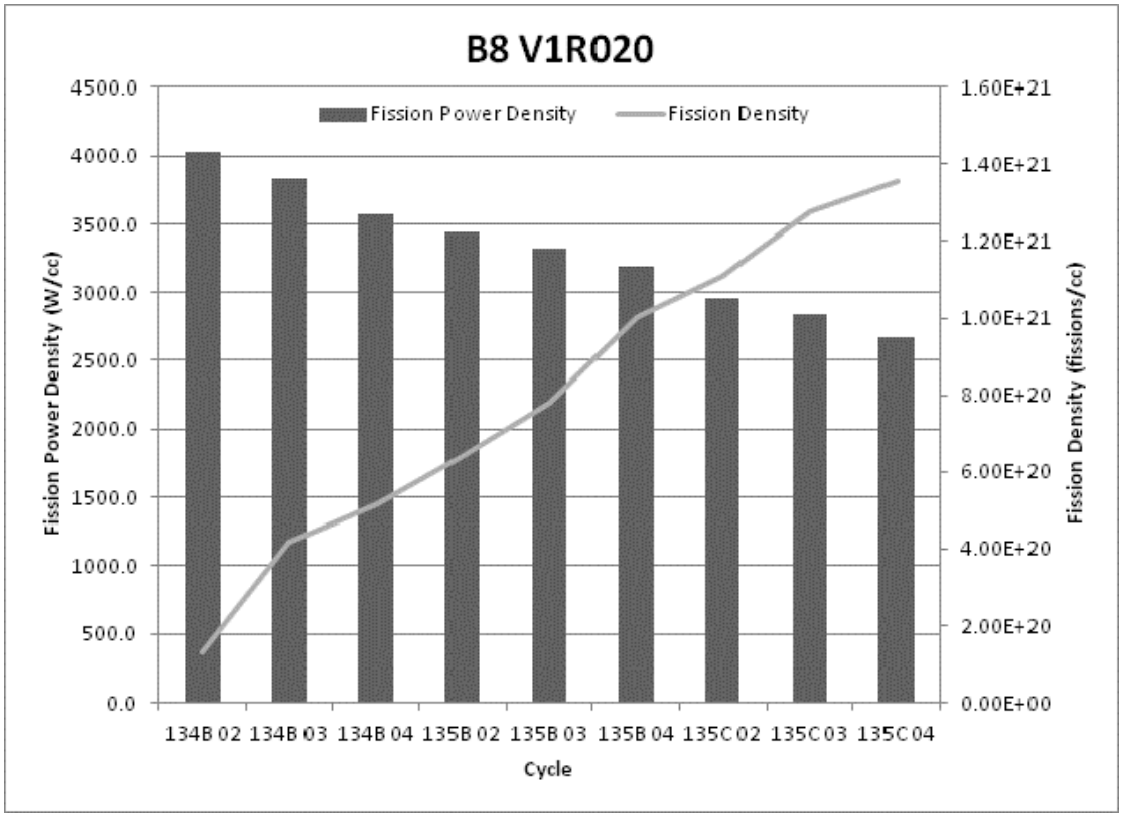
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
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1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
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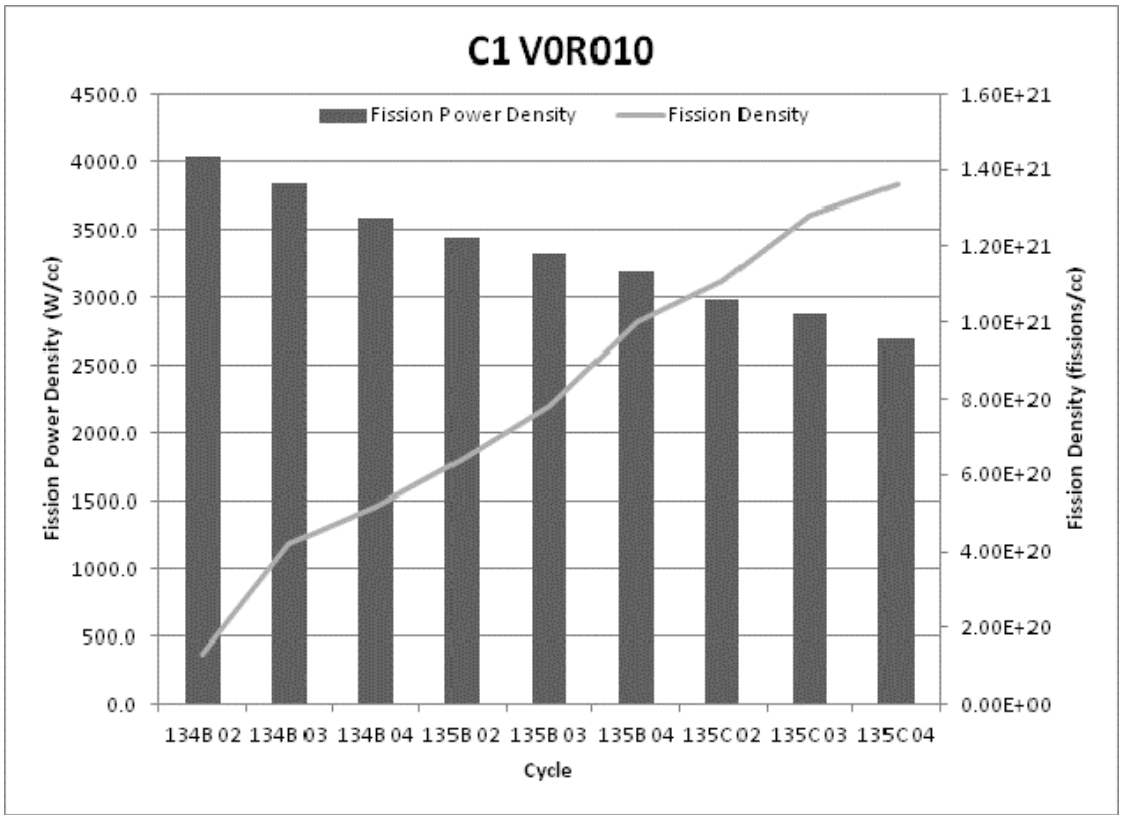
Cycle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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1.60E+21
1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
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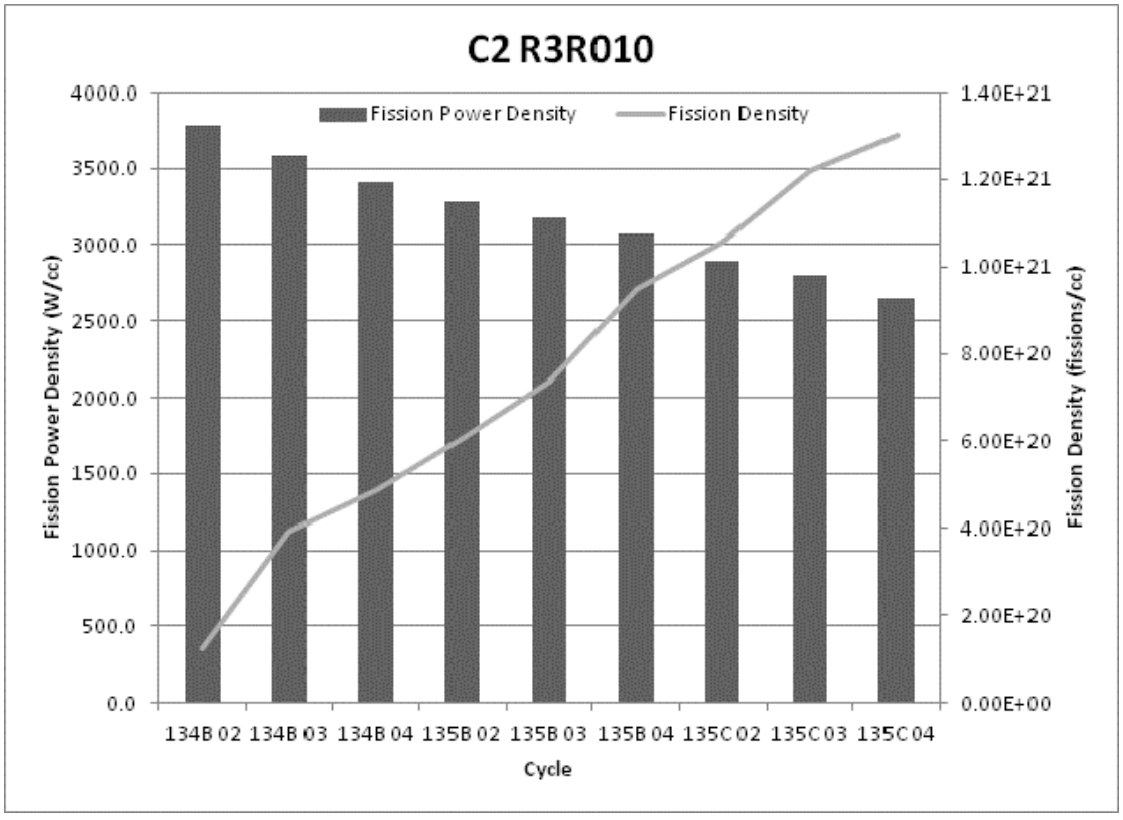
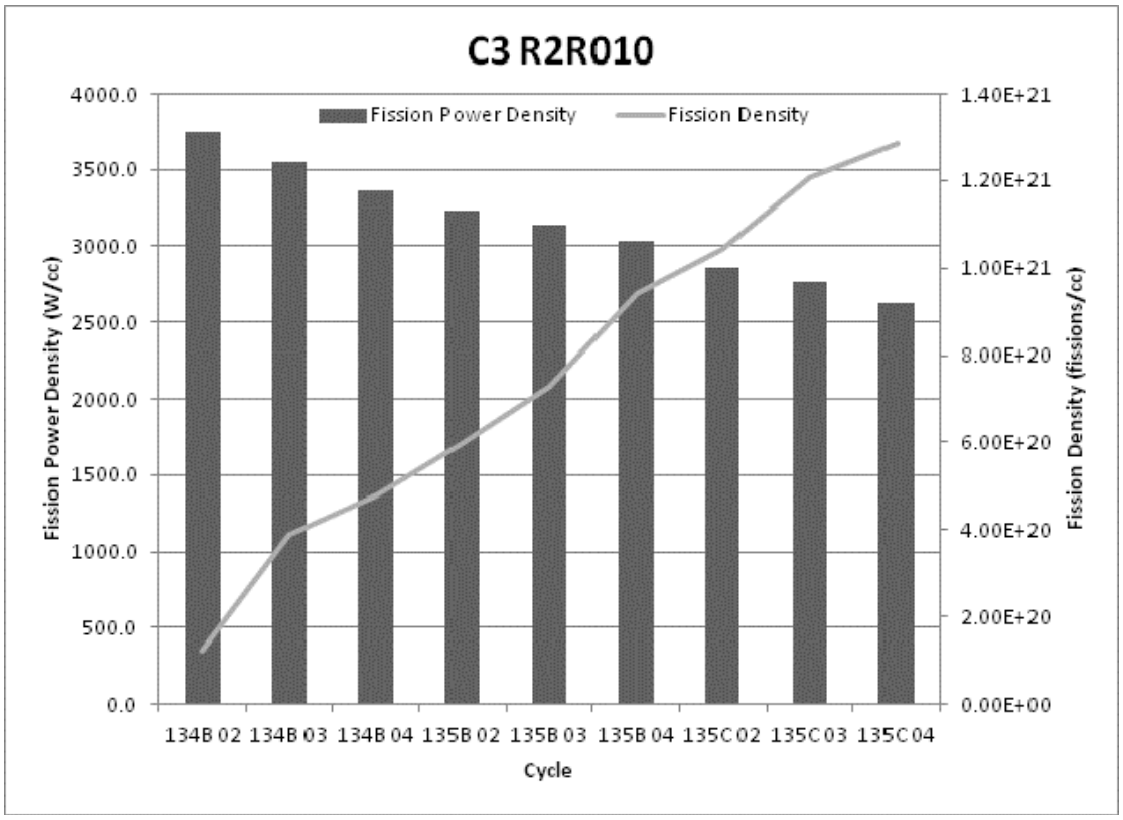
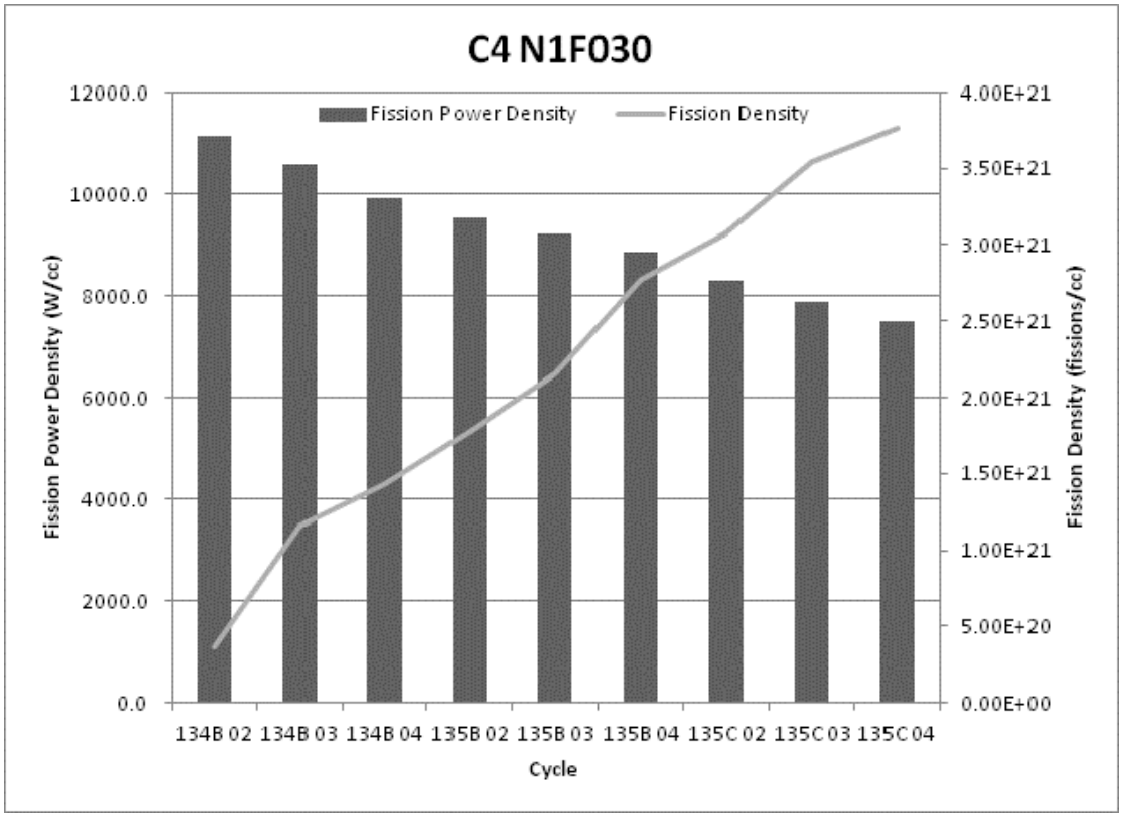
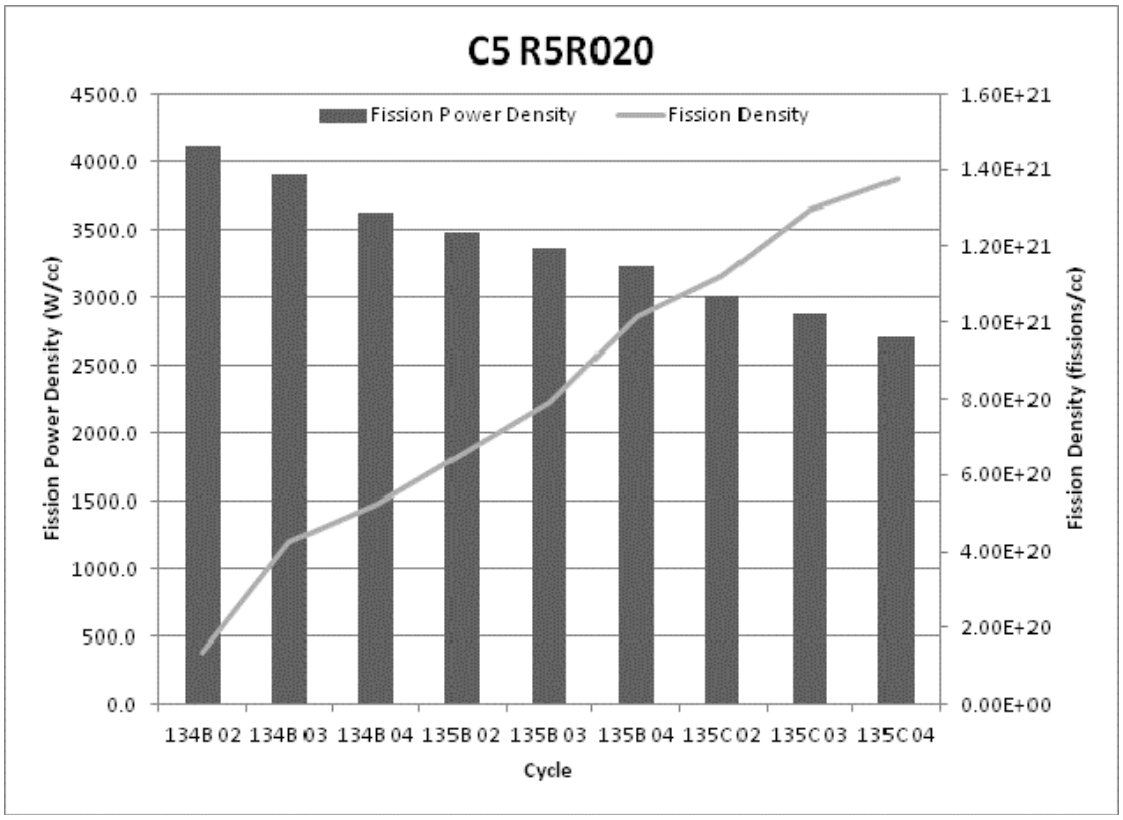
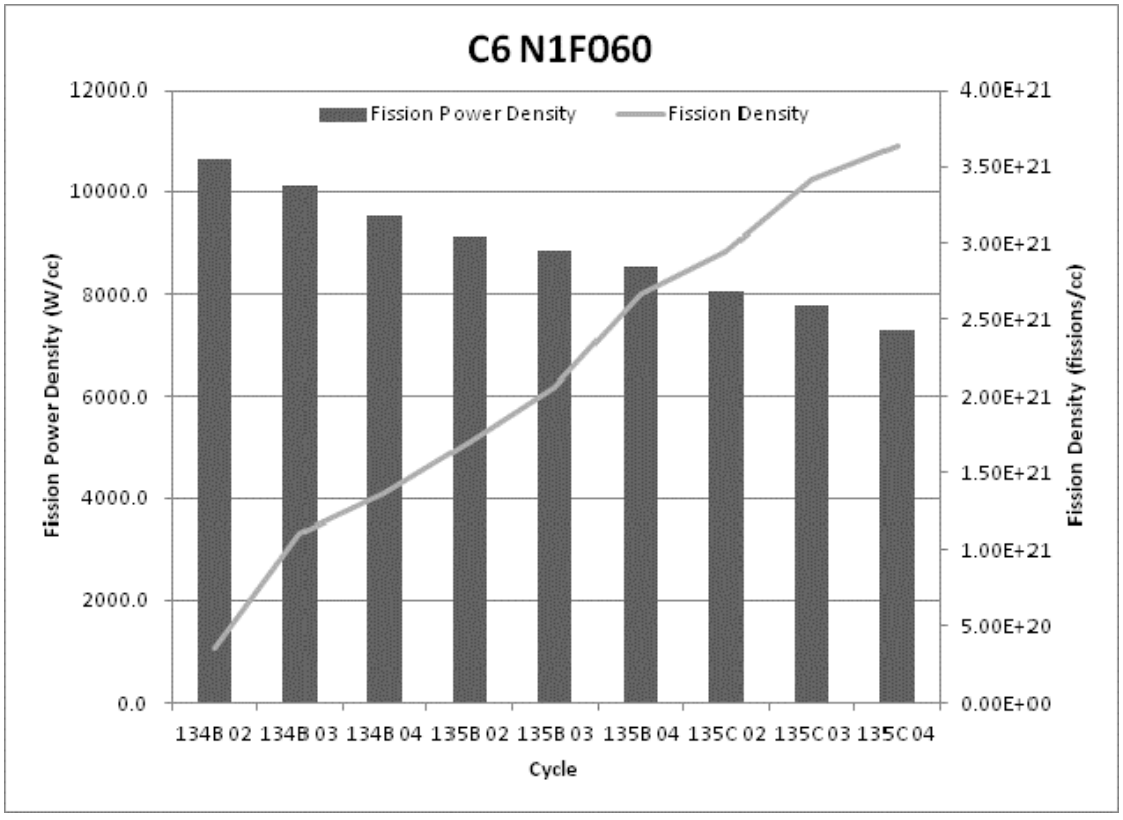
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle

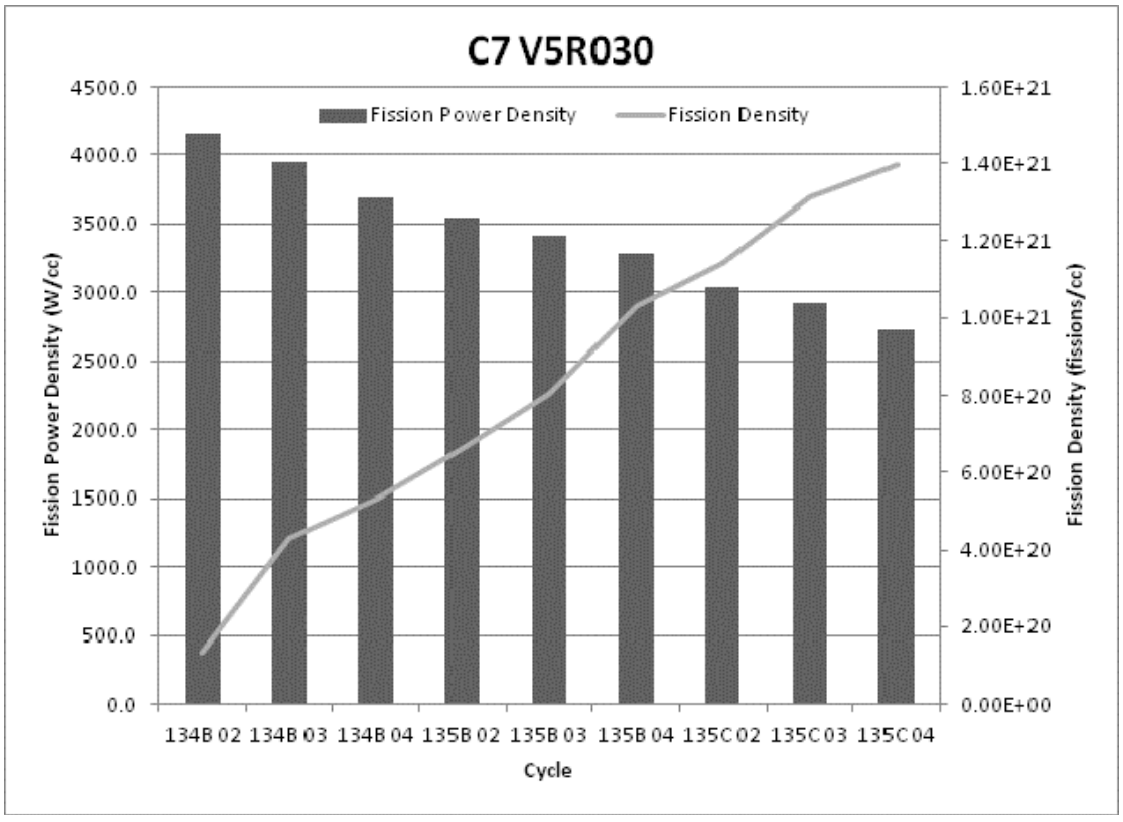

C2 R3R010
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
4.00E+20
2.00E+20
0.00E+00
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle

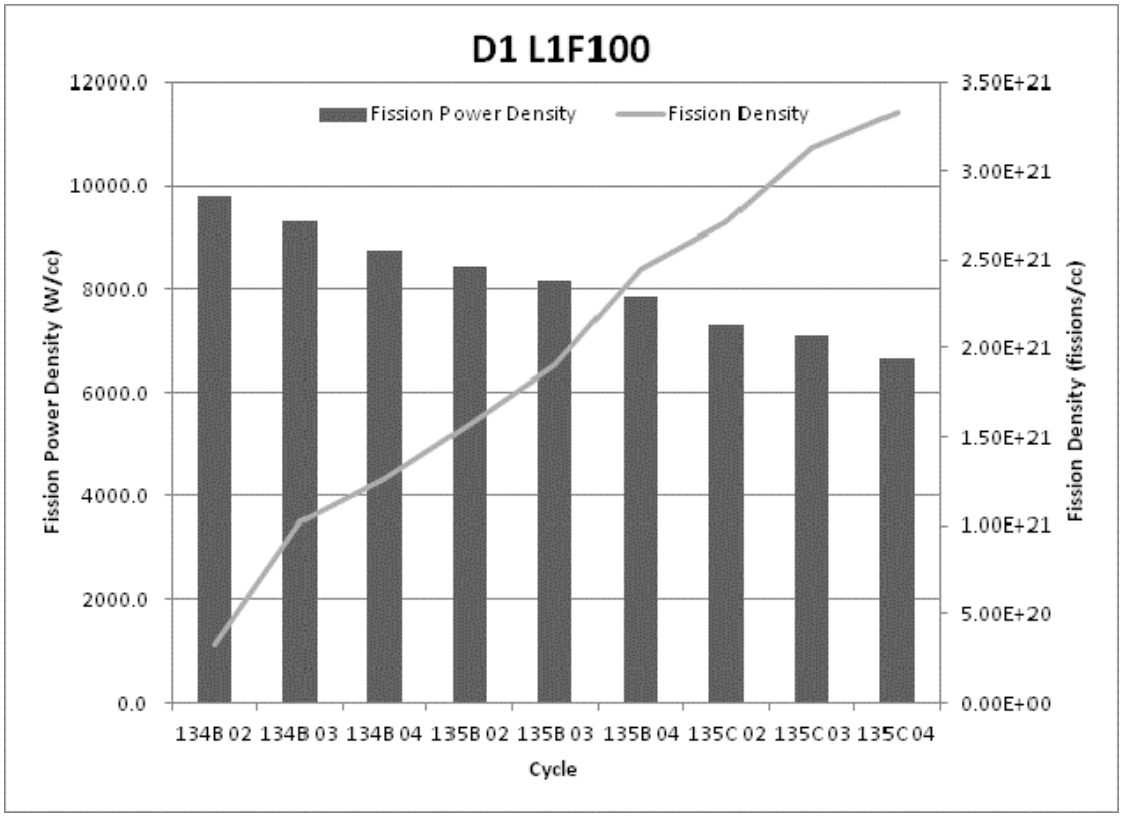

C3 R2R010
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
4.00E+20
2.00E+20
0.00E+00
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle

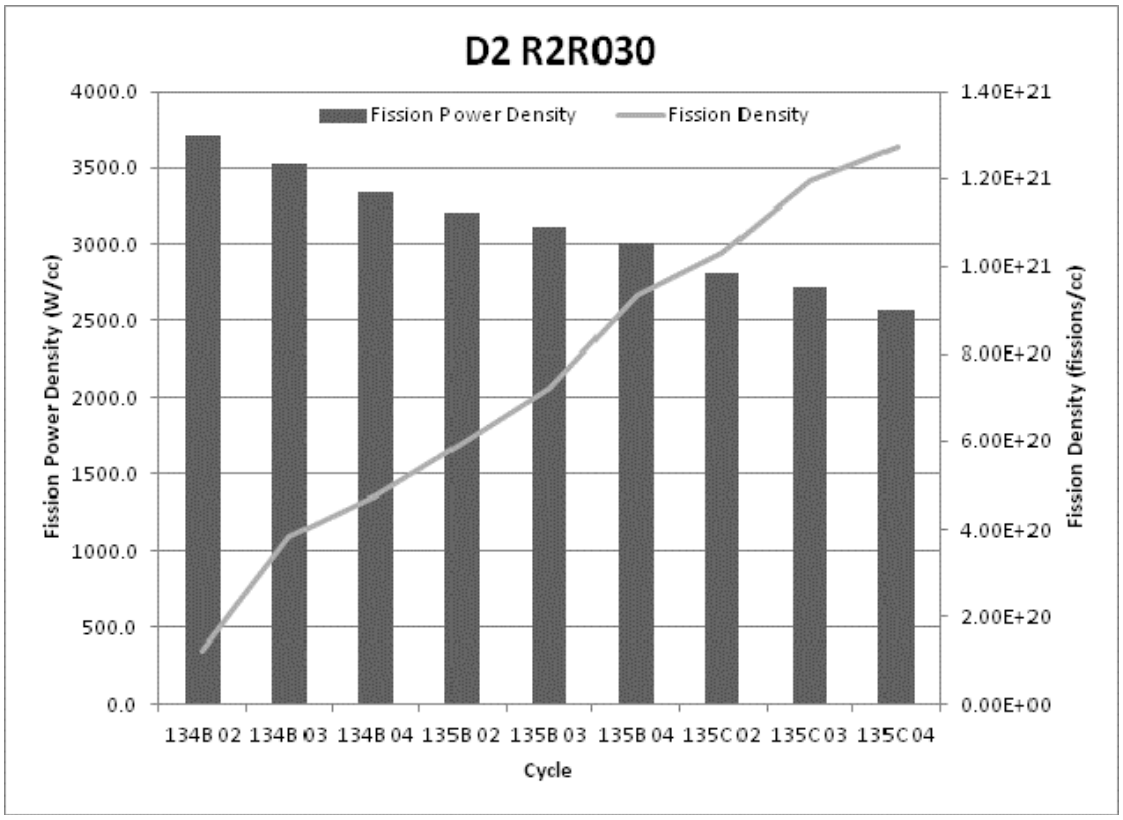

C4 N1F030
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
4.00E+21
3.50E+21
3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
0.00E+00
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle

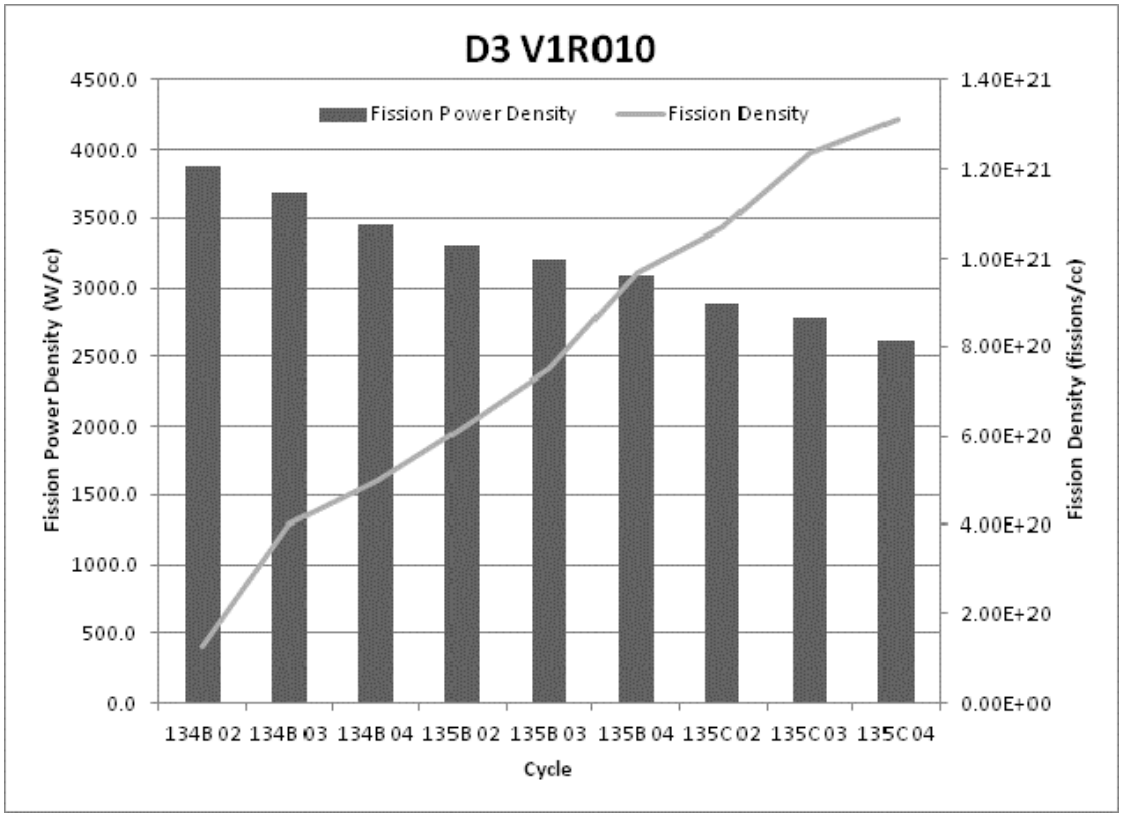

C5 R5R020
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1.60E+21
1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
4.00E+20
2.00E+20
0.00E+00
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle

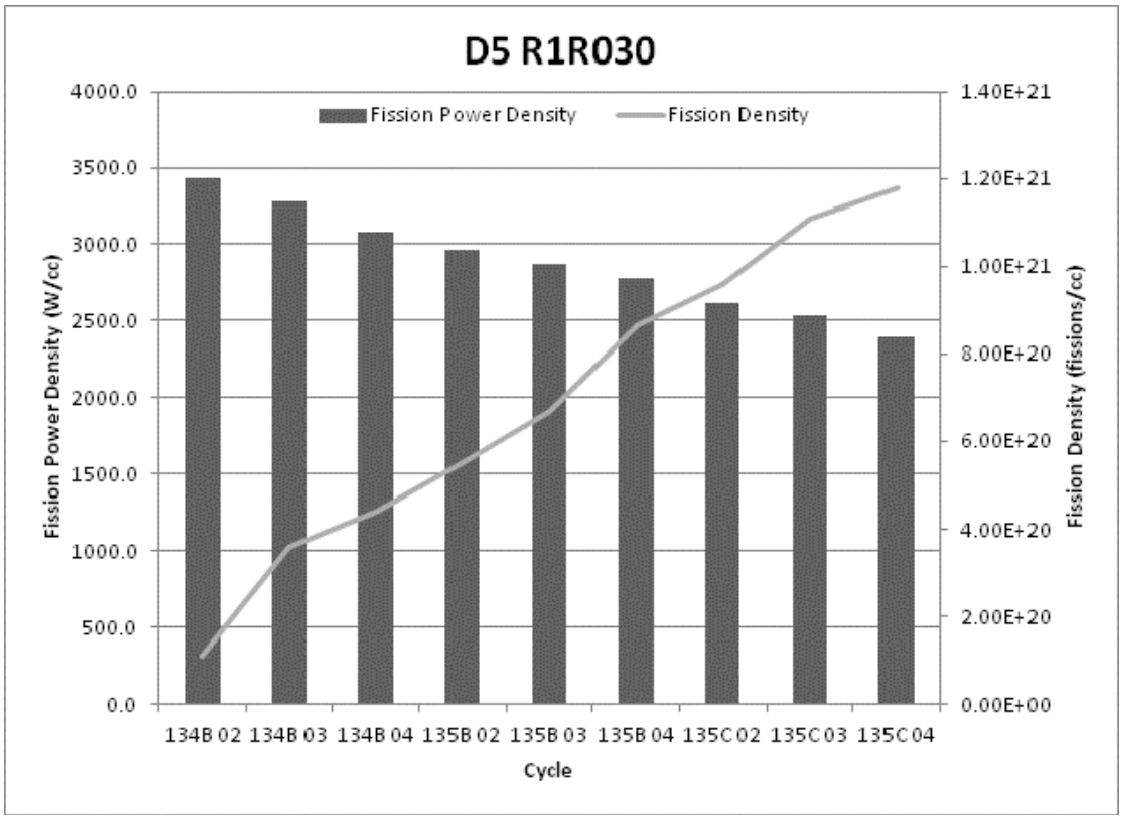

C6 N1F060
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
4.00E+21
3.50E+21
3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
0.00E+00
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle

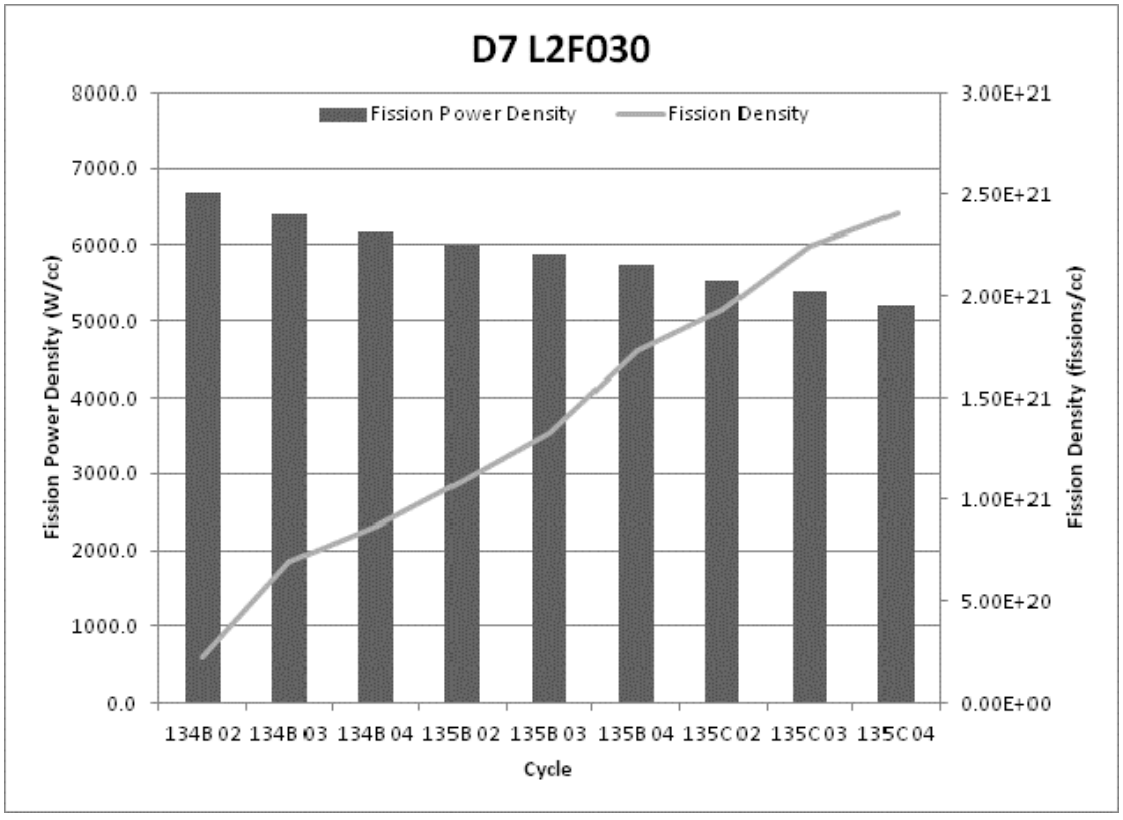

C7 V5R030
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1.60E+21
1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
4.00E+20
2.00E+20
0.00E+00
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle

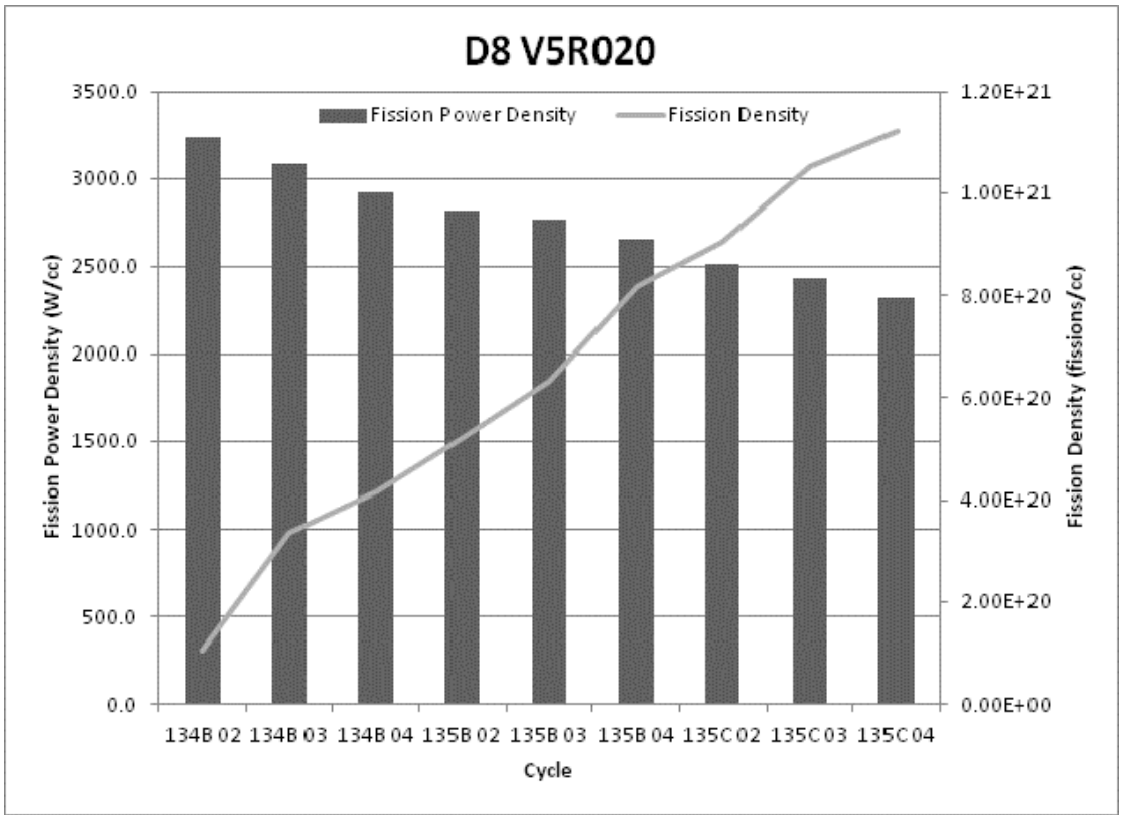

D1 L1F100
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
3.50E+21
3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
0.00E+00
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle


D2 R2R030
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
4.00E+20
2.00E+20
0.00E+00
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle


D3 V1R010
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
4.00E+20
2.00E+20
0.00E+00
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle


D5 R1R030
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
4.00E+20
2.00E+20
0.00E+00
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle


D7 L2F030
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
8000.0
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
0.00E+00
134B 02 134B 03 134B 04 135B 02 135B 03 135B 04 135C 02 135C 03 135C 04
Cycle


D8 V5R020
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1.20E+21
1.00E+21
8.00E+20
6.00E+20
4.00E+20
2.00E+20
0.00E+00
134B 02
134B 03
134B 04
135B 02
135B 03
135B 04
135C 02
135C 03
135C 04
Cycle

Appendix B

Lillo Letter to Finley

INTEROFFICE MEMORANDUM

Idaho National Laboratory INL

Date: January 9, 2007

To: M. R. Finlay MS 6188 3-7572

From: M. A. Lillo MS 3885 6-5843

Subject: MCNP-Calculated Gradients Across RERTR-6 and RERTR-7A Miniplates Irradiated in ATR.

8.1.1 References

8. M. R. Finlay email communication to G. S. Chang, "Subject: power gradient across RERTR plates", December 19, 2006 (Attachment 1).
9. D. M. Wachs email communication to G. S. Chang and M. A. Lillo, attachment "RERTR-6 matrix as-built.xls", March 27, 2006.
10. D. M. Wachs intra-laboratory memorandum to Distribution, DMW-002-006, "As-Built Constituent Masses for RERTR-7A Mini-plate Experiment", March 6, 2006.

8.1.2 Discussion

As requested, calculations were performed to characterize the power gradient across each RERTR-6 and RERTR-7A miniplate. This memo reports the MCNP-calculated gradients for both the RERTR-6 and RERTR-7A miniplates irradiated in ATR. Figures 1 and 2 were generated by the MCNP models used to perform RERTR-6 and RERTR-7A calculations, respectively. The thermal neutron flux local-to-average ratios (L2ARs) and fission rate L2ARs were calculated for the RERTR-6 miniplates irradiated in the ATR B-12 position and the RERTR-7A miniplates irradiated in the ATR B-11 position.

8.1.3 Results

The calculated thermal neutron flux L2AR and fission rate L2AR for RERTR-6 are tabulated in Tables 1 and 2, respectively. The calculated thermal neutron flux L2AR and fission rate L2AR for RERTR-7A is tabulated in Tables 3 and 4, respectively. Figures 3 through 6 were included to illustrate the data trends from the plate edge located nearest the core center (Node 1) to the plate edge located farthest from the core center (Node 20).

cc: D. M. Wachs, MS 6188
G. S. Chang, MS 3750
M. A. Lillo letter file (MAL-01-07)

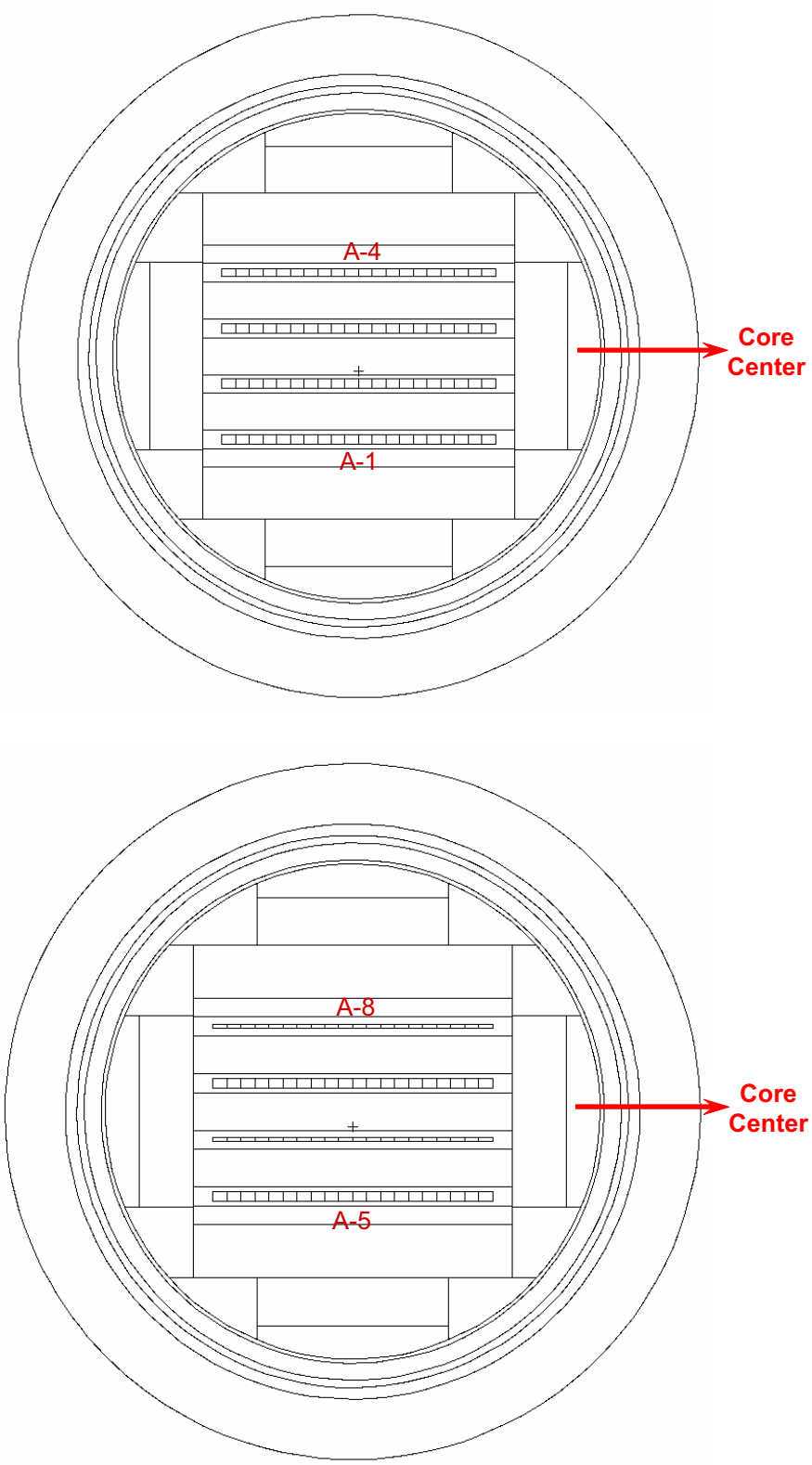


Figure 17 - RERTR-6 capsule A miniplates A-1 thru A-8 irradiated in ATR B-12 position.

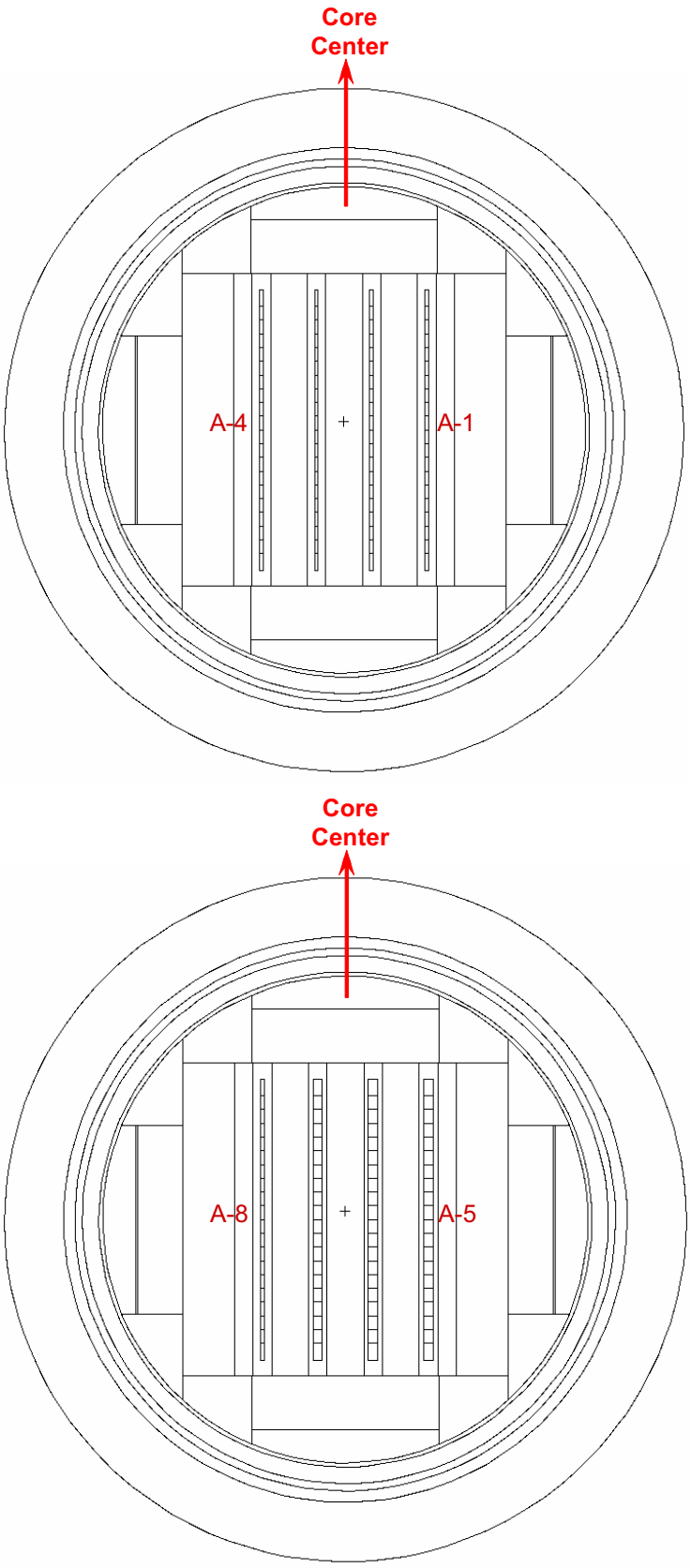


Figure 18 - RERTR-7A capsule A miniplates A-1 thru A-8 irradiated in ATR B-11 position.

Table 1 - RERTR-6 thermal neutron flux local to average ratio (L2AR) along the plate width (from core center plate edge to outer plate edge)

	Fuel	Fuel	Core Edge									Position									Outer Edge
ID	Phase	Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6A-1	---	blank	1.28	1.30	1.25	1.18	1.16	1.11	1.09	1.06	1.02	0.99	0.95	0.93	0.93	0.88	0.88	0.83	0.82	0.79	0.78	0.76
6A-2	U-7Mo	disp	1.41	1.30	1.26	1.19	1.16	1.12	1.09	1.06	1.02	1.00	0.95	0.92	0.92	0.85	0.85	0.83	0.80	0.77	0.75	0.75
6A-3	---	blank	1.44	1.33	1.26	1.21	1.21	1.15	1.07	1.06	1.00	0.96	0.95	0.92	0.90	0.87	0.83	0.82	0.78	0.75	0.74	0.76
6A-4	U-10Mo	thick foil	1.49	1.33	1.26	1.17	1.15	1.11	1.04	1.03	0.96	0.96	0.93	0.93	0.91	0.87	0.82	0.82	0.80	0.80	0.80	0.82
6A-5	U-7Mo	disp	1.48	1.32	1.25	1.22	1.13	1.10	1.05	1.03	1.02	0.98	0.94	0.90	0.89	0.87	0.85	0.85	0.80	0.79	0.77	0.77
6A-6	U-10Mo	dual foil	1.45	1.37	1.24	1.21	1.15	1.10	1.10	1.07	1.01	0.96	0.91	0.89	0.89	0.86	0.82	0.83	0.81	0.79	0.76	0.78
6A-7	---	blank	1.41	1.34	1.23	1.16	1.17	1.14	1.10	1.07	1.04	1.01	0.98	0.93	0.90	0.86	0.83	0.81	0.80	0.76	0.74	0.72
6A-8	U-7Mo	foil	1.40	1.31	1.23	1.21	1.16	1.11	1.06	1.06	0.98	0.97	0.95	0.91	0.90	0.91	0.87	0.82	0.81	0.79	0.80	0.75
6B-1	U-7Mo	disp	1.46	1.33	1.25	1.22	1.14	1.07	1.06	1.02	1.00	0.97	0.93	0.92	0.88	0.85	0.85	0.84	0.81	0.79	0.80	0.78
6B-2	U-7Mo	disp	1.52	1.39	1.31	1.23	1.18	1.10	1.13	1.04	0.99	0.95	0.93	0.89	0.84	0.83	0.83	0.82	0.78	0.76	0.73	0.75
6B-3	U-10Mo	foil	1.50	1.40	1.30	1.25	1.20	1.12	1.10	1.03	0.97	0.94	0.92	0.89	0.88	0.82	0.82	0.79	0.78	0.75	0.77	0.76
6B-4	U-7Mo	foil	1.45	1.31	1.26	1.20	1.13	1.13	1.08	1.02	1.01	0.96	0.97	0.92	0.87	0.91	0.85	0.81	0.83	0.79	0.75	0.76
6B-5	U-7Mo	disp	1.51	1.38	1.24	1.24	1.15	1.08	1.07	1.01	0.99	0.95	0.92	0.91	0.87	0.86	0.85	0.82	0.82	0.79	0.75	0.77
6B-6	U-7Mo	foil	1.54	1.40	1.31	1.20	1.18	1.09	1.05	1.00	1.02	0.96	0.91	0.91	0.87	0.81	0.82	0.83	0.82	0.77	0.75	0.77
6B-7	U-10Mo	foil	1.51	1.40	1.30	1.25	1.16	1.12	1.09	1.05	0.97	0.93	0.88	0.87	0.88	0.86	0.83	0.82	0.79	0.77	0.75	0.77
6B-8	U-10Mo	disp	1.45	1.30	1.26	1.22	1.16	1.11	1.05	1.04	1.01	0.93	0.91	0.90	0.88	0.88	0.85	0.84	0.82	0.81	0.78	0.79
6C-1	U-10Mo	foil	1.45	1.34	1.27	1.22	1.15	1.11	1.02	1.01	0.98	0.95	0.92	0.90	0.91	0.88	0.87	0.85	0.81	0.79	0.79	0.76
6C-2	U-7Mo	disp	1.53	1.36	1.28	1.21	1.19	1.12	1.06	1.01	0.98	0.97	0.94	0.90	0.88	0.84	0.80	0.82	0.77	0.77	0.80	0.78
6C-3	U-7Mo	disp	1.57	1.41	1.28	1.23	1.17	1.11	1.05	1.01	0.98	0.99	0.91	0.86	0.86	0.87	0.84	0.80	0.80	0.78	0.75	0.75
6C-4	U-7Mo	foil	1.44	1.36	1.27	1.19	1.12	1.09	1.08	1.03	0.98	0.98	0.94	0.90	0.88	0.87	0.87	0.83	0.82	0.79	0.79	0.78
6C-5	U-7Mo	disp	1.47	1.34	1.26	1.22	1.15	1.12	1.06	1.00	0.98	0.97	0.93	0.90	0.88	0.86	0.86	0.81	0.81	0.83	0.77	0.78
6C-6	U-7Mo	foil	1.52	1.40	1.27	1.18	1.18	1.10	1.07	1.01	1.01	0.94	0.95	0.89	0.87	0.85	0.83	0.81	0.77	0.78	0.77	0.80
6C-7	U-10Mo	disp	1.46	1.36	1.29	1.21	1.15	1.11	1.05	1.05	1.00	0.96	0.94	0.91	0.87	0.84	0.83	0.81	0.80	0.78	0.78	0.79
6C-8	---	blank	1.32	1.27	1.26	1.20	1.15	1.11	1.08	1.05	1.01	0.98	0.97	0.94	0.93	0.90	0.86	0.83	0.81	0.80	0.77	0.74
6D-1	U-10Mo	foil	1.47	1.37	1.26	1.22	1.14	1.09	1.05	1.03	1.00	0.98	0.90	0.92	0.88	0.87	0.87	0.84	0.81	0.80	0.78	0.75
6D-2	U-7Mo	disp	1.48	1.39	1.30	1.25	1.16	1.11	1.06	1.04	0.97	0.96	0.94	0.89	0.87	0.85	0.83	0.82	0.78	0.77	0.75	0.77
6D-3	U-10Mo	disp	1.45	1.36	1.28	1.20	1.16	1.10	1.06	1.04	1.03	0.98	0.96	0.91	0.89	0.84	0.84	0.82	0.80	0.78	0.76	0.75
6D-4	---	blank	1.31	1.28	1.24	1.20	1.16	1.12	1.09	1.06	1.00	1.00	0.97	0.93	0.90	0.88	0.87	0.82	0.83	0.80	0.79	0.75
6D-5	U-7Mo	disp	1.40	1.30	1.27	1.17	1.14	1.11	1.07	1.03	1.04	0.97	0.95	0.93	0.91	0.90	0.86	0.82	0.81	0.78	0.78	0.76
6D-6	---	blank	1.36	1.28	1.28	1.24	1.17	1.10	1.09	1.06	0.99	0.97	0.94	0.91	0.87	0.85	0.87	0.85	0.83	0.80	0.78	0.76
6D-7	U-10Mo	thick foil	1.57	1.39	1.29	1.22	1.18	1.10	1.06	1.01	0.98	0.94	0.92	0.88	0.88	0.84	0.84	0.79	0.77	0.78	0.79	0.77
6D-8	U-10Mo	disp	1.47	1.35	1.26	1.21	1.16	1.11	1.09	1.03	0.99	0.95	0.96	0.87	0.86	0.87	0.84	0.82	0.81	0.81	0.78	0.77

Table 2 - RERTR-6 fission rate tally local to average ratio (L2AR) along the plate width (from core center plate edge toward outer plate edge).

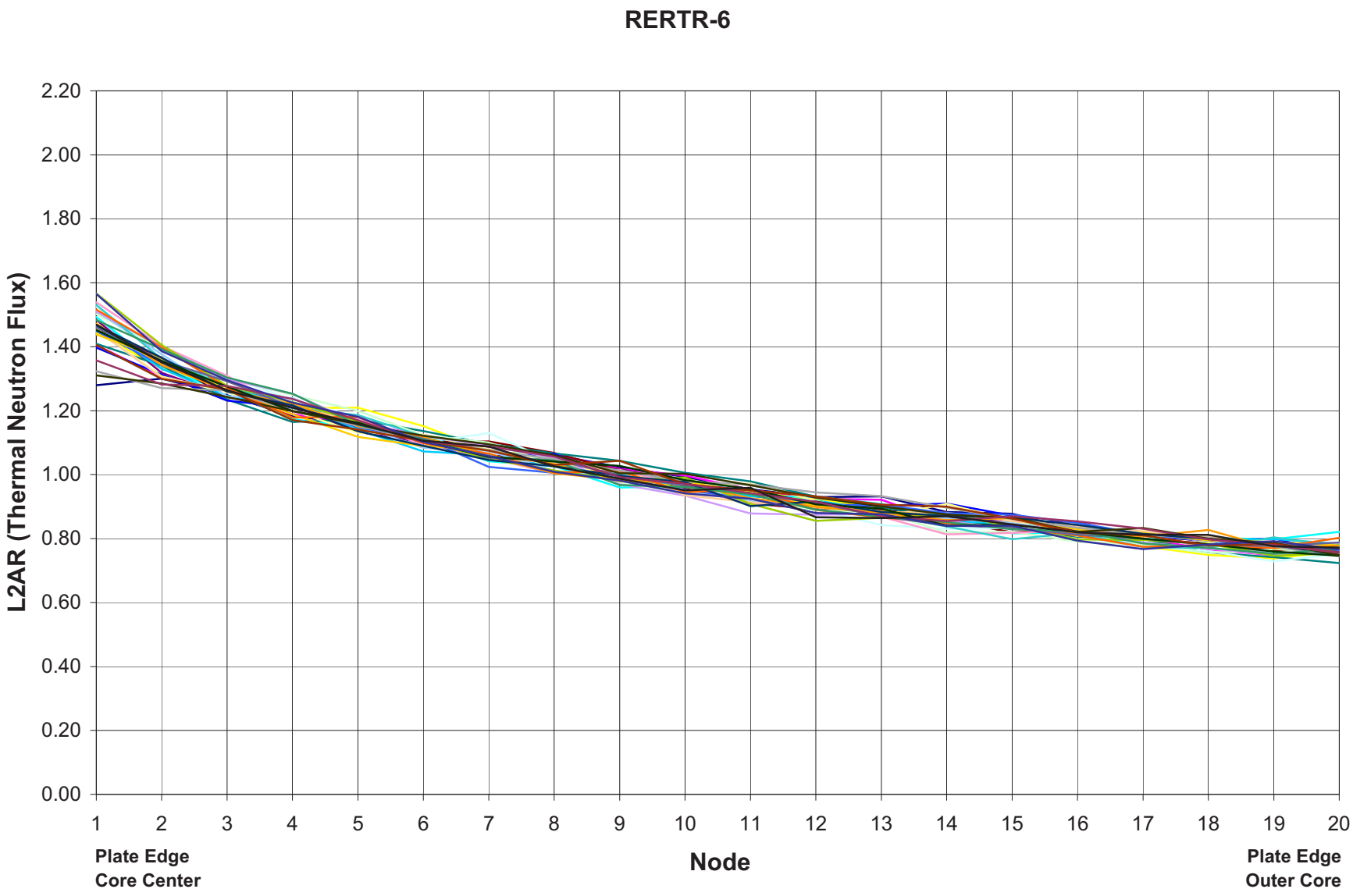
	Fuel	Fuel	Core Edge									Position									Outer Edge
ID	Phase	Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6A-1	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6A-2	U-7Mo	disp	1.41	1.31	1.26	1.19	1.16	1.12	1.08	1.06	1.02	1.00	0.95	0.92	0.92	0.85	0.85	0.83	0.80	0.76	0.75	0.75
6A-3	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6A-4	U-10Mo	thick foil	1.49	1.33	1.26	1.18	1.15	1.11	1.04	1.03	0.96	0.96	0.93	0.93	0.91	0.87	0.82	0.82	0.80	0.80	0.80	0.82
6A-5	U-7Mo	disp	1.49	1.32	1.24	1.22	1.13	1.10	1.05	1.03	1.02	0.98	0.94	0.90	0.89	0.87	0.85	0.85	0.80	0.79	0.76	0.77
6A-6	U-10Mo	dual foil	1.43	1.35	1.22	1.20	1.14	1.09	1.09	1.05	0.99	0.94	0.89	0.88	0.87	0.84	0.82	0.83	0.81	0.79	0.76	0.78
6A-7	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6A-8	U-7Mo	foil	1.40	1.31	1.23	1.21	1.16	1.11	1.05	1.06	0.98	0.97	0.95	0.91	0.90	0.91	0.87	0.82	0.81	0.79	0.80	0.75
6B-1	U-7Mo	disp	1.47	1.33	1.25	1.22	1.14	1.07	1.06	1.03	1.00	0.97	0.93	0.92	0.88	0.85	0.85	0.84	0.82	0.80	0.80	0.78
6B-2	U-7Mo	disp	1.53	1.39	1.31	1.23	1.18	1.10	1.13	1.04	1.00	0.95	0.92	0.89	0.84	0.83	0.83	0.82	0.78	0.76	0.73	0.75
6B-3	U-10Mo	foil	1.51	1.40	1.30	1.25	1.20	1.12	1.10	1.03	0.97	0.94	0.92	0.89	0.89	0.82	0.82	0.79	0.78	0.75	0.77	0.76
6B-4	U-7Mo	foil	1.45	1.31	1.26	1.20	1.13	1.12	1.08	1.02	1.01	0.96	0.97	0.92	0.87	0.91	0.85	0.81	0.83	0.79	0.75	0.76
6B-5	U-7Mo	disp	1.51	1.38	1.24	1.24	1.15	1.08	1.08	1.01	0.99	0.95	0.92	0.92	0.87	0.87	0.85	0.82	0.82	0.79	0.75	0.77
6B-6	U-7Mo	foil	1.54	1.40	1.31	1.20	1.18	1.09	1.05	1.00	1.02	0.97	0.91	0.92	0.86	0.81	0.82	0.82	0.82	0.77	0.75	0.77
6B-7	U-10Mo	foil	1.51	1.40	1.30	1.25	1.16	1.12	1.09	1.06	0.97	0.93	0.88	0.87	0.88	0.85	0.83	0.82	0.79	0.77	0.75	0.77
6B-8	U-10Mo	disp	1.45	1.30	1.26	1.22	1.16	1.10	1.05	1.04	1.01	0.94	0.91	0.90	0.88	0.88	0.85	0.84	0.82	0.81	0.78	0.79
6C-1	U-10Mo	foil	1.45	1.35	1.28	1.21	1.15	1.11	1.02	1.01	0.98	0.95	0.92	0.90	0.91	0.88	0.87	0.85	0.81	0.79	0.79	0.76
6C-2	U-7Mo	disp	1.53	1.36	1.28	1.21	1.19	1.12	1.06	1.01	0.98	0.97	0.94	0.90	0.87	0.83	0.80	0.82	0.78	0.77	0.81	0.78
6C-3	U-7Mo	disp	1.57	1.41	1.28	1.22	1.16	1.10	1.05	1.01	0.98	0.99	0.91	0.86	0.86	0.87	0.84	0.80	0.80	0.79	0.75	0.76
6C-4	U-7Mo	foil	1.44	1.36	1.27	1.19	1.12	1.09	1.08	1.03	0.98	0.98	0.94	0.91	0.89	0.87	0.87	0.83	0.82	0.79	0.79	0.78
6C-5	U-7Mo	disp	1.48	1.35	1.26	1.22	1.15	1.12	1.06	1.00	0.99	0.97	0.93	0.90	0.88	0.86	0.86	0.81	0.81	0.82	0.77	0.78
6C-6	U-7Mo	foil	1.52	1.40	1.27	1.17	1.18	1.09	1.07	1.01	1.01	0.95	0.95	0.90	0.87	0.85	0.83	0.81	0.77	0.78	0.77	0.81
6C-7	U-10Mo	disp	1.46	1.35	1.29	1.21	1.16	1.11	1.05	1.04	0.99	0.96	0.94	0.91	0.87	0.84	0.83	0.81	0.80	0.78	0.78	0.79
6C-8	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6D-1	U-10Mo	foil	1.47	1.37	1.26	1.22	1.13	1.09	1.04	1.02	0.99	0.98	0.90	0.92	0.88	0.87	0.87	0.84	0.82	0.80	0.78	0.75
6D-2	U-7Mo	disp	1.49	1.39	1.31	1.25	1.16	1.11	1.06	1.04	0.96	0.96	0.94	0.89	0.87	0.85	0.83	0.82	0.78	0.77	0.75	0.77
6D-3	U-10Mo	disp	1.45	1.36	1.27	1.20	1.16	1.10	1.06	1.04	1.03	0.98	0.96	0.91	0.89	0.84	0.85	0.82	0.80	0.78	0.76	0.75
6D-4	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6D-5	U-7Mo	disp	1.41	1.30	1.27	1.17	1.14	1.10	1.07	1.03	1.04	0.97	0.95	0.93	0.90	0.90	0.86	0.82	0.81	0.78	0.78	0.76
6D-6	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6D-7	U-10Mo	thick foil	1.57	1.39	1.29	1.22	1.18	1.10	1.06	1.01	0.98	0.94	0.92	0.88	0.88	0.84	0.84	0.79	0.77	0.78	0.79	0.77
6D-8	U-10Mo	disp	1.48	1.36	1.27	1.21	1.16	1.10	1.09	1.03	0.99	0.95	0.96	0.87	0.86	0.87	0.84	0.82	0.81	0.81	0.78	0.77

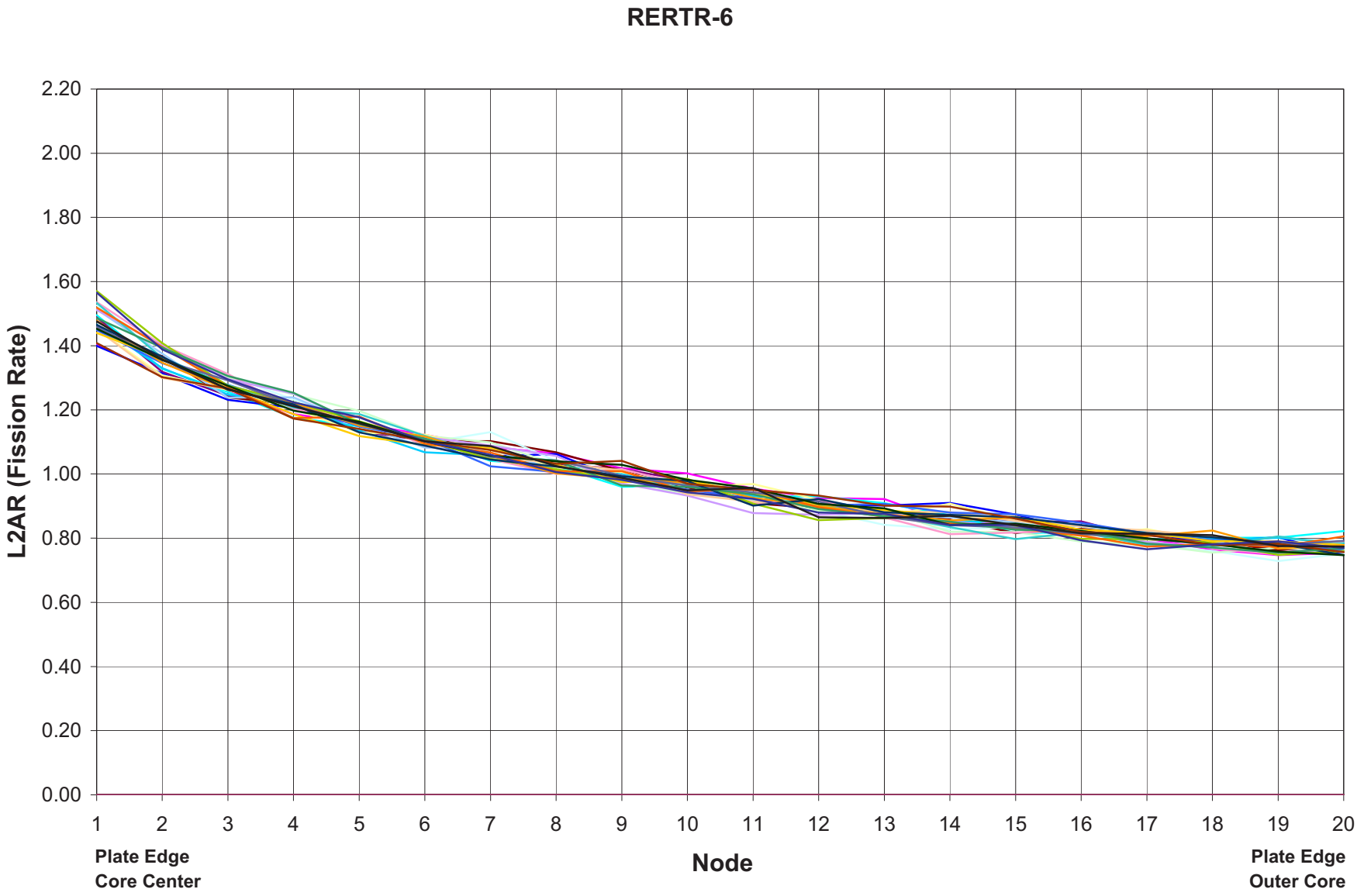
Table 3 - RERTR-7A thermal neutron flux local to average ratio (L2AR) along the plate width (from core center plate edge toward outer plate edge)

	Fuel	Fuel	Core Edge									Position									Outer Edge
ID	Phase	Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
7A-1	---	blank	1.25	1.22	1.19	1.17	1.15	1.12	1.09	1.07	1.06	1.03	0.99	0.96	0.92	0.92	0.90	0.84	0.82	0.80	0.77	0.74
7A-2	---	blank	1.27	1.23	1.22	1.17	1.15	1.13	1.09	1.08	1.05	1.02	0.99	0.95	0.94	0.90	0.87	0.86	0.80	0.79	0.76	0.73
7A-3	---	blank	1.27	1.24	1.21	1.20	1.15	1.13	1.13	1.06	1.03	1.01	0.98	0.97	0.93	0.91	0.88	0.84	0.82	0.79	0.75	0.70
7A-4	---	blank	1.24	1.22	1.20	1.16	1.14	1.10	1.08	1.06	1.05	1.03	0.98	0.97	0.96	0.94	0.90	0.87	0.82	0.79	0.76	0.73
7A-5	U-7Mo	disp	1.74	1.48	1.35	1.21	1.16	1.10	1.03	0.98	0.96	0.93	0.88	0.85	0.83	0.81	0.80	0.79	0.76	0.76	0.77	0.81
7A-6	U-10Mo	disp	2.05	1.65	1.45	1.28	1.19	1.08	1.02	0.94	0.89	0.85	0.82	0.79	0.77	0.75	0.73	0.73	0.74	0.72	0.75	0.79
7A-7	U-7Mo	disp	2.01	1.61	1.41	1.26	1.20	1.10	0.99	0.94	0.89	0.87	0.84	0.82	0.79	0.76	0.74	0.73	0.73	0.74	0.74	0.82
7A-8	U-12Mo	foil	1.63	1.44	1.34	1.24	1.17	1.11	1.06	1.01	0.97	0.93	0.91	0.87	0.83	0.83	0.82	0.79	0.77	0.77	0.77	0.76
7B-1	U-7Mo	disp	1.75	1.46	1.34	1.24	1.15	1.09	1.02	0.98	0.95	0.93	0.90	0.86	0.83	0.82	0.81	0.79	0.76	0.76	0.76	0.80
7B-2	U-7Mo	disp	2.03	1.63	1.44	1.31	1.19	1.10	1.02	0.94	0.89	0.85	0.81	0.79	0.77	0.74	0.74	0.73	0.74	0.73	0.75	0.80
7B-3	U-7Mo	disp	2.00	1.63	1.46	1.29	1.19	1.09	1.01	0.94	0.90	0.86	0.83	0.81	0.77	0.75	0.74	0.72	0.73	0.72	0.74	0.81
7B-4	U-12Mo	foil	1.63	1.43	1.37	1.26	1.16	1.07	1.06	1.00	0.96	0.92	0.91	0.88	0.83	0.83	0.80	0.78	0.76	0.76	0.77	0.79
7B-5	U-10Mo	foil	1.64	1.42	1.34	1.24	1.17	1.10	1.04	1.00	0.96	0.95	0.92	0.87	0.84	0.82	0.80	0.79	0.78	0.77	0.78	0.77
7B-6	U-10Mo	disp	1.92	1.57	1.43	1.27	1.17	1.10	1.02	0.96	0.92	0.87	0.86	0.81	0.79	0.77	0.75	0.73	0.73	0.74	0.76	0.81
7B-7	U-10Mo	foil	1.80	1.54	1.38	1.30	1.19	1.09	1.06	1.00	0.95	0.92	0.87	0.83	0.82	0.79	0.79	0.77	0.75	0.74	0.75	0.66
7B-8	U-7Mo	foil	1.56	1.42	1.31	1.24	1.19	1.10	1.05	1.01	0.98	0.96	0.92	0.87	0.86	0.84	0.82	0.80	0.79	0.76	0.76	0.76
7C-1	U-12Mo	foil	1.65	1.41	1.33	1.24	1.16	1.08	1.05	1.03	0.97	0.92	0.91	0.88	0.84	0.82	0.81	0.80	0.77	0.77	0.77	0.78
7C-2	U-10Mo	foil	1.90	1.61	1.42	1.29	1.19	1.10	1.04	0.98	0.91	0.87	0.82	0.82	0.79	0.75	0.75	0.74	0.73	0.74	0.76	0.79
7C-3	U-10Mo	foil	1.82	1.52	1.40	1.30	1.21	1.11	1.05	0.97	0.92	0.88	0.88	0.83	0.78	0.78	0.77	0.76	0.74	0.74	0.74	0.78
7C-4	U-7Mo	foil	1.66	1.46	1.34	1.25	1.15	1.11	1.06	0.99	0.94	0.91	0.89	0.87	0.84	0.84	0.80	0.80	0.78	0.76	0.76	0.78
7C-5	U-10Mo	foil	1.68	1.45	1.32	1.24	1.16	1.10	1.05	0.99	0.97	0.91	0.90	0.86	0.85	0.83	0.82	0.80	0.79	0.77	0.77	0.77
7C-6	U-12Mo	foil	1.95	1.60	1.44	1.32	1.17	1.09	1.03	0.96	0.91	0.88	0.84	0.82	0.78	0.75	0.75	0.74	0.74	0.72	0.73	0.78
7C-7	U-7Mo	disp	1.99	1.62	1.43	1.31	1.18	1.09	1.02	0.98	0.91	0.87	0.81	0.79	0.78	0.76	0.72	0.71	0.73	0.72	0.76	0.82
7C-8	U-7Mo	disp	1.75	1.47	1.33	1.24	1.14	1.07	1.04	0.99	0.95	0.92	0.91	0.88	0.84	0.82	0.80	0.78	0.79	0.76	0.74	0.79
7D-1	U-7Mo	disp	1.64	1.40	1.28	1.19	1.15	1.07	1.06	1.03	1.01	0.95	0.93	0.88	0.86	0.83	0.83	0.81	0.78	0.77	0.76	0.78
7D-2	---	blank	1.55	1.43	1.35	1.24	1.22	1.12	1.08	1.03	1.00	0.95	0.92	0.88	0.85	0.83	0.81	0.78	0.76	0.74	0.74	0.72
7D-3	U-7Mo	disp	1.65	1.41	1.31	1.23	1.17	1.11	1.06	1.01	1.00	0.94	0.89	0.90	0.87	0.84	0.81	0.78	0.78	0.76	0.72	0.75
7D-4	---	blank	1.41	1.34	1.29	1.22	1.15	1.11	1.09	1.05	1.02	0.98	0.94	0.92	0.90	0.87	0.85	0.81	0.78	0.77	0.74	0.74
7D-5	---	blank	1.43	1.38	1.30	1.21	1.18	1.09	1.08	1.05	1.03	0.96	0.96	0.94	0.88	0.86	0.84	0.80	0.78	0.75	0.75	0.73
7D-6	U-10Mo	foil	1.75	1.50	1.37	1.27	1.17	1.09	1.06	1.00	0.98	0.92	0.88	0.87	0.83	0.80	0.79	0.78	0.75	0.71	0.72	0.76
7D-7	U-10Mo	foil	1.95	1.57	1.41	1.27	1.15	1.06	1.02	0.96	0.92	0.88	0.84	0.81	0.80	0.80	0.75	0.73	0.74	0.74	0.76	0.82
7D-8	U-7Mo	disp	1.80	1.49	1.34	1.25	1.13	1.06	1.02	0.98	0.97	0.91	0.88	0.85	0.85	0.81	0.79	0.78	0.76	0.76	0.77	0.81

Table 4 - RERTR-7A fission rate tally local to average ratio (L2AR) along the plate width (from core center plate edge toward outer plate edge)

	Fuel	Fuel	Core Edge									Position									Outer Edge
ID	Phase	Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
7A-1	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
7A-2	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
7A-3	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
7A-4	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
7A-5	U-7Mo	disp	1.75	1.48	1.35	1.21	1.16	1.10	1.03	0.97	0.96	0.93	0.88	0.85	0.83	0.81	0.80	0.79	0.76	0.77	0.77	0.81
7A-6	U-10Mo	disp	2.06	1.65	1.45	1.28	1.18	1.07	1.02	0.94	0.89	0.85	0.82	0.79	0.77	0.75	0.73	0.73	0.74	0.72	0.75	0.79
7A-7	U-7Mo	disp	2.01	1.61	1.41	1.26	1.20	1.10	0.98	0.94	0.89	0.87	0.84	0.82	0.79	0.76	0.74	0.73	0.74	0.74	0.75	0.83
7A-8	U-12Mo	foil	1.63	1.45	1.34	1.23	1.16	1.11	1.06	1.01	0.97	0.93	0.91	0.87	0.83	0.83	0.82	0.79	0.78	0.77	0.77	0.76
7B-1	U-7Mo	disp	1.75	1.46	1.34	1.24	1.15	1.09	1.02	0.98	0.95	0.93	0.89	0.86	0.83	0.82	0.81	0.79	0.76	0.76	0.76	0.81
7B-2	U-7Mo	disp	2.03	1.64	1.44	1.30	1.19	1.10	1.02	0.94	0.89	0.85	0.81	0.79	0.77	0.74	0.74	0.73	0.74	0.73	0.76	0.81
7B-3	U-7Mo	disp	2.01	1.63	1.46	1.29	1.19	1.09	1.01	0.94	0.90	0.86	0.83	0.81	0.78	0.75	0.74	0.72	0.73	0.73	0.74	0.81
7B-4	U-12Mo	foil	1.63	1.43	1.37	1.26	1.16	1.07	1.06	1.00	0.96	0.92	0.91	0.88	0.83	0.83	0.81	0.79	0.76	0.76	0.77	0.79
7B-5	U-10Mo	foil	1.63	1.42	1.34	1.24	1.17	1.10	1.04	1.00	0.96	0.95	0.91	0.87	0.84	0.82	0.80	0.79	0.78	0.77	0.78	0.77
7B-6	U-10Mo	disp	1.93	1.57	1.43	1.27	1.17	1.10	1.02	0.96	0.92	0.87	0.86	0.81	0.79	0.77	0.75	0.74	0.73	0.74	0.76	0.82
7B-7	U-10Mo	foil	1.80	1.53	1.38	1.30	1.18	1.08	1.05	0.99	0.94	0.91	0.86	0.82	0.81	0.79	0.79	0.77	0.74	0.74	0.74	0.76
7B-8	U-7Mo	foil	1.56	1.42	1.31	1.24	1.19	1.10	1.04	1.01	0.98	0.96	0.91	0.88	0.86	0.84	0.82	0.80	0.79	0.76	0.76	0.76
7C-1	U-12Mo	foil	1.65	1.41	1.33	1.24	1.16	1.08	1.05	1.03	0.97	0.92	0.91	0.89	0.84	0.82	0.81	0.80	0.78	0.77	0.77	0.78
7C-2	U-10Mo	foil	1.90	1.61	1.42	1.29	1.19	1.10	1.04	0.98	0.91	0.87	0.82	0.82	0.80	0.75	0.75	0.74	0.73	0.74	0.76	0.79
7C-3	U-10Mo	foil	1.82	1.53	1.40	1.30	1.21	1.11	1.05	0.97	0.91	0.88	0.87	0.83	0.79	0.78	0.78	0.76	0.74	0.74	0.75	0.78
7C-4	U-7Mo	foil	1.66	1.46	1.34	1.25	1.15	1.11	1.06	0.99	0.94	0.91	0.89	0.87	0.84	0.84	0.81	0.80	0.79	0.76	0.76	0.78
7C-5	U-10Mo	foil	1.68	1.45	1.31	1.23	1.16	1.09	1.05	0.99	0.97	0.91	0.90	0.86	0.85	0.83	0.81	0.80	0.79	0.77	0.77	0.77
7C-6	U-12Mo	foil	1.96	1.60	1.44	1.32	1.17	1.09	1.03	0.96	0.91	0.88	0.84	0.82	0.79	0.75	0.75	0.74	0.74	0.73	0.73	0.78
7C-7	U-7Mo	disp	1.99	1.62	1.43	1.31	1.18	1.09	1.02	0.97	0.91	0.87	0.81	0.79	0.78	0.76	0.72	0.71	0.73	0.73	0.76	0.83
7C-8	U-7Mo	disp	1.75	1.47	1.32	1.24	1.13	1.07	1.04	0.98	0.95	0.92	0.91	0.87	0.84	0.82	0.80	0.78	0.79	0.76	0.75	0.79
7D-1	U-7Mo	disp	1.64	1.40	1.28	1.19	1.14	1.07	1.06	1.03	1.01	0.95	0.93	0.88	0.86	0.83	0.83	0.81	0.78	0.77	0.76	0.78
7D-2	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
7D-3	U-7Mo	disp	1.65	1.41	1.31	1.23	1.17	1.11	1.06	1.01	1.00	0.94	0.89	0.90	0.87	0.84	0.81	0.78	0.78	0.76	0.72	0.75
7D-4	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
7D-5	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
7D-6	U-10Mo	foil	1.75	1.50	1.36	1.27	1.17	1.09	1.06	1.00	0.98	0.92	0.88	0.87	0.83	0.80	0.79	0.78	0.75	0.71	0.72	0.77
7D-7	U-10Mo	foil	1.96	1.57	1.41	1.27	1.15	1.06	1.02	0.96	0.92	0.88	0.84	0.81	0.80	0.80	0.75	0.74	0.74	0.74	0.76	0.82
7D-8	U-7Mo	disp	1.80	1.49	1.34	1.25	1.13	1.06	1.02	0.98	0.96	0.90	0.89	0.85	0.85	0.81	0.78	0.78	0.76	0.76	0.77	0.81


RERTR-6
L2AR (Thermal Neutron Flux)
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Plate Edge
Core Center
Node
Plate Edge
Outer Core


RERTR-6
L2AR (Fission Rate)
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1
2
3
4
5
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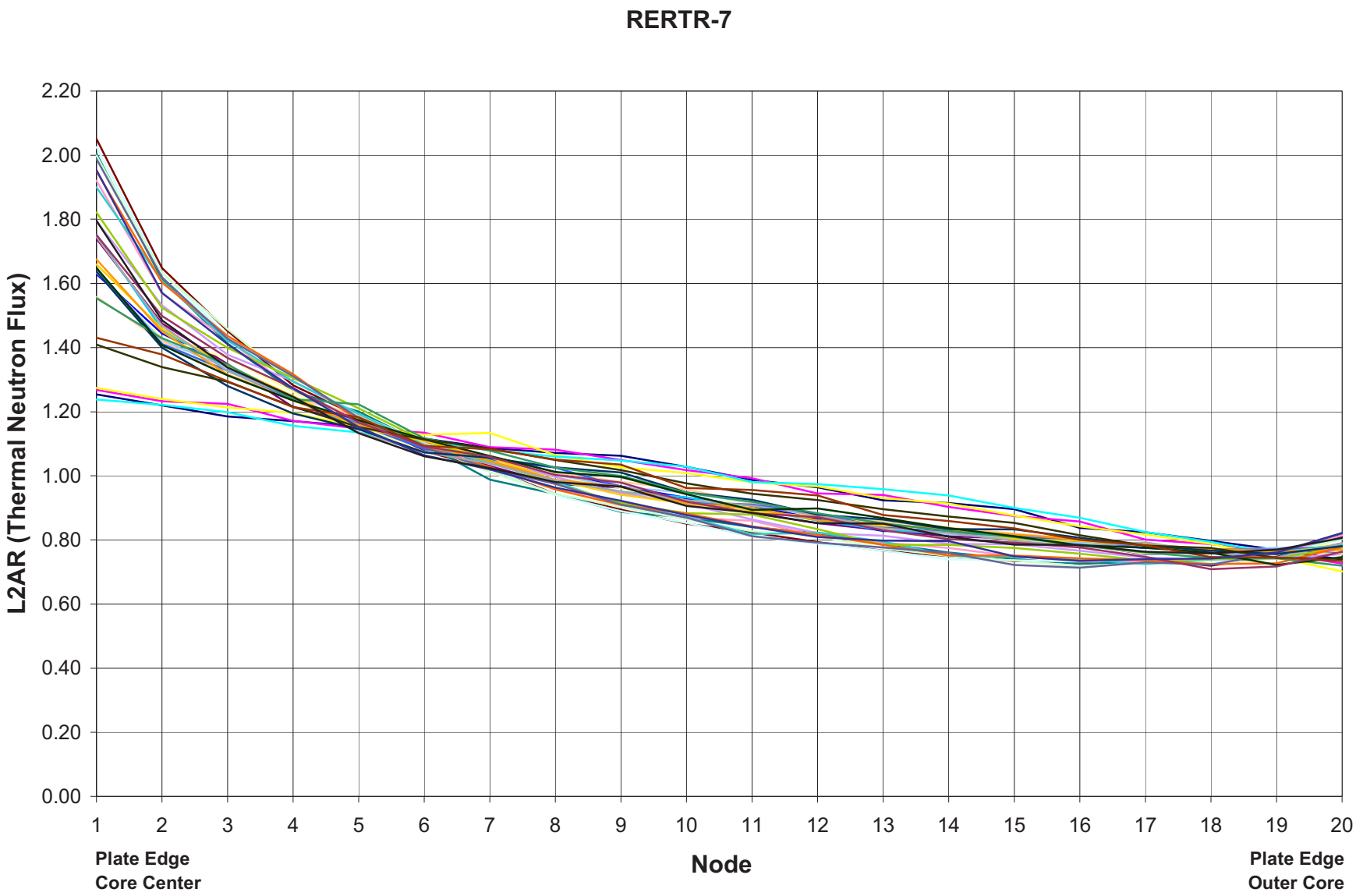
20
Plate Edge
Core Center
Node
Plate Edge
Outer Core


RERTR-7
L2AR (Thermal Neutron Flux)
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2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1
2
3
4
5
6
7
8
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19
20
Plate Edge
Core Center
Node
Plate Edge
Outer Core

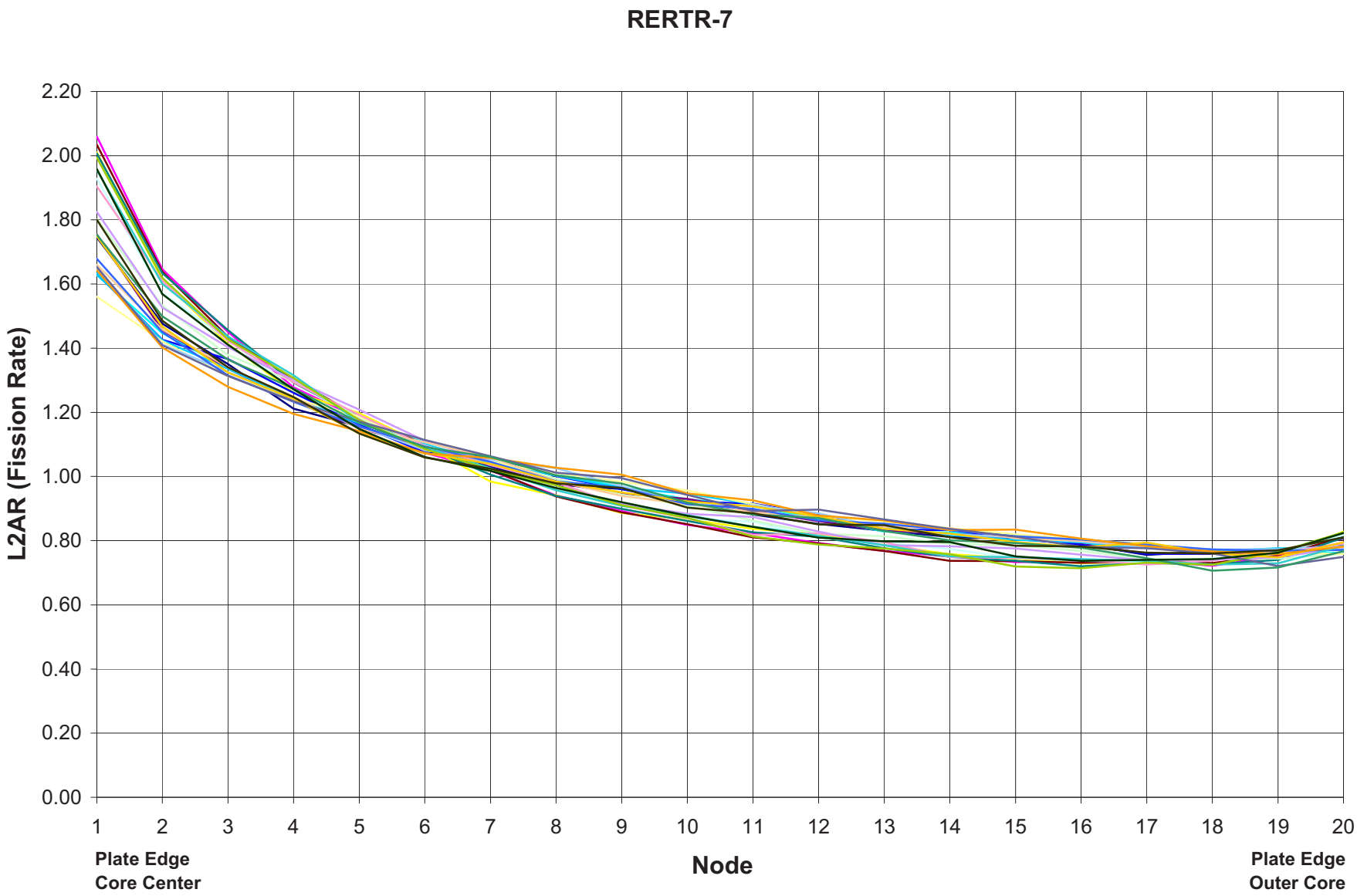
RERTR-7
L2AR (Fission Rate)
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
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Plate Edge
Core Center
Node
Plate Edge
Outer Core

Michael R Finlay/FINLMR/FN/INEEL/US

12/19/2006 01:07 PM

To: Gray S Chang/GSC/CC01/INEEL/US@INEL

cc: Daniel M Wachs/WACHDM/CC01/INEEL/US@INEL, Baxter.Hayes@icp.doe.gov, Adam B Robinson/ROBIAB/CC01/INEEL/US@INEL,

bcc:

Subject: power gradient across RERTR plates

Hi Gray,

I have some interesting results from our gamma scans from RERTR-7. We see a large gradient in the transverse orientation decreasing from the core edge to the outer edge. We did not see such a large gradient in RERTR-6. I know there are some significant differences between RERTR-6 & 7 including increased enrichment and different location that may be contributing factors.

You prepared an analysis of this effect in RERTR 4 & 5 and the ratio from core edge to outer edge was ~ 2. We were not able to confirm this however because the plates were rotated between cycles and therefore the gradient was largely nullified and we only performed axial gamma scans at that time.

Can I ask you to perform a similar analysis for RERTR-6 & 7? It would be really useful to confirm the results we have. I am happy to show you what the gamma scan ratios are but feel that it would be more valuable exercise if you were to perform the analysis and not know what we have already measured.

If you have any questions on this exercise feel free to give me a call. I can also give you a job code if you need it.

Ross Finlay
RERTR Program
Materials and Fuels Complex
Idaho National Laboratory
P.O. Box 1625
Idaho Falls, ID 83415-6188
tel: (208) 533-7572
fax: (208) 533-7863

Daniel M Wachs/WACHDM/CC01/INEEL/US 03/27/2006 10:36 AM	To	Gray S Chang/GSC/CC01/INEEL/US@INEL, Misti A Lillo/LILLMA/CC01/INEEL/US@INEL
	cc	
	bcc	
	Subject	

Gray,

One of the plates got out of order on the table. Use this revised version.
I hope its not too late.

Dan


RERTR-6 matrix as-built.xls

Dr. Daniel M. Wachs
Nuclear Fuels and Materials Dept.
Idaho National Laboratory
(208) 533-7604 office
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daniel.wachs@inl.gov

Table 1. Constituent masses for each RERTR-6 mini-plate.

Fuel Plate	Fuel Type	Plate ID	Fuel Phase Composition	Martix Phase	Foil Thickness (mm)	Fuel Alloy Mass	Fuel Phase Constituent Masses (g)					Matrix Phase Mass (g)	Matrix Phase Constituent Masses (g)										Cladding Mass (g)
							Total U	U-235	Mo	Si	Cr		Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	other	Al-6061
6A-1	blank	BLANK1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	9.729
6A-2	disp	R1R010	U-7Mo	Al-6061	---	6.550	6.152	1.169	0.398	---	---	1.370	1.320	0.008	0.010	0.004	0.002	0.014	0.005	0.003	0.002	0.002	5.330
6A-3	blank	BLANK3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	9.729
6A-4	foil	L2F020	U-10Mo	---	0.508	13.630	12.160	2.400	1.470	---	---	---	---	---	---	---	---	---	---	---	---	---	6.190
6A-5	disp	R5R010	U-7Mo	Al-0.5 Si	---	6.530	6.134	1.165	0.396	---	---	1.430	1.423	0.007	---	---	---	---	---	---	---	---	5.330
6A-6	foil	L1F090	U-10Mo	---	0.254	7.580	6.820	1.340	0.760	---	---	---	---	---	---	---	---	---	---	---	---	---	7.960
6A-7	blank	BLANK4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	9.729
6A-8	foil	NIF090	U-7Mo	---	0.254	6.970	6.490	1.280	0.480	---	---	---	---	---	---	---	---	---	---	---	---	---	7.960
6B-1	disp	R1R020	U-7Mo	Al-6061	---	6.630	6.124	1.167	0.506	---	---	1.380	1.330	0.008	0.010	0.004	0.002	0.014	0.005	0.003	0.002	0.002	5.330
6B-2	disp	R2R020	U-7Mo	Al-2 Si	---	6.530	5.944	1.153	0.586	---	---	1.420	1.392	0.028	---	---	---	---	---	---	---	---	5.330
6B-3	disp	V0R020	U-10Mo	Al	---	6.810	6.062	1.164	0.748	---	---	1.310	1.31	---	---	---	---	---	---	---	---	---	7.960
6B-4	foil	N1F010	U-7Mo	---	0.254	7.150	6.650	1.310	0.500	---	---	---	---	---	---	---	---	---	---	---	---	---	7.960
6B-5	disp	R3R030	U-7Mo	Al-4043	---	6.540	6.143	1.167	0.397	---	---	1.410	1.313	0.074	0.011	0.004	7E-04	7E-04	---	0.001	0.003	0.002	5.330
6B-6	foil	N1F040	U-7Mo	---	0.254	7.470	6.950	1.370	0.520	---	---	---	---	---	---	---	---	---	---	---	---	---	7.960
6B-7	foil	L1F040	U-10Mo	---	0.254	6.660	5.990	1.180	0.670	---	---	---	---	---	---	---	---	---	---	---	---	---	7.960
6B-8	disp	V1R020	U-10Mo	Al-6061	---	6.800	6.055	1.162	0.745	---	---	1.410	1.359	0.008	0.010	0.004	0.002	0.014	0.005	0.004	0.002	0.002	5.330
6C-1	disp	V0R010	U-10Mo	Al	---	6.800	6.058	1.163	0.742	---	---	1.320	1.32	---	---	---	---	---	---	---	---	---	7.960
6C-2	disp	R3R010	U-7Mo	Al-4043	---	6.540	6.145	1.168	0.395	---	---	1.410	1.313	0.074	0.011	0.004	7E-04	7E-04	---	0.001	0.003	0.002	5.330
6C-3	disp	R2R010	U-7Mo	Al-2 Si	---	6.540	5.960	1.156	0.580	---	---	1.420	1.392	0.028	---	---	---	---	---	---	---	---	5.330
6C-4	foil	N1F030	U-7Mo	---	0.254	7.430	6.910	1.360	0.520	---	---	---	---	---	---	---	---	---	---	---	---	---	7.960
6C-5	disp	R5R020	U-7Mo	Al-0.5 Si	---	6.530	6.135	1.166	0.395	---	---	1.420	1.413	0.007	---	---	---	---	---	---	---	---	5.330
6C-6	foil	N1F060	U-7Mo	---	0.254	7.240	6.740	1.330	0.500	---	---	---	---	---	---	---	---	---	---	---	---	---	7.960
6C-7	disp	V5R030	U-10Mo	Al-0.5 Si	---	6.820	6.072	1.165	0.748	---	---	1.330	1.323	0.007	---	---	---	---	---	---	---	---	7.960
6C-8	blank	BLANK5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	9.729
6D-1	foil	L1F100	U-10Mo	---	0.254	6.920	6.250	1.230	0.670	---	---	---	---	---	---	---	---	---	---	---	---	---	7.960
6D-2	disp	R2R030	U-7Mo	Al-2 Si	---	6.530	5.951	1.155	0.579	---	---	1.420	1.392	0.028	---	---	---	---	---	---	---	---	5.330
6D-3	disp	V1R010	U-10Mo	Al-6061	---	6.790	6.143	1.160	0.647	---	---	1.370	1.320	0.008	0.010	0.004	0.002	0.014	0.005	0.003	0.002	0.002	5.330
6D-4	blank	BLANK6	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	9.729
6D-5	disp	R1R030	U-7Mo	Al-6061	---	6.530	6.139	1.166	0.391	---	---	1.380	1.330	0.008	0.010	0.004	0.002	0.014	0.005	0.003	0.002	0.002	5.330
6D-6	blank	BLANK9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	9.729
6D-7	foil	L2F030	U-10Mo	---	0.508	13.280	11.850	2.340	1.430	---	---	---	---	---	---	---	---	---	---	---	---	---	6.190
6D-8	disp	V5R020	U-10Mo	Al-0.5 Si	---	6.790	6.050	1.161	0.740	---	---	1.320	1.313	0.007	---	---	---	---	---	---	---	---	7.960
Totals:							174.077	33.747	16.513	0.000	0.000	22.120	21.561	0.302	0.071	0.027	0.012	0.071	0.026	0.020	0.016	0.015	230.234

Table 2. Constituent densities for RERTR-6 mini-plates based on nominal fuel meat volume.

Fuel Plate	Fuel Phase Composition	Fuel Meat Volume (cc)	Fuel Phase Constituent Densities (g/cm3)					Matrix Phase Dens. (g/cm3)	Matrix Phase Constituent Densities (g/cc)									
			Total U	U-235	Mo	Si	Cr	Al	Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	other
6A-1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6B-5	U-7Mo	0.957	6.428	1.222	0.416	---	---	1.432	1.379	0.009	0.010	0.004	0.002	0.014	0.005	0.004	0.002	0.002
6A-3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6A-4	U-10Mo	0.794	15.306	3.021	1.850	---	---	---	---	---	---	---	---	---	---	---	---	---
6A-5	U-7Mo	0.957	6.410	1.217	0.414	---	---	1.494	1.487	0.007	---	---	---	---	---	---	---	---
6A-6	U-10Mo	0.397	17.169	3.373	1.913	---	---	---	---	---	---	---	---	---	---	---	---	---
6A-7	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6A-8	U-7Mo	0.397	16.338	3.222	1.208	---	---	---	---	---	---	---	---	---	---	---	---	---
6B-1	U-7Mo	0.957	6.399	1.219	0.529	---	---	1.442	1.389	0.009	0.010	0.004	0.002	0.014	0.005	0.004	0.002	0.002
6B-2	U-7Mo	0.957	6.211	1.205	0.612	---	---	1.484	1.454	0.030	---	---	---	---	---	---	---	---
6B-3	U-10Mo	0.957	6.334	1.216	0.782	---	---	---	---	---	---	---	---	---	---	---	---	---
6B-4	U-7Mo	0.397	16.741	3.298	1.259	---	---	---	---	---	---	---	---	---	---	---	---	---
6B-5	U-7Mo	0.957	6.419	1.219	0.415	---	---	1.473	1.372	0.077	0.012	0.004	0.001	---	---	0.001	---	0.002
6B-6	U-7Mo	0.397	17.496	3.449	1.309	---	---	---	---	---	---	---	---	---	---	---	---	---
6B-7	U-10Mo	0.397	15.079	2.971	1.687	---	---	---	---	---	---	---	---	---	---	---	---	---
6B-8	U-10Mo	0.957	6.327	1.214	0.778	---	---	1.473	1.420	0.009	0.010	0.004	0.002	0.015	0.006	0.004	0.002	0.002
6C-1	U-10Mo	0.957	6.330	1.215	0.775	---	---	---	---	---	---	---	---	---	---	---	---	---
6C-2	U-7Mo	0.957	6.421	1.220	0.413	---	---	1.473	1.372	0.077	0.012	0.004	0.001	---	---	0.001	---	0.002
6C-3	U-7Mo	0.957	6.228	1.208	0.606	---	---	1.484	1.454	0.030	---	---	---	---	---	---	---	---
6C-4	U-7Mo	0.397	17.395	3.424	1.309	---	---	---	---	---	---	---	---	---	---	---	---	---
6C-5	U-7Mo	0.957	6.411	1.218	0.413	---	---	1.484	1.476	0.007	---	---	---	---	---	---	---	---
6C-6	U-7Mo	0.397	16.967	3.348	1.259	---	---	---	---	---	---	---	---	---	---	---	---	---
6A-7	U-10Mo	0.957	6.345	1.217	0.782	---	---	1.390	1.383	0.007	---	---	---	---	---	---	---	---
6C-8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6D-1	U-10Mo	0.397	15.734	3.096	1.687	---	---	---	---	---	---	---	---	---	---	---	---	---
6C-3	U-7Mo	0.957	6.218	1.207	0.605	---	---	1.484	1.454	0.030	---	---	---	---	---	---	---	---
6D-3	U-10Mo	0.957	6.419	1.212	0.676	---	---	1.432	1.379	0.009	0.010	0.004	0.002	0.014	0.005	0.004	0.002	0.002
6D-4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6B-5	U-7Mo	0.957	6.415	1.218	0.409	---	---	1.442	1.389	0.009	0.010	0.004	0.002	0.014	0.005	0.004	0.002	0.002
6D-6	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6D-7	U-10Mo	0.794	14.916	2.945	1.800	---	---	---	---	---	---	---	---	---	---	---	---	---
6D-8	U-10Mo	0.957	6.322	1.213	0.773	---	---	1.379	1.37241	0.0069	---	---	---	---	---	---	---	---

Idaho National Laboratory **Intra-Laboratory Memorandum**

March 6, 2006
DMW-002-06

TO: Distribution

FROM: D. M.Wachs Nuclear Fuels and Materials Dept.

SUBJECT: **As-Built Constituent Densities for the RERTR-7A Mini-plate Experiment**

The constituent density of each element included in the RERTR-7A experiment is calculated to enable neutronic analysis. As-built mass data was collected for each plate and has been smeared over the nominal fuel meat volume. The experiment matrix is shown in Table 1.

RERTR-7A Experiment MatrixŃ As Loaded				
Capsule	**Column 1**	**Column 2**	**Column 3**	**Column 4**
A-Top	A1 DUM11 BLANK	A2 DUM14 BLANK	A3 DUM12 BLANK	A4 DUM8 BLANK
A-Bottom	A5 R3R040 U-7Mo Roll Al 4043 Matrix	A6 V5R040 U-7Mo Roll Al-0.5Si Matrix	A7 R5R030 U-10Mo Roll Al-0.5 Si Matrix	A8 H1F020 U-12Mo FSW 0.010" Foil
B-Top	B1 R1R040 U-7Mo Roll Al 6061 Matrix	B2 R2R040 U-7Mo Roll Al-2Si Matrix	B3 R0R010 U-7Mo Roll Pure Al Matrix	B4 H1T010 U-12Mo TLPB 0.010" Foil
B-Bottom	B5 L1F01L U-10Mo FSW Holed Foil	B6 V5R050 U-7Mo Roll Al-0.5Si Matrix	B7 L1F140 U-10Mo FSW 0.010" Foil	B8 MZ25 U-7Mo Roll Zr Clad CNEA
C-Top	C1 H1F030 U-12Mo FSW 0.010" Foil	C2 L1T020 U-10Mo TLPB 0.010" Foil	C3 L1F110 U-10Mo FSW 0.010" Foil	C4 MZ50 U-7Mo Roll Zr Clad CNEA
C-Bottom	C5 L1F120 U-10Mo FSW 0.010" Foil	C6 H1T020 U-12Mo TLPB 0.010" Foil	C7 R3R050 U-7Mo Roll Al 4043 Matrix	C8 R5R040 U-10Mo Roll Al-0.5 Si Matrix
D-Top	D1 R1R050 U-7Mo Roll Al 6061 Matrix	D2 DUM13 BLANK	D3 R0R020 U-7Mo Roll Pure Al Matrix	D4 DUM19 BLANK
D-Bottom	D5 DUM05 BLANK	D6 L1F160 U-10Mo FSW 0.010" Foil	D7 L2F040 U-10Mo TLPB 0.020" Foil	D8 R2R050 U-7Mo Roll Al-2Si Matrix

Table 1. RERTR-7A experiment matrix.

The mass of fuel alloy included in each plate is based on measurements performed during fabrication. Prior to assembling the monolithic plates, the weight of the foil is recorded.

This value is therefore used as a reliable reference for fuel alloy mass. The masses of both the fuel alloy and matrix material are recorded prior to pellet pressing. The final pellet mass is typically less than the total of the two masses and mass losses are assumed to be equally divided (by volume) between the matrix and fuel alloy. These final compact masses and the assumed component masses are recorded in the as-built data package and are used as the reference in this document. The foil and compact masses are tabulated in Table 2.

Fuel Plate	Fuel Type	Plate ID	Fuel Phase Comp.	Matrix Phase	Foil Mass (gm)	Fuel Comp. Mass (gm)	Fuel Alloy Mass (gm)	Matrix Mass (gm)
A-1	blank	---	---	---	---	---	---	---
A-2	blank	---	---	---	---	---	---	---
A-3	blank	---	---	---	---	---	---	---
A-4	blank	---	---	---	---	---	---	---
A-5	disp	R3R040	U-7Mo	Al-4043	---	7.95	6.521	1.431
A-6	disp	V5R040	U-10Mo	Al-0.5 Si	---	8.18	6.807	1.369
A-7	disp	R5R030	U-7Mo	Al-0.5 Si	---	7.96	6.535	1.422
A-8	foil	H1F020	U-12Mo	---	6.43	---	---	---
B-1	disp	R1R040	U-7Mo	Al-6061	---	7.96	6.580	1.380
B-2	disp	R2R040	U-7Mo	Al-2 Si	---	7.95	6.531	1.420
B-3	disp	R0R010	U-7Mo	Al	---	7.95	6.533	1.422
B-4	foil	H1T010	U-12Mo	---	6.27	---	---	---
B-5	foil	L1FOIL*	U-10Mo	---	5.90	---	---	---
B-6	disp	V5R050	U-10Mo	Al-0.5 Si	---	8.15	6.782	1.372
B-7	foil	L1F140	U-10Mo	---	6.52	---	---	---
B-8	foil	MZ25	U-7Mo	---	6.35	---	---	---
C-1	foil	H1F030	U-12Mo	--	6.62	---	---	---
C-2	foil	L1T020	U-10Mo	--	6.39	---	---	---
C-3	foil	L1F110	U-10Mo	--	6.57	---	---	---
C-4	foil	MZ50	U-7Mo	---	11.90	---	---	---
C-5	foil	L1F120	U-10Mo	--	6.62	---	---	---
C-6	foil	H1T020	U-12Mo	---	6.15	---	---	---
C-7	disp	R3R050	U-7Mo	Al-4043	---	7.97	6.535	1.432
C-8	disp	R5R040	U-7Mo	Al-0.5 Si	---	7.96	6.526	1.426
D-1	disp	R1R050	U-7Mo	Al-6061	---	7.92	6.538	1.380
D-2	blank	---	---	---	---	---	---	---
D-3	disp	R0R020	U-7Mo	Al	---	7.95	6.528	1.420
D-4	blank	---	---	---	---	---	---	---
D-5	blank	---	---	---	---	---	---	---
D-6	foil	L1F160	U-10Mo	---	5.41	---	---	---
D-7	foil	L2F040	U-10Mo	---	12.04	---	---	---
D-8	disp	R2R050	U-7Mo	Al-2 Si	---	7.95	6.529	1.418

*Holed Foil

Table 2. Fuel meat masses from as-built data.

The amount of fuel alloy and matrix material incorporated into each fuel compact is set to achieve the target uranium density of 6 g-U/cc. Consequently, fuel alloys with higher molybdenum content require a higher fuel alloy volume fraction. The data used to calculate the

target volume fraction for both fuel phases is shown in Table 3. These values are used during scoping analysis of each experiment until as-built data is available.

Alloy	Alloy Density (g/cm3)	Alloy U Density (g/cm3)	Volume % Alloy	Alloy Mass (g)	Matrix Mass (g)	Fuel Meat Mass (g)	U Mass (g)	Mo Mass (g)
U-7Mo	17.53	16.31	36.8%	6.172	1.633	7.805	5.742	0.432
U-10Mo	17.02	15.32	39.2%	6.379	1.572	7.951	5.742	0.574

Table 3. Dispersion fuel masses for fuel meat loading targets of 6.0 g-U/cc.

The fuel alloy used in each mini-plate is based on a nominal target composition (either U-7Mo or U-10Mo in wt%). The alloy is fabricated by blending known amounts of uranium and molybdenum. Samples from each alloy batch are examined in the MFC Analytical Lab to determine the uranium isotopics and composition. The isotopic analysis yielded a uranium enrichment of 58%. The molybdenum content typically varies less than 0.5% from the nominal target and nominal values are used to calculate the uranium and molybdenum content in each plate from the fuel alloy content.

A variety of different matrix materials are used in the mini-plates including aluminum, Al-6061, Al-4043, Al-0.5 Si, and Al-2.0 Si. The composition of the aluminum alloys vary but average values are used to estimate the amount of minor elements incorporated into the fuel meat of each plate. The composition (in wt%) of matrix component is summarized in the Table 4.

Matrix Compositions	Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	other
Al-6061	96.35	0.6	0.7	0.275	0.1	1.0	0.375	0.25	0.15	0.15
Al-4043	93.1	5.25	0.8	0.3	0.05	0.05		0.1	0.2	0.15
Al-2.0Si	80	20								
Al-0.5Si	95	5								
Al	100									

Table 4. Compositions of matrix materials used in dispersion fuel meats (in wt%).

Based on this information the constituent masses for each component are calculated for each mini-plate and are shown in Table 5. The constituent densities are then calculated and shown in Table 6 based on the nominal fuel meat volumes of 0.397 cm3, 0.794 cm3, and 0.957 cm3 for monolithic, thick monolithic, and dispersion, respectively.

Fuel Plate	Fuel Type	Plate ID	Fuel Phase Composition	Martix Phase	Foil Thickness (mm)	Fuel Meat Mass	Fuel Phase Constituent Masses (g)				
							Total U	U-235	Mo	Si	Cr
A-1	blank	---	---	---	---	--	---	---	---	---	---
A-2	blank	---	---	---	---	---	---	---	---	---	---
A-3	blank	---	---	---	---	---	---	---	---	---	---
A-4	blank	---	---	---	---	---	---	---	---	---	---
A-5	disp	R3R040	U-7Mo	Al-4043	---	7.950	6.060	3.530	0.459	---	---
A-6	disp	V5R040	U-10Mo	Al-0.5 Si	---	8.180	6.130	3.550	0.681	---	---
A-7	disp	R5R030	U-7Mo	Al-0.5 Si	---	7.96	6.080	3.54	0.458	---	---
A-8	foil	H1F020	U-12Mo	---	0.254	6.430	5.650	3.330	0.780	---	---
B-1	disp	R1R040	U-7Mo	Al-6061	---	7.960	6.120	3.550	0.460	---	---
B-2	disp	R2R040	U-7Mo	Al-2 Si	---	7.950	6.070	3.530	0.460	---	---
B-3	disp	R0R010	U-7Mo	Al	---	7.950	6.080	3.530	0.448	---	---
B-4	foil	H1T010	U-12Mo	---	0.254	6.270	5.520	3.210	0.750	---	---
B-5	foil	L1FOIL	U-10Mo	---	0.254	5.900	5.300	3.160	0.600	---	---
B-6	disp	V5R050	U-10Mo	Al-0.5 Si	--	8.150	6.100	3.540	0.678	---	---
B-7	foil	L1F140	U-10Mo	---	0.254	6.520	5.860	3.410	0.660	---	---
B-8	foil	MZ25	U-7Mo	---	0.254	6.350	5.900	1.170	0.450	---	---
C-1	foil	H1F030	U-12Mo	--	0.254	6.620	5.820	3.380	0.800	---	---
C-2	foil	L1T020	U-10Mo	--	0.254	6.390	5.740	3.420	0.650	---	---
C-3	foil	L1F110	U-10Mo	--	0.254	6.570	5.910	3.440	0.660	---	---
C-4	foil	MZ50	U-7Mo	---	0.508	11.900	10.900	2.160	1.000	---	---
C-5	foil	L1F120	U-10Mo	--	0.254	6.620	5.960	3.470	0.660	---	---
C-6	foil	H1T020	U-12Mo	---	0.254	6.150	5.400	3.190	0.750	---	---
C-7	disp	R3R050	U-7Mo	Al-4043	---	7.970	6.080	3.540	0.458	---	---
C-8	disp	R5R040	U-7Mo	Al-0.5 Si	---	7.96	6.070	3.54	0.464	---	---
D-1	disp	R1R050	U-7Mo	Al-6061	--	7.920	6.080	3.540	0.460	---	---
D-2	blank	---	---	---	---	---	---	---	---	---	---
D-3	disp	R0R020	U-7Mo	Al	---	7.950	6.080	3.530	0.450	---	---
D-4	blank	---	---	---	---	---	---	---	---	---	---
D-5	blank	---	---	---	---	---	---	---	---	---	---
D-6	foil	L1F160	U-10Mo	---	0.254	5.41	4.870	2.83	0.540	---	---
D-7	foil	L2F040	U-10Mo	---	0.508	12.040	10.820	6.310	1.220	---	---
D-8	disp	R2R050	U-7Mo	Al-2 Si	---	7.950	6.070	3.530	0.462	---	---
Totals:							156.670	84.930	15.458	0.000	0.000

Matrix Phase Mass (g)	Matrix Phase Constituent Masses (g)										Cladding Mass (g)	
	Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	other	Zr	Al-6061
---	--	---	---	---	---	---	---	---	---	---		9.729
---	---	---	---	---	---	---	---	---	---	---		9.729
---	---	---	---	---	---	---	---	---	---	---		9.729
---	---	---	---	---	---	---	---	---	---	---		9.729
1.431	1.332	0.075	0.011	0.004	7E-04	7E-04	---	0.001	0.003	0.002		5.330
1.369	1.3622	0.007	---	---	---	---	---	---	---	---		5.330
1.422	1.4149	0.007	---	---	---	---	---	---	---	---		5.330
---	---	---	---	---	---	---	---	---	---	---		7.960
1.380	1.330	0.008	0.010	0.004	0.002	0.014	0.005	0.003	0.002	0.002		5.330
1.420	1.392	0.028	---	---	---	---	---	---	---	---		5.330
1.422	1.31	---	---	---	---	---	---	---	---	---		5.330
---	---	---	---	---	---	---	---	---	---	---		7.960
---	---	---	---	---	---	---	---	---	---	---		7.960
1.372	1.3651	0.007	---	---	---	---	---	---	---	---		5.330
---	---	---	---	---	---	---	---	---	---	---		7.960
---	---	---	---	---	---	---	---	---	---	---	19.369	
---	---	---	---	---	---	---	---	---	---	---		7.960
---	---	---	---	---	---	---	---	---	---	---		7.960
---	---	---	---	---	---	---	---	---	---	---		7.960
---	---	---	---	---	---	---	---	---	---	---	15.062	
---	---	---	---	---	---	---	---	---	---	---		7.960
---	---	---	---	---	---	---	---	---	---	---		7.960
1.432	1.333	0.075	0.011	0.004	7E-04	7E-04	---	0.001	0.003	0.002		5.330
1.426	1.4189	0.007	---	---	---	---	---	---	---	---		5.330
1.380	1.330	0.008	0.010	0.004	0.002	0.014	0.005	0.003	0.002	0.002		5.330
---	---	---	---	---	---	---	---	---	---	---		9.729
1.420	1.420	---	---	---	---	---	---	---	---	---		5.330
---	---	---	---	---	---	---	---	---	---	---		9.729
---	---	---	---	---	---	---	---	---	---	---		9.729
---	---	---	---	---	---	---	---	---	---	---		7.960
---	---	---	---	---	---	---	---	---	---	---		6.190
1.418	1.390	0.028	---	---	---	---	---	---	---	---		5.330
16.892	16.397	0.252	0.042	0.016	0.006	0.029	0.010	0.010	0.010	0.008	34.431	217.853

Table 5. Constituent masses for each RERTR-7A mini-plate.

Fuel Plate	Fuel Phase Composition	Fuel Meat Volume (cc)	Fuel Phase Constituent Densities (g/cm3)					Matrix Phase Dens. (g/cm3)	Matrix Phase Constituent Densities (g/cc)									
			Total U	U-235	Mo	Si	Cr	Al	Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	other
6A-1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6B-5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6A-3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6A-4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6A-5	U-7Mo	0.957	6.332	3.689	0.480	---	---	1.495	1.392	0.079	0.012	0.004	0.001	---	---	0.001	---	0.002
6A-6	U-10Mo	0.957	6.405	3.710	0.712	---	---	1.431	1.423	0.007	---	---	---	---	---	---	---	---
6A-7	U-7Mo	0.957	6.353	3.699	0.479	---	---	1.486	1.478	0.007	---	---	---	---	---	---	---	---
6A-8	U-12Mo	0.397	14.223	8.383	1.964	---	---	--	---	---	---	---	---	---	---	---	---	---
6B-1	U-7Mo	0.957	6.395	3.710	0.481	---	---	1.442	1.389	0.009	0.010	0.004	0.002	0.014	0.005	0.004	0.002	0.002
6B-2	U-7Mo	0.957	6.343	3.689	0.481	---	---	1.484	1.454	0.030	---	---	---	---	---	---	---	---
6B-3	U-7Mo	0.957	6.353	3.689	0.468	---	---	1.486	1.369	---	---	---	---	---	---	---	---	---
6B-4	U-12Mo	0.397	13.896	8.081	1.888	---	---	--	---	---	---	---	---	---	---	---	---	---
6B-5	U-10Mo	0.397	13.342	7.955	1.510	---	---	--	---	---	---	---	---	---	---	---	---	---
6B-6	U-10Mo	0.957	6.374	3.699	0.708	---	---	1.434	1.426	0.007	---	---	---	---	---	---	---	---
6B-7	U-10Mo	0.397	14.752	8.584	1.662	---	---	--	---	---	---	---	---	---	---	---	---	---
6B-8	U-7Mo	0.397	14.853	2.945	1.133	---	---	--	---	---	---	---	---	---	---	---	---	---
6C-1	U-12Mo	0.397	14.651	8.509	2.014	---	---	--	---	---	---	---	---	---	---	---	---	---
6C-2	U-10Mo	0.397	14.450	8.610	1.636	---	---	--	---	---	---	---	---	---	---	---	---	---
6C-3	U-10Mo	0.397	14.878	8.660	1.662	---	---	--	---	---	---	---	---	---	---	---	---	---
6C-4	U-7Mo	0.794	13.720	2.719	1.259	---	---	--	---	---	---	---	---	---	---	---	---	---
6C-5	U-10Mo	0.397	15.004	8.735	1.662	---	---	--	---	---	---	---	---	---	---	---	---	---
6C-6	U-12Mo	0.397	13.594	8.031	1.888	---	---	--	---	---	---	---	---	---	---	---	---	---
6A-7	U-7Mo	0.957	6.353	3.699	0.479	---	---	1.496	1.393	0.079	0.012	0.004	0.001	---	---	0.001	---	0.002
6C-8	U-7Mo	0.957	6.343	3.699	0.485	---	---	1.490	1.483	0.007	---	---	---	---	---	---	---	---
6D-1	U-7Mo	0.957	6.353	3.699	0.481	---	---	1.442	1.389	0.009	0.010	0.004	0.002	0.014	0.005	0.004	0.002	0.002
6C-3	---	---	---	---	---	---	---	--	---	---	---	---	---	---	---	---	---	---
6D-3	U-7Mo	0.957	6.353	3.689	0.470	---	---	1.484	1.484	---	---	---	---	---	---	---	---	---
6D-4	---	---	---	---	---	---	---	--	---	---	---	---	---	---	---	---	---	---
6B-5	---	---	---	---	---	---	---	--	---	---	---	---	---	---	---	---	---	---
6D-6	U-10Mo	0.397	12.260	7.124	1.359	---	---	--	---	---	---	---	---	---	---	---	---	---
6D-7	U-10Mo	0.794	13.619	7.942	1.536	---	---	--	---	---	---	---	---	---	---	---	---	---
6D-8	U-7Mo	0.957	6.343	3.689	0.483	---	---	1.482	1.452	0.030	---	---	---	---	---	---	---	---

Table 6. Constituent densities for RERTR-7A mini-plates based on nominal fuel meat volume.