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RERTR-7 Irradiation Summary Report

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SUMMARY

The Reduced Enrichment for Research and Test Reactor (RERTR) experiment RERTR-7A, was designed to test several modified fuel designs to target fission densities representative of a peak low enriched uranium (LEU) burnup in excess of 90% U-235 at peak experiment power sufficient to generate a peak surface heat flux of approximately 300 W/cm^2. The RERTR-7B experiment was designed as a high power test of 'second generation' dispersion fuels at peak experiment power sufficient to generate a surface heat flux on the order of 230 W/cm^2.[1]

The following report summarizes the life of the RERTR-7A and RERTR-7B experiments through end of irradiation, including as-run neutronic analyses, thermal analyses and hydraulic testing results.

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ACRONYMS

Al	aluminum
ATR	Advanced Test Reactor
CNEA	Comisión Nacional de Energía Atómica (The National Atomic Enerty Commission) Argentina
EFPD	effective full power days
FSW	friction stir weld
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
TLPB	transient liquid phase bonding
TS	thermal spray
U	uranium
U-Mo	uranium-molybdenum
Zr	zirconium

RERTR-7 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-7A experiment was designed to test several modified fuel designs to target fission densities representative of a peak low enriched uranium (LEU) burnup in excess of 90% U-235 at peak experiment power sufficient to generate a peak surface heat flux of approximately 300 W/cm^2. The RERTR-7B experiment was designed as a high power test of 'second generation' dispersion fuels at peak experiment power sufficient to generate a surface heat flux on the order of 230 W/cm^2.[2, 1]

The RERTR-8 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-8 experiment matrix is shown in Table 1.

Table 1. RERTR-7A experiment matrix loading diagram.[1]

RERTR-7A Experiment Matrix				
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-0.5Si 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 2. RERTR-7B experiment matrix loading diagram.[1]

RERTR-7B Experiment Matrix				
Capsule	**Column 1**	**Column 2**	**Column 3**	**Column 4**
A Top	A1 BLANK	A2 BLANK	A3 BLANK	A4 BLANK
A Bottom	A5 BLANK	A6 BLANK	A7 BLANK	A8 BLANK
B Top	B1 BLANK	B2 BLANK	B3 BLANK	B4 BLANK
B Bottom	B5 BLANK	B6 BLANK	B7 BLANK	B8 BLANK
C Top	C1 F3R010 U-7Mo-2Zr Roll Al 4043 Matrix	C2 R0R010 U-7Mo Al Matrix	C3 R3R010 U-7Mo Al 4043 Matrix	C4 D3R010 U-7Mo-1Ti Roll Al 4043 Matrix
C Bottom	C5 BLANK	C6 BLANK	C7 BLANK	C8 BLANK
D Top	D1 BLANK	D2 BLANK	D3 BLANK	D4 BLANK
D Bottom	D5 BLANK	D6 BLANK	D7 BLANK	D8 BLANK

2. CONSTITUENT MASSES AND DENSITIES

The constituent masses and densities for the RERTR-7A and -7B plates were obtained from the as-built plate summary sheets. Table 3 summarizes the constituent masses and densities for the plates in the RERTR-7A experiment and Table 4 summarizes the constituent masses and densities for the plates in the RERTR-7B experiment.

Table 3. Constituent masses and densities for RERTR-7A 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	Blank	--	--	--	--	--	--	--	--
A3	Blank	--	--	--	--	--	--	--	--
A4	Blank	--	--	--	--	--	--	--	--
A5	R3R040	6.060	3.530	0.459	1.431	6.809	3.966	0.516	1.608
A6	V5R040	6.130	3.550	0.681	1.369	6.811	3.944	0.757	1.521
A7	R5R030	6.080	3.540	0.458	1.422	6.909	4.023	0.520	1.616
A8	H1F020	5.650	3.330	0.780	--	14.487	8.538	2.000	--
B1	R1R040	6.120	3.550	0.460	1.380	7.116	4.128	0.535	1.605
B2	R2R040	6.070	3.530	0.460	1.420	6.670	3.879	0.505	1.560
B3	R0R010	6.080	3.530	0.448	1.422	6.909	4.011	0.509	1.616
B4	H1T010	5.520	3.210	0.750	--	14.526	8.447	1.974	--
B5	L1F01L	5.300	3.160	0.600	--	15.143	9.029	1.714	--
B6	V5R050	6.100	3.540	0.678	1.372	6.703	3.890	0.745	1.508
B7	L1F140	5.860	3.410	0.660	--	15.421	8.974	1.737	--
B8	MZ 25*	5.900	1.170	0.450	--	14.861	2.947	1.134	--
C1	H1F030	5.820	3.380	0.800	--	14.550	8.450	2.000	--
C2	L1T020	5.740	3.420	0.650	--	15.105	9.000	1.711	--
C3	L1F110	5.910	3.440	0.660	--	15.154	8.821	1.692	--
C4	MZ 50*	10.900	2.160	1.000	--	13.728	2.720	1.259	--
C5	L1F120	5.960	3.470	0.660	--	15.282	8.897	1.692	--
C6	H1T020	5.400	3.190	0.750	--	14.595	8.622	2.027	--
C7	R3R050	6.080	3.540	0.458	1.432	6.909	4.023	0.520	1.627
C8	R5R040	6.070	3.540	0.464	1.426	6.898	4.023	0.527	1.620
D1	R1R050	6.080	3.540	0.460	1.380	7.070	4.116	0.535	1.605
D2	Blank	--	--	--	--	--	--	--	--
D3	R0R020	6.080	3.530	0.450	1.420	6.831	3.966	0.506	1.596
D4	Blank	--	--	--	--	--	--	--	--
D5	Blank	--	--	--	--	--	--	--	--
D6	L1F160	4.870	2.830	0.540	--	15.219	8.844	1.688	--
D7	L2F040	10.820	6.310	1.220	--	15.457	9.014	1.743	--
D8	R2R050	6.070	3.530	0.462	1.418	6.898	4.011	0.525	1.611

Table 4. Constituent masses and densities for RERTR-7B plates[2].

Fuel Plate ID	Fuel Plate #	Fuel Constituent Masses					Constituent Densities				
		Total-U (g)	U-235 (g)	Mo (g)	Zr/Ti (g)	Matrix (g)	Total-U (g/cc)	U-235 (g/cc)	Mo (g/cc)	Zr/Ti (g/cc)	Matrix (g/cc)
A1	Blank	--	--	--	--	--	--	--	--	--	--
A2	Blank	--	--	--	--	--	--	--	--	--	--
A3	Blank	--	--	--	--	--	--	--	--	--	--
A4	Blank	--	--	--	--	--	--	--	--	--	--
A5	Blank	--	--	--	--	--	--	--	--	--	--
A6	Blank	--	--	--	--	--	--	--	--	--	--
A7	Blank	--	--	--	--	--	--	--	--	--	--
A8	Blank	--	--	--	--	--	--	--	--	--	--
B1	Blank	--	--	--	--	--	--	--	--	--	--
B2	Blank	--	--	--	--	--	--	--	--	--	--
B3	Blank	--	--	--	--	--	--	--	--	--	--
B4	Blank	--	--	--	--	--	--	--	--	--	--
B5	Blank	--	--	--	--	--	--	--	--	--	--
B6	Blank	--	--	--	--	--	--	--	--	--	--
B7	Blank	--	--	--	--	--	--	--	--	--	--
B8	Blank	--	--	--	--	--	--	--	--	--	--
C1	F3R010	5.991	3.475	0.461	0.132 (Zr)	1.656	6.260	3.631	0.482	0.138 (Zr)	1.730
C2	R0R010	5.930	3.439	0.447	--	1.693	6.196	3.594	0.467	--	1.769
C3	R3R010	5.886	3.414	0.443	--	1.681	6.150	3.567	0.463	--	1.757
C4	D3R010	5.942	3.446	0.452	0.065 (Ti)	1.652	6.209	3.601	0.472	0.067 (Ti)	1.726
C5	Blank	--	--	--	--	--	--	--	--	--	--
C6	Blank	--	--	--	--	--	--	--	--	--	--
C7	Blank	--	--	--	--	--	--	--	--	--	--
C8	Blank	--	--	--	--	--	--	--	--	--	--
D1	Blank	--	--	--	--	--	--	--	--	--	--
D2	Blank	--	--	--	--	--	--	--	--	--	--
D3	Blank	--	--	--	--	--	--	--	--	--	--
D4	Blank	--	--	--	--	--	--	--	--	--	--
D5	Blank	--	--	--	--	--	--	--	--	--	--
D6	Blank	--	--	--	--	--	--	--	--	--	--
D7	Blank	--	--	--	--	--	--	--	--	--	--
D8	Blank	--	--	--	--	--	--	--	--	--	--

3. EXPERIMENT HARDWARE

The experiment hardware configuration is identical for the RERTR-7A and -7B experiments. A list of irradiation hardware drawings used for analysis is given in Table 5.

Table 5. RERTR-7A/B irradiation hardware drawing list.

Drawing Number	Drawing Title
DWG-630223	RERTR ATR Large B-Position Irradiation Experiment Assembly
DWG-630233	ATR Large B-Position Basket
DWG-630231	ATR Top Spacer Assembly
DWG-630225	ATR Upper Spacer Assembly
DWG-630229	ATR Bottom Spacer Assembly
DWG-630227	ATR Large B-Position Fuel Capsule Assembly
DWG-630237	Fuel Capsule
DWG-630239	Capsule Cap
DWG-630244	RERTR Mini-Plate
DWG-630238	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-630244 and DWG-630238, respectively) and RERTR miniplate capsule assembly are shown in Figure 2, Figure 3 and Figure 4, 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 miniplate irradiation Assembly.

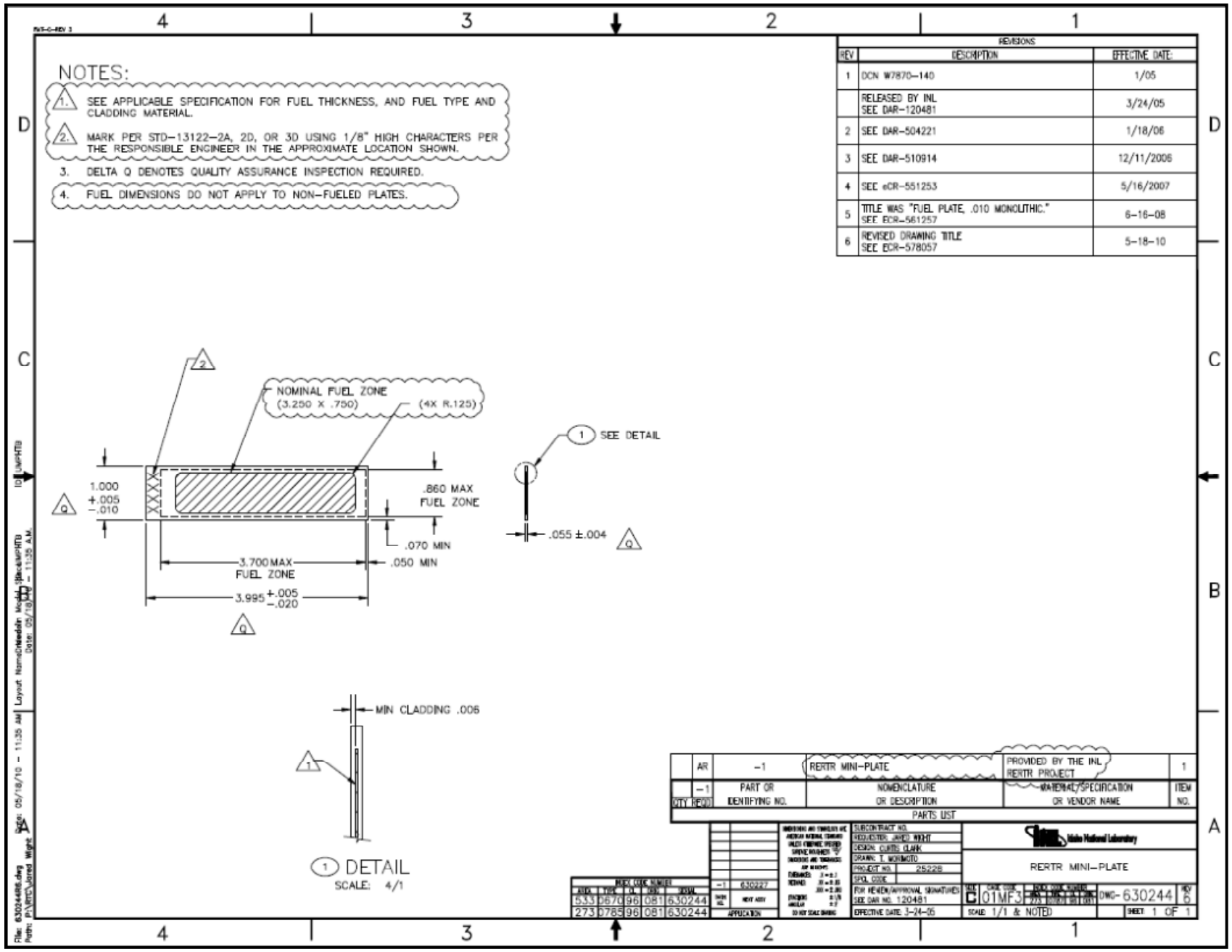

Figure 2. DWG-630244: RERTR monolithic fuel miniplate.

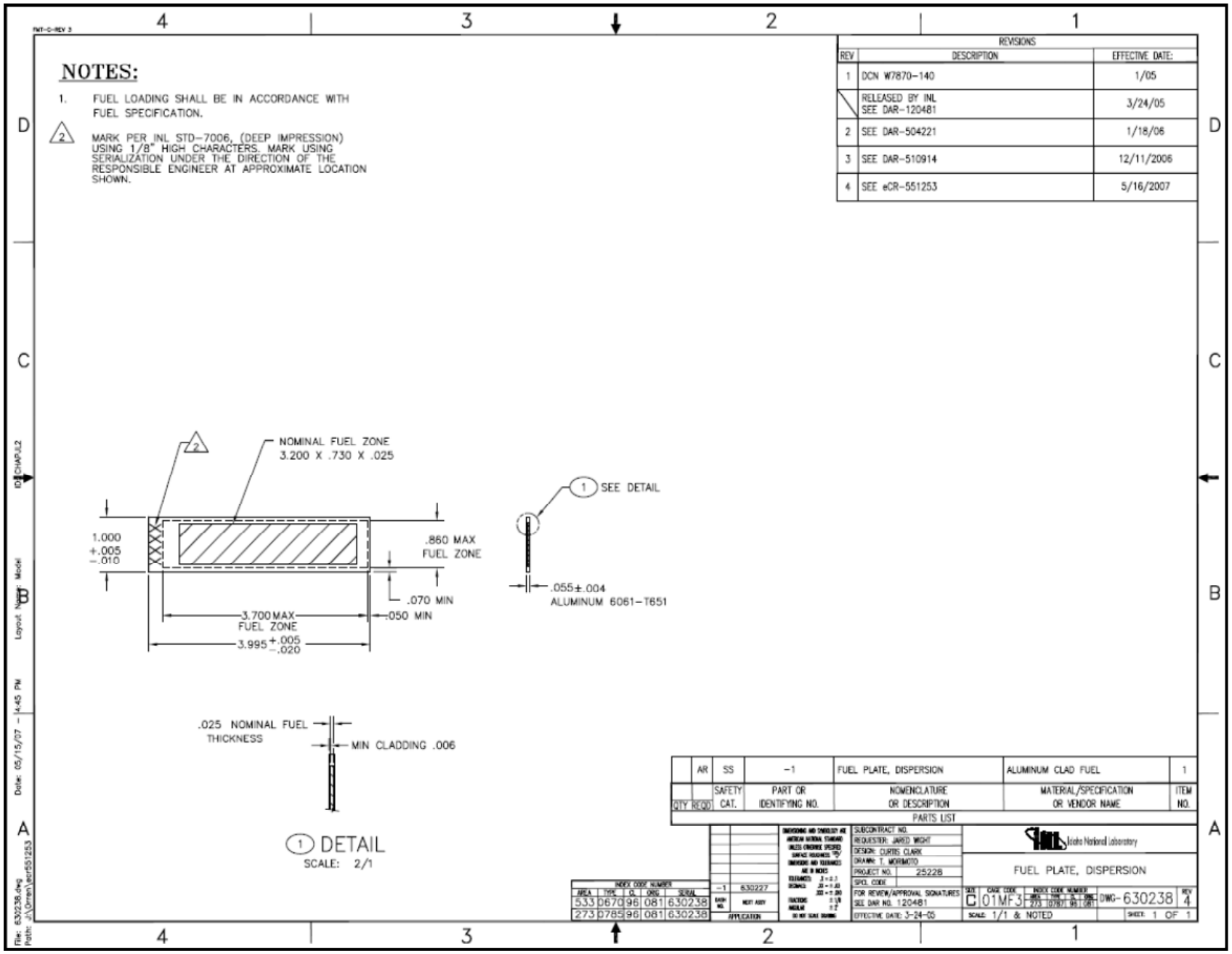

Figure 3. DWG-630238: RERTR dispersion fuel miniplate.

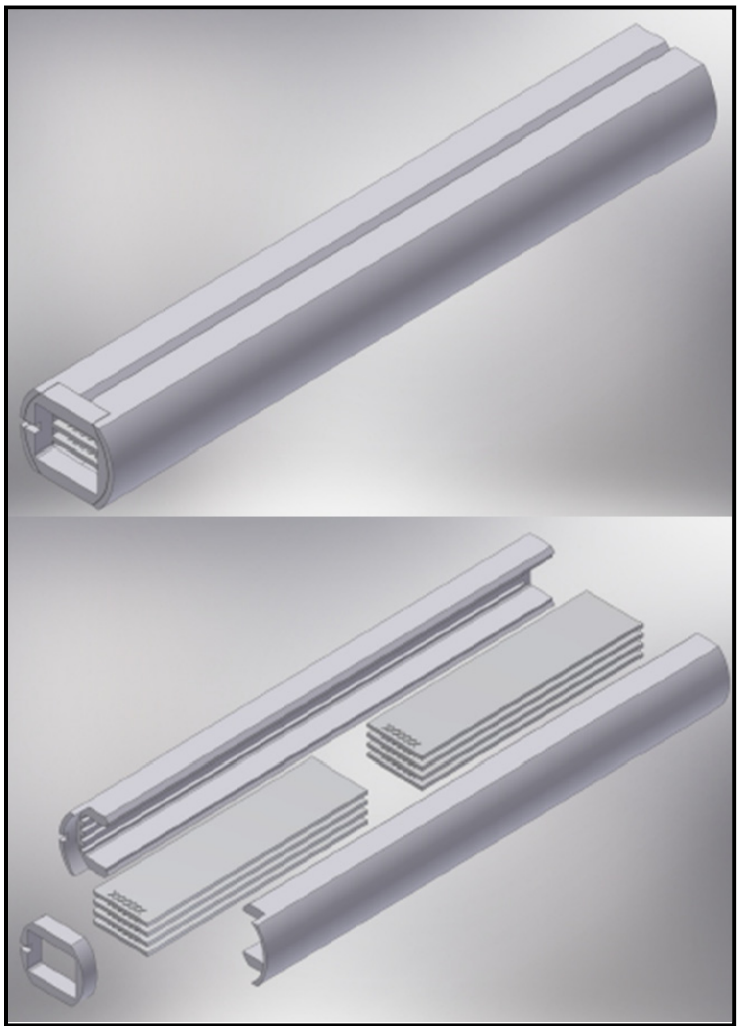

Figure 4. RERTR capsule assembly.

4. IRRADIATION HISTORY

The RERTR-7A test assembly was irradiated in Cycles 136A and 136B in the large-B position B-11. The power of position B-11 in the core is represented by the south lobe power which is the average of the SW, C and SE lobe powers, S = (SW + C + SE)/3. Cycle 136A ran for 50.9 EFPDs with the south lobe power at 23.3 MW (total core power of 106 MW), Cycle 136B ran for 39 EFPDs with the south lobe power at 21.4 MW (total core power 105.9 MW). There was one mid-cycle SCRAM during cycle 136B with a duration of 7 days. This information is tabulated in Table 6.

The RERTR-7B test assembly was irradiated in Cycle 136B in the large-B position B-12. The power of position B-12 is represented by the west lobe power which is the average of the NW, SW and C lobe powers, W = (NW + C + SW)/3. Cycle 136B had a west lobe power of 21.6 MW; there was one mid-cycle SCRAM during cycle 136B with a duration of 7 days. This information is tabulated in Table 7.

Table 6. Irradiation history for the RERTR-7A experiment.

ATR CYCLE	RERTR-7A Capsules Irradiated	Dates Irradiated	Cycle EFPDs	Mid-Cycle SCRAM (days)	South Lobe Source Power (MW)	Total Core Power (MW)
136A	A,B,C,D	11/24/2005 – 1/14/2006	50.9	0	23.3	106.0
136B	A,B,C,D	01/22/2006 – 03/09/2006	39.0	7	23.3	105.9

Table 7. Irradiation history for the RERTR-7B experiment.

ATR CYCLE	RERTR-7B Capsules Irradiated	Dates Irradiated	Cycle EFPDs	Mid-Cycle SCRAM (days)	West Lobe Source Power (MW)	Total Core Power (MW)
136B	C	01/22/2006 – 03/09/2006	39.0	7	21.6	105.9

The power history for each cycle is obtained as in ATR Surveillance Report from the ATR Data Acquisition System (DAS). The plot of each lobe power on an hourly basis for cycle 136B is shown in Figure 5.

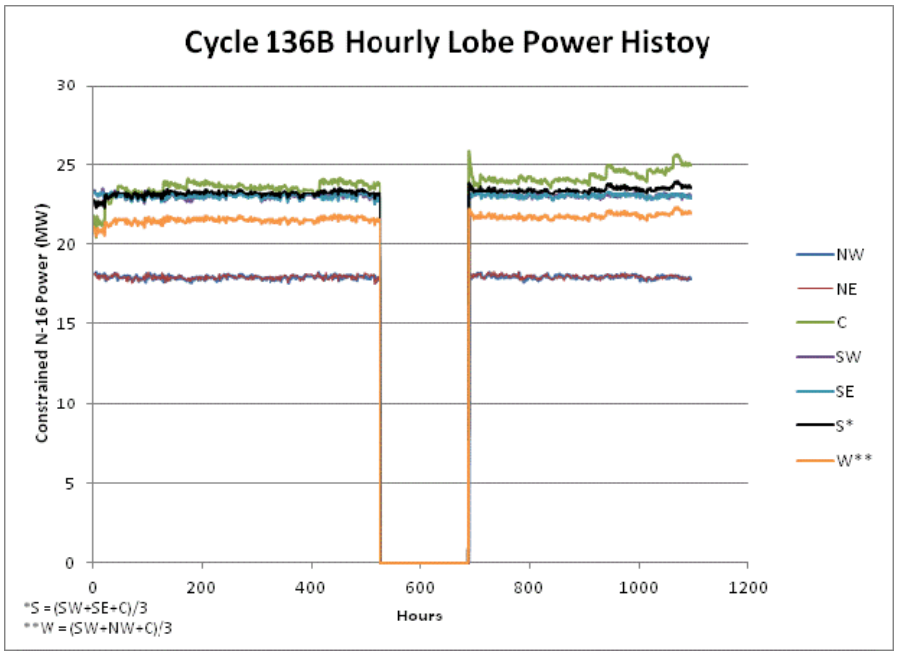

Figure 5. Hourly lobe power history for ATR Cycle 136B.

5. AS-RUN NUCLEAR ANALYSIS

5.1 Neutronics

The as-run calculations were performed using the irradiation history in Table 6 and Table 7 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%.[4] The time intervals used to calculate average plate power and burnup for the plates in RERTR-7A and RERTR-7B are shown in Table 8 and Table 9, respectively. The RERTR-7A end of cycle average plate power and burnup for cycles 136A and 136B are shown in Table 12 and Table 15, respectively. The RERTR-7A average plate power and burnup for cycle 136A are shown in Table 10 through Table 12 and the RERTR-7A average plate power and burnup for cycle 136B are shown in Table 13 through Table 15. The RERTR-7B end of cycle average plate power and burnup for cycle 136B is shown in Table 18, with the average plate power and burnup for the entire cycle shown in Table 16 through Table 18. The plots of the power and burnup as a function of the ATR Cycle time interval are in Appendix A.

Table 8. RERTR-7A Cycle breakdown.

Time Interval	136A (days)	136B (days)
01	1.00E-4	1.00E-4
02	15	12
03	20	13.5
04	15.9	13.5
05	1.00E-3	1.00E-3
EFPDs	50.9	39
Cumulative	50.9	89.9

Table 9. RERTR-7B Cycle breakdown.

Time Interval	136B (days)
01	1.00E-4
02	15
03	15
04	9
05	1.00E-3
EFPDs	39
Cumulative	39

Table 10. RERTR-7A average plate power and burnup for MOC1 136A (15 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	Blank	--	--	--	--	--
A3	Blank	--	--	--	--	--
A4	Blank	--	--	--	--	--
A5	R3R040	984.22	8179.59	259.70	4.52%	3.67E+20
A6	V5R040	793.59	6785.25	215.43	3.81%	3.05E+20
A7	R5R030	823.42	6850.52	217.50	3.81%	3.08E+20
A8	H1F020	1168.61	18920.73	240.29	4.61%	8.49E+20
B1	R1R040	1106.59	9209.71	292.41	5.07%	4.14E+20
B2	R2R040	917.46	7624.66	242.08	4.26%	3.42E+20
B3	R0R010	921.96	7660.44	243.22	4.26%	3.44E+20
B4	H1T010	1342.34	21194.23	269.17	5.31%	9.52E+20
B5	L1F01L	1454.36	21604.47	274.38	5.49%	9.70E+20
B6	V5R050	976.05	8314.10	263.97	4.57%	3.73E+20
B7	L1F140	1263.18	20742.40	263.43	4.91%	9.31E+20
B8	MZ 25	673.77	10773.19	136.82	7.26%	4.84E+20
C1	H1F030	1359.10	22658.06	287.76	5.41%	1.02E+21
C2	L1T020	1206.15	19408.08	246.48	4.62%	8.71E+20
C3	L1F110	1227.84	20315.86	258.01	4.78%	9.12E+20
C4	MZ 50	566.91	8493.51	215.74	6.31%	3.81E+20
C5	L1F120	1364.67	22750.59	288.93	5.31%	1.02E+21
C6	H1T020	1151.68	17833.67	226.49	4.57%	8.01E+20
C7	R3R050	940.81	7836.72	248.82	4.31%	3.52E+20
C8	R5R040	1131.48	9414.07	298.90	5.14%	4.23E+20
D1	R1R050	1226.49	10155.30	322.43	5.59%	4.56E+20
D2	Blank	--	--	--	--	--
D3	R0R020	1226.64	10192.32	323.61	5.61%	4.58E+20
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	L1F160	1112.59	15155.51	192.47	4.33%	6.80E+20
D7	L2F040	771.55	11696.54	297.09	3.05%	5.25E+20
D8	R2R050	886.78	7369.40	233.98	4.07%	3.31E+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-7A average plate power and burnup for MOC2 136A (35 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	Blank	--	--	--	--	--
A3	Blank	--	--	--	--	--
A4	Blank	--	--	--	--	--
A5	R3R040	945.99	7740.44	245.76	10.19%	8.31E+20
A6	V5R040	761.89	6433.03	204.25	8.50%	6.90E+20
A7	R5R030	792.36	6507.73	206.62	8.58%	6.97E+20
A8	H1F020	1128.09	17932.31	227.74	10.38%	1.92E+21
B1	R1R040	1064.65	8706.95	276.45	11.35%	9.35E+20
B2	R2R040	883.21	7235.05	229.71	9.55%	7.75E+20
B3	R0R010	886.93	7263.98	230.63	9.61%	7.79E+20
B4	H1T010	1291.95	19975.90	253.69	11.93%	2.15E+21
B5	L1F01L	1402.70	20639.31	262.12	12.36%	2.19E+21
B6	V5R050	938.53	7872.84	249.96	10.35%	8.45E+20
B7	L1F140	1216.15	19577.62	248.64	11.05%	2.10E+21
B8	MZ 25	635.92	10061.71	127.78	16.19%	1.09E+21
C1	H1F030	1309.49	21367.53	271.37	12.15%	2.30E+21
C2	L1T020	1164.29	18381.64	233.45	10.38%	1.97E+21
C3	L1F110	1183.49	19208.35	243.95	10.77%	2.06E+21
C4	MZ 50	536.08	7960.10	202.19	14.01%	8.58E+20
C5	L1F120	1314.00	21441.32	272.30	11.88%	2.30E+21
C6	H1T020	1111.03	16897.81	214.60	10.20%	1.81E+21
C7	R3R050	905.50	7433.72	236.02	9.78%	7.97E+20
C8	R5R040	1086.78	8883.39	282.05	11.63%	9.54E+20
D1	R1R050	1178.95	9574.09	303.98	12.45%	1.03E+21
D2	Blank	--	--	--	--	--
D3	R0R020	1179.74	9615.34	305.29	12.54%	1.03E+21
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	L1F160	1071.66	14346.93	182.21	9.75%	1.54E+21
D7	L2F040	743.31	11132.24	282.76	6.93%	1.19E+21
D8	R2R050	857.07	7024.94	223.04	9.23%	7.51E+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-7A average plate power and burnup for EOC 136A (50.9 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	Blank	--	--	--	--	--
A3	Blank	--	--	--	--	--
A4	Blank	--	--	--	--	--
A5	R3R040	936.35	7511.43	238.49	14.58%	1.19E+21
A6	V5R040	762.93	6340.55	201.31	12.23%	9.91E+20
A7	R5R030	790.67	6387.45	202.80	12.32%	1.00E+21
A8	H1F020	1118.04	17357.77	220.44	14.80%	2.75E+21
B1	R1R040	1051.19	8410.79	267.04	16.21%	1.33E+21
B2	R2R040	882.71	7099.87	225.42	13.70%	1.11E+21
B3	R0R010	886.80	7129.26	226.35	13.75%	1.12E+21
B4	H1T010	1280.75	19275.79	244.80	17.04%	3.06E+21
B5	L1F01L	1388.89	19590.09	248.79	17.61%	3.12E+21
B6	V5R050	937.40	7710.28	244.80	14.80%	1.21E+21
B7	L1F140	1215.57	19080.13	242.32	15.86%	3.01E+21
B8	MZ 25	604.96	9447.96	119.99	22.85%	1.54E+21
C1	H1F030	1296.80	20595.75	261.57	17.33%	3.28E+21
C2	L1T020	1165.30	17956.09	228.04	14.86%	2.83E+21
C3	L1F110	1182.41	18720.59	237.75	15.41%	2.95E+21
C4	MZ 50	517.16	7594.75	192.91	19.85%	1.22E+21
C5	L1F120	1300.84	20654.37	262.31	16.93%	3.29E+21
C6	H1T020	1112.02	16524.97	209.87	14.63%	2.60E+21
C7	R3R050	904.16	7283.15	231.24	14.04%	1.14E+21
C8	R5R040	1071.19	8559.10	271.75	16.58%	1.36E+21
D1	R1R050	1160.17	9197.33	292.02	17.79%	1.47E+21
D2	Blank	--	--	--	--	--
D3	R0R020	1162.41	9246.84	293.59	17.90%	1.47E+21
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	L1F160	1063.10	13915.43	176.73	13.92%	2.20E+21
D7	L2F040	746.57	11007.47	279.59	9.92%	1.72E+21
D8	R2R050	884.53	6798.83	215.86	13.18%	1.07E+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 13. RERTR-7A average plate power and burnup for MOC1 136B (12.0 EFPD, 62.9 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	Blank	--	--	--	--	--
A3	Blank	--	--	--	--	--
A4	Blank	--	--	--	--	--
A5	R3R040	927.90	7328.32	232.67	17.83%	1.45E+21
A6	V5R040	763.82	6267.09	198.98	14.95%	1.22E+21
A7	R5R030	793.14	6323.44	200.77	15.12%	1.23E+21
A8	H1F020	1111.72	16942.59	215.17	18.06%	3.36E+21
B1	R1R040	1043.94	8205.64	260.53	19.83%	1.63E+21
B2	R2R040	885.50	7017.29	222.80	16.82%	1.37E+21
B3	R0R010	888.12	7034.46	223.34	16.88%	1.37E+21
B4	H1T010	1268.13	18680.23	237.24	20.81%	3.74E+21
B5	L1F01L	1379.79	19011.75	241.45	21.48%	3.80E+21
B6	V5R050	941.31	7620.99	241.97	18.17%	1.48E+21
B7	L1F140	1216.67	18707.40	237.58	19.36%	3.68E+21
B8	MZ 25	582.67	9009.56	114.42	27.62%	1.86E+21
C1	H1F030	1286.68	19991.53	253.89	21.09%	3.99E+21
C2	L1T020	1171.72	17706.16	224.87	18.21%	3.46E+21
C3	L1F110	1186.63	18421.44	233.95	18.88%	3.61E+21
C4	MZ 50	503.72	7334.79	186.30	24.10%	1.48E+21
C5	L1F120	1292.77	20084.50	255.07	20.68%	4.01E+21
C6	H1T020	1115.14	16265.15	206.57	17.93%	3.18E+21
C7	R3R050	906.15	7188.12	228.22	17.22%	1.40E+21
C8	R5R040	1063.26	8346.28	264.99	20.20%	1.66E+21
D1	R1R050	1147.55	8920.48	283.23	21.66%	1.79E+21
D2	Blank	--	--	--	--	--
D3	R0R020	1150.33	8973.83	284.92	21.84%	1.80E+21
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	L1F160	1058.07	13606.48	172.80	17.04%	2.69E+21
D7	L2F040	570.82	10932.76	277.69	12.18%	2.11E+21
D8	R2R050	839.18	6662.31	211.53	16.17%	1.31E+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-7A average plate power and burnup for MOC2 136B (25.5 EFPD, 76.4 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	Blank	--	--	--	--	--
A3	Blank	--	--	--	--	--
A4	Blank	--	--	--	--	--
A5	R3R040	922.27	7195.90	228.47	21.33%	1.74E+21
A6	V5R040	963.11	6201.90	196.91	18.05%	1.47E+21
A7	R5R030	793.95	6266.50	198.96	18.23%	1.48E+21
A8	H1F020	1103.84	16585.84	210.64	21.69%	4.03E+21
B1	R1R040	1034.86	8027.02	254.86	23.75%	1.95E+21
B2	R2R040	884.49	6930.56	220.05	20.25%	1.65E+21
B3	R0R010	886.02	6938.92	220.31	20.32%	1.65E+21
B4	H1T010	1255.18	18192.08	231.04	24.87%	4.47E+21
B5	L1F01L	1370.59	18555.87	235.66	25.70%	4.55E+21
B6	V5R050	939.65	7518.59	238.72	21.91%	1.79E+21
B7	L1F140	1213.60	18374.46	233.36	23.27%	4.42E+21
B8	MZ 25	563.70	8651.81	109.88	32.71%	2.21E+21
C1	H1F030	1274.95	19490.73	247.53	25.26%	4.78E+21
C2	L1T020	1173.34	17466.45	221.82	21.93%	4.17E+21
C3	L1F110	1187.80	18160.93	230.64	22.67%	4.35E+21
C4	MZ 50	492.90	7131.69	181.14	28.70%	1.77E+21
C5	L1F120	1282.95	19602.16	248.95	24.74%	4.80E+21
C6	H1T020	1114.53	16028.10	203.56	21.62%	3.83E+21
C7	R3R050	906.36	7107.72	225.67	20.71%	1.69E+21
C8	R5R040	1054.77	8167.82	259.33	24.20%	1.99E+21
D1	R1R050	1134.67	8694.53	276.05	25.92%	2.14E+21
D2	Blank	--	--	--	--	--
D3	R0R020	1135.60	8727.97	277.11	26.11%	2.15E+21
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	L1F160	1049.97	13318.72	169.15	20.49%	3.23E+21
D7	L2F040	754.57	10881.35	276.39	14.73%	2.55E+21
D8	R2R050	833.21	6542.98	207.74	19.43%	1.58E+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 15. RERTR-7A average plate power and burnup for EOC 136B (39 EFPD, 89.9 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	Blank	--	--	--	--	--
A3	Blank	--	--	--	--	--
A4	Blank	--	--	--	--	--
A5	R3R040	913.62	7037.27	223.43	24.83%	2.03E+21
A6	V5R040	762.24	6125.01	194.47	21.03%	1.71E+21
A7	R5R030	790.83	6169.56	195.88	21.28%	1.73E+21
A8	H1F020	1095.89	16204.74	205.80	25.19%	4.68E+21
B1	R1R040	1023.00	7817.30	248.20	27.55%	2.27E+21
B2	R2R040	884.75	6843.85	217.29	23.63%	1.92E+21
B3	R0R010	885.59	6848.70	217.45	23.69%	1.93E+21
B4	H1T010	1240.90	17666.12	224.36	28.83%	5.18E+21
B5	L1F01L	1356.32	18004.52	228.66	29.83%	5.28E+21
B6	V5R050	934.87	7379.88	234.31	25.54%	2.09E+21
B7	L1F140	1211.13	18022.91	228.89	27.09%	5.15E+21
B8	MZ 25	542.89	8266.35	104.98	37.52%	2.54E+21
C1	H1F030	1261.36	18931.22	240.43	29.30%	5.55E+21
C2	L1T020	1173.89	17182.25	218.21	25.56%	4.86E+21
C3	L1F110	1184.06	17797.85	226.03	26.41%	5.07E+21
C4	MZ 50	479.45	6888.12	174.96	33.11%	2.05E+21
C5	L1F120	1270.01	19051.21	241.95	28.67%	5.57E+21
C6	H1T020	1115.35	15781.65	200.43	25.17%	4.47E+21
C7	R3R050	904.55	7001.17	222.29	24.20%	1.97E+21
C8	R5R040	1043.69	7962.17	252.80	28.15%	2.31E+21
D1	R1R050	1118.95	8434.68	267.80	30.05%	2.48E+21
D2	Blank	--	--	--	--	--
D3	R0R020	1121.57	8483.28	269.34	30.25%	2.49E+21
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	L1F160	1042.32	13024.55	165.41	23.78%	3.75E+21
D7	L2F040	759.86	10842.23	275.39	17.24%	2.99E+21
D8	R2R050	826.32	6410.15	203.52	22.61%	1.84E+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 16. RERTR-7B average plate power and burnup for MOC1 136B (15 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	Blank	--	--	--	--	--
A3	Blank	--	--	--	--	--
A4	Blank	--	--	--	--	--
A5	Blank	--	--	--	--	--
A6	Blank	--	--	--	--	--
A7	Blank	--	--	--	--	--
A8	Blank	--	--	--	--	--
B1	Blank	--	--	--	--	--
B2	Blank	--	--	--	--	--
B3	Blank	--	--	--	--	--
B4	Blank	--	--	--	--	--
B5	Blank	--	--	--	--	--
B6	Blank	--	--	--	--	--
B7	Blank	--	--	--	--	--
B8	Blank	--	--	--	--	--
C1	F3R010	868.39	7376.10	234.19	4.15%	3.31E+20
C2	R0R010	717.49	6053.46	192.20	3.46%	2.72E+20
C3	R3R010	729.68	6021.32	191.18	3.49%	2.70E+20
C4	D3R010	881.96	7368.78	233.96	4.18%	3.31E+20
C5	Blank	--	--	--	--	--
C6	Blank	--	--	--	--	--
C7	Blank	--	--	--	--	--
C8	Blank	--	--	--	--	--
D1	Blank	--	--	--	--	--
D2	Blank	--	--	--	--	--
D3	Blank	--	--	--	--	--
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	Blank	--	--	--	--	--
D7	Blank	--	--	--	--	--
D8	Blank	--	--	--	--	--

*Calculated using nominal fuel meat thickness of 0.0635 cm.

Table 17. RERTR-7B average plate power and burnup for MOC2 136B (30 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	Blank	--	--	--	--	--
A3	Blank	--	--	--	--	--
A4	Blank	--	--	--	--	--
A5	Blank	--	--	--	--	--
A6	Blank	--	--	--	--	--
A7	Blank	--	--	--	--	--
A8	Blank	--	--	--	--	--
B1	Blank	--	--	--	--	--
B2	Blank	--	--	--	--	--
B3	Blank	--	--	--	--	--
B4	Blank	--	--	--	--	--
B5	Blank	--	--	--	--	--
B6	Blank	--	--	--	--	--
B7	Blank	--	--	--	--	--
B8	Blank	--	--	--	--	--
C1	F3R010	835.49	6999.74	222.24	8.09%	6.45E+20
C2	R0R010	689.63	5754.27	182.70	6.73%	5.30E+20
C3	R3R010	701.33	5720.05	181.61	6.78%	5.27E+20
C4	D3R010	849.24	6999.44	222.23	8.16%	6.45E+20
C5	Blank	--	--	--	--	--
C6	Blank	--	--	--	--	--
C7	Blank	--	--	--	--	--
C8	Blank	--	--	--	--	--
D1	Blank	--	--	--	--	--
D2	Blank	--	--	--	--	--
D3	Blank	--	--	--	--	--
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	Blank	--	--	--	--	--
D7	Blank	--	--	--	--	--
D8	Blank	--	--	--	--	--

*Calculated using nominal fuel meat thickness of 0.0635 cm.

Table 18. RERTR-7B average plate power and burnup for EOC 136B (39 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	Blank	--	--	--	--	--
A3	Blank	--	--	--	--	--
A4	Blank	--	--	--	--	--
A5	Blank	--	--	--	--	--
A6	Blank	--	--	--	--	--
A7	Blank	--	--	--	--	--
A8	Blank	--	--	--	--	--
B1	Blank	--	--	--	--	--
B2	Blank	--	--	--	--	--
B3	Blank	--	--	--	--	--
B4	Blank	--	--	--	--	--
B5	Blank	--	--	--	--	--
B6	Blank	--	--	--	--	--
B7	Blank	--	--	--	--	--
B8	Blank	--	--	--	--	--
C1	F3R010	827.94	6847.06	217.39	10.42%	8.30E+20
C2	R0R010	689.19	5689.95	180.66	8.69%	6.83E+20
C3	R3R010	700.30	5650.02	179.39	8.76%	6.79E+20
C4	D3R010	842.81	6853.73	217.61	10.51%	8.30E+20
C5	Blank	--	--	--	--	--
C6	Blank	--	--	--	--	--
C7	Blank	--	--	--	--	--
C8	Blank	--	--	--	--	--
D1	Blank	--	--	--	--	--
D2	Blank	--	--	--	--	--
D3	Blank	--	--	--	--	--
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	Blank	--	--	--	--	--
D7	Blank	--	--	--	--	--
D8	Blank	--	--	--	--	--

*Calculated using nominal fuel meat thickness of 0.0635 cm.

5.2 Gradients

The MCNP-calculated power gradients[6] 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-7A experiment; the gradients were not calculated for the RERTR-7B experiment.

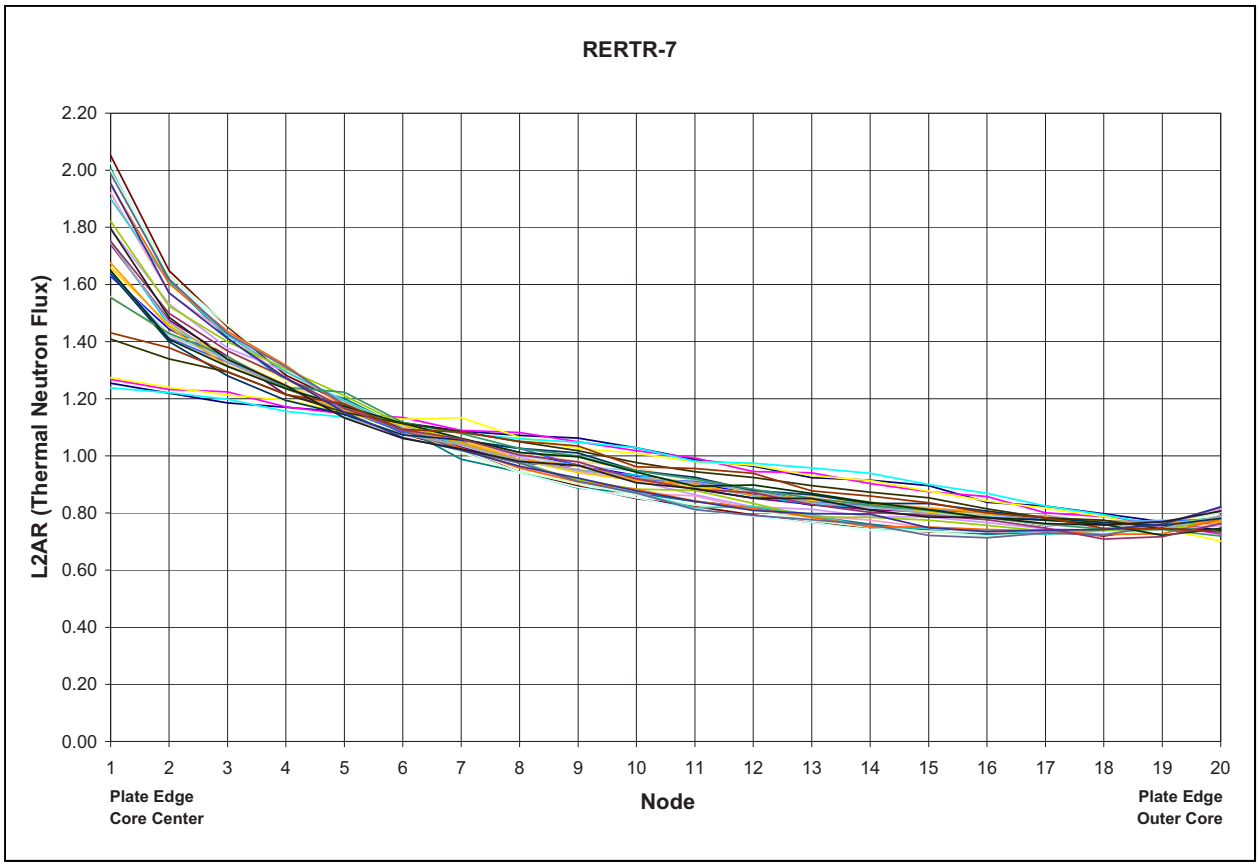

Figure 6. RERTR-7A fuel miniplates thermal neutron flux L2ARs in transverse direction.[6]

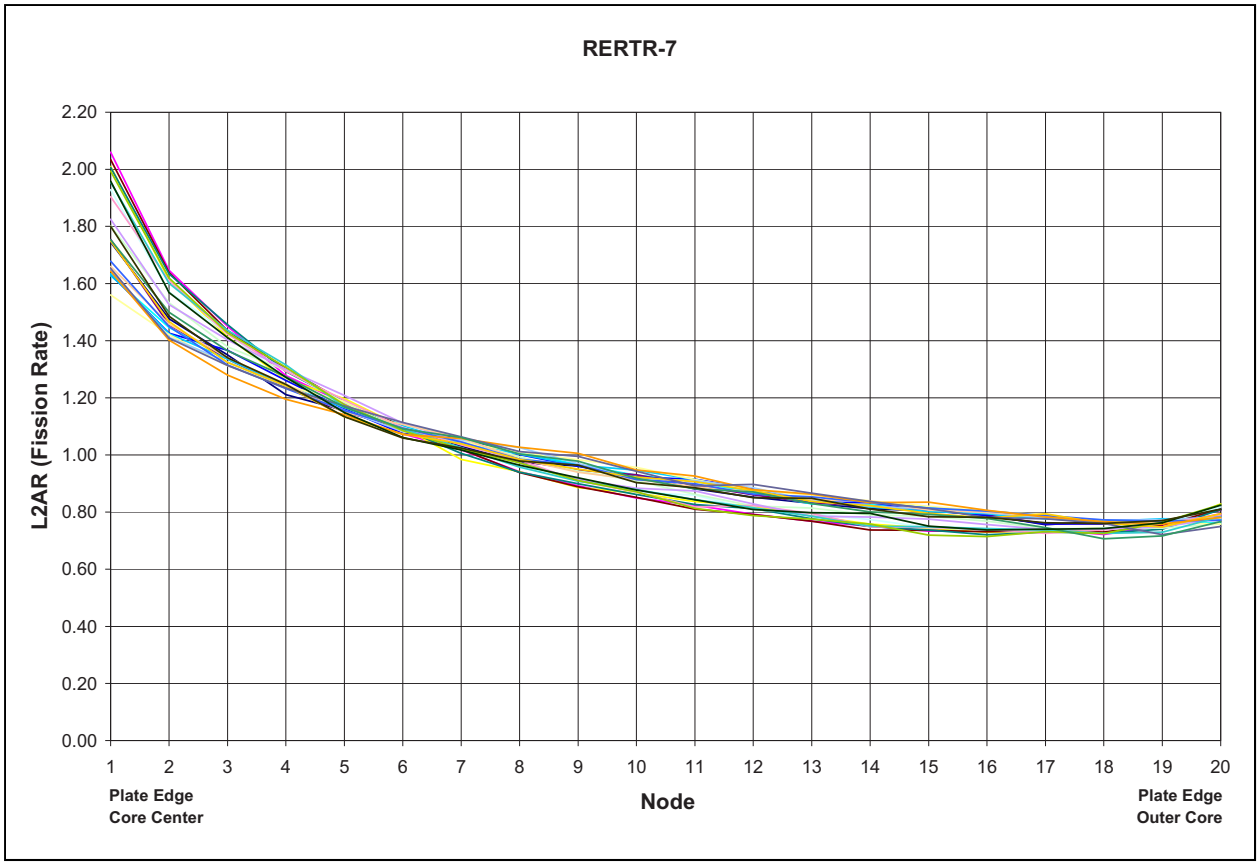

Figure 7. RERTR-7A fuel miniplates fission rate L2ARs in transverse direction.[6]

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 19.

Table 19. Loss coefficients for the RERTR irradiation test vehicle components.[7]

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

Based on the results from the hydraulic testing, the orifice was removed leaving the capsule in the "Vehicle" configuration to provide an ATR coolant flow rate through the capsules of 2727 cm^3/sec.[8]

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[9] 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 10):

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

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.

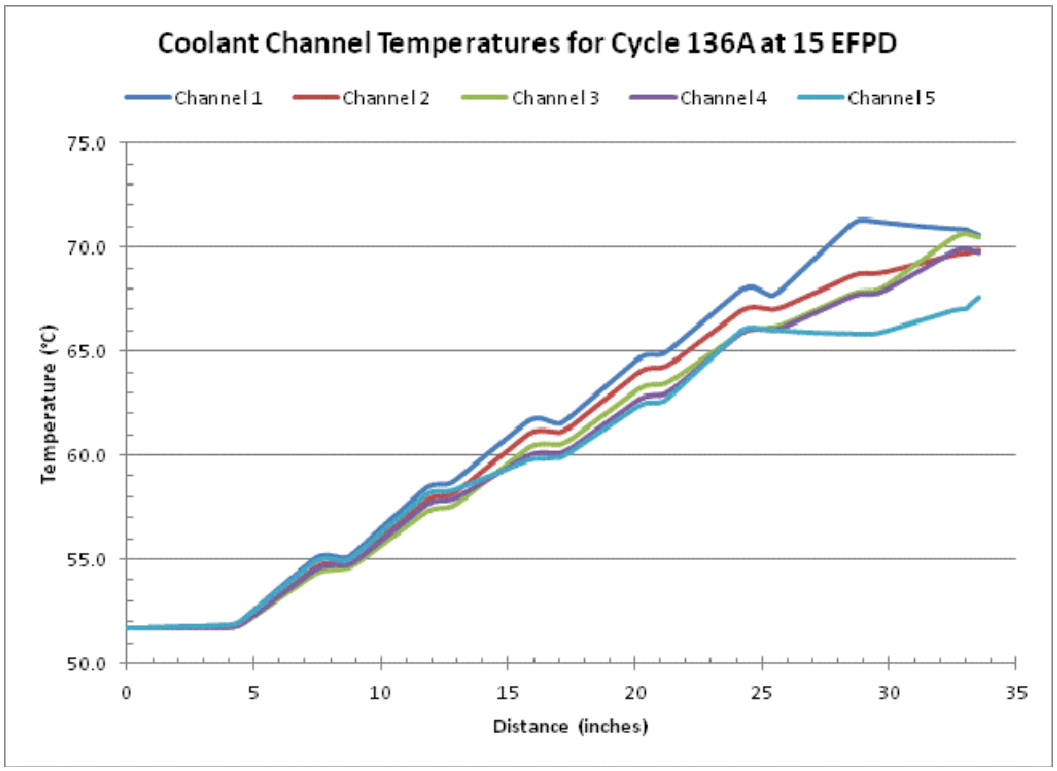

Figure 8. RERTR-7A coolant temperature as a function of location along the test assembly for Cycle 136A at 15 EFPD.

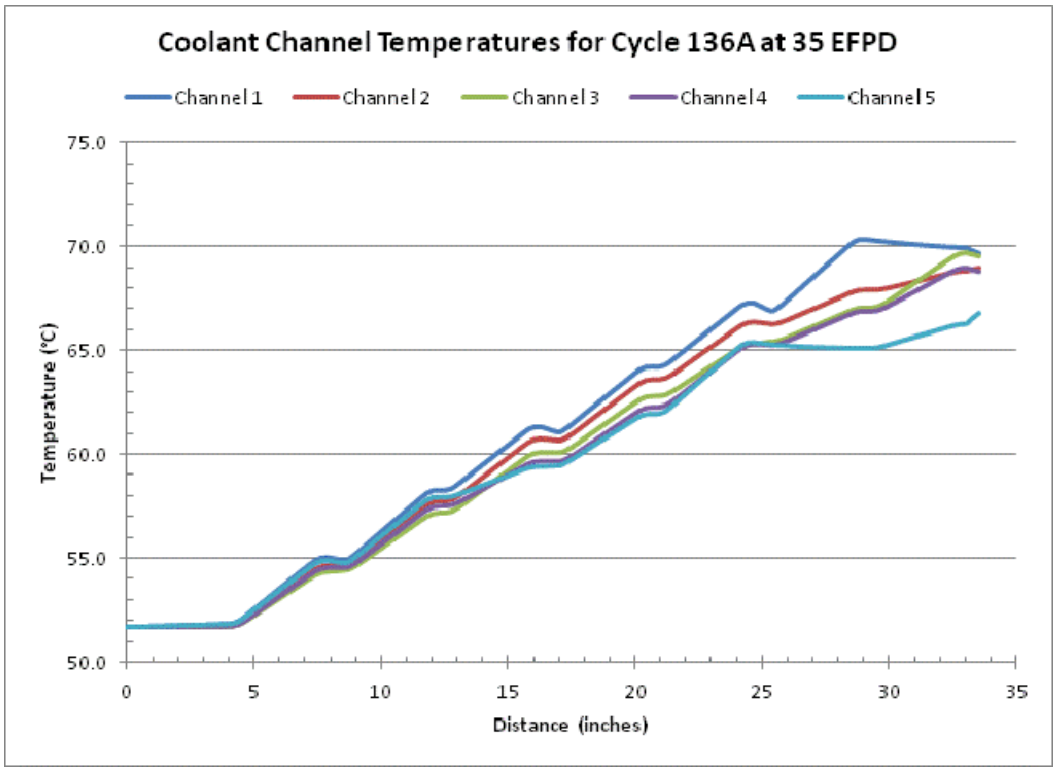

Figure 9. RERTR-7A coolant temperature as a function of location along the test assembly for Cycle 136A at 18 EFPD.

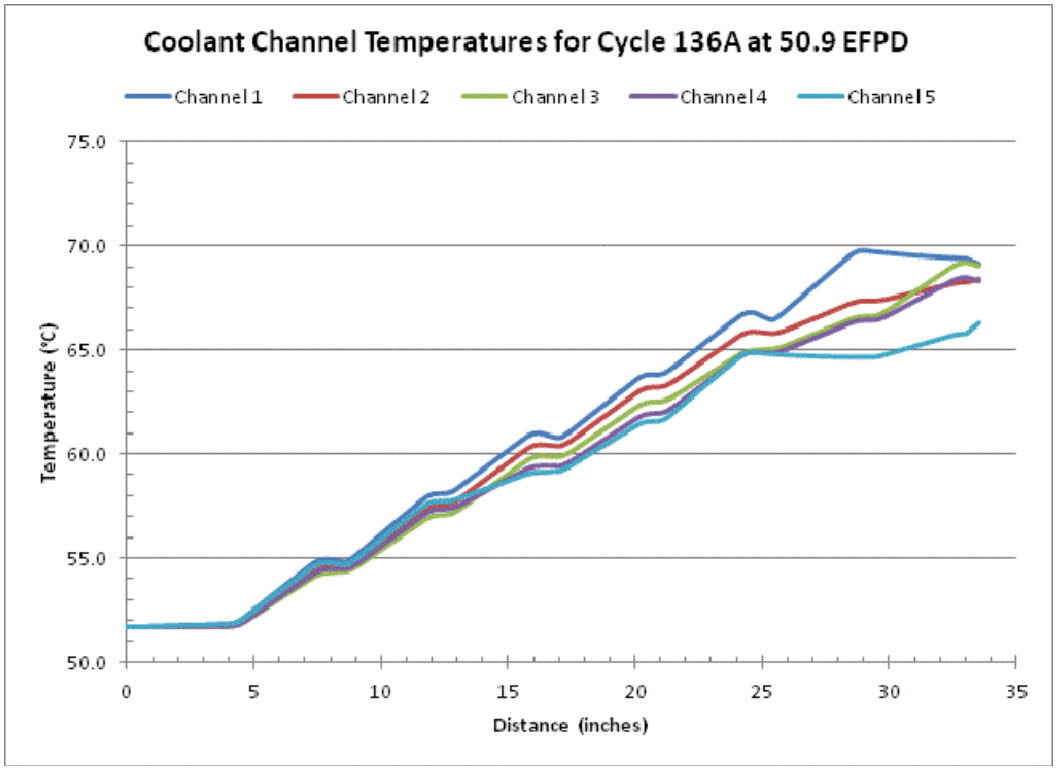

Figure 10. RERTR-7A coolant temperature as a function of location along the test assembly for Cycle 136A at 50.9 EFPD.

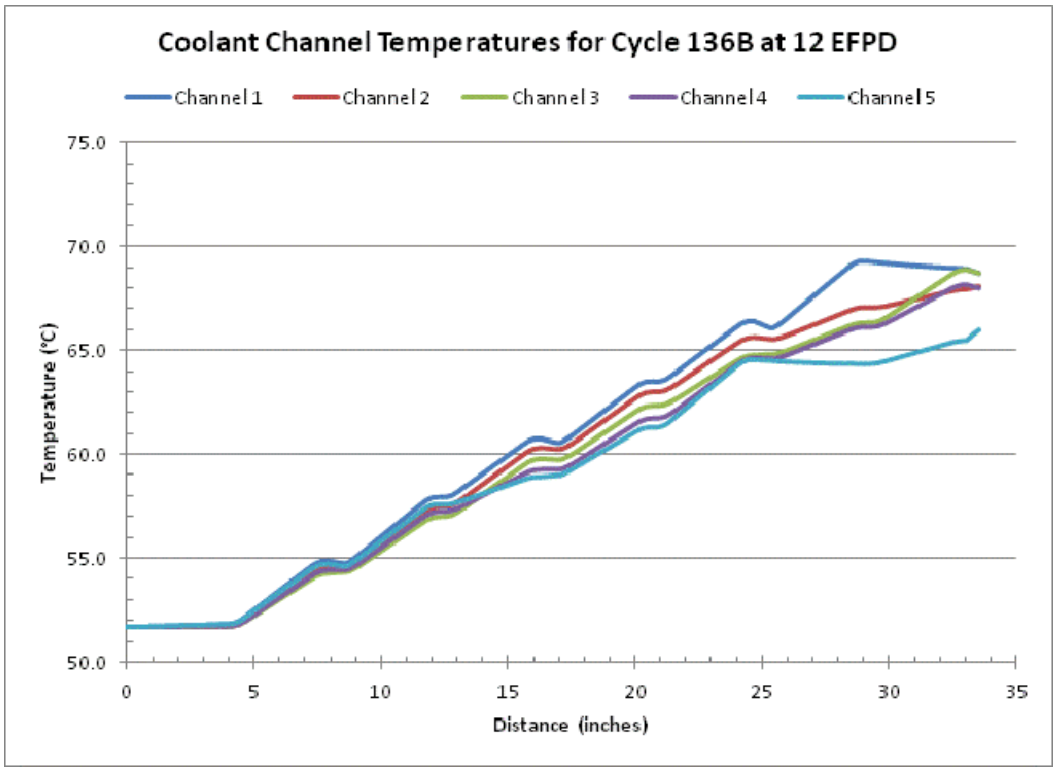

Figure 11. RERTR-7A coolant temperature as a function of location along the test assembly for Cycle 146B at 12 EFPD.

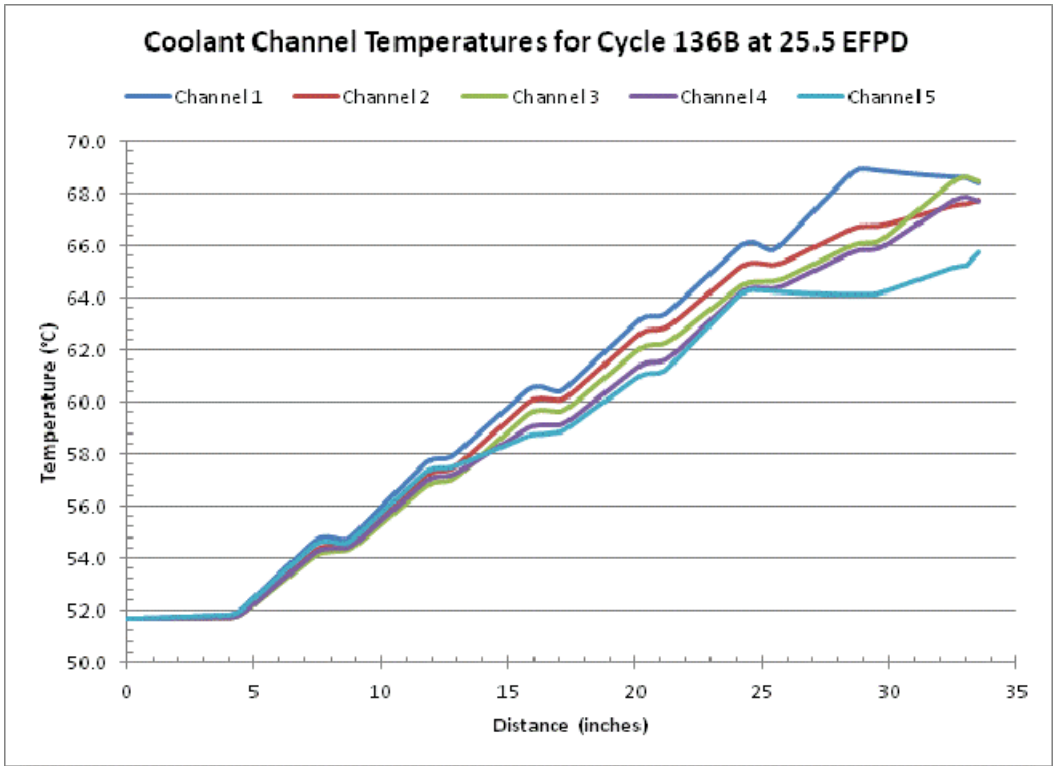

Figure 12. RERTR-7A coolant temperature as a function of location along the test assembly for Cycle 146B at 25.5 EFPD.

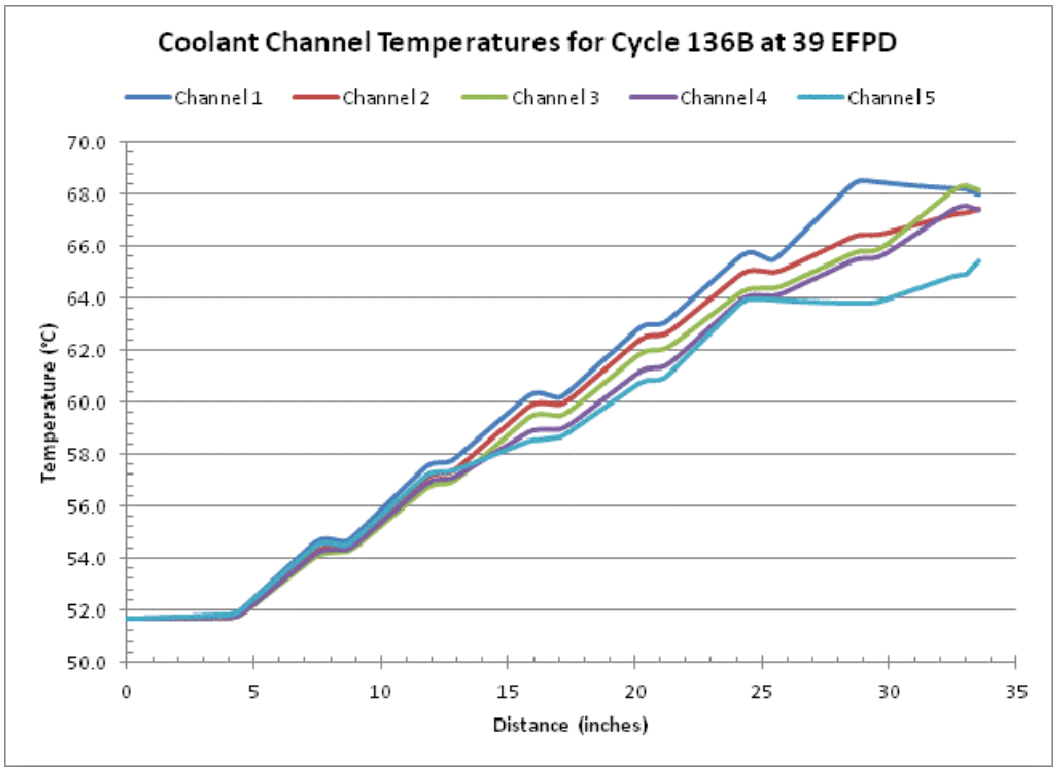

Figure 13. RERTR-7A coolant temperature as a function of location along the test assembly for Cycle 146B at 39 EFPD.

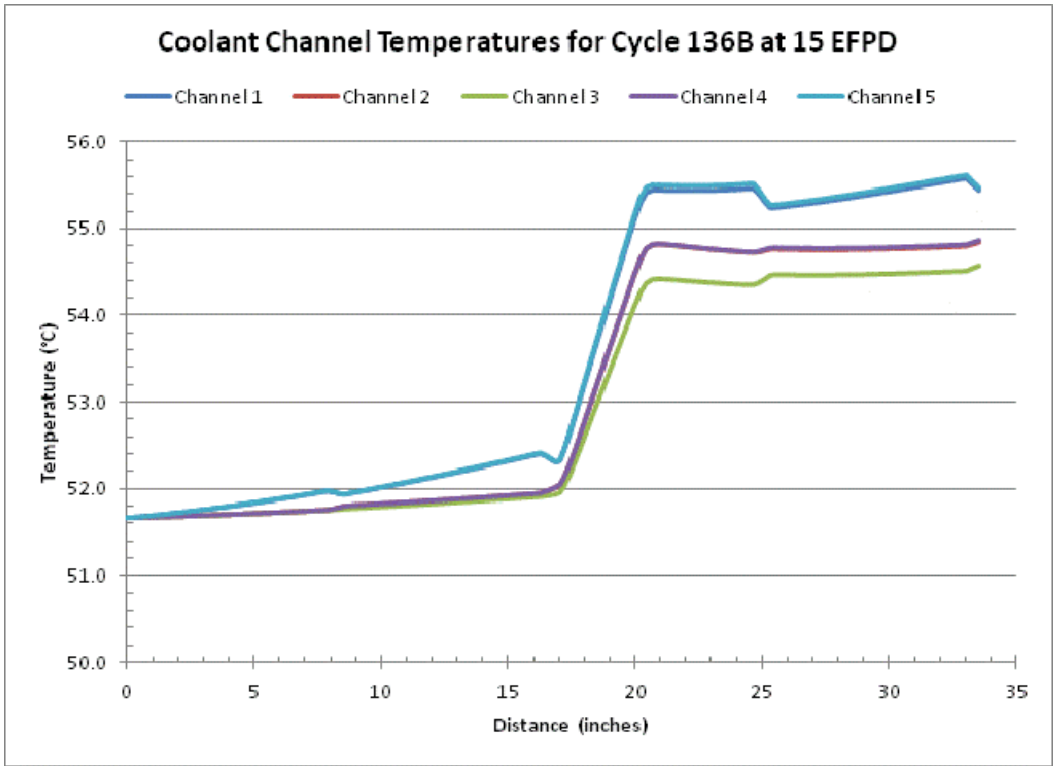

Figure 14. RERTR-7B coolant temperature as a function of location along the test assembly for Cycle 146B at 15 EFPD.

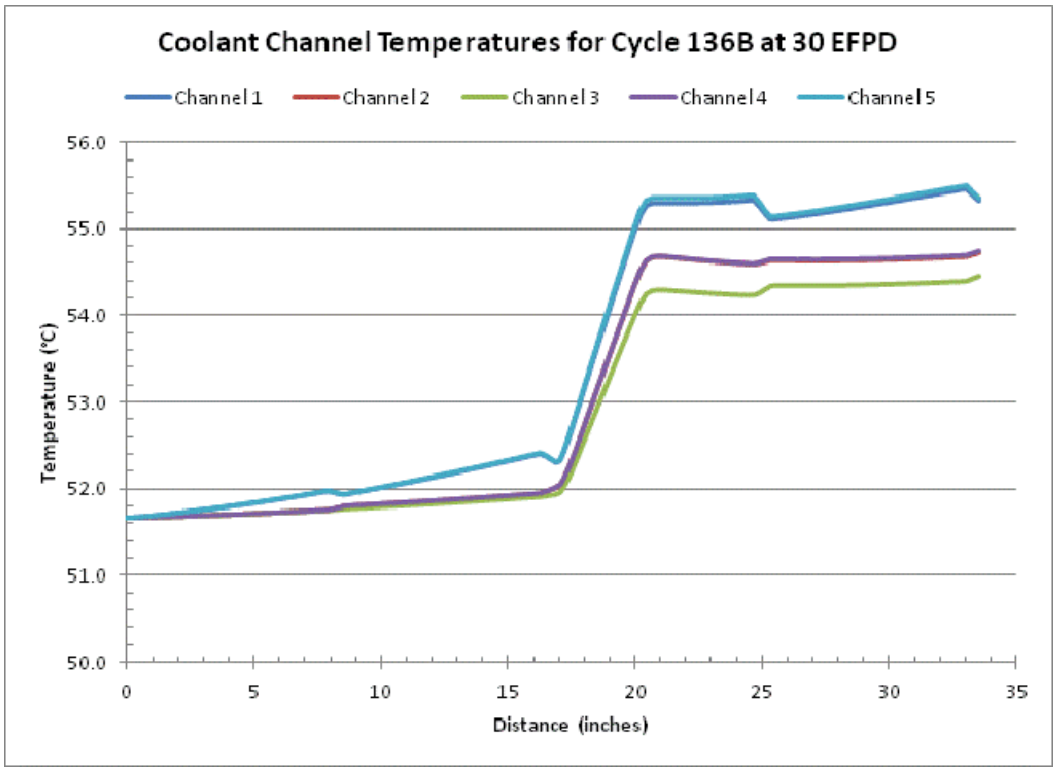

Figure 15. RERTR-7B coolant temperature as a function of location along the test assembly for Cycle 146B at 30 EFPD.

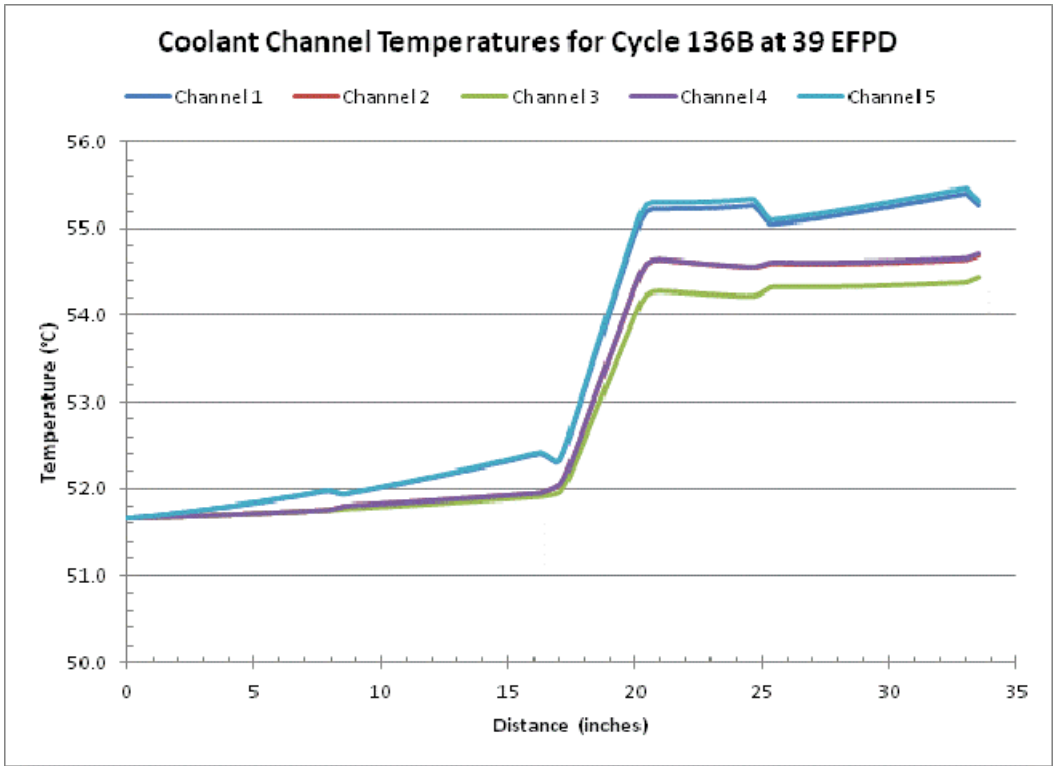

Figure 16. RERTR-7B coolant temperature as a function of location along the test assembly for Cycle 146B at 39 EFPD.

7.2 Plate Surface Temperature

The maximum, minimum, and average plate temperatures for each cycle are provided in Table 20 through **Error! Reference source not found.**.

Table 20. RERTR-7A plate surface temperatures for Cycle 136A (50.9 EFPD).

Plate Location	Plate ID	Maximum Temp (°C)	Minimum Temp (°C)	Average Temp (°C)
A1	Blank	--	--	--
A2	Blank	--	--	--
A3	Blank	--	--	--
A4	Blank	--	--	--
A5	R3R040	99.65	48.46	80.76
A6	V5R040	91.01	49.00	76.02
A7	R5R030	91.19	48.97	76.15
A8	H1F020	96.67	48.72	78.92
B1	R1R040	106.59	53.87	84.86
B2	R2R040	96.84	53.72	79.71
B3	R0R010	96.85	53.70	79.75
B4	H1T010	102.76	53.85	82.65
B5	L1F01L	105.84	54.13	86.39
B6	V5R050	101.97	53.71	84.61
B7	L1F140	101.17	53.69	84.15
B8	MZ 25	82.92	55.63	72.53
C1	H1F030	110.08	59.58	89.97
C2	L1T020	101.62	59.35	85.29
C3	L1F110	102.57	58.69	85.79
C4	MZ 50	97.26	57.81	82.01
C5	L1F120	112.43	60.63	92.86
C6	H1T020	100.95	60.45	86.19
C7	R3R050	103.55	59.71	87.82
C8	R5R040	112.54	58.96	92.68
D1	R1R050	119.19	63.73	97.29
D2	Blank	--	--	--
D3	R0R020	114.18	62.51	94.96
D4	Blank	--	--	--
D5	Blank	--	--	--
D6	L1F160	98.59	64.89	86.62
D7	L2F040	113.96	63.95	96.52
D8	R2R050	83.42	64.32	76.37

Table 21. RERTR-7A plate surface temperatures for Cycle 136B (39 EFPD).

Plate Location	Plate ID	Maximum Temp (°C)	Minimum Temp (°C)	Average Temp (°C)
A1	Blank	--	--	--
A2	Blank	--	--	--
A3	Blank	--	--	--
A4	Blank	--	--	--
A5	R3R040	97.13	48.68	79.20
A6	V5R040	89.85	49.09	75.29
A7	R5R030	90.02	49.07	75.42
A8	H1F020	94.17	48.94	77.37
B1	R1R040	103.26	53.82	82.90
B2	R2R040	95.42	53.65	78.82
B3	R0R010	95.31	53.66	78.78
B4	H1T010	99.11	53.82	80.52
B5	L1F01L	102.12	54.11	84.07
B6	V5R050	100.01	53.64	83.37
B7	L1F140	98.83	53.65	82.62
B8	MZ 25	79.76	55.53	70.51
C1	H1F030	106.13	59.19	87.43
C2	L1T020	99.61	58.96	83.95
C3	L1F110	100.37	58.28	84.28
C4	MZ 50	93.71	57.41	79.74
C5	L1F120	108.48	60.17	90.22
C6	H1T020	98.86	60.03	84.74
C7	R3R050	101.70	59.23	86.45
C8	R5R040	108.86	58.48	90.21
D1	R1R050	114.62	63.09	94.25
D2	Blank	--	--	--
D3	R0R020	110.04	61.86	92.11
D4	Blank	--	--	--
D5	Blank	--	--	--
D6	L1F160	96.07	64.20	84.71
D7	L2F040	112.68	63.13	95.42
D8	R2R050	81.78	63.55	75.04

Table 22. RERTR-7B plate surface temperatures for Cycle 136B (39 EFPD).

Plate Location	Plate ID	Maximum Temp (°C)	Minimum Temp (°C)	Average Temp (°C)
A1	Blank	--	--	--
A2	Blank	--	--	--
A3	Blank	--	--	--
A4	Blank	--	--	--
A5	Blank	--	--	--
A6	Blank	--	--	--
A7	Blank	--	--	--
A8	Blank	--	--	--
B1	Blank	--	--	--
B2	Blank	--	--	--
B3	Blank	--	--	--
B4	Blank	--	--	--
B5	Blank	--	--	--
B6	Blank	--	--	--
B7	Blank	--	--	--
B8	Blank	--	--	--
C1	F3R010	96.53	51.74	79.32
C2	R0R010	87.85	51.85	74.42
C3	R3R010	87.65	51.86	74.29
C4	D3R010	96.62	51.76	79.35
C5	Blank	--	--	--
C6	Blank	--	--	--
C7	Blank	--	--	--
C8	Blank	--	--	--
D1	Blank	--	--	--
D2	Blank	--	--	--
D3	Blank	--	--	--
D4	Blank	--	--	--
D5	Blank	--	--	--
D6	Blank	--	--	--
D7	Blank	--	--	--
D8	Blank	--	--	--

8. REFERENCES

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3. RERTR Project Personnel, “RERTR 7B-C Irradiation Experiments in the Advanced Test Reactor,” RERTR-7B-C, January 2006.
4. M. A. Lillo, G. S. Chang,“RERTR-7A As-Run Physics Analysis and Test Train Isotopes Radiological Characterization Versus Cooling Time,” EDF-6857 Rev 2, January 2007.
5. M. A. Lillo, G. S. Chang, “RERTR-7B Capsule C As-Run Physics Analysis and Test Train Isotopes Radiological Characterization Versus Cooling Time,” EDF-6919, June 2006.
6. 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)
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8. Wachs, D. M., 2007, “Estimation of Critical Thermal Hydraulic Conditions for RERTR-7,” EDF-5671, February 2006.
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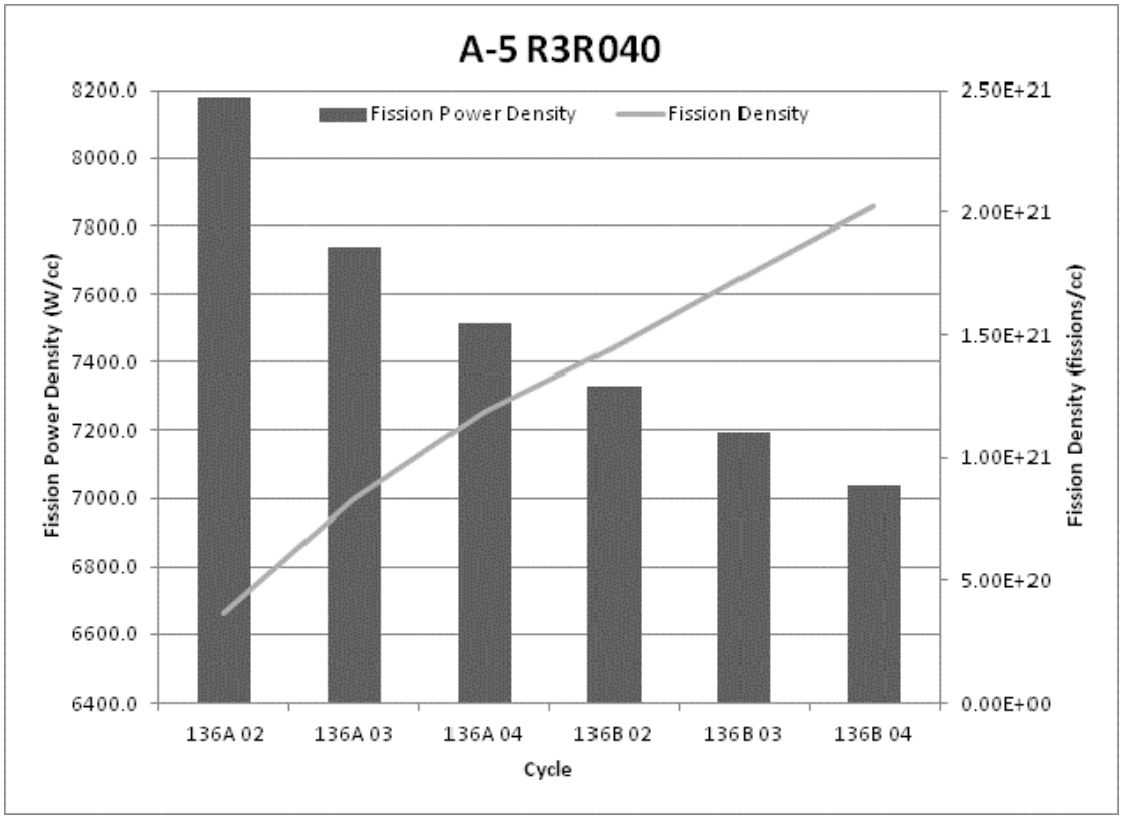
10. R. H. Perry, D. W. Green, “Perry’s Chemical Engineer’s Handbook,” 7th Edition, McGraw-Hill, 1997.

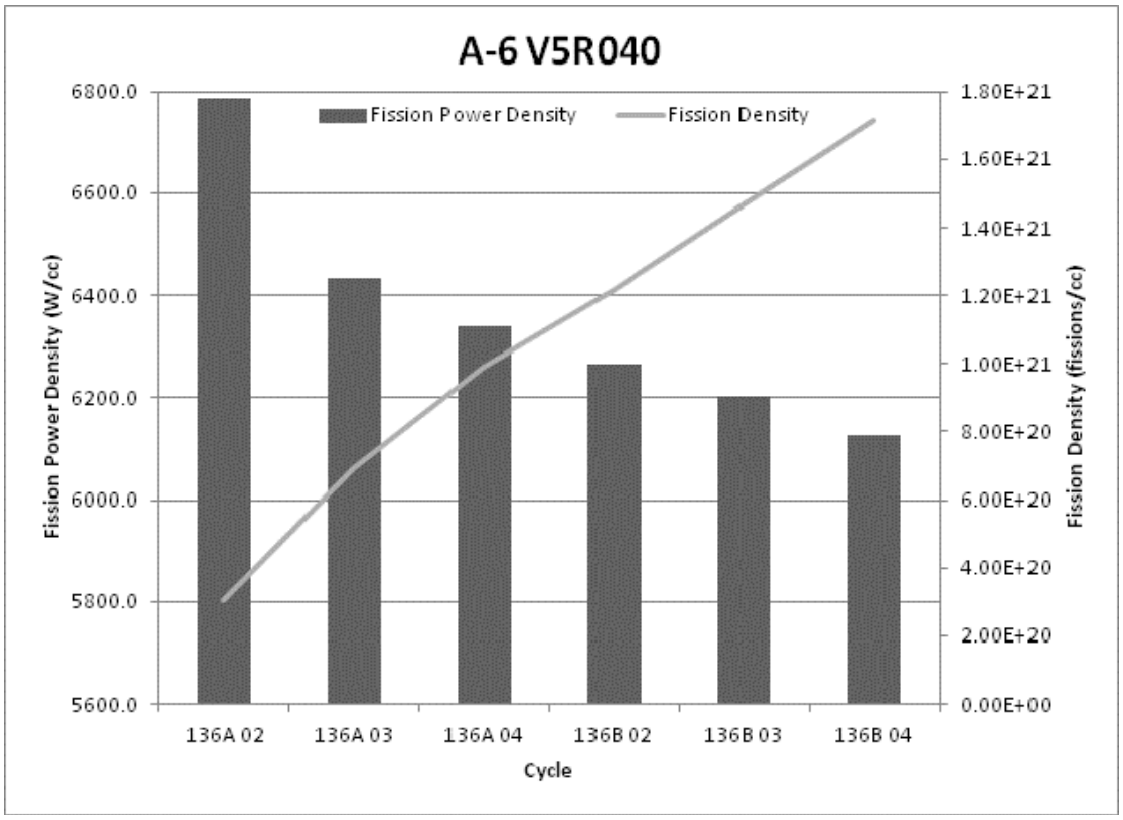
Appendix A

Individual Plate Power and Burnup Plots

Appendix A
Individual Plate Power and Burnup Plots

A-1. RERTR-7A

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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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6400.0
6200.0
6000.0
5800.0
5600.0
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1.60E+21
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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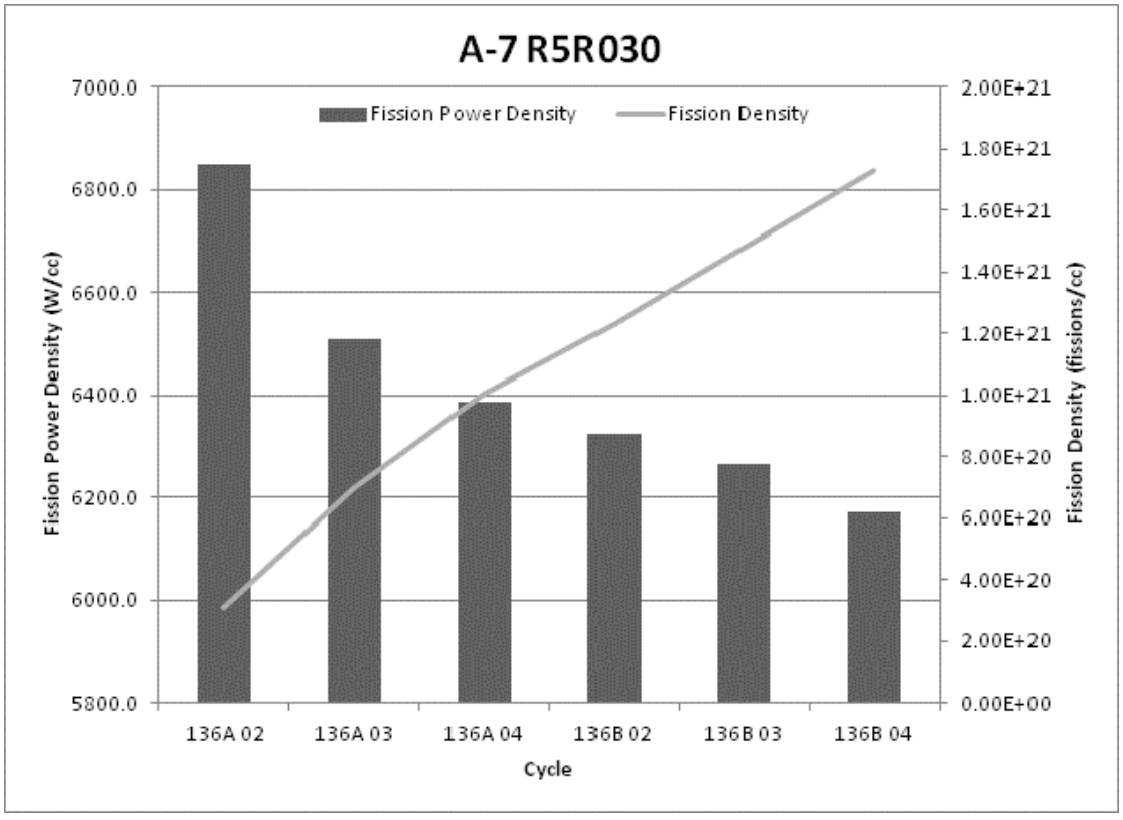
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle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Fission Density (fissions/cc)
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6400.0
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6000.0
5800.0
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1.60E+21
1.40E+21
1.20E+21
1.00E+21
8.00E+20
6.00E+20
4.00E+20
2.00E+20
0.00E+00
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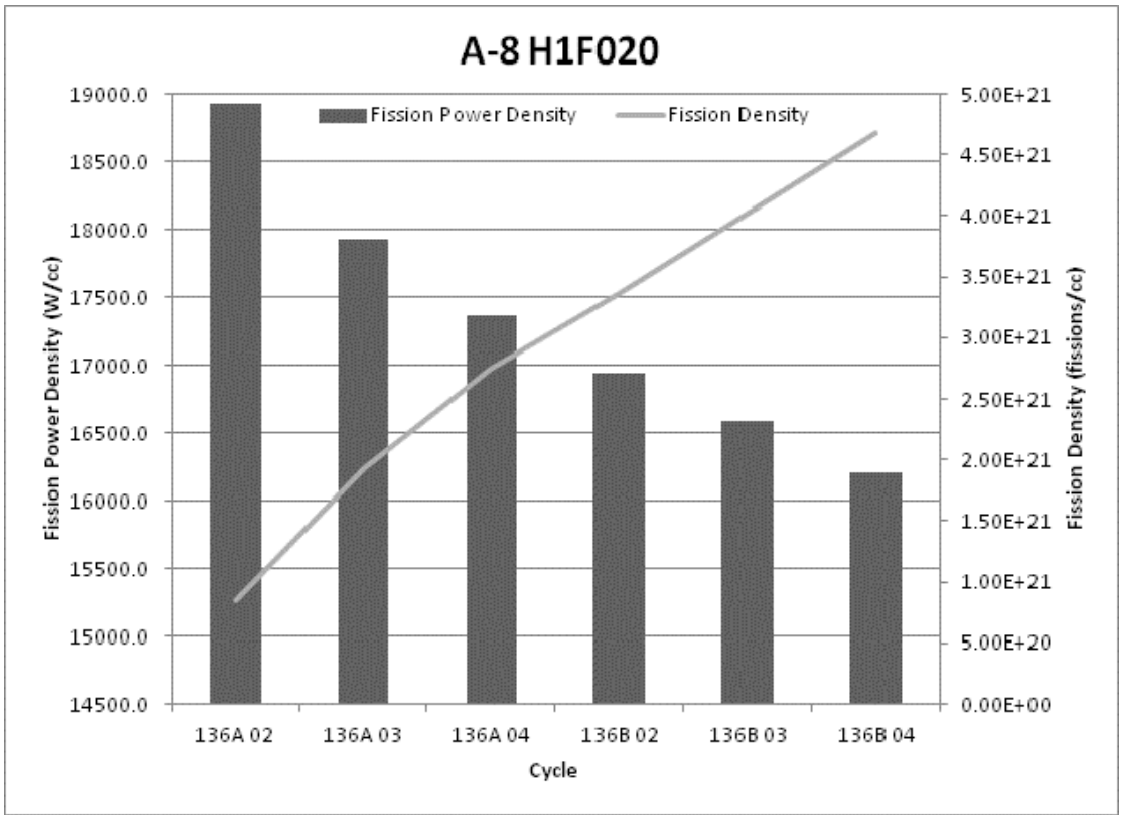
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle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Fission Density
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Fission Density (fissions/cc)
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3.00E+21
2.50E+21
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1.50E+21
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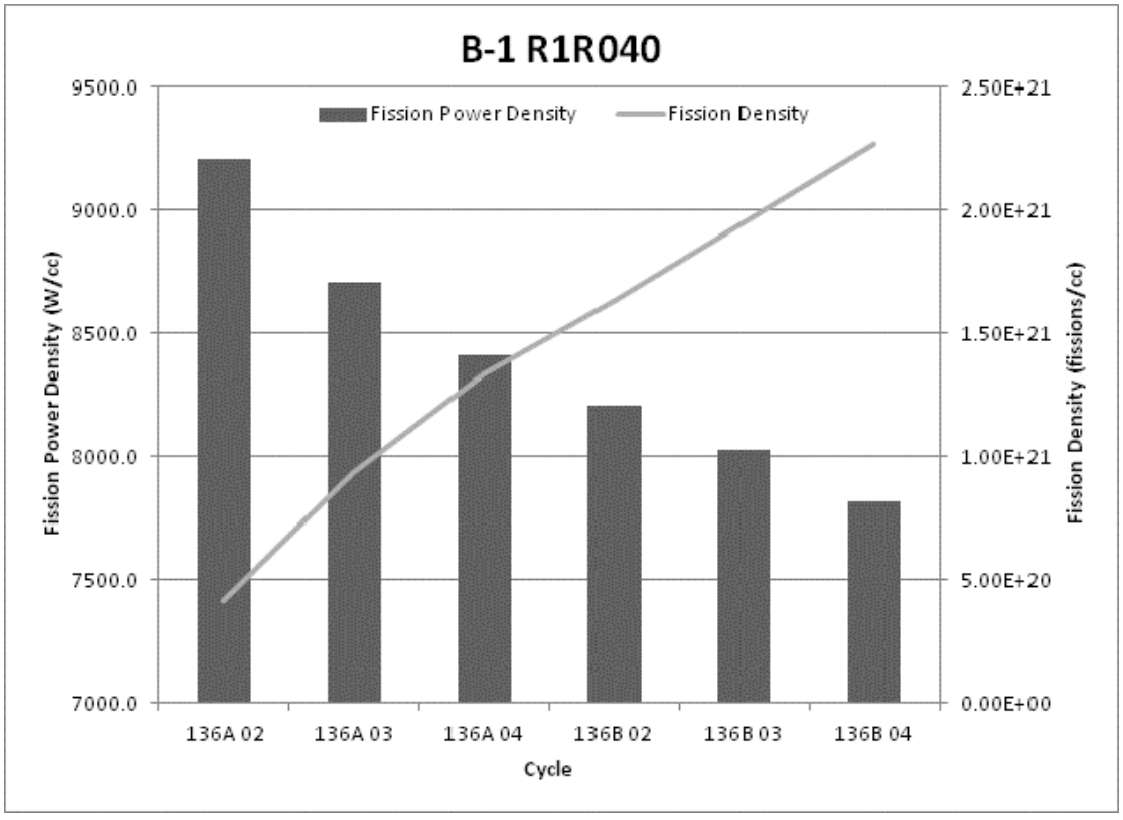
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle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Fission Density (fissions/cc)
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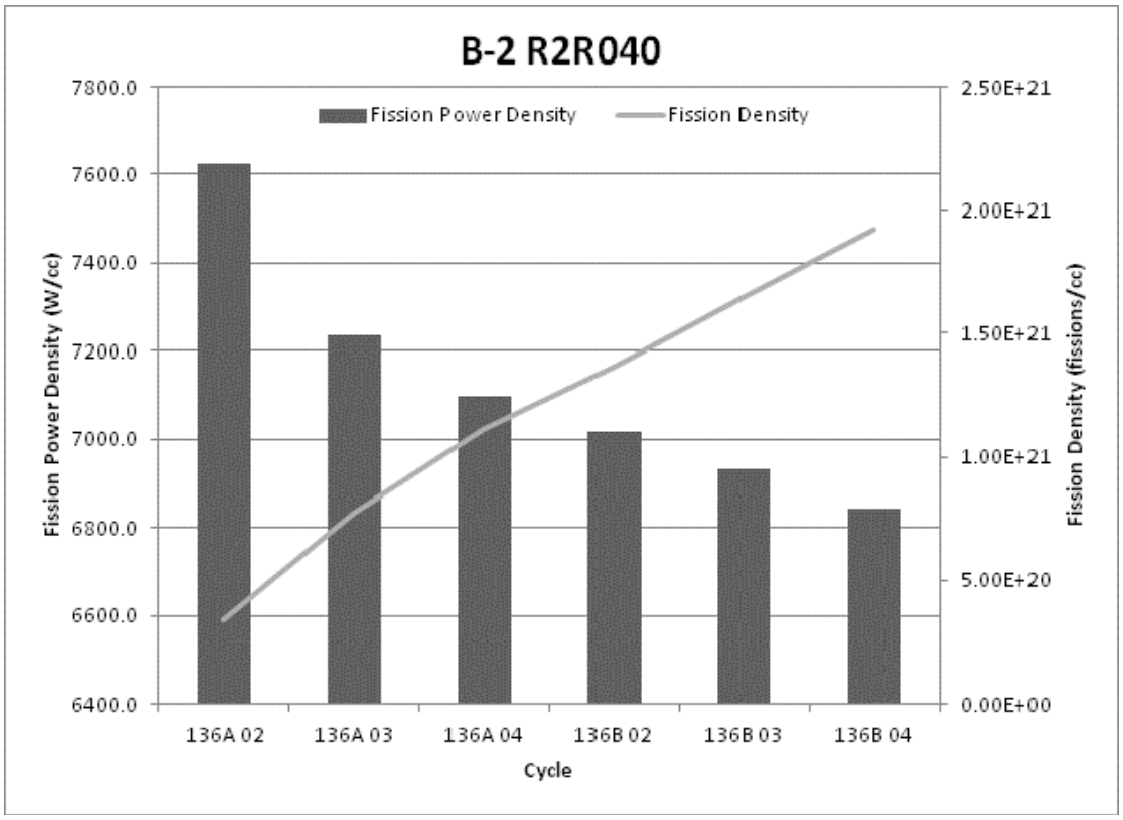
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle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Fission Power Density (W/cc)
Fission Density (fissions/cc)
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6600.0
6400.0
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1.50E+21
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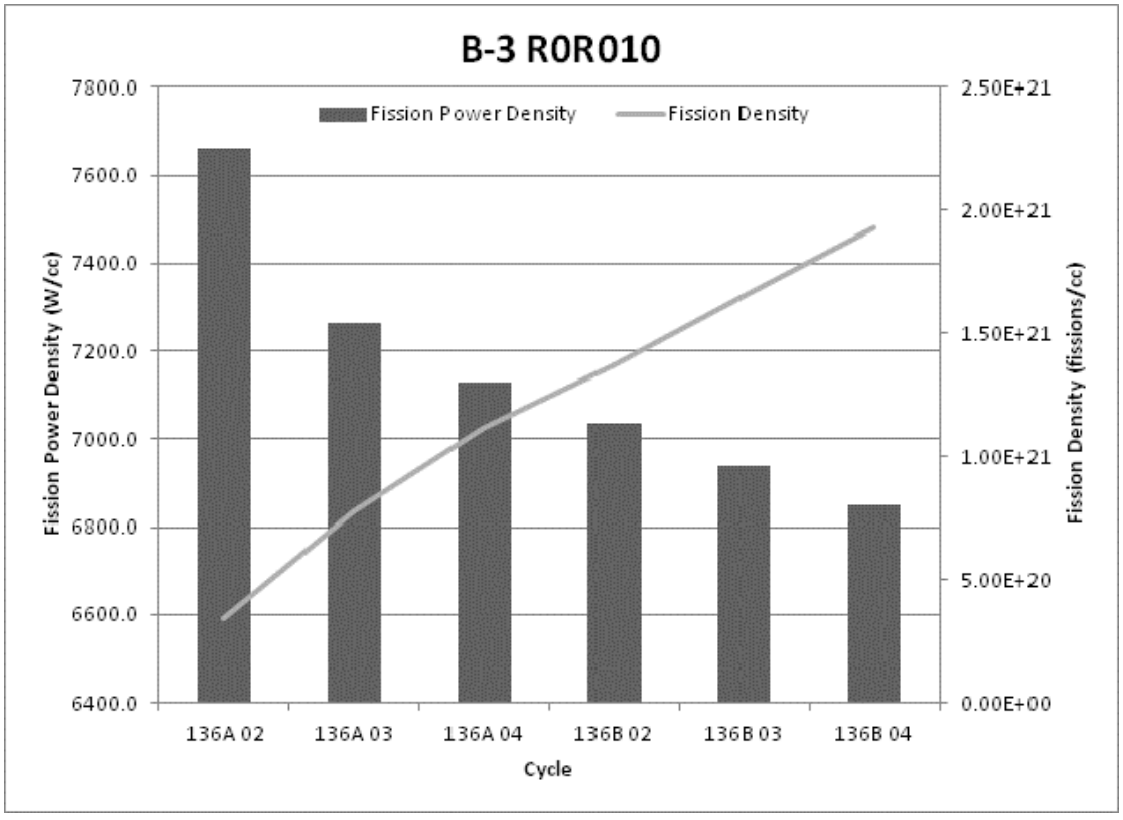
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle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Fission Density (fissions/cc)
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6600.0
6400.0
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2.00E+21
1.50E+21
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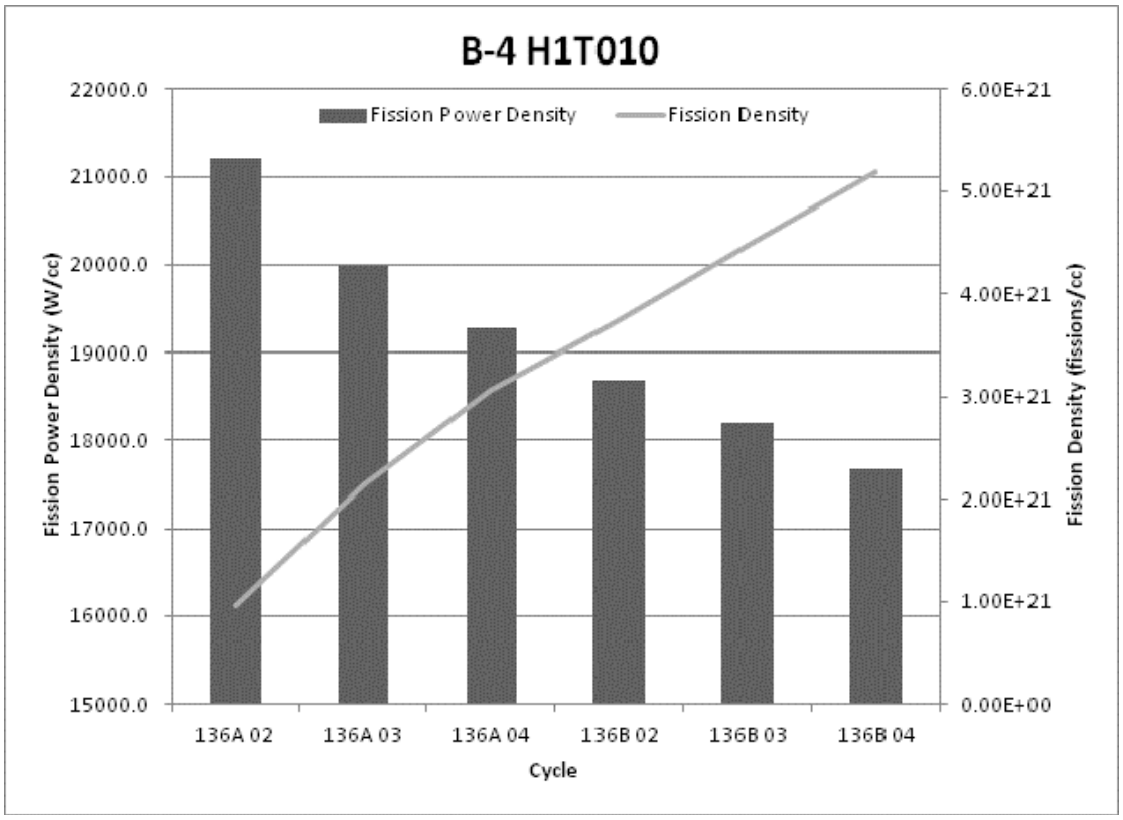
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle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Fission Density (fissions/cc)
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4.00E+21
3.00E+21
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136A 03
136A 04
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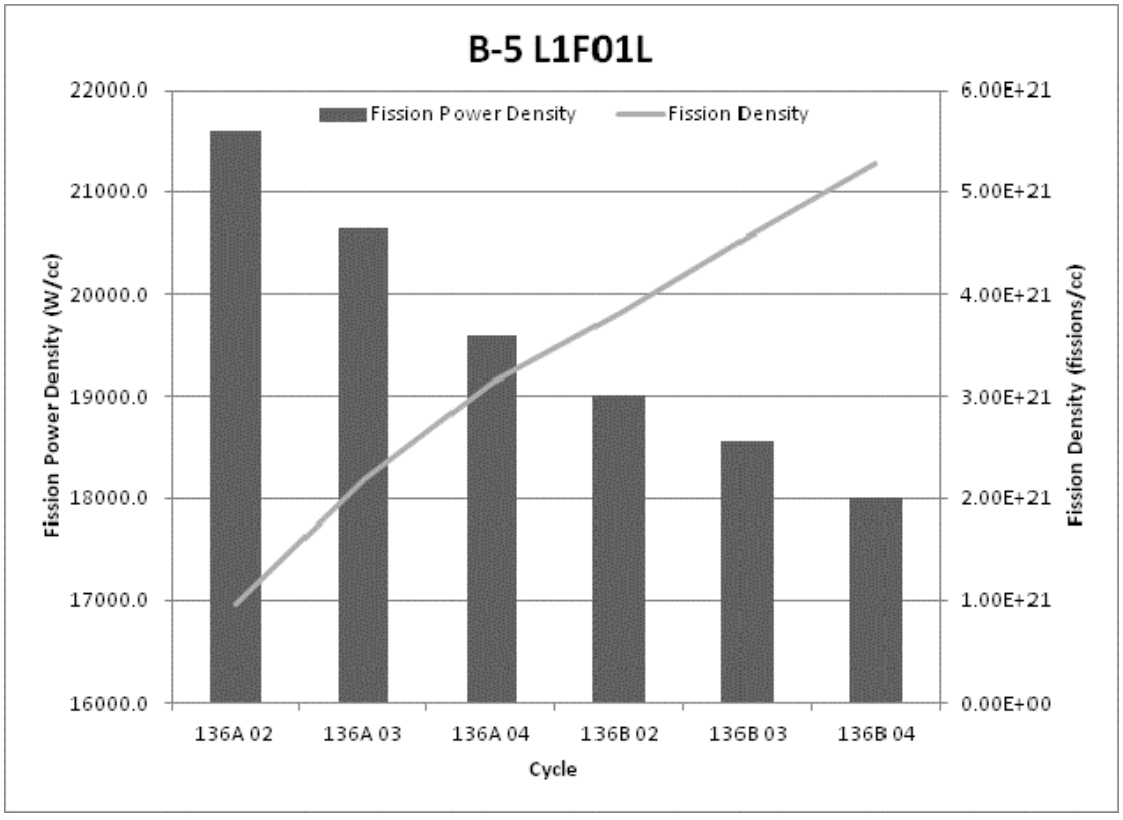
136B 03
136B 04
Cycle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136A 03
136A 04
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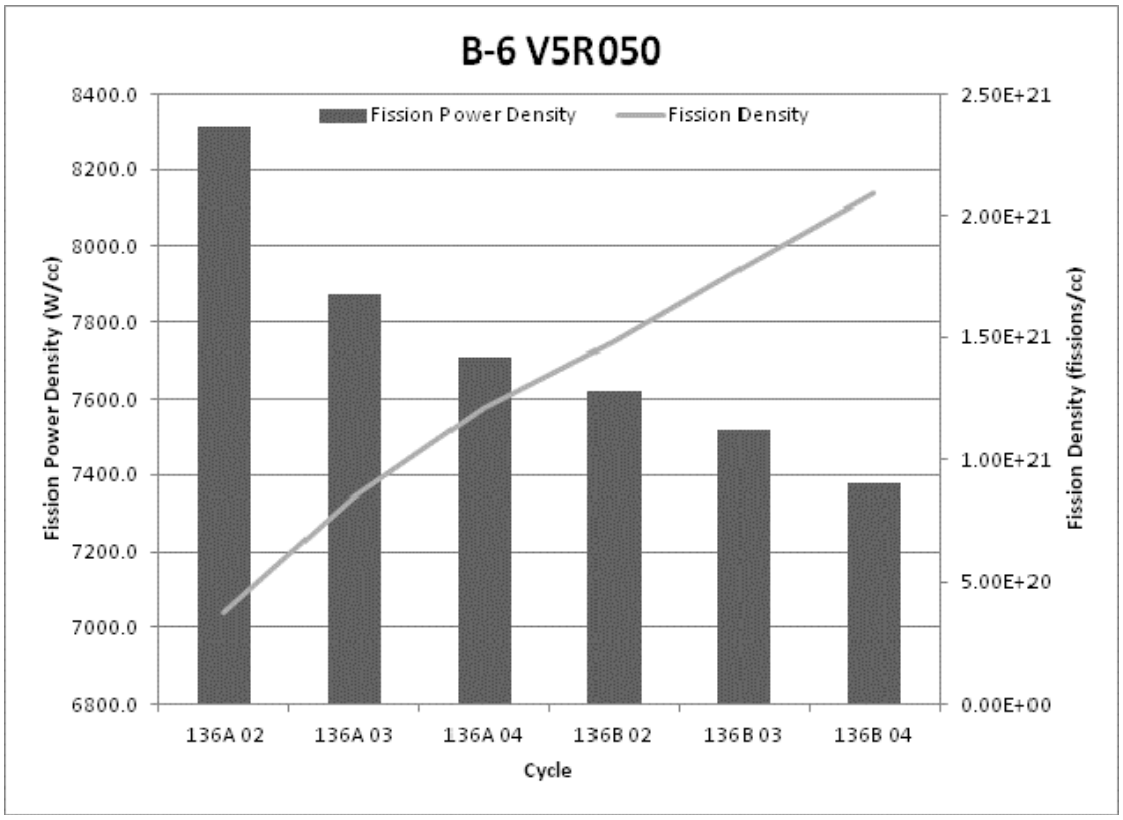
136B 03
136B 04
Cycle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1.50E+21
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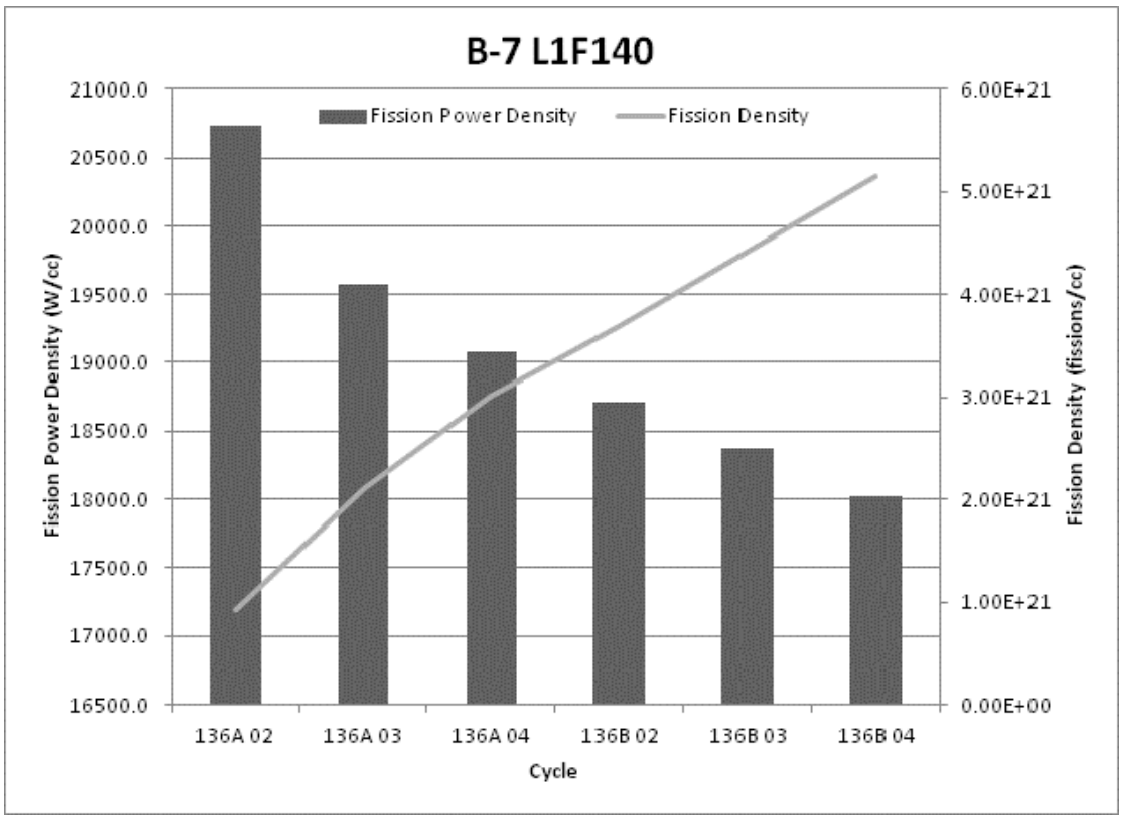
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle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136A 03
136A 04
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136B 03
136B 04
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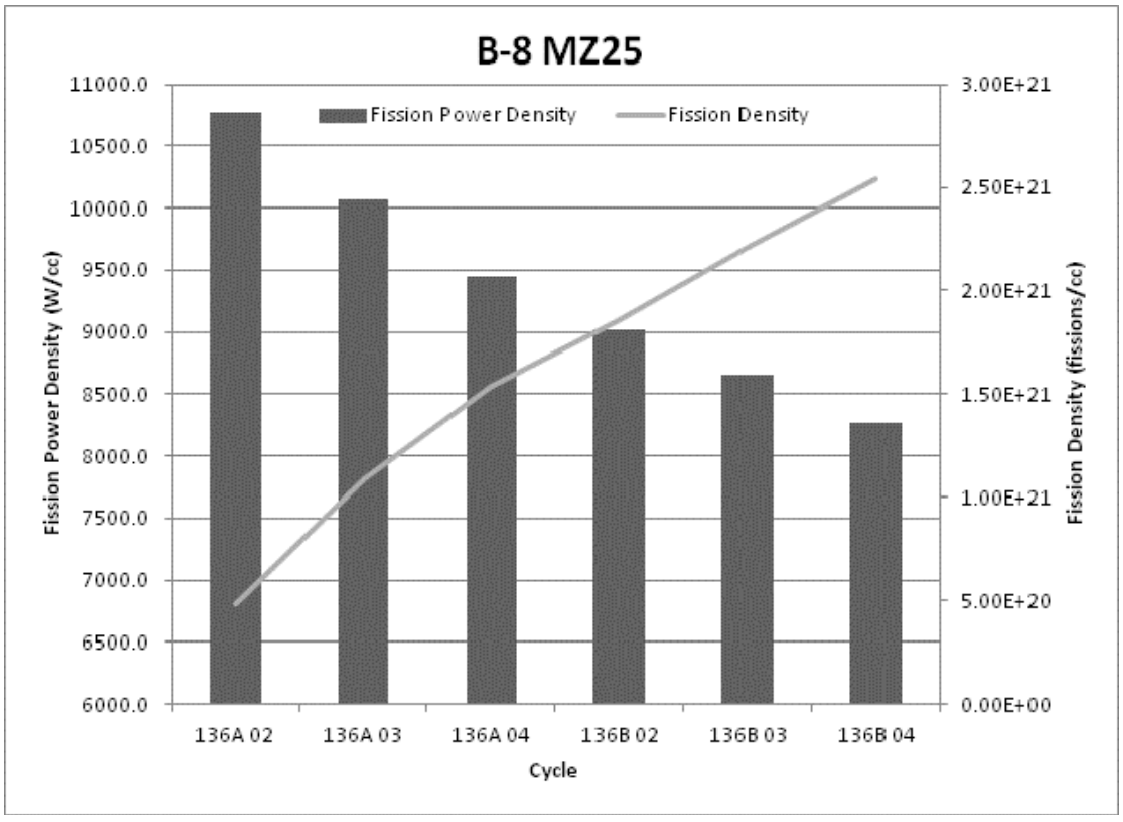
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Fission Density (fissions/cc)
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1.50E+21
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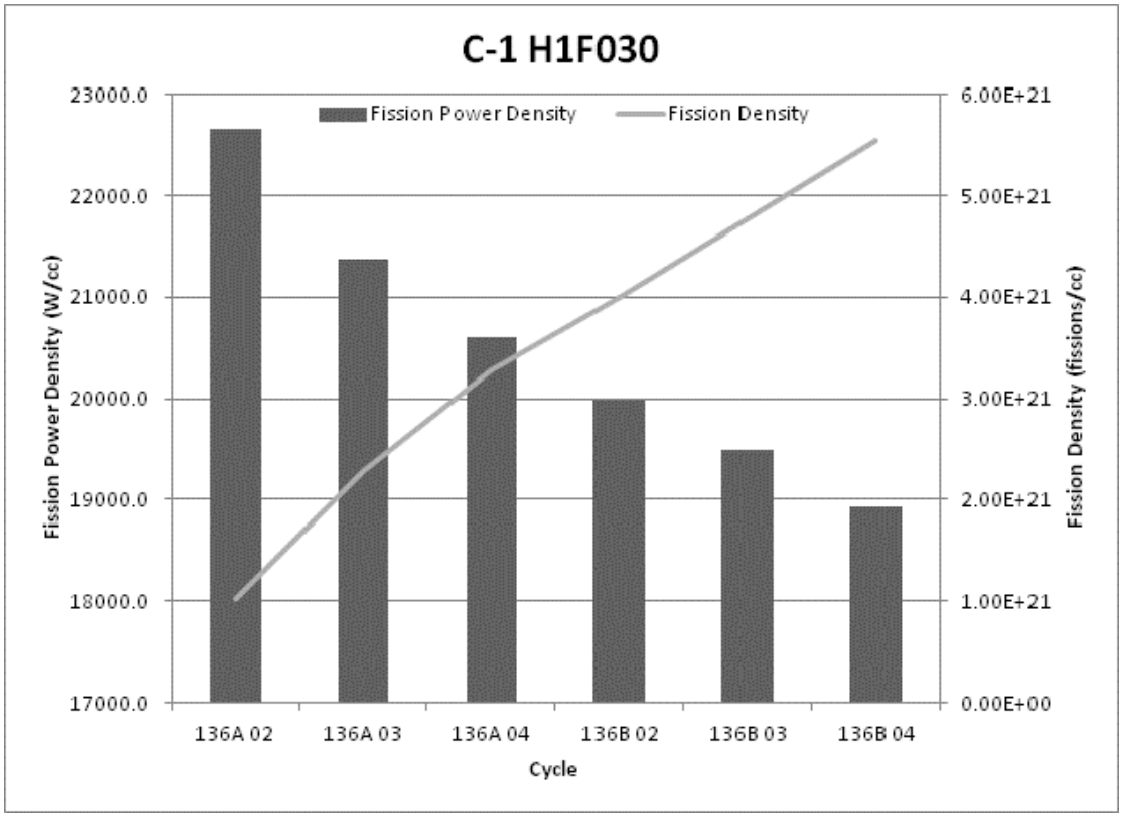
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle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Fission Density (fissions/cc)
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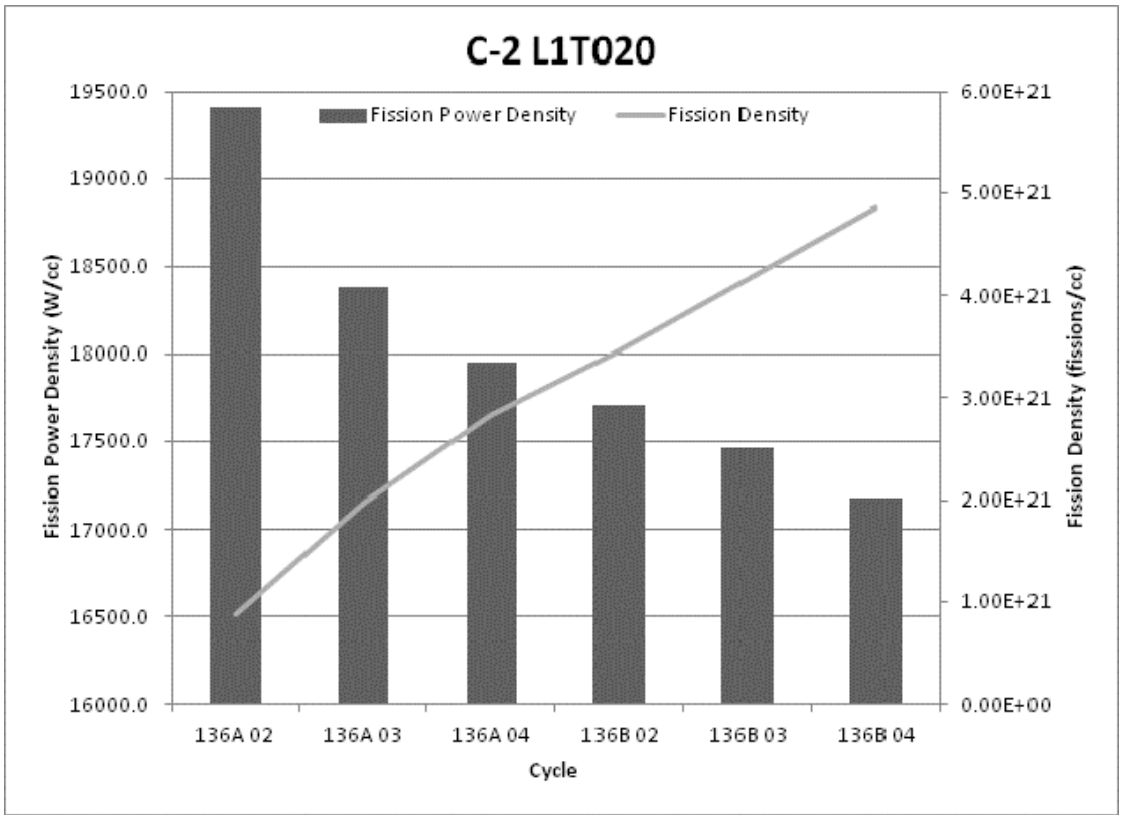
136A 02
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle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Fission Power Density (W/cc)
Fission Density (fissions/cc)
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18000.0
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16000.0
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5.00E+21
4.00E+21
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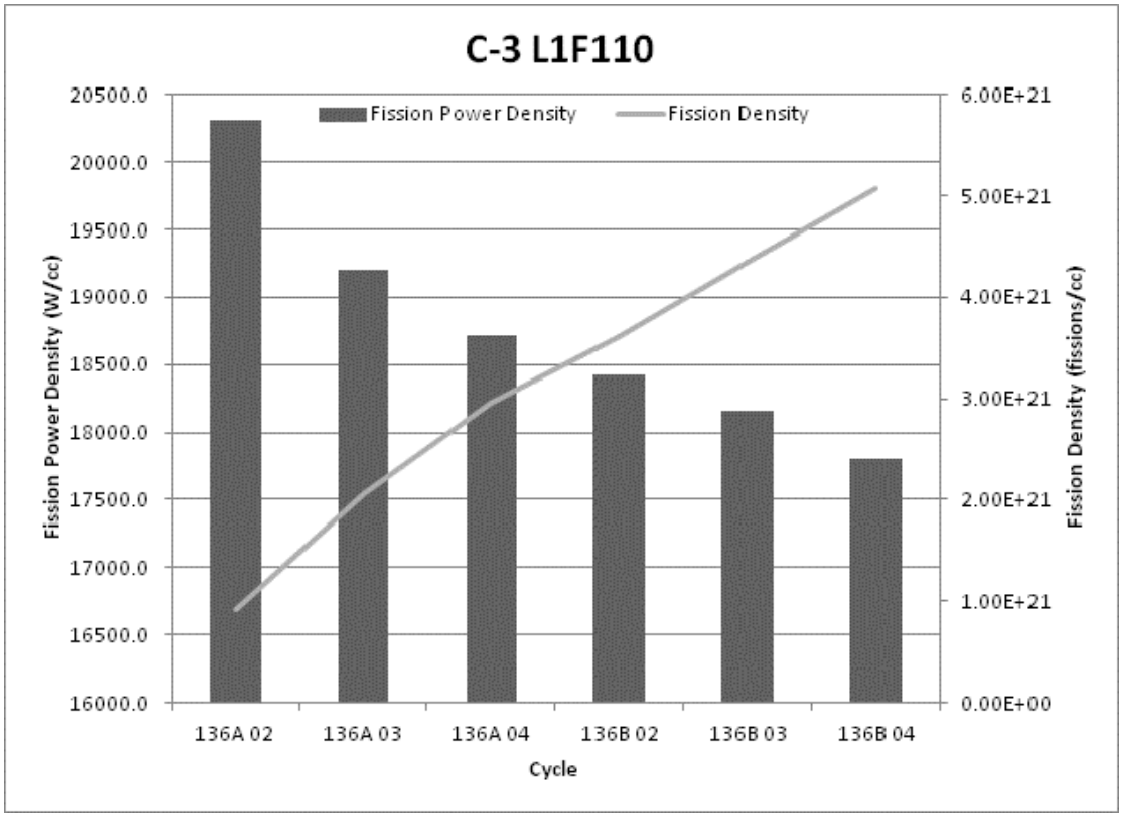
136A 02
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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20000.0
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18500.0
18000.0
17500.0
17000.0
16500.0
16000.0
6.00E+21
5.00E+21
4.00E+21
3.00E+21
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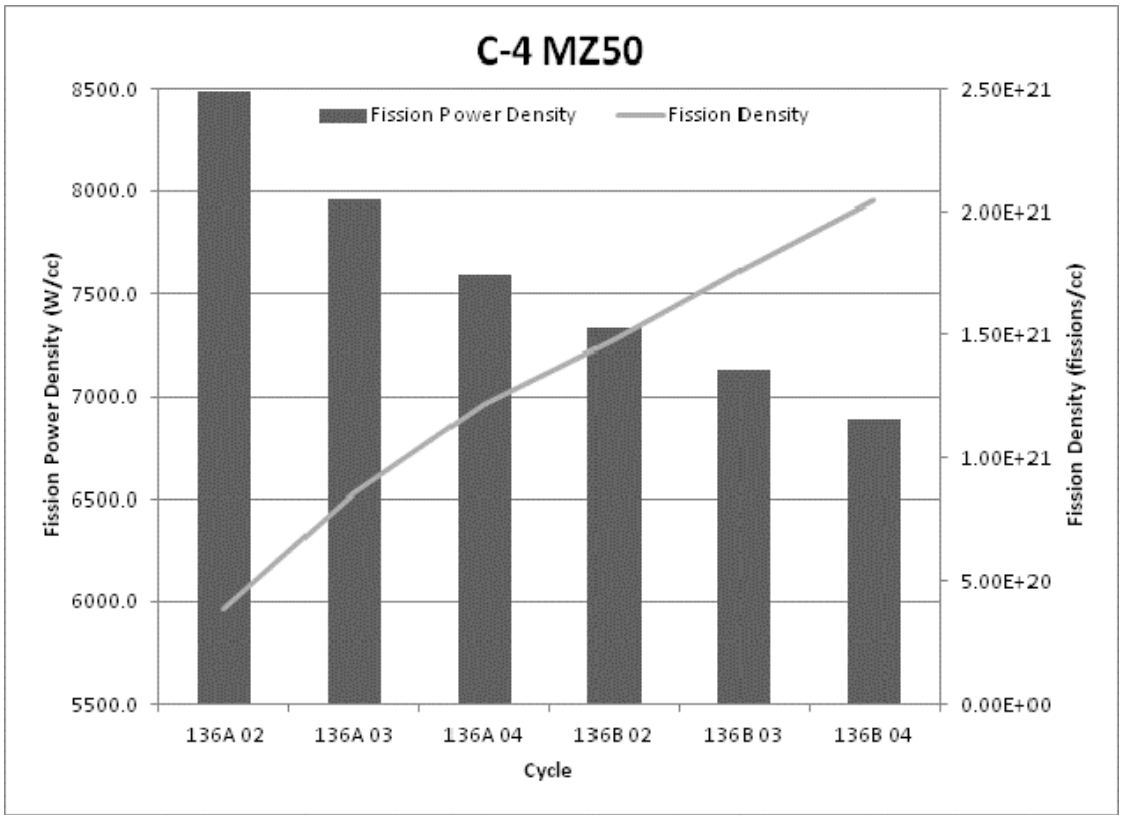
1.00E+21
0.00E+00
136A 02
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle


C-4 MZ50
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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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8000.0
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7000.0
6500.0
6000.0
5500.0
2.50E+21
2.00E+21
1.50E+21
1.00E+21
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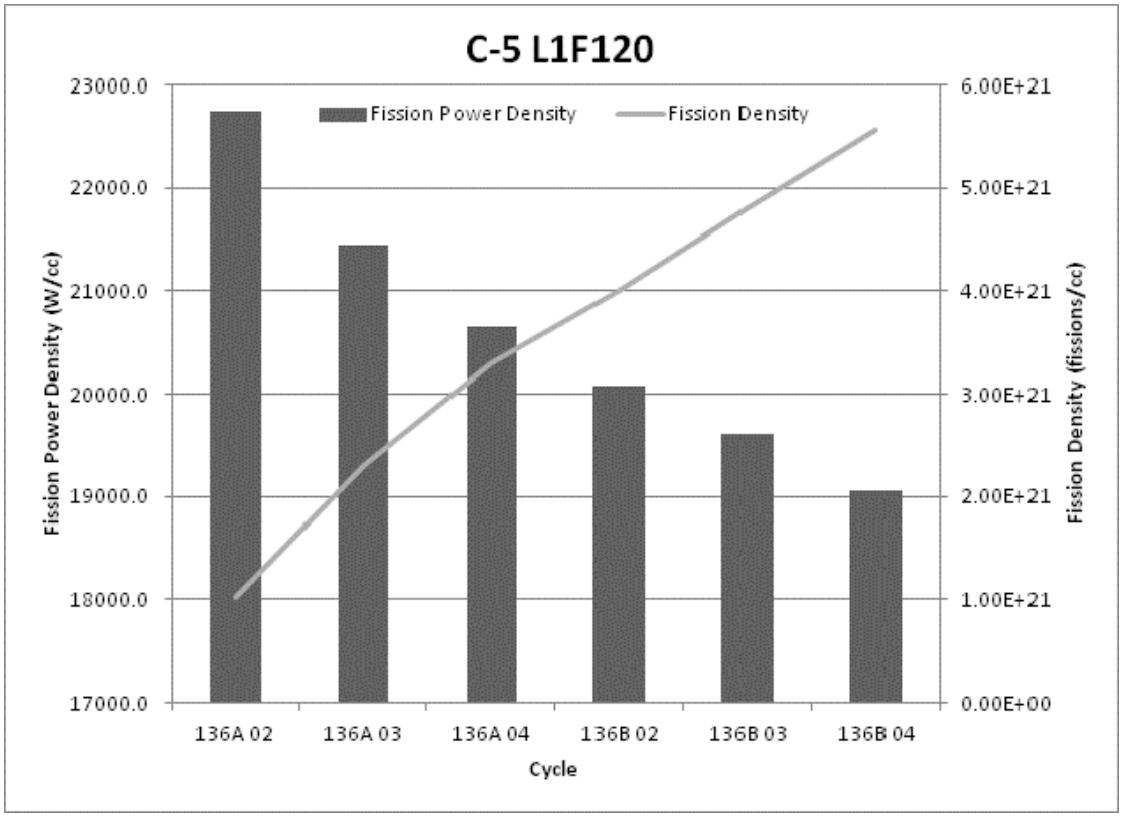
0.00E+00
136A 02
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle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Fission Power Density (W/cc)
Fission Density (fissions/cc)
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21000.0
20000.0
19000.0
18000.0
17000.0
6.00E+21
5.00E+21
4.00E+21
3.00E+21
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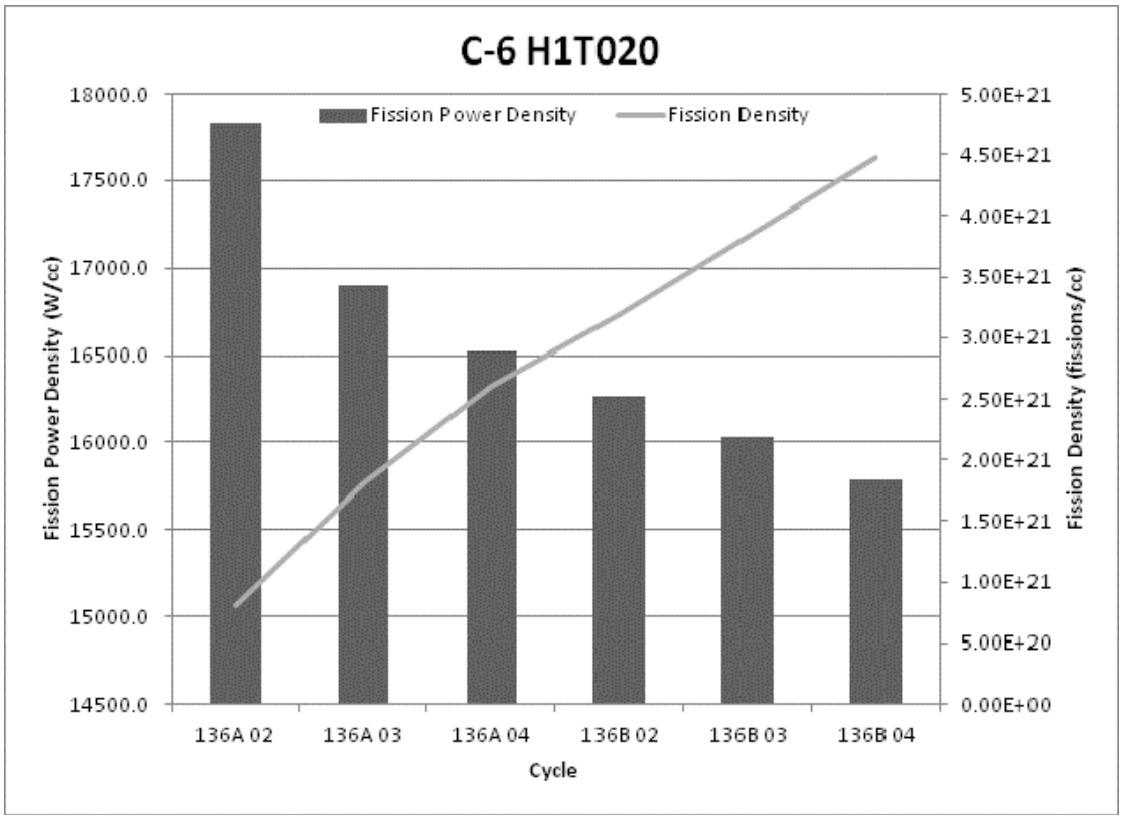
136A 02
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle


C-6 H1T020
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Fission Density
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Fission Density (fissions/cc)
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16500.0
16000.0
15500.0
15000.0
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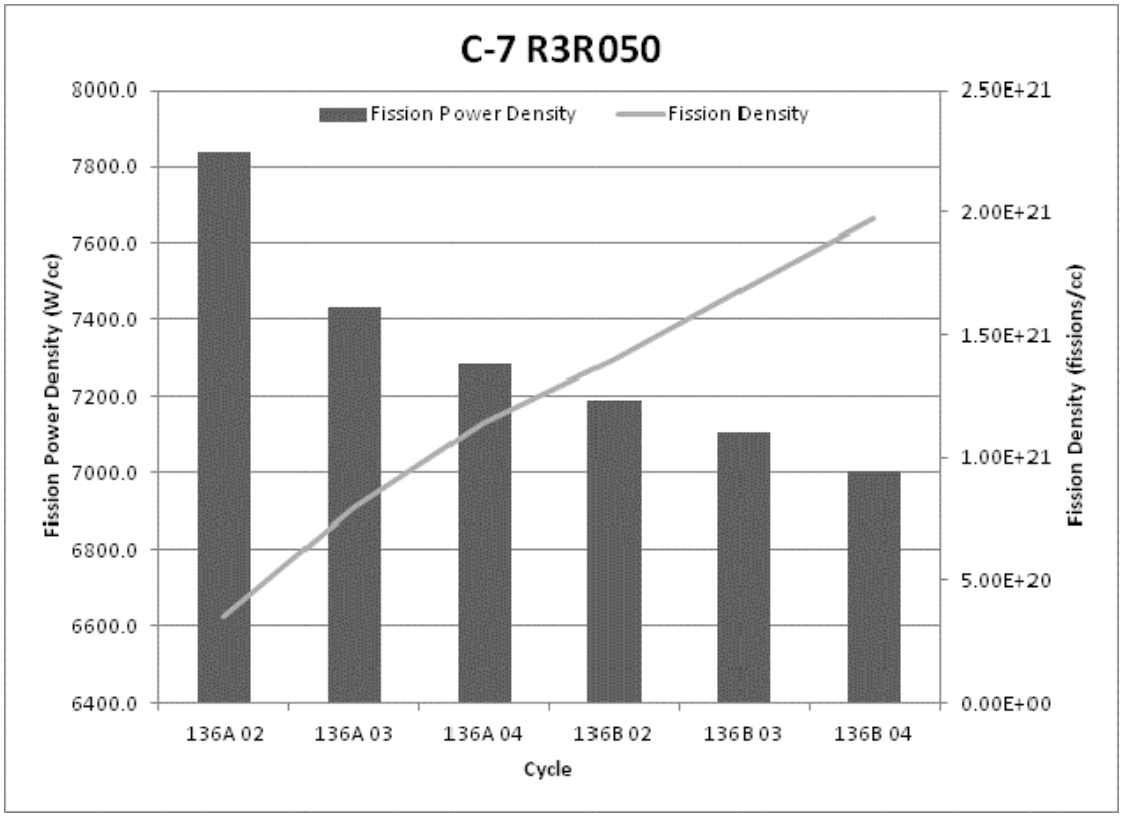
4.50E+21
4.00E+21
3.50E+21
3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
0.00E+00
136A 02
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle


C-7 R3R050
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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
8000.0
7800.0
7600.0
7400.0
7200.0
7000.0
6800.0
6600.0
6400.0
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
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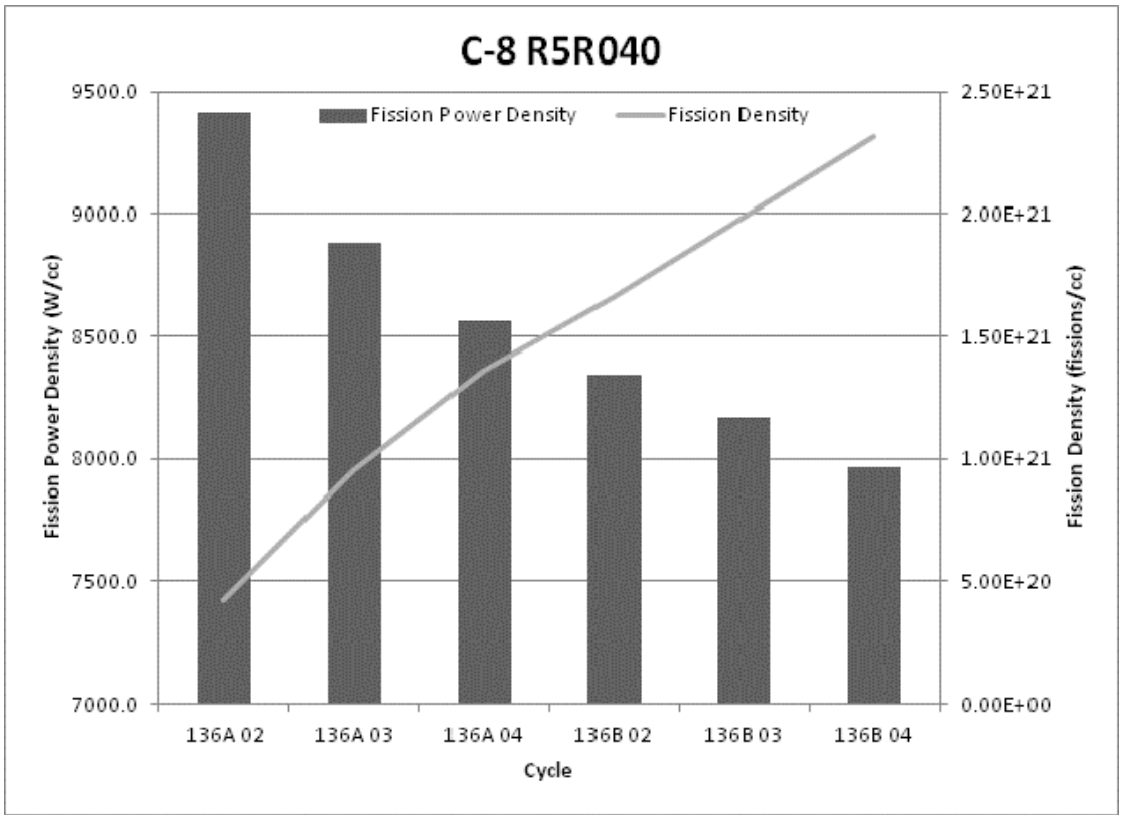
136A 02
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle


C-8 R5R040
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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
9500.0
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8000.0
7500.0
7000.0
2.50E+21
2.00E+21
1.50E+21
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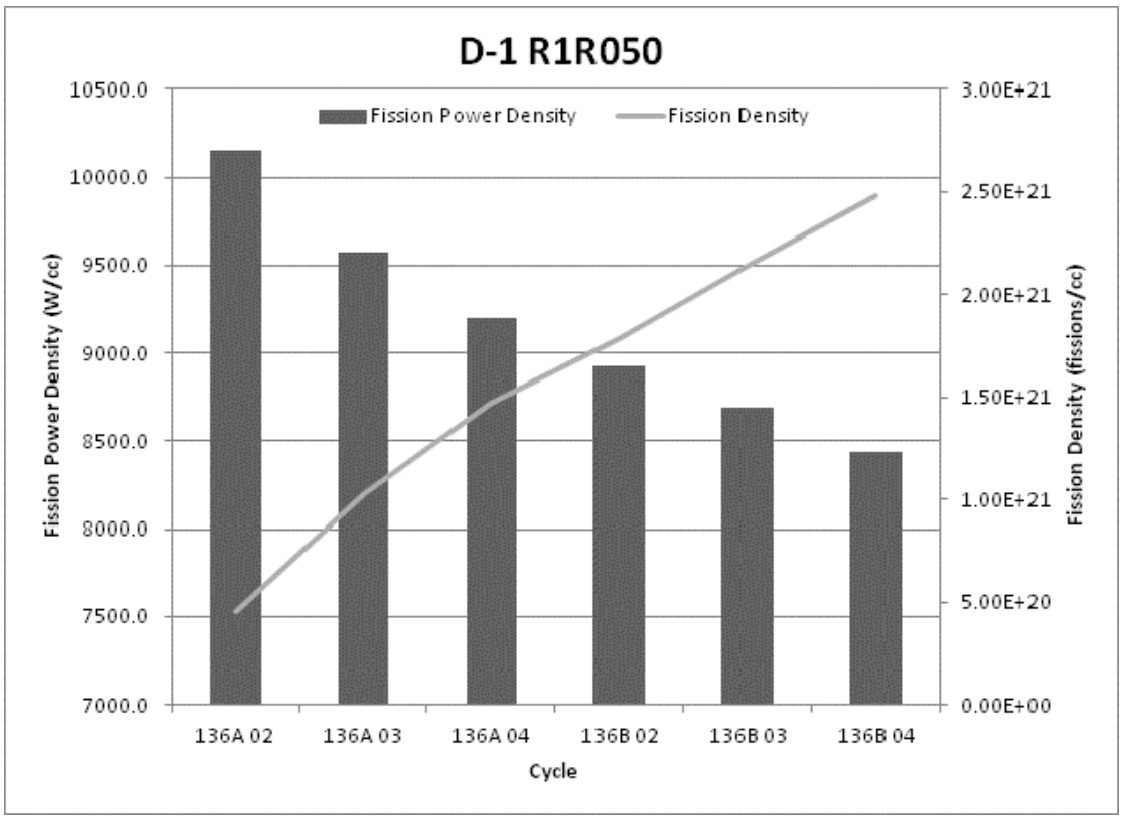
136A 02
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle


D-1 R1R050
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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
10500.0
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9500.0
9000.0
8500.0
8000.0
7500.0
7000.0
3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
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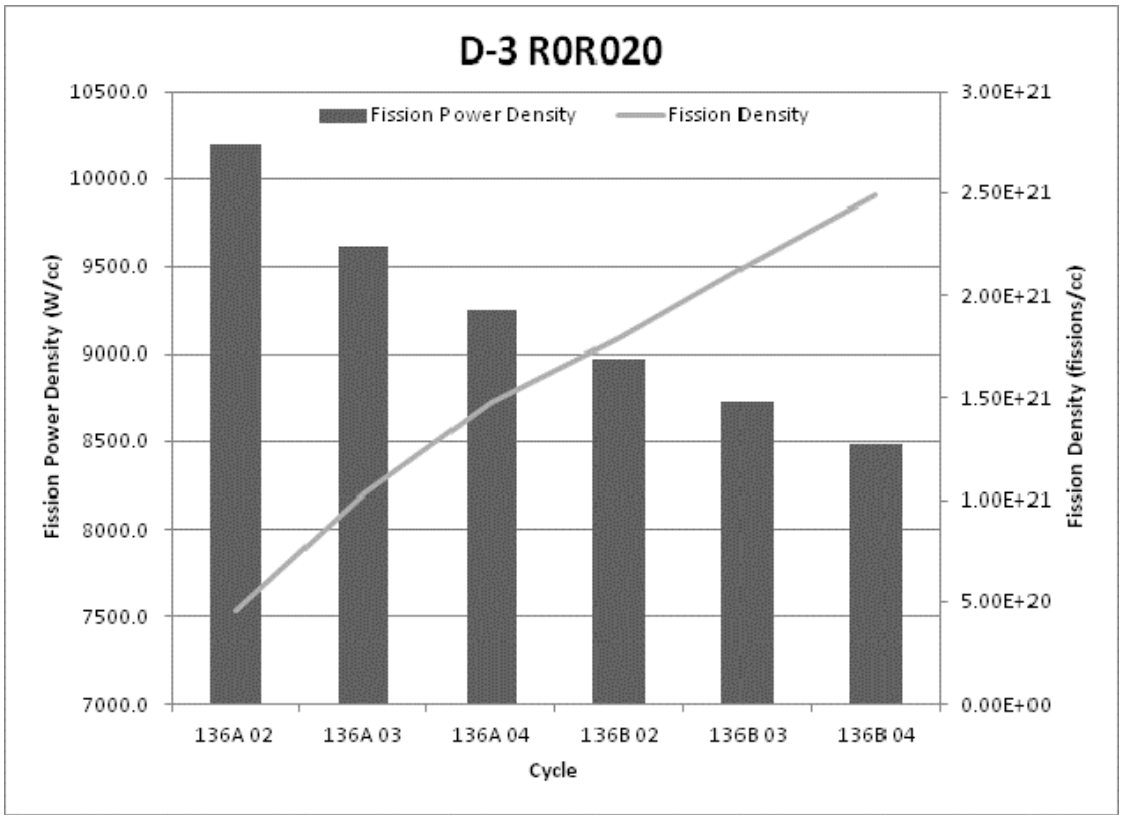
136A 02
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle


D-3 R0R020
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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
10500.0
10000.0
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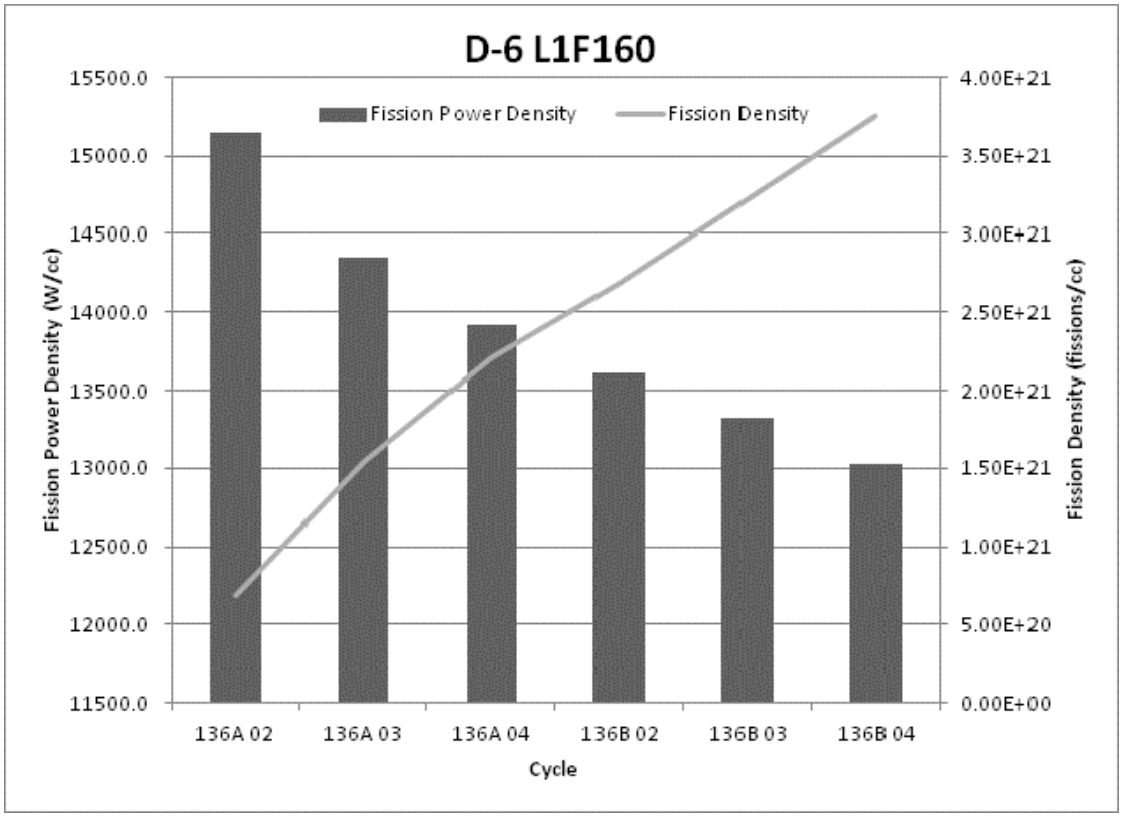
9000.0
8500.0
8000.0
7500.0
7000.0
3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
0.00E+00
136A 02
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle


D-6 L1F160
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Fission Density (fissions/cc)
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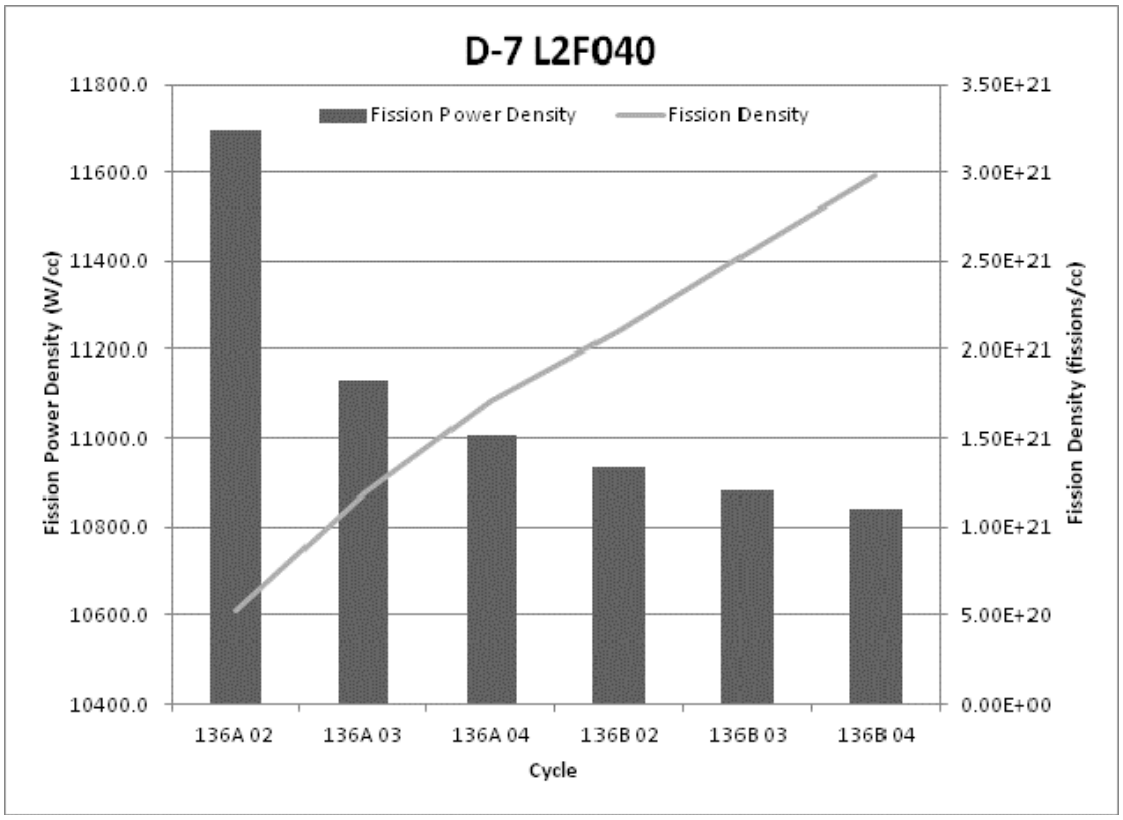
14000.0
13500.0
13000.0
12500.0
12000.0
11500.0
4.00E+21
3.50E+21
3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
0.00E+00
136A 02
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle


D-7 L2F040
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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11400.0
11200.0
11000.0
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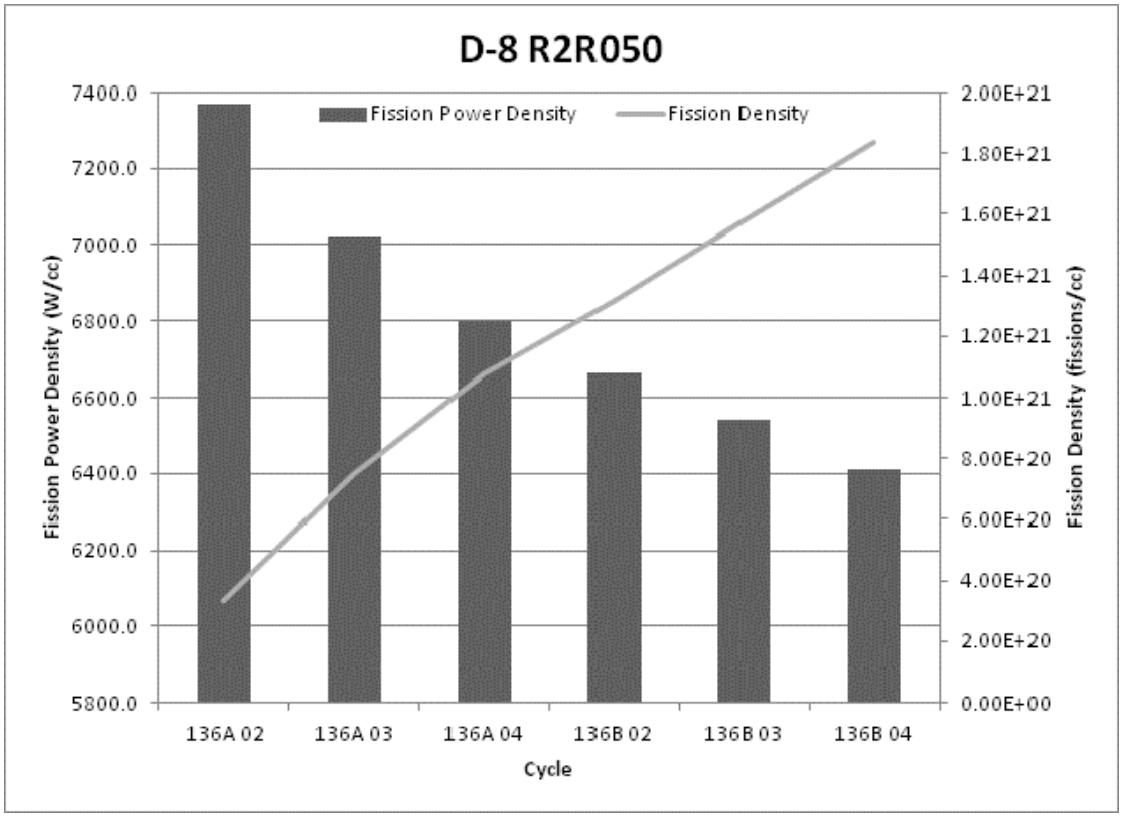
10400.0
3.50E+21
3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
0.00E+00
136A 02
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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6600.0
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1.40E+21
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1.00E+21
8.00E+20
6.00E+20
4.00E+20
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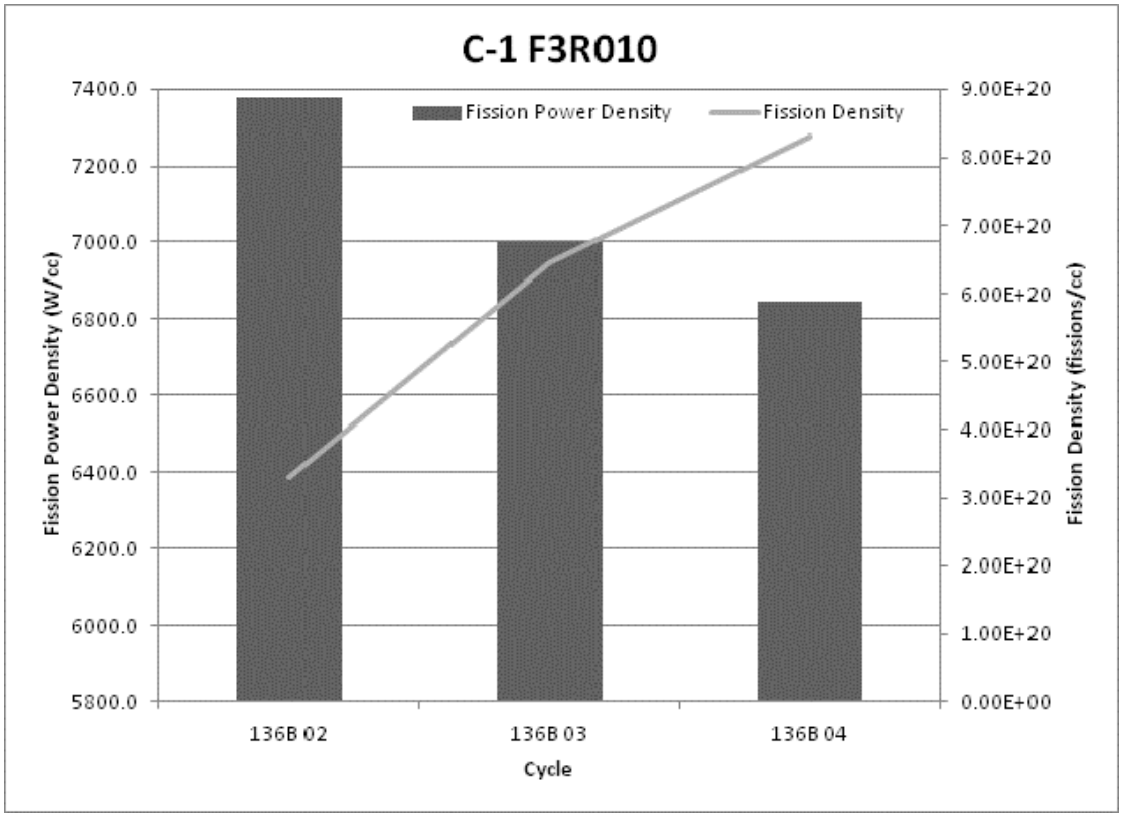
136A 02
136A 03
136A 04
136B 02
136B 03
136B 04
Cycle

A-2. RERTR-7B


C-1 F3R010
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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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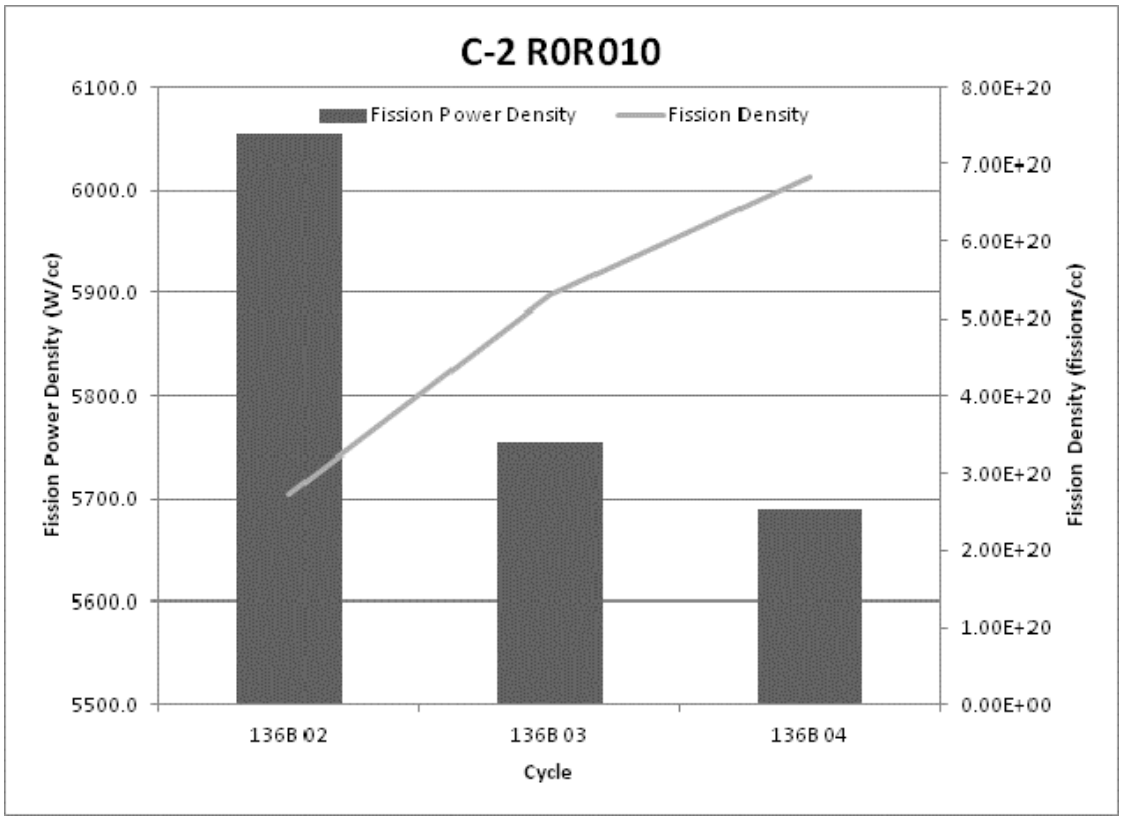
6600.0
6400.0
6200.0
6000.0
5800.0
9.00E+20
8.00E+20
7.00E+20
6.00E+20
5.00E+20
4.00E+20
3.00E+20
2.00E+20
1.00E+20
0.00E+00
136B 02
136B 03
136B 04
Cycle


C-2 R0R010
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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
6100.0
6000.0
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5700.0
5600.0
5500.0
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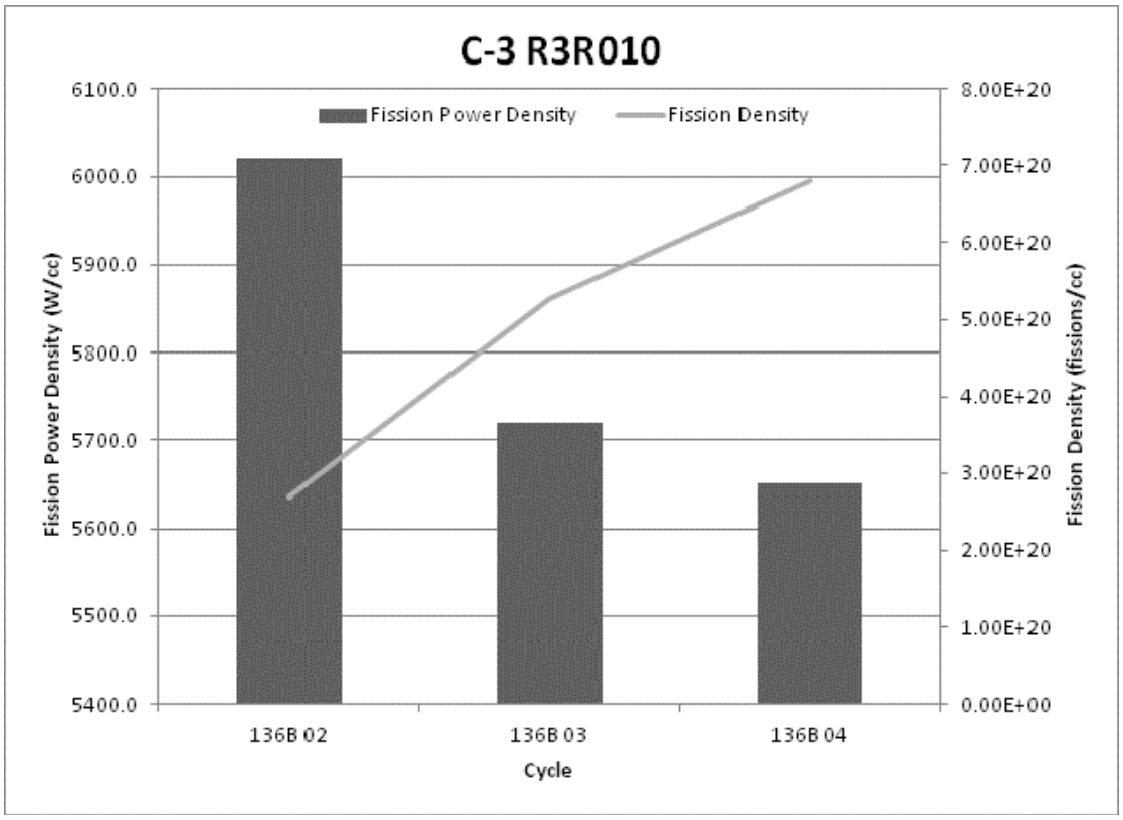
7.00E+20
6.00E+20
5.00E+20
4.00E+20
3.00E+20
2.00E+20
1.00E+20
0.00E+00
136B 02
136B 03
136B 04
Cycle


C-3 R3R010
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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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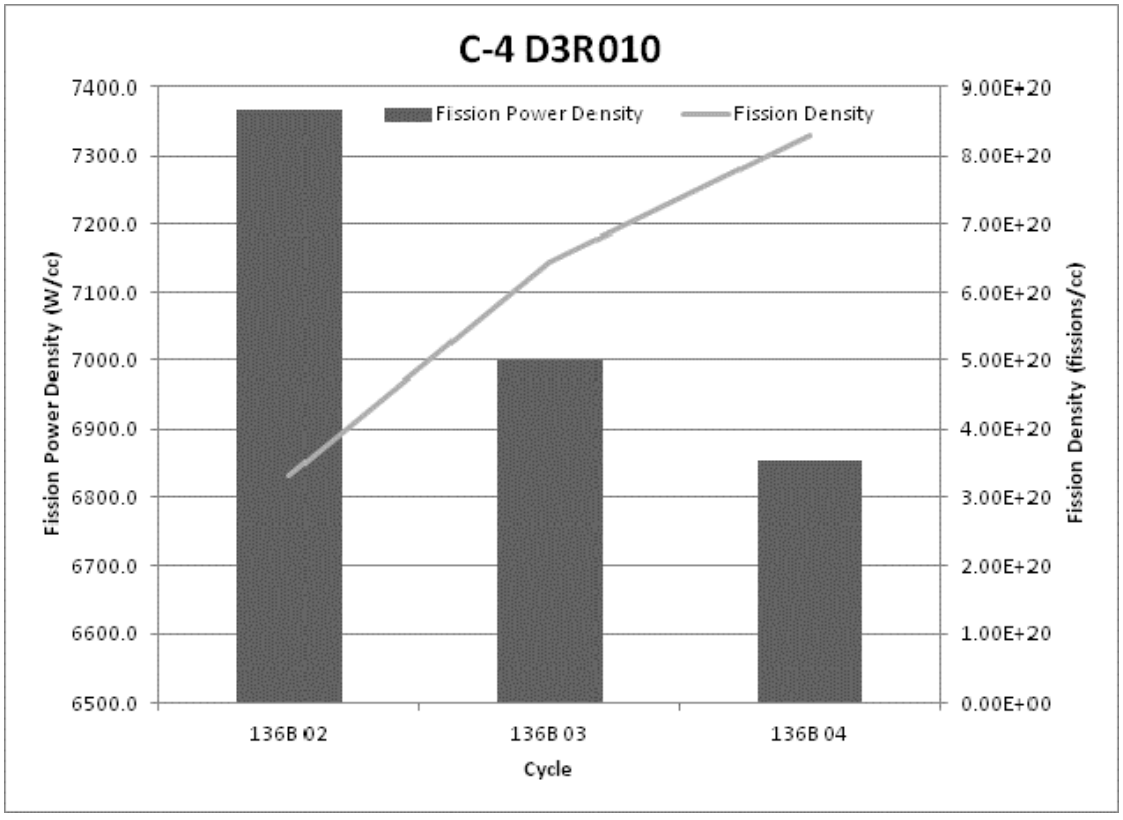
5700.0
5600.0
5500.0
5400.0
8.00E+20
7.00E+20
6.00E+20
5.00E+20
4.00E+20
3.00E+20
2.00E+20
1.00E+20
0.00E+00
136B 02
136B 03
136B 04
Cycle


C-4 D3R010
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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
7400.0
7300.0
7200.0
7100.0
7000.0
6900.0
6800.0
6700.0
6600.0
6500.0
9.00E+20
8.00E+20
7.00E+20
6.00E+20
5.00E+20
4.00E+20
3.00E+20
2.00E+20
1.00E+20
0.00E+00
136B 02
136B 03
136B 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

11. M. R. Finlay email communication to G. S. Chang, "Subject: power gradient across RERTR plates", December 19, 2006 (Attachment 1).
12. D. M. Wachs email communication to G. S. Chang and M. A. Lillo, attachment "RERTR-6 matrix as-built.xls", March 27, 2006.
13. 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)

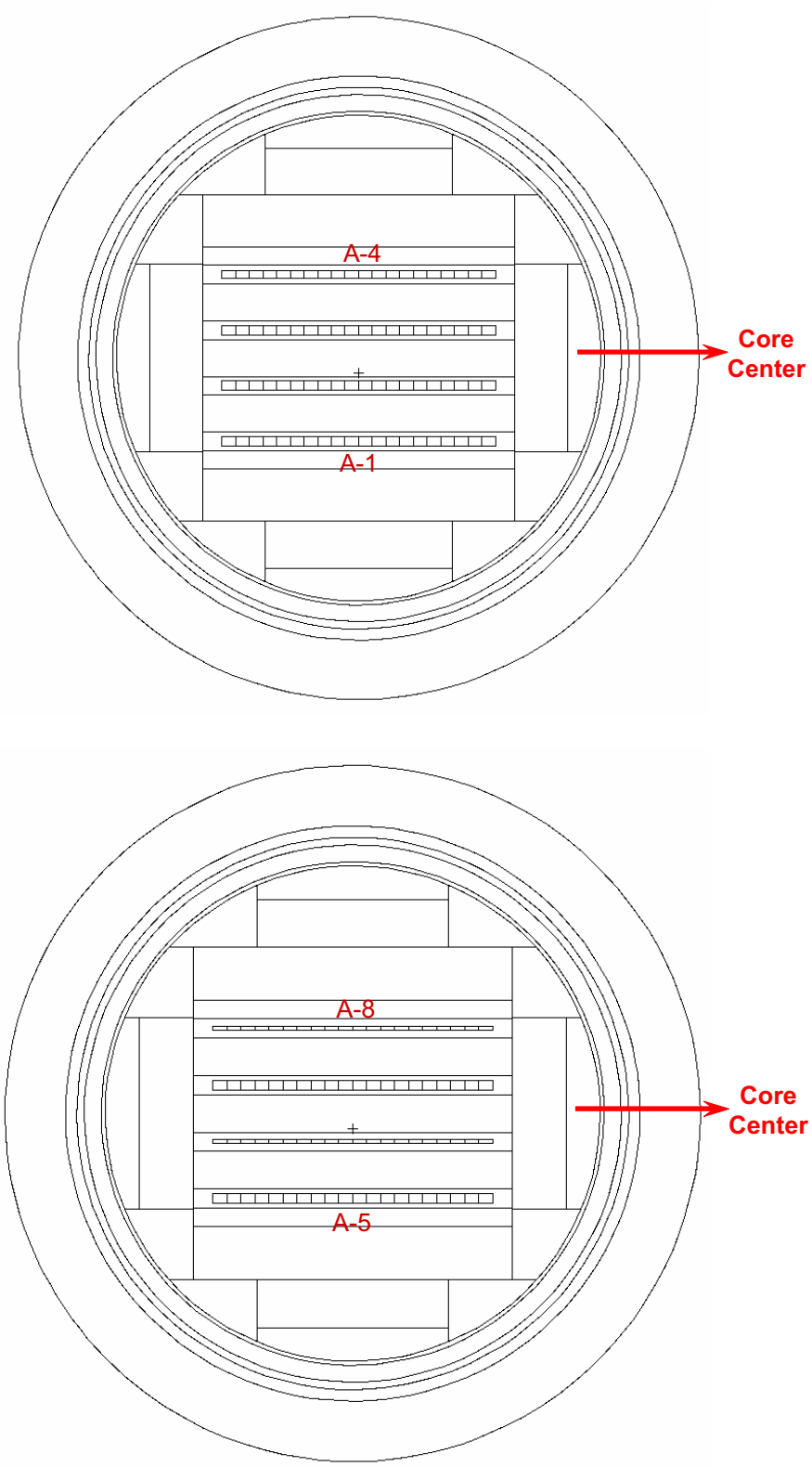


Figure 17 - RERTR-6 capsule A miniplates A-1 thru A-8 irradiated in ATR B-12 position.

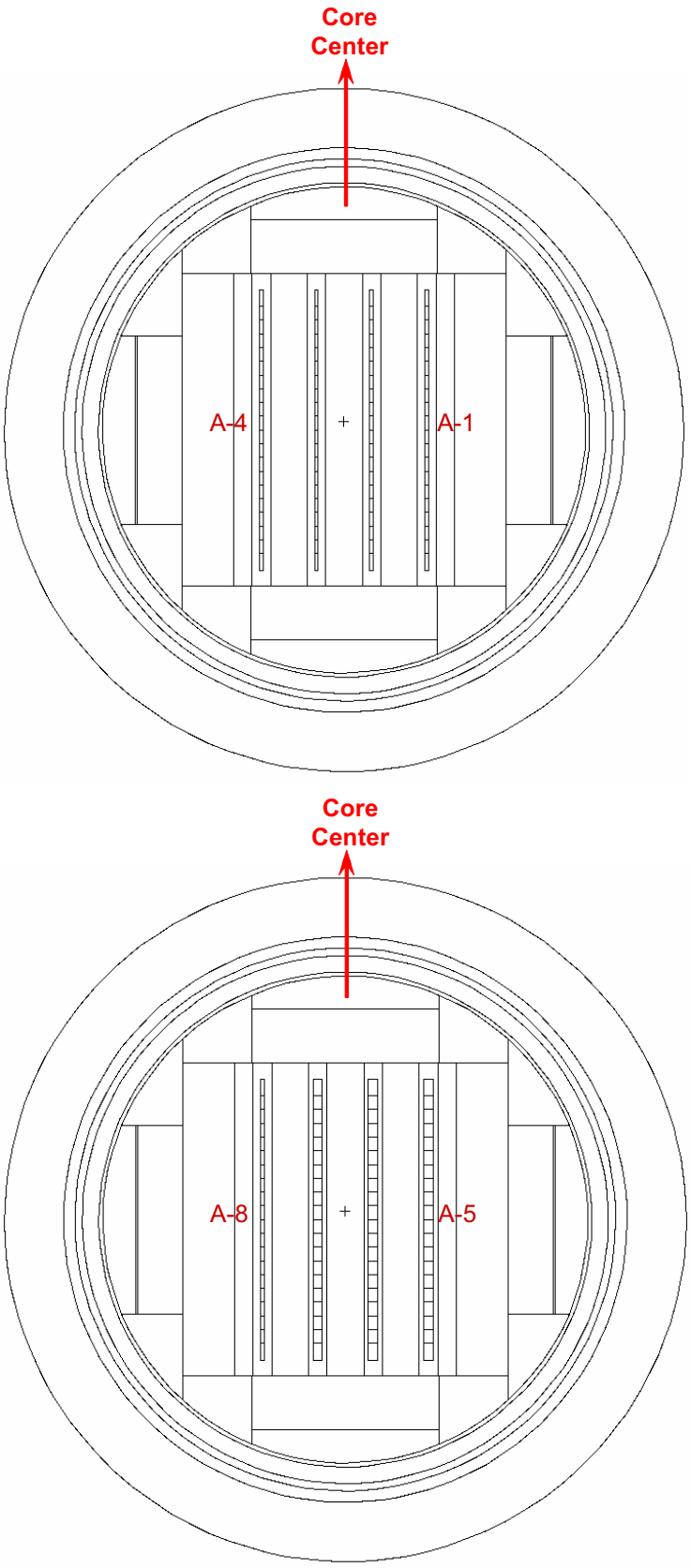


Figure 18 - RERTR-7A capsule A miniplates A-1 thru A-8 irradiated in ATR B-11 position.

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).

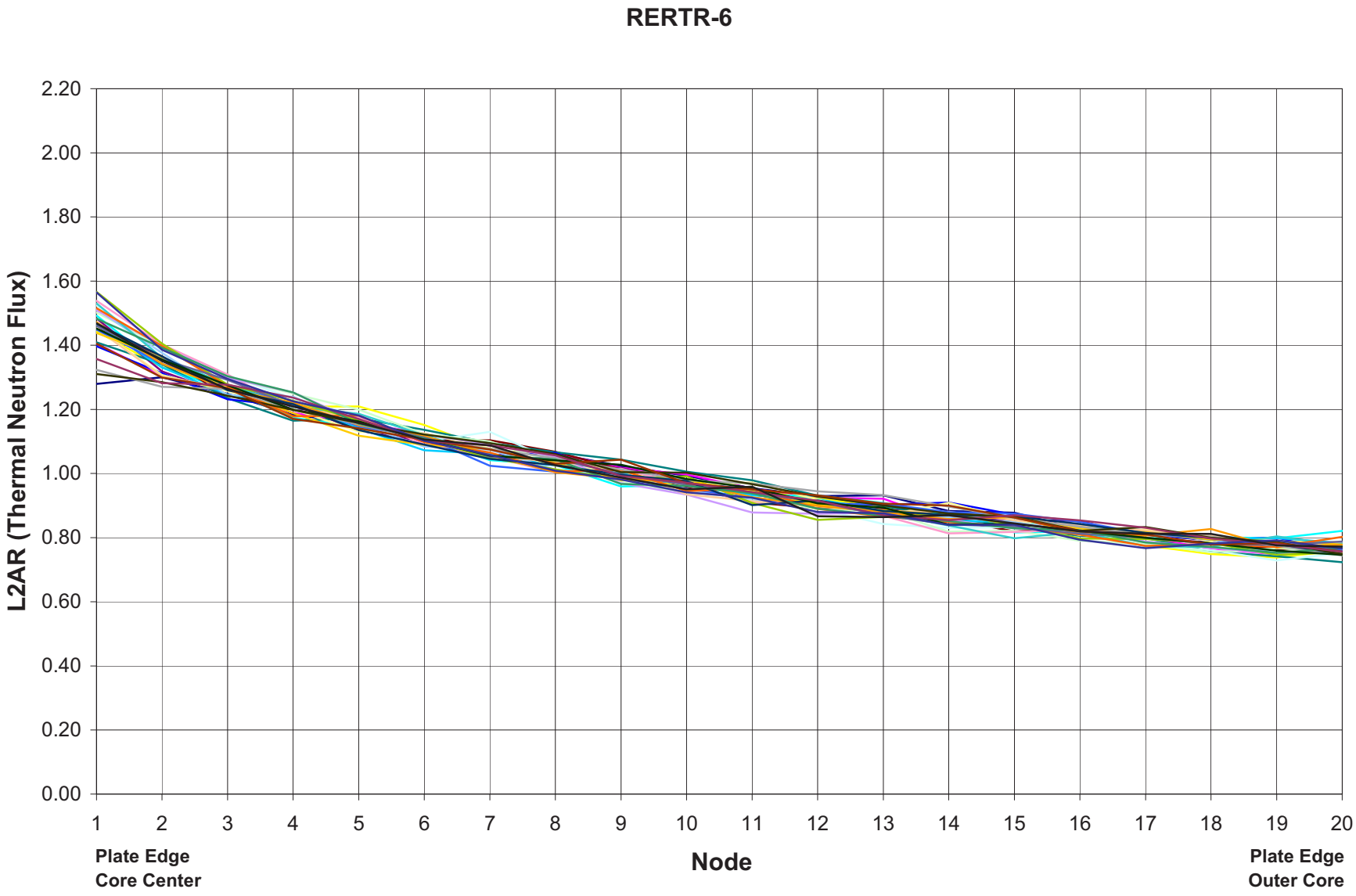
	Fuel	Fuel	Core Edge									Position									Outer Edge
ID	Phase	Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6A-1	---	blank	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6A-2	U-7Mo	disp	1.41	1.31	1.26	1.19	1.16	1.12	1.08	1.06	1.02	1.00	0.95	0.92	0.92	0.85	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
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11
12
13
14
15
16
17
18
19
20
Plate Edge
Core Center
Node
Plate Edge
Outer Core

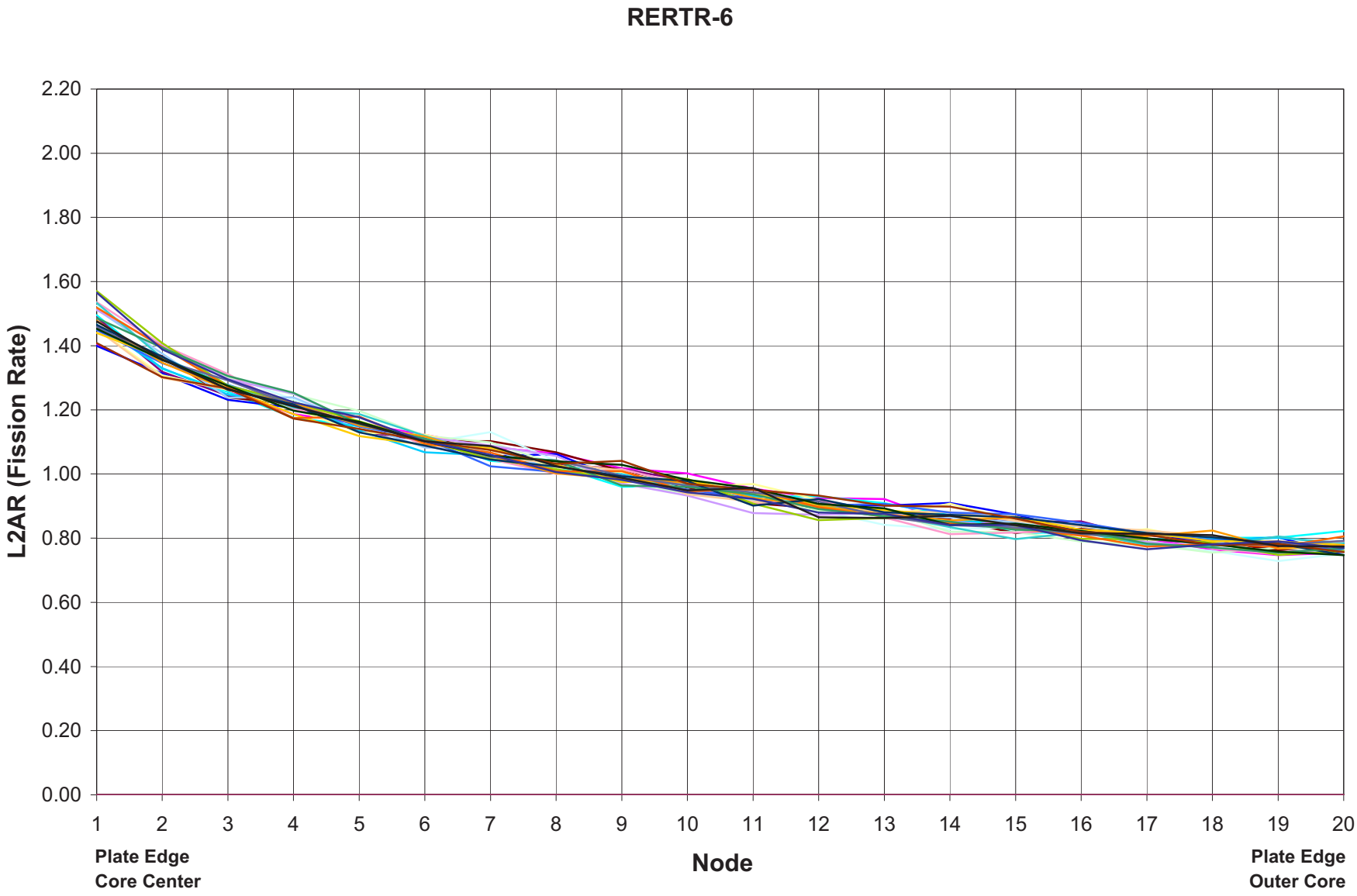
RERTR-6
L2AR (Fission Rate)
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1
2
3
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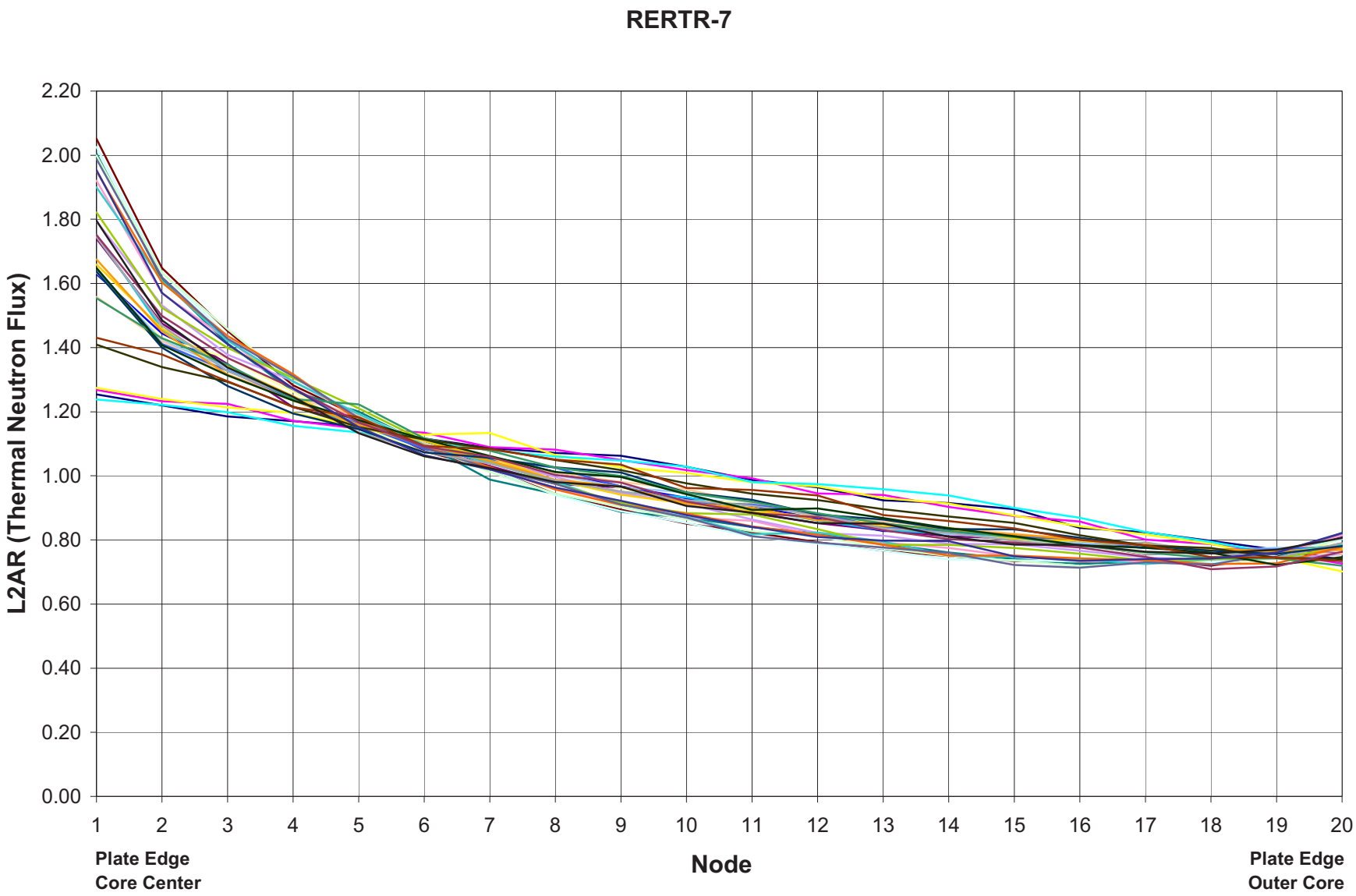
Plate Edge
Core Center
Node
Plate Edge
Outer Core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L2AR (Thermal Neutron Flux)
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1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1
2
3
4
5
6
7
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11
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13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

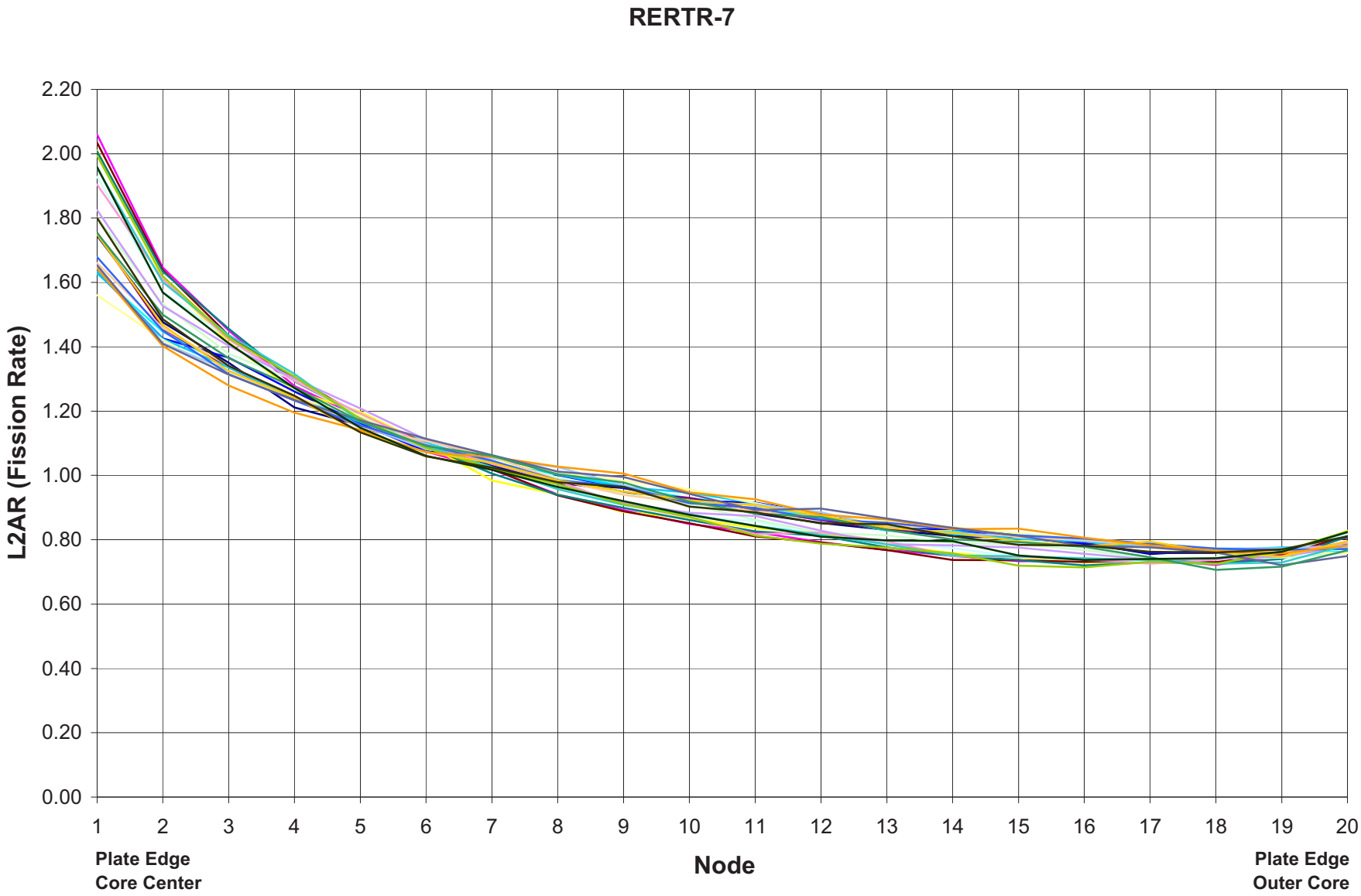
RERTR-7
L2AR (Fission Rate)
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
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Plate Edge
Core Center
Node
Plate Edge
Outer Core

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

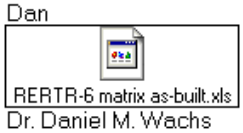
Daniel M Wachs/WACHDM/CC01/INEEL/US
03/27/2006 10:36 AM

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



Dr. Daniel M. Wachs
Nuclear Fuels and Materials Dept.
Idaho National Laboratory
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(208) 604-4994 cell
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.