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RERTR-8 Irradiation Summary Report

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SUMMARY

The Reduced Enrichment for Research and Test Reactor (RERTR) experiment RERTR-8, was designed to test monolithic mini-fuel plates fabricated via hot isostatic pressing (HIP), the effect of molybdenum (Mo) content on the monolithic fuel behavior, and the efficiency of ternary additions to dispersion fuel particles on the interaction layer behavior at higher burnup.[1]

The following report summarizes the life of the RERTR-8 experiment through end of irradiation, including as-run neutronic analysis, thermal analysis and hydraulic testing results.

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FIGURES

TABLES

ACRONYMS

Al	aluminum
ATR	Advanced Test Reactor
EFPD	effective full power days
HIP	hot isostatic pressing
L2AR	local-to-average ratio
MCNP	Monte Carlo N-Particle
Mo	molybdenum
RERTR	Reduced Enrichment Research and Test Reactor
Si	silicon
TS	thermal spray
U	uranium
U-Mo	uranium-molybdenum
Zr	zirconium

RERTR-8 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-8 experiment was designed to test monolithic mini-fuel plates fabricated via hot isostatic pressing (HIP), the effect of molybdenum (Mo) content on the monolithic fuel behavior, and the efficiency of ternary additions to dispersion fuel particles on the interaction layer behavior at higher burnup[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-8 experiment matrix loading diagram.[1]

RERTR-8 Experiment Matrix				
Capsule	**Column 1**	**Column 2**	**Column 3**	**Column 4**
A Top	A1 U_3Si_2 Al U0R060	A2 U-10Mo FSW 0.01" foil L1F200	A3 U-7Mo-1 Ti Al-4043 D3R040	A4 U-7Mo-2Zr Al-4043 F3R030
A Bottom	A5 Blank Al 6061 DUMB 07	A6 Blank Al 6061 DUMB 06	A7 Blank Al 6061 DUMB 03	A8 Blank Al 6061 DUMB 02
B Top	B1 Blank Al 6061 DUMB 14	B2 Blank Al 6061 DUMB 13	B3 Blank Al 6061 DUMB 11	B4 Blank Al 6061 DUMB 08
B Bottom	B5 U-12Mo HIP 0.010" foil Borated Al H1P02B	B6 Blank Al 6061 DUMB 09	B7 Blank Al 6061 DUMB 10	B8 Blank Al 6061 DUMB 12
C Top	C1 U-10 Mo HIP 0.010" foil L1P020	C2 U-8Mo FSW 0.010" foil J1F020	C3 U-10Mo FSW 0.010" foil L1F190	C4 U-12Mo HIP 0.010" foil H1P010
C Bottom	C5 U-7Mo-1Ti Al-4043 D3R030	C6 U_3Si_2 Al U0R040	C7 U-7Mo Al-4043 R3R060	C8 U-7Mo-2Zr Al-4043 F3R040
D Top	D1 Blank Al 6061 DUMB 21	D2 U-7Mo Mg Matrix R9R010	D3 Blank Al 6061 DUMB 17	D4 Blank Al 6061 DUMB 15
D Bottom	D5 Blank Al 6061 DUMB 20	D6 Blank Al 6061 DUMB 19	D7 Blank Al 6061 DUMB 18	D8 Blank Al 6061 DUMB 16

2. CONSTITUENT MASSES AND DENSITIES

Table 2. Constituent masses and densities for RERTR-8 plates[2].

Fuel Plate ID	Fuel Plate #	Fuel Constituent Masses				Constituent Densities			
		Total-U (g)	U-235 (g)	Mo (g)	Ti/Zr/ B-10/Si (g)	Total-U (g/cc)	U-235 (g/cc)	Mo (g/cc)	Ti/Zr/ B-10/Si (g/cc)
A1	U0R060	4.999	3.742	--	1.756 (Si)	4.984	3.731	--	1.751 (Si)
A2	L1F200	5.520	3.200	0.613	--	15.333	8.889	1.703	--
A3	D3R040	5.980	3.475	0.455	0.060 (Ti)	6.133	3.564	0.467	0.062 (Ti)
A4	F3R030	5.869	3.410	0.451	0.129 (Zr)	6.013	3.494	0.463	0.132 (Zr)
A5	Blank	--	--	--	--	--	--	--	--
A6	Blank	--	--	--	--	--	--	--	--
A7	Blank	--	--	--	--	--	--	--	--
A8	Blank	--	--	--	--	--	--	--	--
B1	Blank	--	--	--	--	--	--	--	--
B2	Blank	--	--	--	--	--	--	--	--
B3	Blank	--	--	--	--	--	--	--	--
B4	Blank	--	--	--	--	--	--	--	--
B5	H1P02B	5.807	3.348	0.792	0.003 (B-10)	14.701	8.476	2.005	0.008 (B-10)
B6	Blank	--	--	--	--	--	--	--	--
B7	Blank	--	--	--	--	--	--	--	--
B8	Blank	--	--	--	--	--	--	--	--
C1	L1P020	5.893	3.430	0.655	--	15.306	8.909	1.701	--
C2	J1F020	6.126	3.567	0.533	--	15.953	9.289	1.388	--
C3	L1F190	5.564	3.230	0.619	--	15.328	8.898	1.705	--
C4	H1P010	5.770	3.320	0.655	--	14.719	8.469	1.671	--
C5	D3R030	5.932	3.447	0.774	0.064 (Ti)	6.041	3.510	0.788	0.065 (Ti)
C6	U0R040	5.024	3.761	--	1.776 (Si)	4.897	3.666	--	1.731 (Si)
C7	R3R060	5.911	3.530	0.445	--	6.019	3.595	0.453	--
C8	F3R040	5.861	3.406	0.451	0.129 (Zr)	6.042	3.511	0.465	0.133 (Zr)
D1	Blank	--	--	--	--	--	--	--	--
D2	R9R010	6.017	3.513	0.453	--	6.261	3.656	0.471	--
D3	Blank	--	--	--	--	--	--	--	--
D4	Blank	--	--	--	--	--	--	--	--
D5	Blank	--	--	--	--	--	--	--	--
D6	Blank	--	--	--	--	--	--	--	--
D7	Blank	--	--	--	--	--	--	--	--
D8	Blank	--	--	--	--	--	--	--	--

3. EXPERIMENT HARDWARE

The experiment hardware configuration is identical to that used in the RERTR-7A and -7B experiments. A list of irradiation hardware drawings used for analysis is given in Table 3.

Table 3. RERTR-8 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.

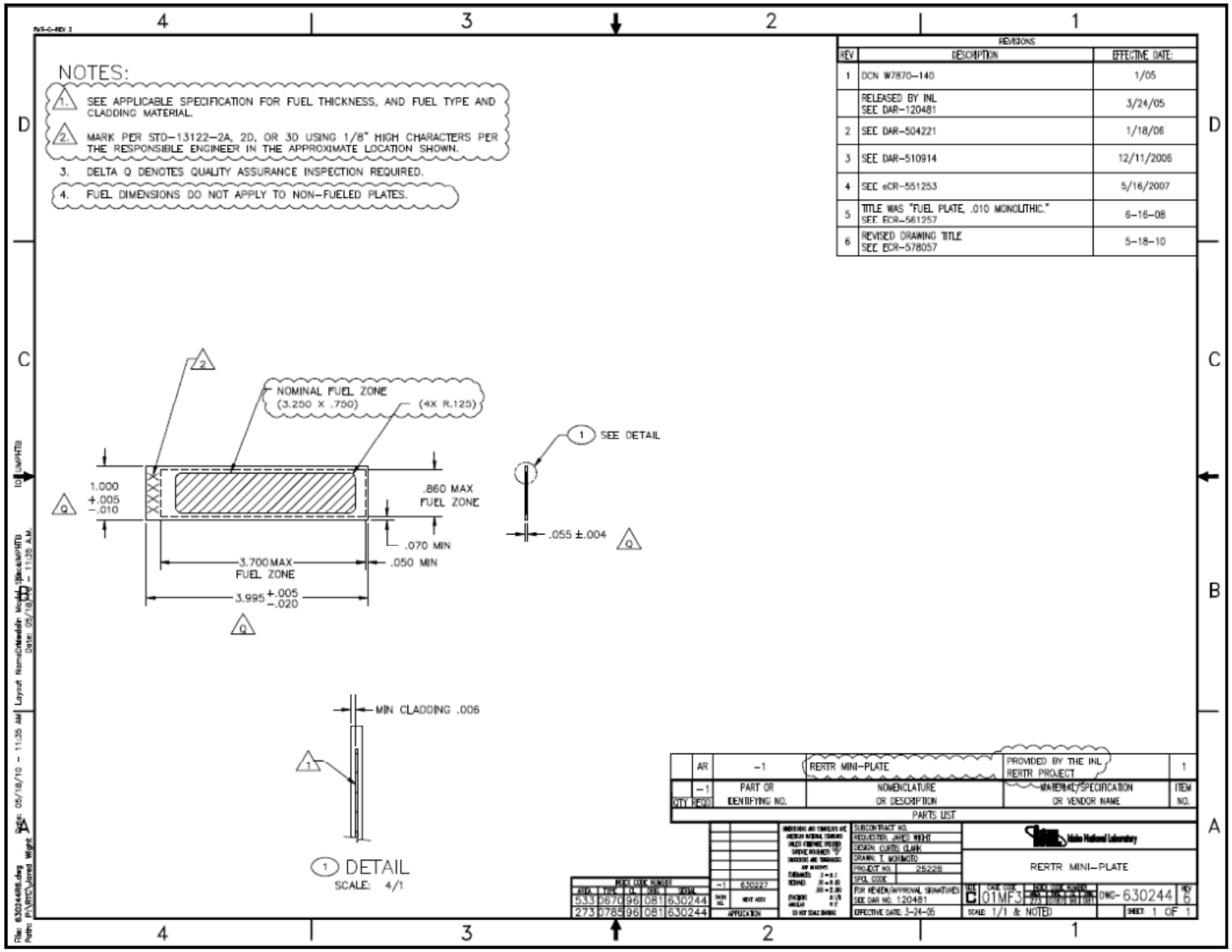


Figure 2. DWG-630244: RERTR monolithic fuel miniplate.

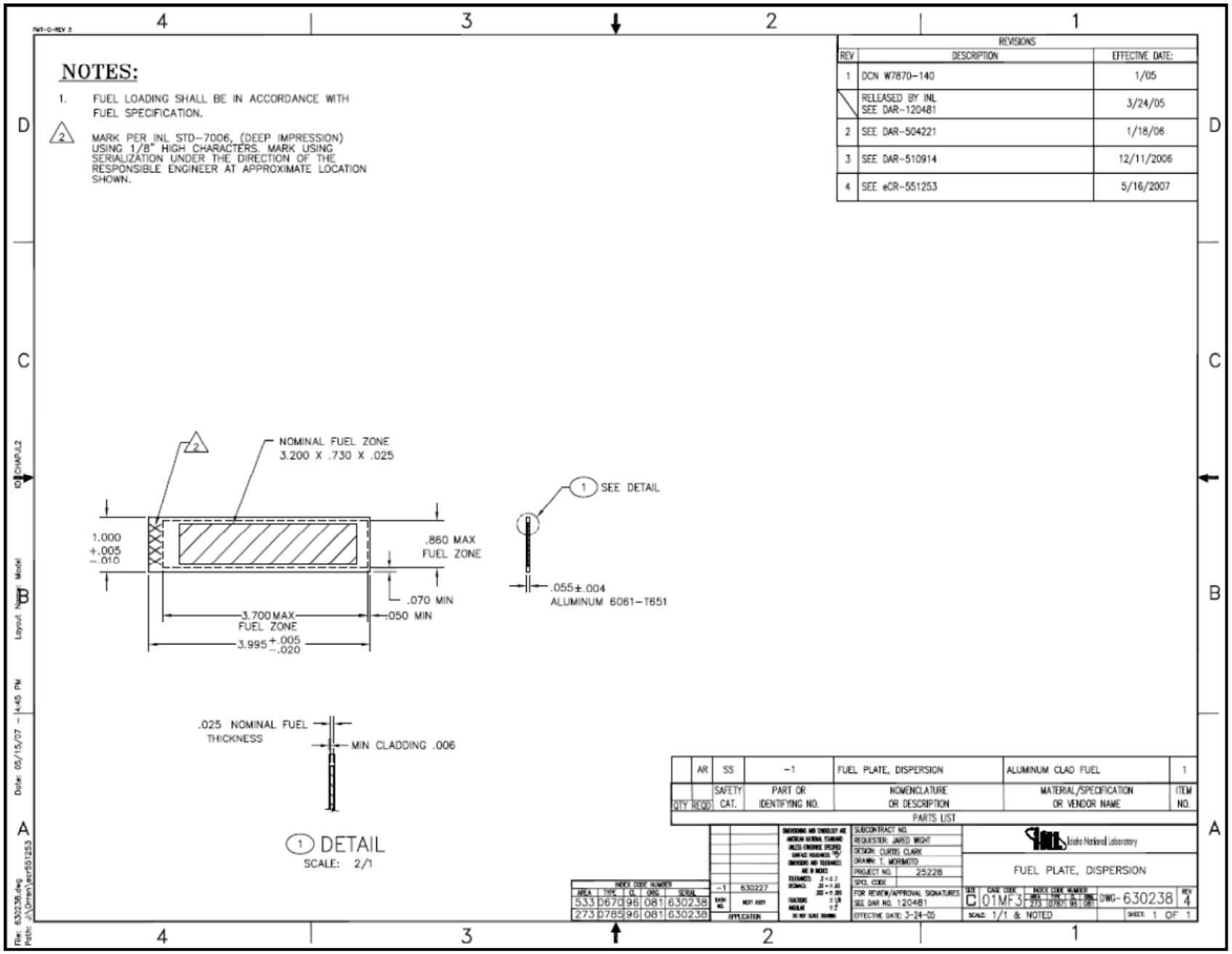


Figure 3. DWG-630238: RERTR dispersion fuel miniplate.

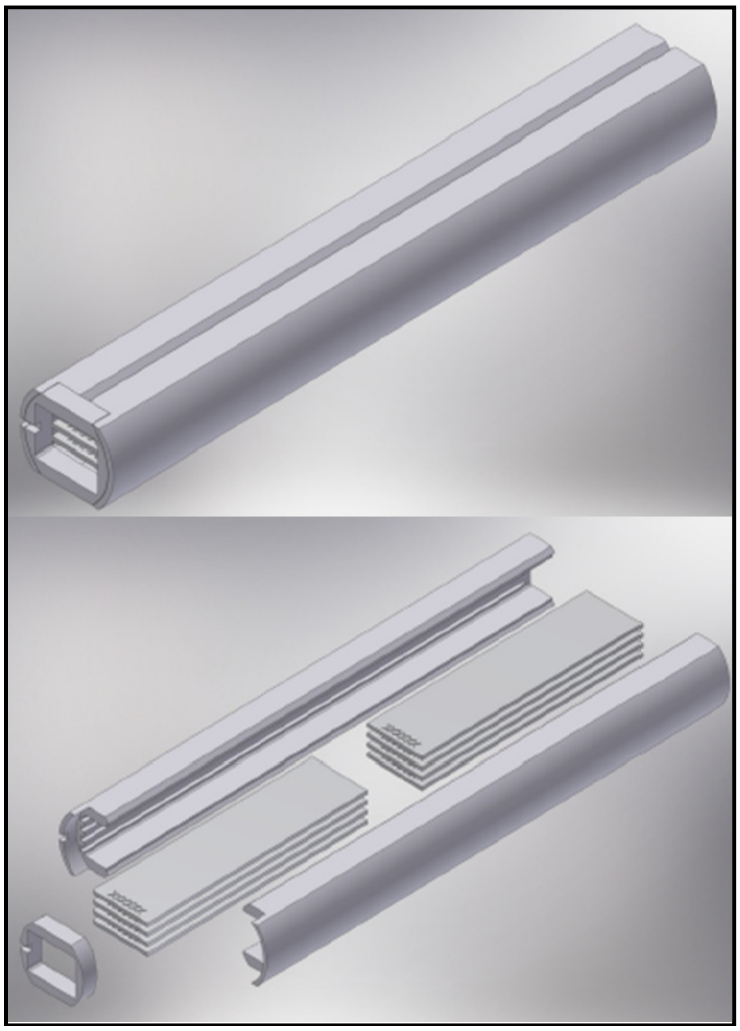


Figure 4. RERTR capsule assembly.

4. IRRADIATION HISTORY

The RERTR-8 test assembly was irradiated in Cycles 138A and 138B. This experiment was irradiated in the large-B position B-11 during cycle 138A and in the large-B position B-12 during cycle 138B. 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. 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 138A ran for 58.1 EFPDs at 23.87 MW (total core power of 107.6 MW), Cycle 138B ran for 46.6 EFPDs at 21.4 MW (total core power 107.3 MW). This information is tabulated in Table 4.

Table 4. Irradiation history for the RERTR-8 experiment.

ATR CYCLE	RERTR-8 Capsules Irradiated	Dates Irradiated	Cycle EFPDs	West Lobe Source Power (MW)	South Lobe Source Power (MW)	Total Core Power (MW)
138A	A,B,C,D	10/12/2006 – 12/09/2006	58.1	--	23.87	107.6
138B	A,B,C,D	12/26/2006 – 2/10/2007	46.6	21.4		107.3

The power history for each cycle is obtained as in ATR Surveillance Report from the ATR Data Acquisition System (DAS). The plots of each lobe power on an hourly basis are shown in Figure 5 and Figure 6 for cycle 138A and 138B, respectively.

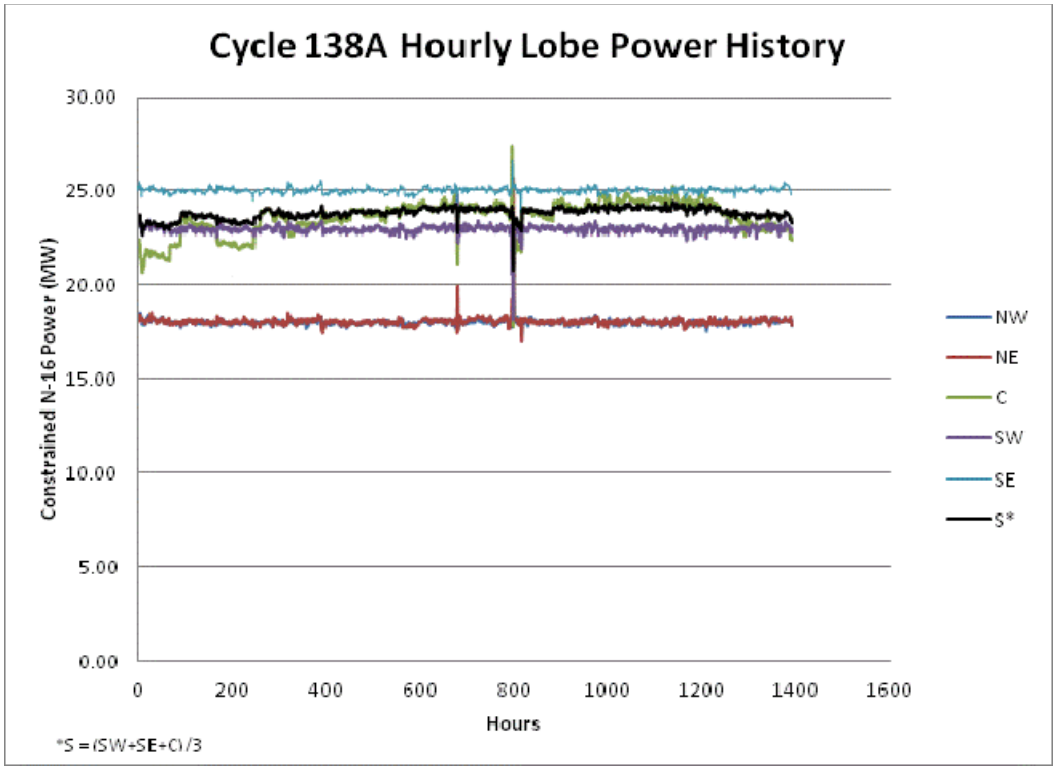


Figure 5. Hourly lobe power history for ATR Cycle 138A.

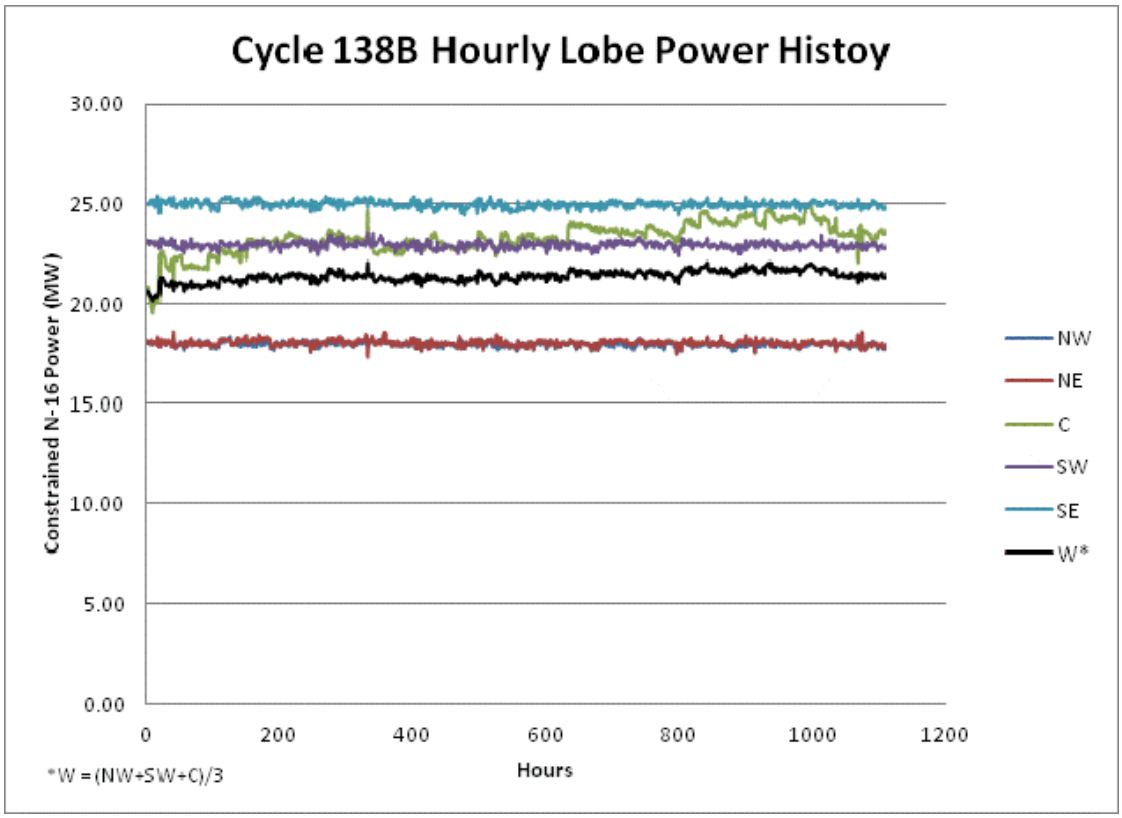


Figure 6. Hourly lobe power history for ATR Cycle 138B.

5. AS-RUN NUCLEAR ANALYSIS

5.1 Neutronics

The as-run calculations were performed using the irradiation history in Table 4 and the Monte Carlo N-Particle (MCNP) code. The calculated as-run fission heat rates and as-run U-235 burnup results for the fueled miniplates reported have an uncertainty band (1σ) of 2.5%.[3] The time intervals used to calculate average plate power and burnup is shown in Table 5. The end of cycle average plate power and burnup for cycles 138A and 138B are shown in Table 8 and Table 11, respectively. The average plate power and burnup for cycle 138A are shown in Table 6 through Table 8 and the average plate power and burnup for cycle 138B are shown in Table 9 through Table 11. The plots of the power and burnup as a function of the ATR Cycle time interval are in Appendix A.

Table 5. Cycle breakdown.

Time Interval	138A (days)	138B (days)
01	1.00E-4	1.00E-4
02	18	18
03	18	18.1
04	22.1	10.5
05	1.00E-3	1.00E-3
EFPDs	58.1	46.60
Cumulative	58.1	104.7

Table 6. Average plate power and burnup for MOC1 138A (18 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	U0R060	857.71	7277.06	231.05	4.55%	3.94E+20
A2	L1F200	834.24	12890.52	163.71	3.97%	6.97E+20
A3	D3R040	677.99	5766.75	183.09	3.89%	3.12E+20
A4	F3R030	817.21	6788.17	215.52	4.69%	3.67E+20
A5	Blank	--	--	--	--	--
A6	Blank	--	--	--	--	--
A7	Blank	--	--	--	--	--
A8	Blank	--	--	--	--	--
B1	Blank	--	--	--	--	--
B2	Blank	--	--	--	--	--
B3	Blank	--	--	--	--	--
B4	Blank	--	--	--	--	--
B5	H1P02B	1809.30	30082.71	382.05	8.55%	1.63E+21
B6	Blank	--	--	--	--	--
B7	Blank	--	--	--	--	--
B8	Blank	--	--	--	--	--
C1	L1P020	1412.47	23302.71	295.94	6.57%	1.26E+21
C2	J1F020	1209.91	20297.86	257.78	5.52%	1.10E+21
C3	L1F190	1213.47	18903.30	240.07	5.71%	1.02E+21
C4	H1P010	1421.78	23017.45	292.32	6.67%	1.25E+21
C5	D3R030	1068.68	9410.07	298.77	6.39%	5.09E+20
C6	U0R040	970.14	8293.14	263.31	5.14%	4.49E+20
C7	R3R060	939.99	7914.68	251.29	5.28%	4.28E+20
C8	F3R040	1126.46	9334.65	269.38	6.34%	5.05E+20
D1	Blank	--	--	--	--	--
D2	R9R010	1482.30	11599.48	368.28	7.62%	6.27E+20
D3	Blank	--	--	--	--	--
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	Blank	--	--	--	--	--
D7	Blank	--	--	--	--	--
D8	Blank	--	--	--	--	--

Table 7. Average plate power and burnup for MOC2 138A (36.0 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	U0R060	829.67	6924.77	219.86	8.94%	7.68E+20
A2	L1F200	810.33	12322.86	156.50	7.74%	1.36E+21
A3	D3R040	656.95	5515.45	175.12	7.64%	6.10E+20
A4	F3R030	789.11	6451.64	204.84	9.10%	7.16E+20
A5	Blank	--	--	--	--	--
A6	Blank	--	--	--	--	--
A7	Blank	--	--	--	--	--
A8	Blank	--	--	--	--	--
B1	Blank	--	--	--	--	--
B2	Blank	--	--	--	--	--
B3	Blank	--	--	--	--	--
B4	Blank	--	--	--	--	--
B5	H1P02B	1740.84	27965.33	355.16	16.46%	3.14E+21
B6	Blank	--	--	--	--	--
B7	Blank	--	--	--	--	--
B8	Blank	--	--	--	--	--
C1	L1P020	1367.38	21958.07	278.87	12.78%	2.45E+21
C2	J1F020	1173.70	19242.04	244.37	10.77%	2.14E+21
C3	L1F190	1178.73	17940.91	227.85	11.08%	1.99E+21
C4	H1P010	1377.97	21708.21	275.69	12.97%	2.42E+21
C5	D3R030	1027.50	8863.94	281.43	12.33%	9.88E+20
C6	U0R040	938.07	7872.89	249.96	10.11%	8.74E+20
C7	R3R060	908.89	7515.18	238.61	10.25%	8.35E+20
C8	F3R040	1081.96	8777.06	278.67	12.35%	9.79E+20
D1	Blank	--	--	--	--	--
D2	R9R010	1429.15	10872.66	345.21	14.72%	1.22E+21
D3	Blank	--	--	--	--	--
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	Blank	--	--	--	--	--
D7	Blank	--	--	--	--	--
D8	Blank	--	--	--	--	--

Table 8. Average plate power and burnup for EOC 138A (58.1 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	U0R060	824.67	6773.04	215.04	14.11%	1.22E+21
A2	L1F200	812.47	12163.49	154.48	12.29%	2.17E+21
A3	D3R040	656.85	5445.79	172.90	12.18%	9.72E+20
A4	F3R030	782.25	6300.93	200.05	14.38%	1.13E+21
A5	Blank	--	--	--	--	--
A6	Blank	--	--	--	--	--
A7	Blank	--	--	--	--	--
A8	Blank	--	--	--	--	--
B1	Blank	--	--	--	--	--
B2	Blank	--	--	--	--	--
B3	Blank	--	--	--	--	--
B4	Blank	--	--	--	--	--
B5	H1P02B	1705.52	26507.07	336.64	25.52%	4.90E+21
B6	Blank	--	--	--	--	--
B7	Blank	--	--	--	--	--
B8	Blank	--	--	--	--	--
C1	L1P020	1354.04	21181.29	269.00	20.03%	3.85E+21
C2	J1F020	1180.17	18914.59	240.22	17.03%	3.40E+21
C3	L1F190	1186.20	17651.26	224.17	17.51%	3.16E+21
C4	H1P010	1364.71	20940.89	265.95	20.35%	3.81E+21
C5	D3R030	1018.07	8616.78	273.58	19.37%	1.56E+21
C6	U0R040	941.74	7761.39	246.42	15.97%	1.39E+21
C7	R3R060	908.75	7387.04	234.54	16.23%	1.33E+21
C8	F3R040	1067.96	8485.62	269.42	19.36%	1.54E+21
D1	Blank	--	--	--	--	--
D2	R9R010	1403.75	10393.75	330.00	22.98%	1.91E+21
D3	Blank	--	--	--	--	--
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	Blank	--	--	--	--	--
D7	Blank	--	--	--	--	--
D8	Blank	--	--	--	--	--

Table 9. Average plate power and burnup for MOC1 138B (18 EFPD, cumulative 76.1 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	U0R060	651.96	5250.82	166.71	17.42%	1.50E+21
A2	L1F200	661.26	9709.10	123.31	15.25%	2.69E+21
A3	D3R040	534.23	4360.82	138.46	15.14%	1.21E+21
A4	F3R030	626.95	4956.66	157.37	17.74%	1.40E+21
A5	Blank	--	--	--	--	--
A6	Blank	--	--	--	--	--
A7	Blank	--	--	--	--	--
A8	Blank	--	--	--	--	--
B1	Blank	--	--	--	--	--
B2	Blank	--	--	--	--	--
B3	Blank	--	--	--	--	--
B4	Blank	--	--	--	--	--
B5	H1P02B	1272.36	18999.66	241.30	30.88%	5.92E+21
B6	Blank	--	--	--	--	--
B7	Blank	--	--	--	--	--
B8	Blank	--	--	--	--	--
C1	L1P020	1030.98	15617.88	198.35	24.38%	4.70E+21
C2	J1F020	912.57	14221.09	180.61	20.85%	4.16E+21
C3	L1F190	913.89	13220.81	167.90	21.49%	3.88E+21
C4	H1P010	1027.34	15262.81	193.84	24.73%	4.63E+21
C5	D3R030	774.99	6401.10	203.23	23.68%	1.91E+21
C6	U0R040	738.64	5953.93	189.04	19.68%	1.71E+21
C7	R3R060	710.63	5651.66	179.44	20.00%	1.63E+21
C8	F3R040	807.22	6254.14	198.57	23.65%	1.88E+21
D1	Blank	--	--	--	--	--
D2	R9R010	--	--	--	--	--
D3	Blank	--	--	--	--	--
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	Blank	--	--	--	--	--
D7	Blank	--	--	--	--	--
D8	Blank	--	--	--	--	--

Table 10. Average plate power and burnup for MOC2 138B (36.1 EFPD, cumulative 94.2 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	U0R060	631.09	5018.31	159.33	20.54%	1.77E+21
A2	L1F200	640.26	9280.29	117.86	18.05%	3.20E+21
A3	D3R040	517.05	4175.31	132.57	17.93%	1.43E+21
A4	F3R030	606.74	4739.82	150.49	21.04%	1.66E+21
A5	Blank	--	--	--	--	--
A6	Blank	--	--	--	--	--
A7	Blank	--	--	--	--	--
A8	Blank	--	--	--	--	--
B1	Blank	--	--	--	--	--
B2	Blank	--	--	--	--	--
B3	Blank	--	--	--	--	--
B4	Blank	--	--	--	--	--
B5	H1P02B	1220.71	17782.90	225.85	35.92%	6.88E+21
B6	Blank	--	--	--	--	--
B7	Blank	--	--	--	--	--
B8	Blank	--	--	--	--	--
C1	L1P020	993.98	14759.47	187.45	28.55%	5.49E+21
C2	J1F020	883.71	13528.43	171.81	24.54%	4.89E+21
C3	L1F190	886.19	12593.89	159.94	25.23%	4.56E+21
C4	H1P010	991.62	14439.69	183.38	28.88%	5.41E+21
C5	D3R030	746.39	6071.90	192.78	27.78%	2.23E+21
C6	U0R040	714.80	5679.56	180.33	23.27%	2.02E+21
C7	R3R060	685.20	5374.79	170.65	23.50%	1.92E+21
C8	F3R040	778.43	5935.27	188.44	27.67%	2.20E+21
D1	Blank	--	--	--	--	--
D2	R9R010	--	--	--	--	--
D3	Blank	--	--	--	--	--
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	Blank	--	--	--	--	--
D7	Blank	--	--	--	--	--
D8	Blank	--	--	--	--	--

Table 11. Average plate power and burnup for EOC 138B (46.6 EFPD, cumulative 104.7 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	U0R060	626.64	4923.02	165.31	22.41%	1.93E+21
A2	L1F200	641.88	9190.04	116.71	19.70%	3.49E+21
A3	D3R040	516.93	4133.75	131.25	19.61%	1.56E+21
A4	F3R030	601.85	4644.73	147.47	22.96%	1.81E+21
A5	Blank	--	--	--	--	--
A6	Blank	--	--	--	--	--
A7	Blank	--	--	--	--	--
A8	Blank	--	--	--	--	--
B1	Blank	--	--	--	--	--
B2	Blank	--	--	--	--	--
B3	Blank	--	--	--	--	--
B4	Blank	--	--	--	--	--
B5	H1P02B	1189.30	16923.08	214.92	38.74%	7.42E+21
B6	Blank	--	--	--	--	--
B7	Blank	--	--	--	--	--
B8	Blank	--	--	--	--	--
C1	L1P020	985.74	14358.55	182.35	30.95%	5.95E+21
C2	J1F020	881.80	13271.83	168.55	26.67%	5.32E+21
C3	L1F190	883.53	12341.83	156.74	27.43%	4.95E+21
C4	H1P010	980.80	14009.60	177.92	31.31%	5.86E+21
C5	D3R030	734.26	5886.40	186.89	30.13%	2.42E+21
C6	U0R040	711.41	5573.82	176.97	25.30%	2.20E+21
C7	R3R060	685.05	5303.26	168.38	25.61%	2.09E+21
C8	F3R040	767.61	5766.89	183.10	29.98%	2.38E+21
D1	Blank	--	--	--	--	--
D2	R9R010	--	--	--	--	--
D3	Blank	--	--	--	--	--
D4	Blank	--	--	--	--	--
D5	Blank	--	--	--	--	--
D6	Blank	--	--	--	--	--
D7	Blank	--	--	--	--	--
D8	Blank	--	--	--	--	--

5.2 Gradients

The MCNP-calculated power gradients[4] in the transverse and axial directions are represented by the thermal neutron flux and fission rate local-2-average ratios (L2ARs) as a function of position. Figure 7 and Figure 8 depict the power gradient in the transverse direction and Figure 9 and Figure 10 depict the power gradient in the axial direction (see appendix B for L2AR gradient tables).

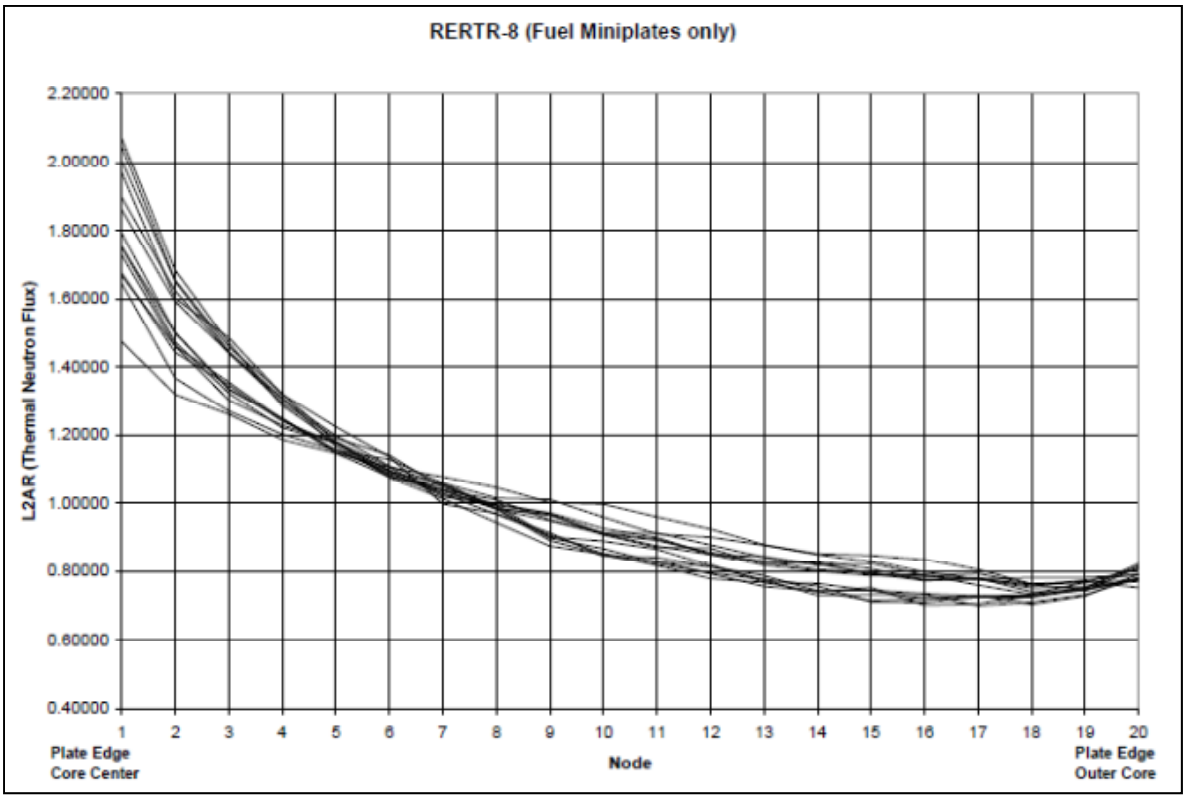


Figure 7. RERTR-8 fuel miniplates thermal neutron flux L2ARs in transverse direction.[4]

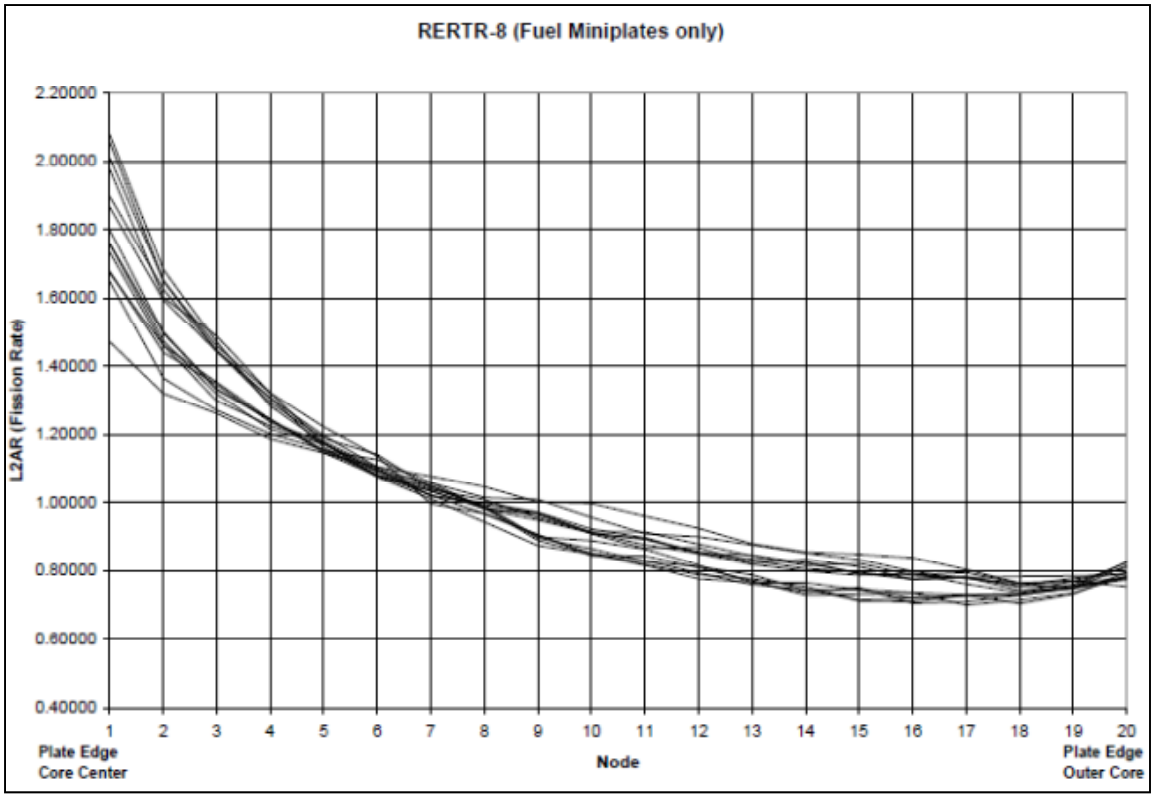


Figure 8. RERTR-8 fuel miniplates fission rate L2ARs in transverse direction.[4]

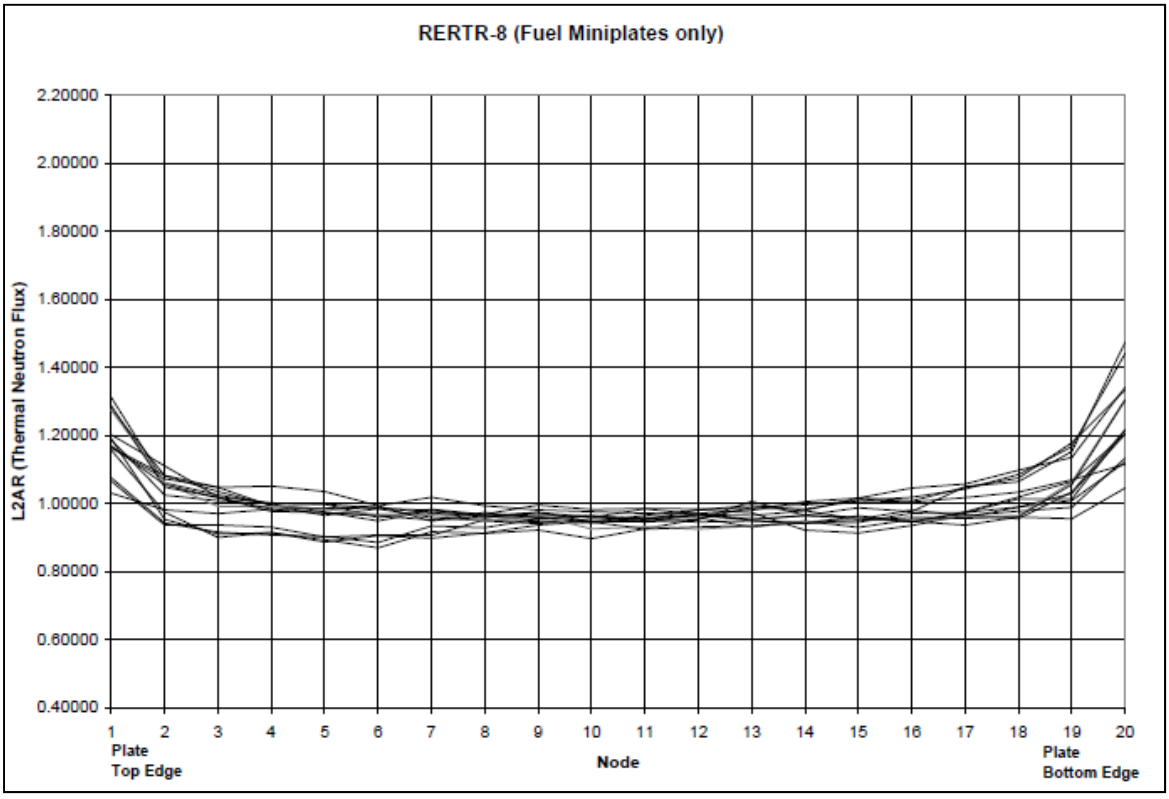


Figure 9. RERTR-8 fuel miniplates thermal neutron flux L2ARs in axial direction.[4]

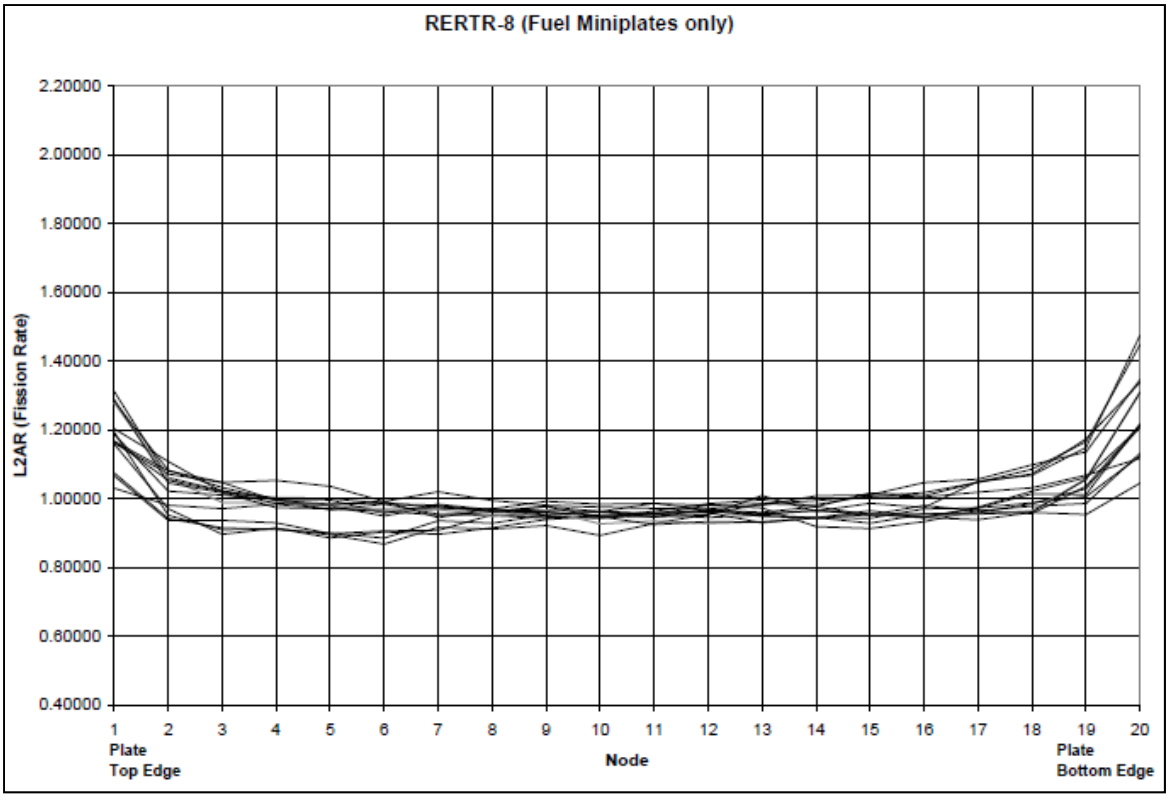


Figure 10. RERTR-8 fuel miniplates fission rate L2ARs in axial direction.[4]

6. HYDRAULIC TESTING

A fully assembled irradiation test vehicle (with simulated fuel plates) was used for testing. The test vehicle was fabricated such that the orifice plates could be easily changed. The hydraulic resistance of the RERTR Large B-Position irradiation test vehicle with various orifice plate sizes were calculated, the results are shown in Table 12.

Table 12. Loss coefficients for the RERTR irradiation test vehicle components.[5]

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

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.[6]

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[7] 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 8):

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

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 11 through Figure 16.

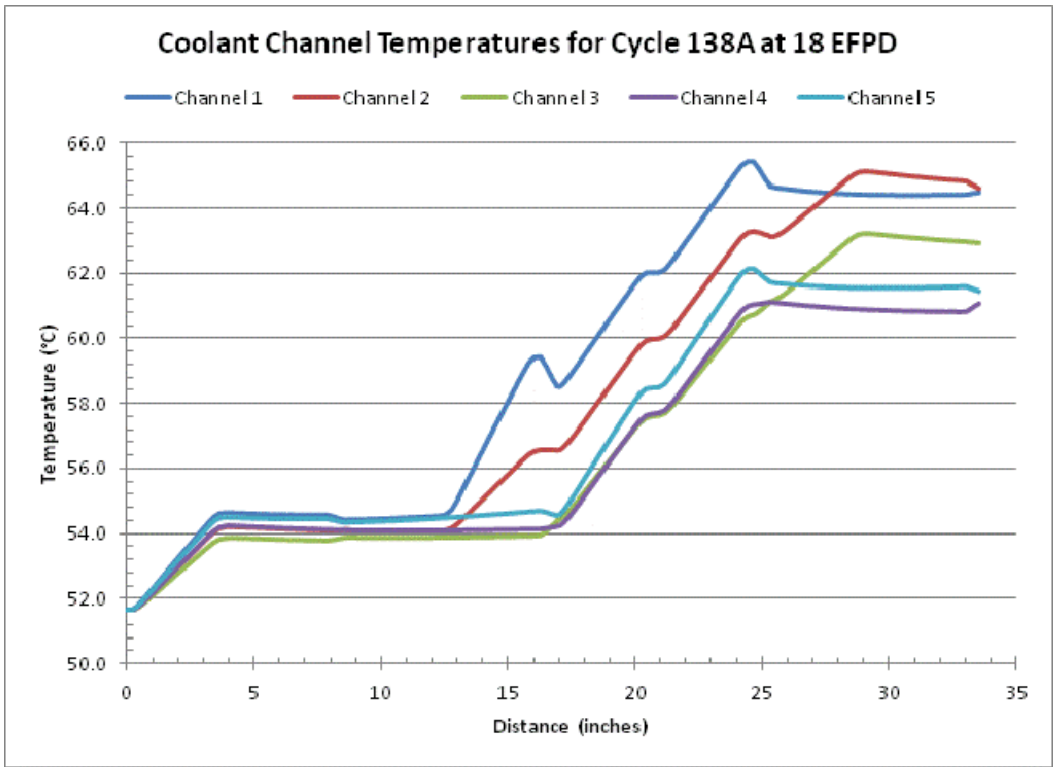


Figure 11. RERTR-8 coolant temperature as a function of location along the test assembly for Cycle 138A at 18 EFPD.

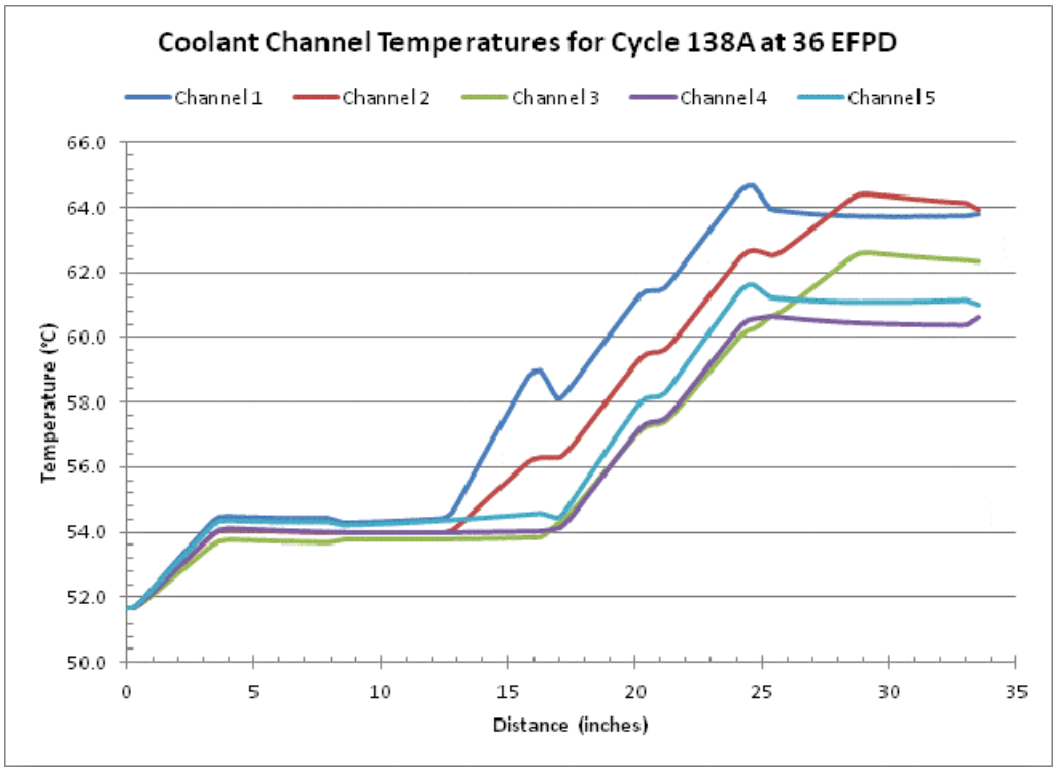


Figure 12. RERTR-8 coolant temperature as a function of location along the test assembly for Cycle 138A at 36 EFPD.

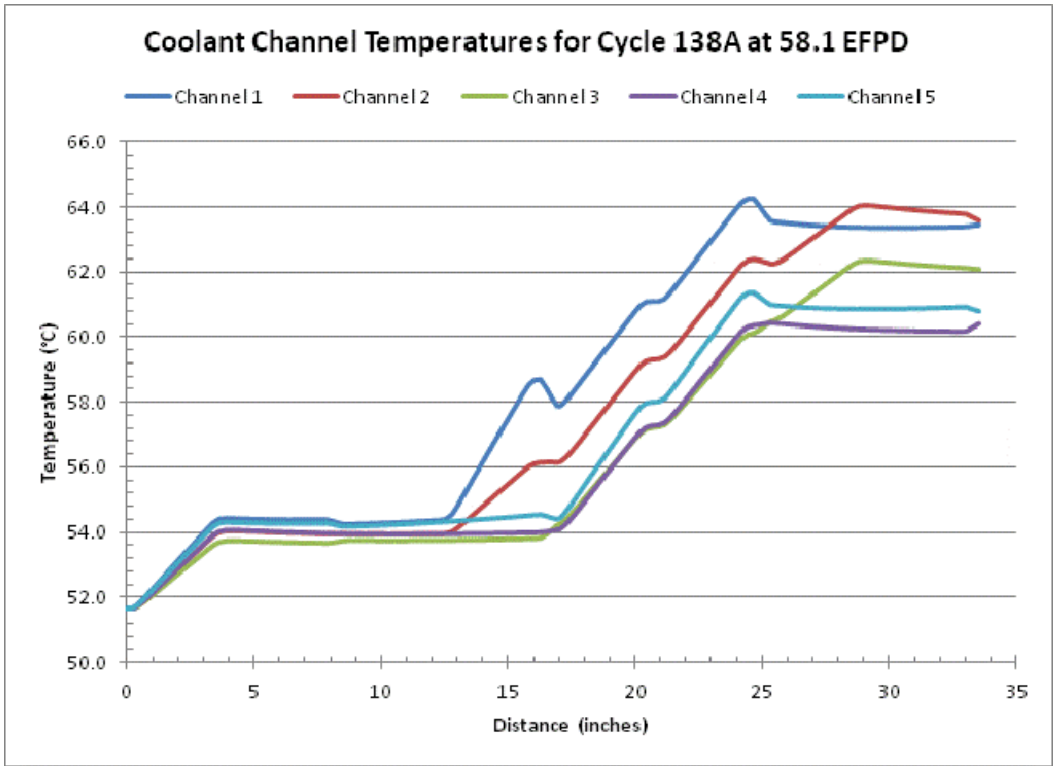


Figure 13. RERTR-8 coolant temperature as a function of location along the test assembly for Cycle 138A at 58.1 EFPD.

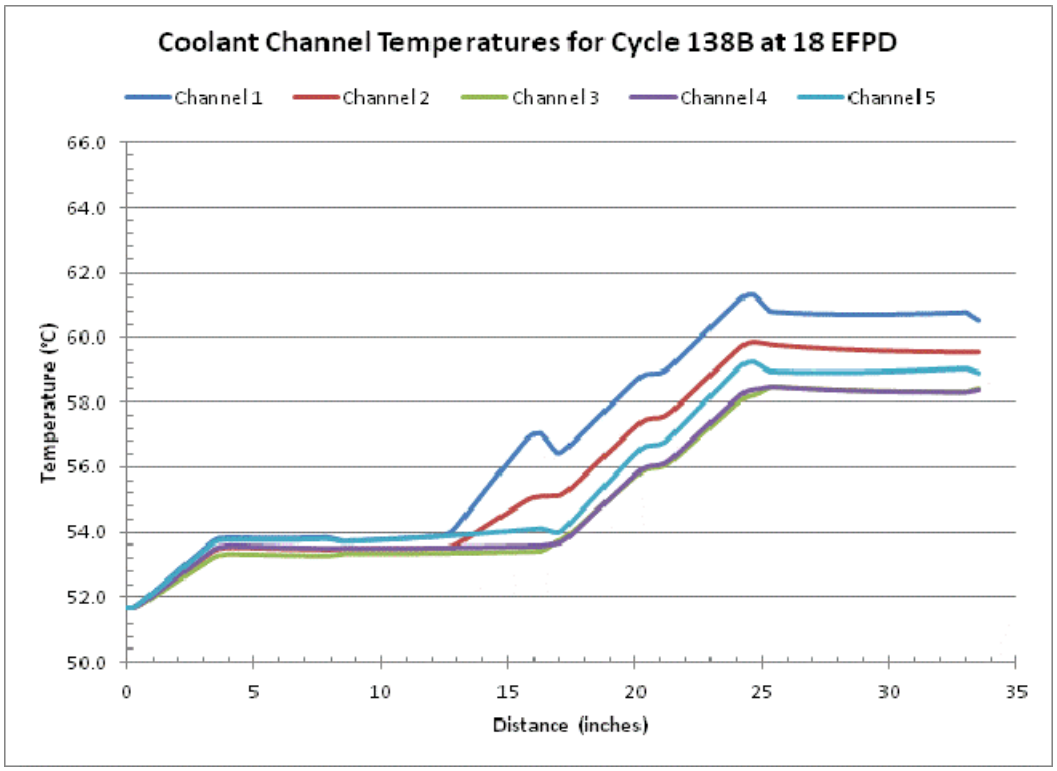


Figure 14. RERTR-8 coolant temperature as a function of location along the test assembly for Cycle 138B at 18 EFPD.

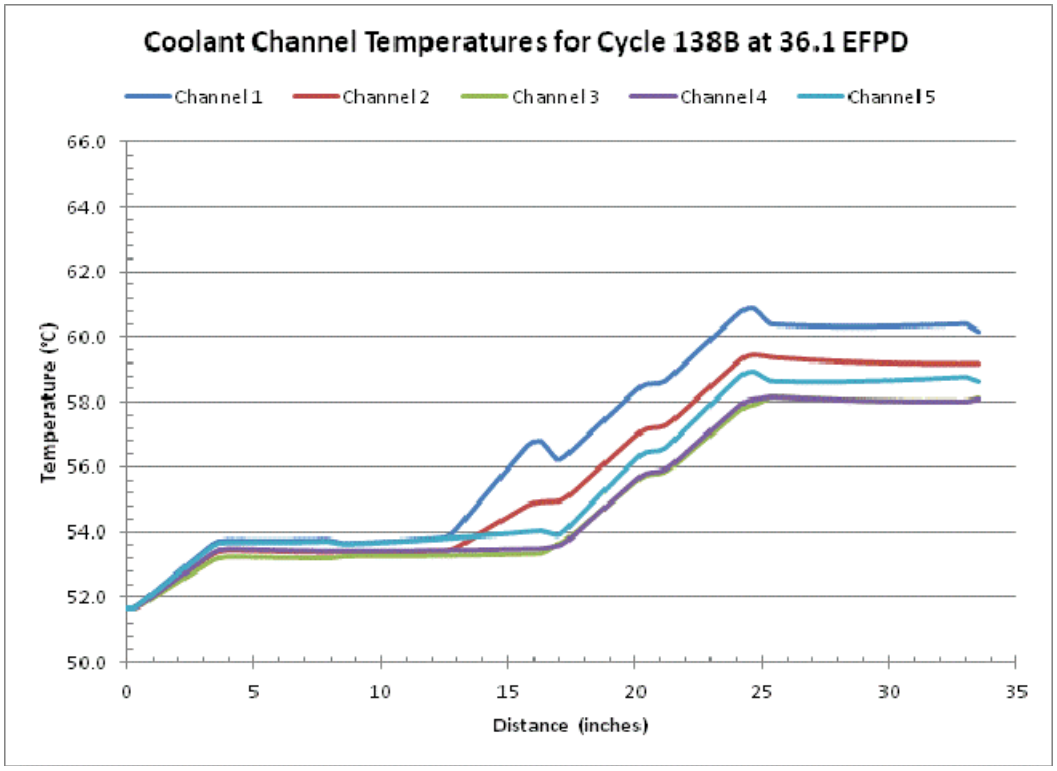


Figure 15. RERTR-8 coolant temperature as a function of location along the test assembly for Cycle 138B at 36.1 EFPD.

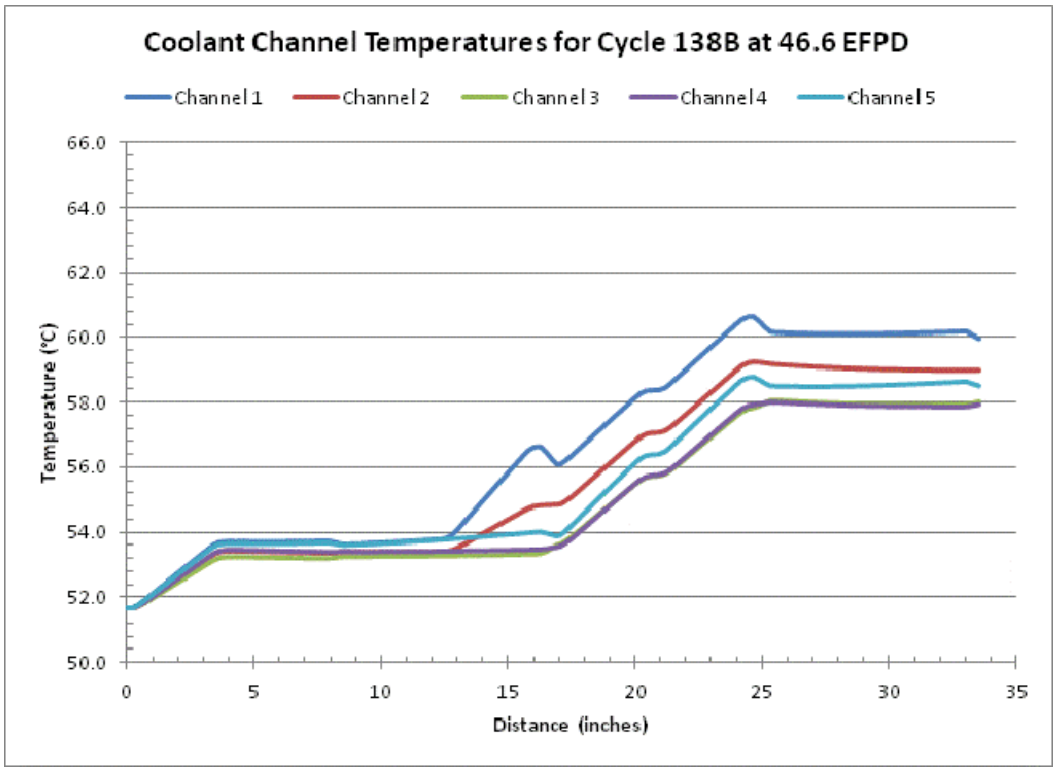


Figure 16. RERTR-8 coolant temperature as a function of location along the test assembly for Cycle 138B at 46.6 EFPD.

7.2 Plate Surface Temperature

The maximum, minimum, and average plate temperatures for each cycle are provided in Table 13 through Table 14.

Table 13. Plate surface temperatures for Cycle 138A at 58.1 EFPD.

Plate Location	Plate ID	Maximum Temp (°C)	Minimum Temp (°C)	Average Temp (°C)
A1	U0R060	95.61	51.01	72.63
A2	L1F200	83.12	51.56	67.03
A3	D3R040	86.18	51.31	68.51
A4	F3R030	93.08	51.19	71.43
A5	Blank	--	--	--
A6	Blank	--	--	--
A7	Blank	--	--	--
A8	Blank	--	--	--
B1	Blank	--	--	--
B2	Blank	--	--	--
B3	Blank	--	--	--
B4	Blank	--	--	--
B5	H1P02B	117.72	49.58	92.46
B6	Blank	--	--	--
B7	Blank	--	--	--
B8	Blank	--	--	--
C1	L1P020	109.10	55.97	88.07
C2	J1F020	100.26	54.47	82.90
C3	L1F190	96.48	54.10	80.65
C4	H1P010	106.35	53.88	85.89
C5	D3R030	112.17	57.09	91.43
C6	U0R040	103.56	55.49	86.25
C7	R3R060	100.32	55.08	84.32
C8	F3R040	109.38	55.00	89.22
D1	Blank	--	--	--
D2	R9R010	117.33	58.06	95.54
D3	Blank	--	--	--
D4	Blank	--	--	--
D5	Blank	--	--	--
D6	Blank	--	--	--
D7	Blank	--	--	--
D8	Blank	--	--	--

Table 14. Plate surface temperatures for Cycle 138B at 46.6 EFPD.

Plate Location	Plate ID	Maximum Temp (°C)	Minimum Temp (°C)	Average Temp (°C)
A1	U0R060	85.16	51.27	67.57
A2	L1F200	76.22	51.64	63.62
A3	D3R040	78.79	51.44	64.85
A4	F3R030	83.56	51.40	66.82
A5	Blank	--	--	--
A6	Blank	--	--	--
A7	Blank	--	--	--
A8	Blank	--	--	--
B1	Blank	--	--	--
B2	Blank	--	--	--
B3	Blank	--	--	--
B4	Blank	--	--	--
B5	H1P02B	96.99	50.71	79.76
B6	Blank	--	--	--
B7	Blank	--	--	--
B8	Blank	--	--	--
C1	L1P020	92.96	54.91	77.92
C2	J1F020	87.65	53.81	74.78
C3	L1F190	84.86	53.59	73.08
C4	H1P010	90.82	53.59	76.24
C5	D3R030	95.32	55.70	80.46
C6	U0R040	90.59	54.56	77.66
C7	R3R060	88.34	54.31	76.27
C8	F3R040	93.37	54.38	78.91
D1	Blank	--	--	--
D2	R9R010	59.22	58.13	58.62
D3	Blank	--	--	--
D4	Blank	--	--	--
D5	Blank	--	--	--
D6	Blank	--	--	--
D7	Blank	--	--	--
D8	Blank	--	--	--

8. REFERENCES

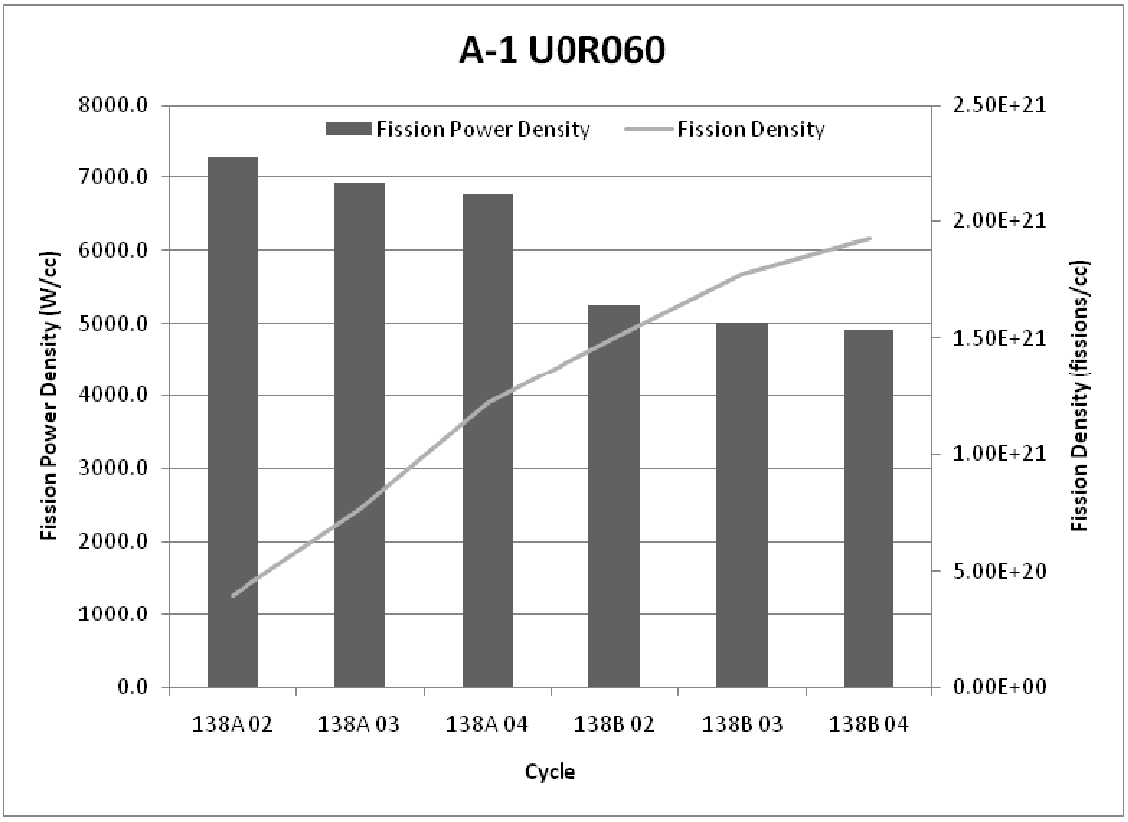
1. Wachs, D. M. "RERTR Fuel Development and Qualification Plan," INL/EXT-05-01017 Rev 4, August 2009.
2. RERTR Project Personnel, 2007, "RERTR 8 Irradiation Experiment in the Advanced Test Reactor: As-Built Data Package" RERTR-8, October 2006.
3. M. A. Lillo, G. S. Chang,"RERTR-8 As-Run Physics Analysis and Test Train Isotopes Radiological Characterization Versus Cooling Time," EDF-7868, April 2007.
4. M. A. Lillo, G. S. Chang, "MCNP-Calculated Gradients Across RERTR-8 Miniplates Irradiated in ATR," ECAR-234, July 2008.
5. Wachs, D. M., "RERTR Large B Position Irradiation Vehicle Flow Test," EDF-8292, July 2007.
6. Wachs, D. M., "Thermal Estimation of Critical Thermal Hydraulic Conditions for RERTR-8," EDF-7325, October 2006.
7. P. E. Murray, "Validation of ABAQUS Standard 6.7-3 Heat Transfer," ECAR-131, January 2008.
8. R. H. Perry, D. W. Green, "Perry's Chemical Engineer's Handbook," 7th Edition, McGraw-Hill, 1997.

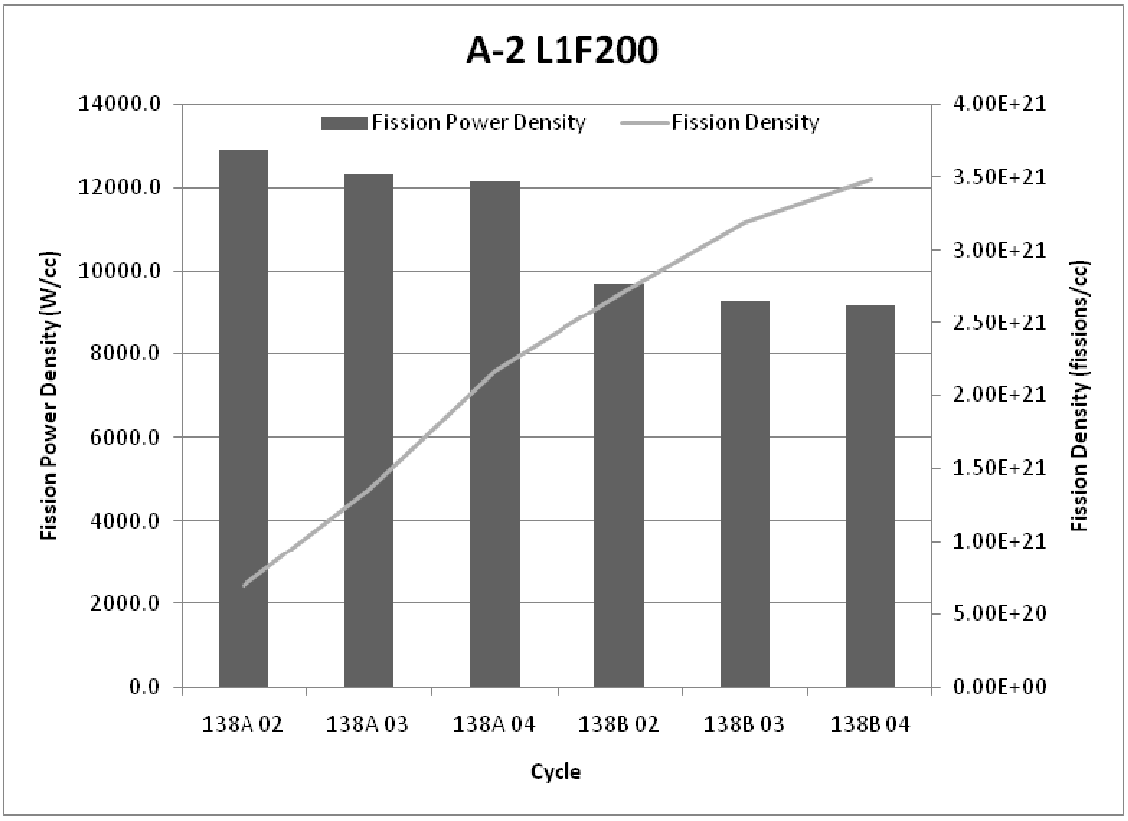
Appendix A

Individual Plate Power and Burnup Plots

Appendix A
Individual Plate Power and Burnup Plots

A-1. RERTR-8

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Fission Density (fissions/cc)
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1.50E+21
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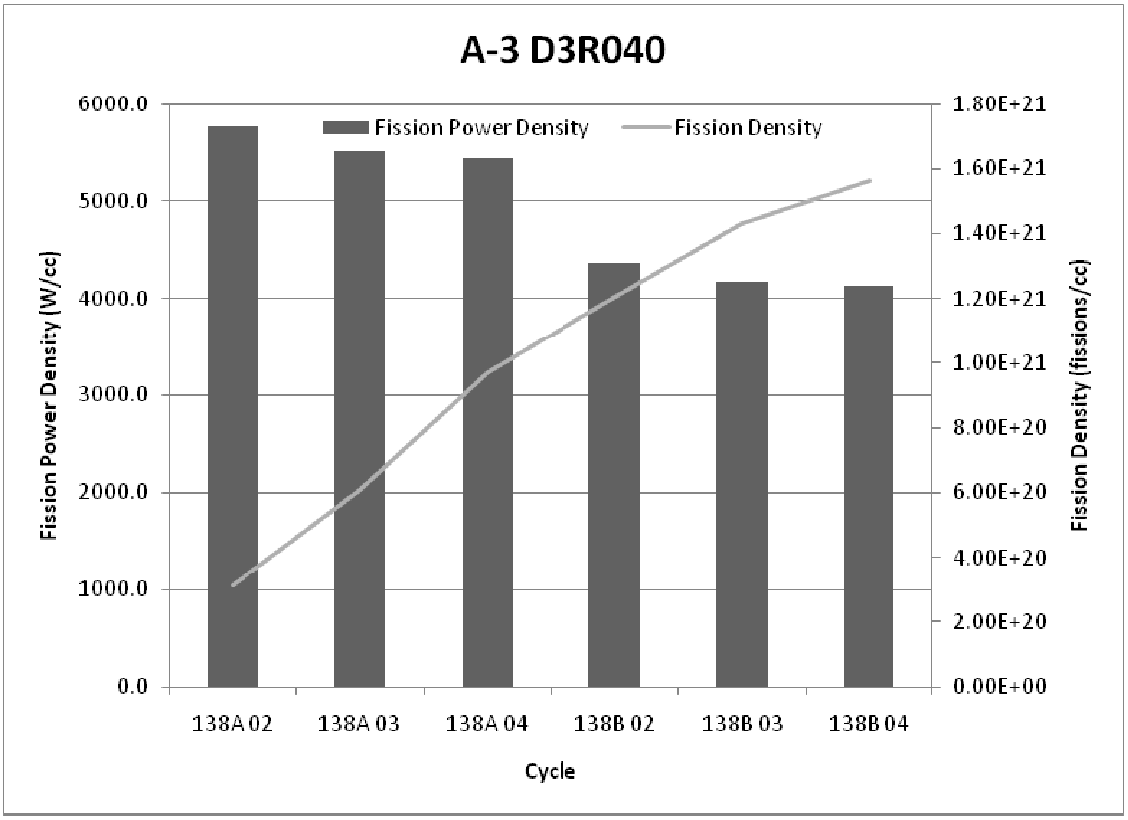
138A 03
138A 04
138B 02
138B 03
138B 04
Cycle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Fission Density (fissions/cc)
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3000.0
2000.0
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138A 03
138A 04
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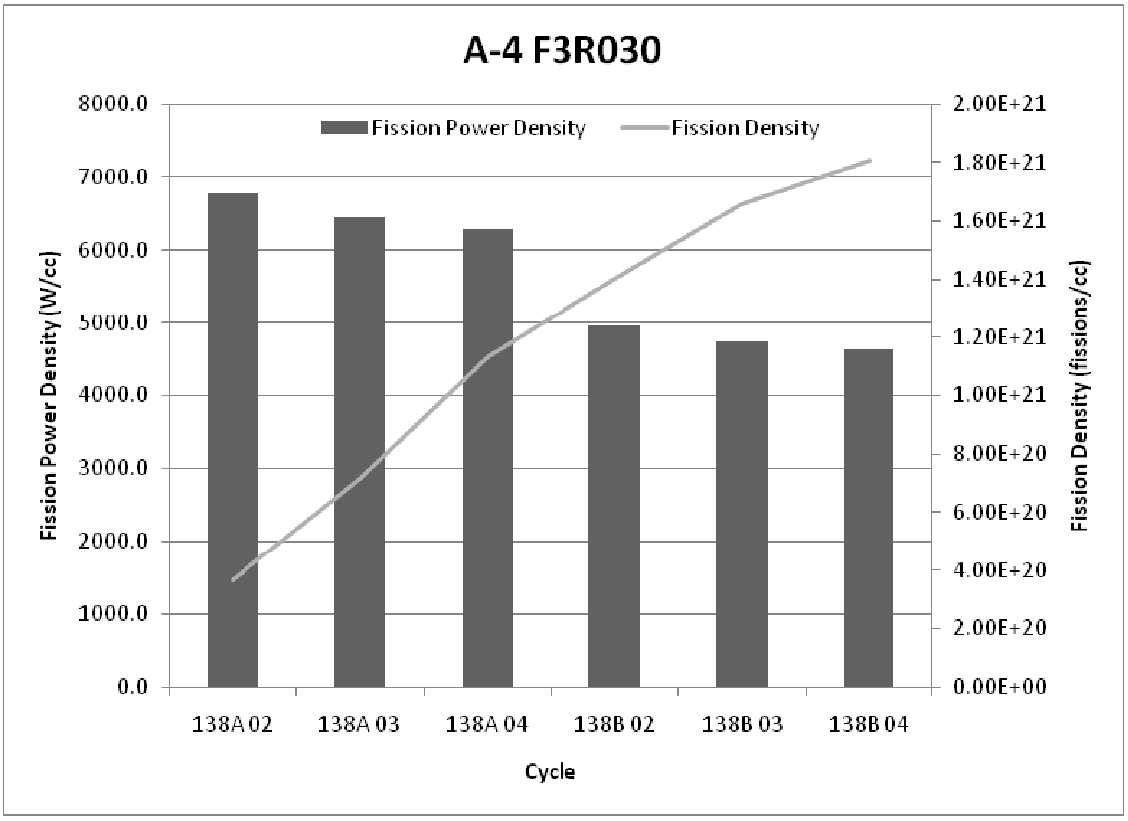
138B 03
138B 04
Cycle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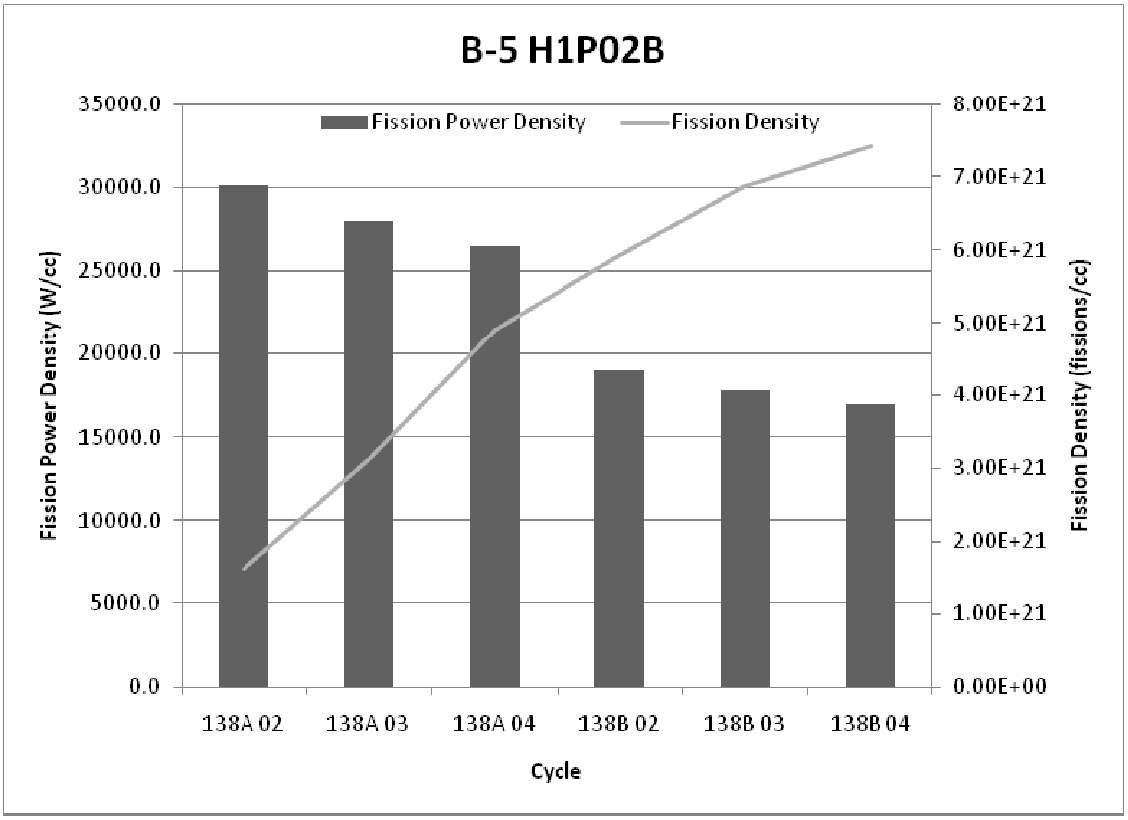
138A 03
138A 04
138B 02
138B 03
138B 04
Cycle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Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
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20000.0
15000.0
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4.00E+21
3.00E+21
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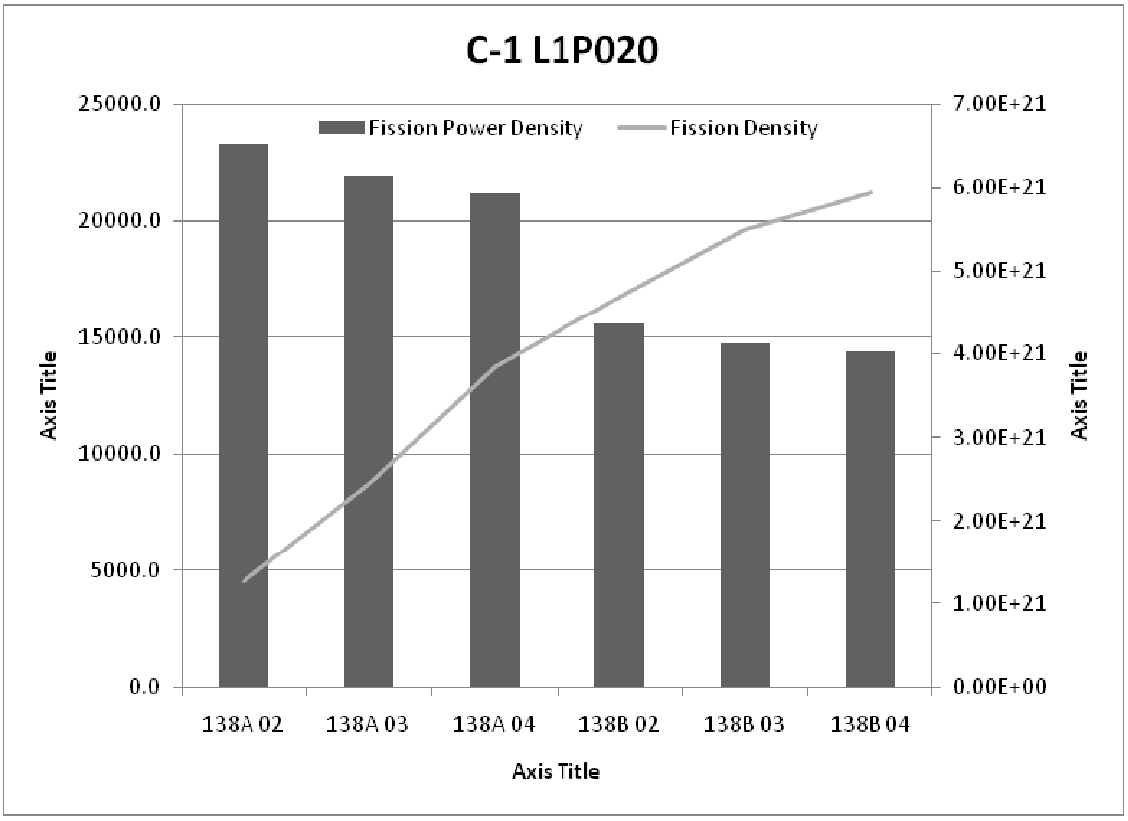
138A 03
138A 04
138B 02
138B 03
138B 04
Cycle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2.00E+21
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Axis Title
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138A 03
138A 04
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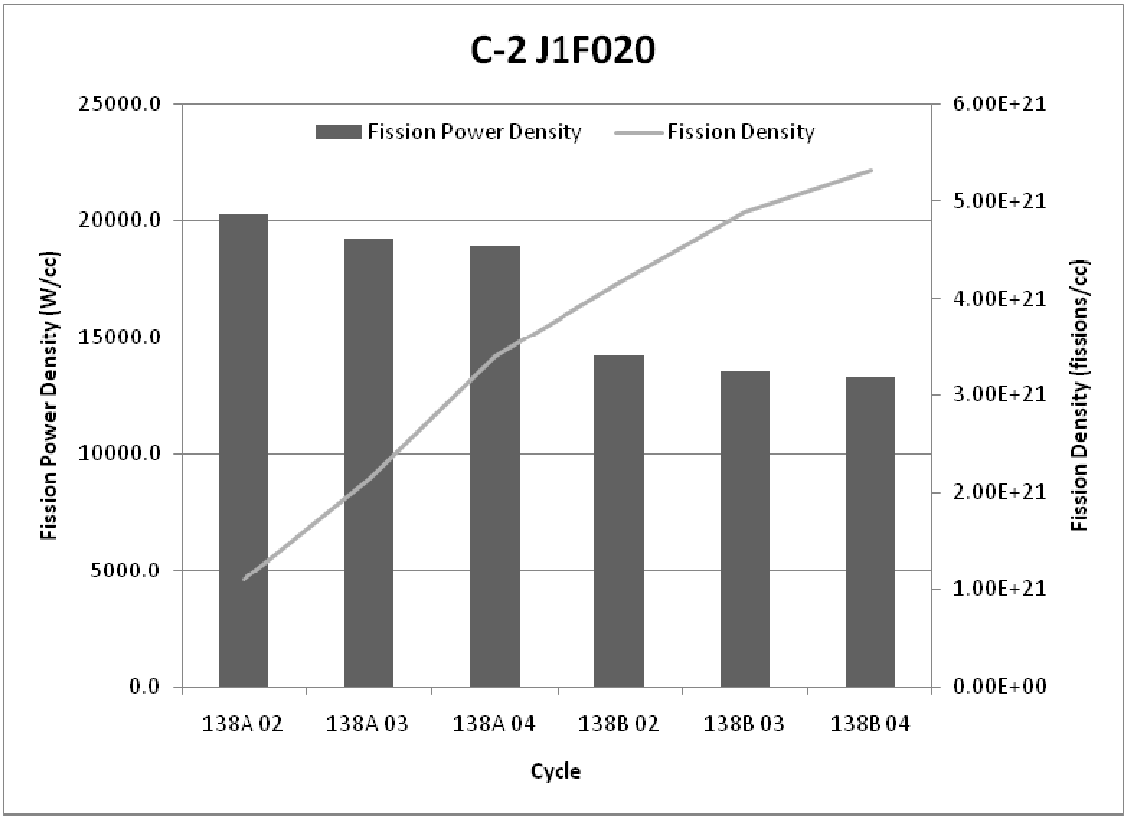
138B 03
138B 04
Axis Title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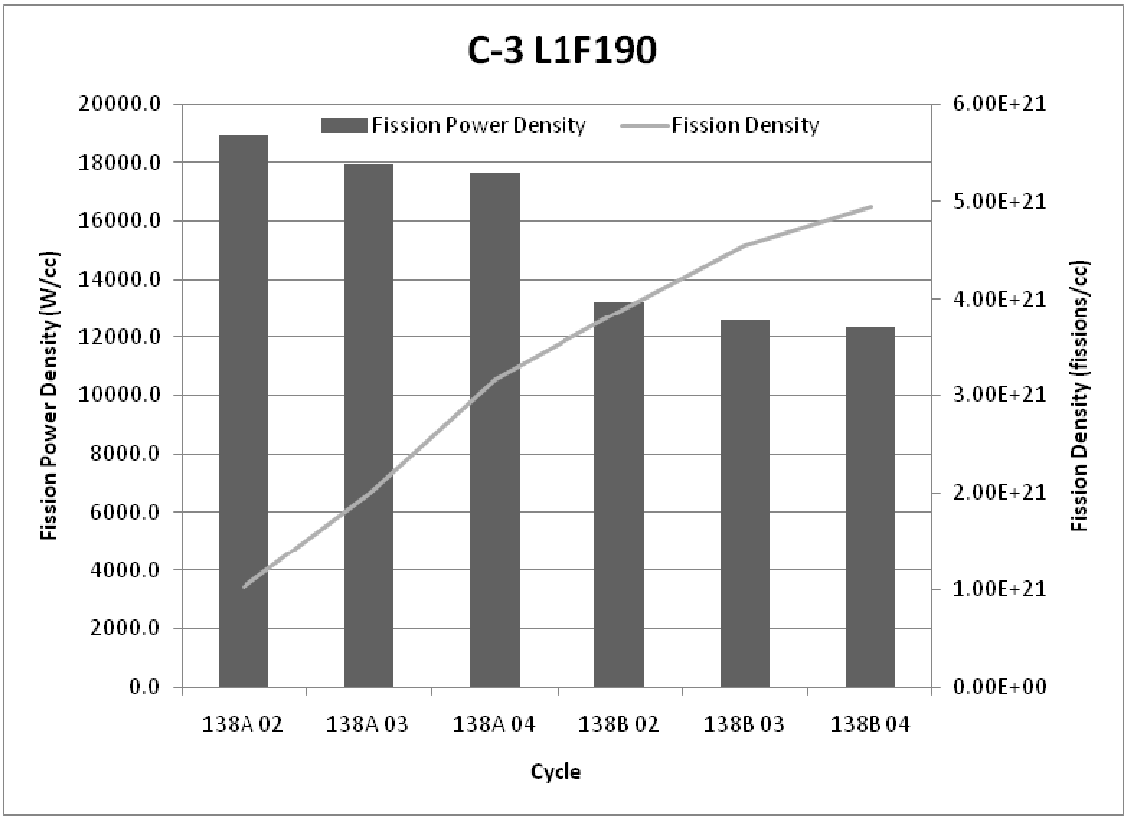
5.00E+21
4.00E+21
3.00E+21
2.00E+21
1.00E+21
0.00E+00
Fission Power Density (W/cc)
Fission Density (fissions/cc)
138A 02
138A 03
138A 04
138B 02
138B 03
138B 04
Cycle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138A 03
138A 04
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138B 03
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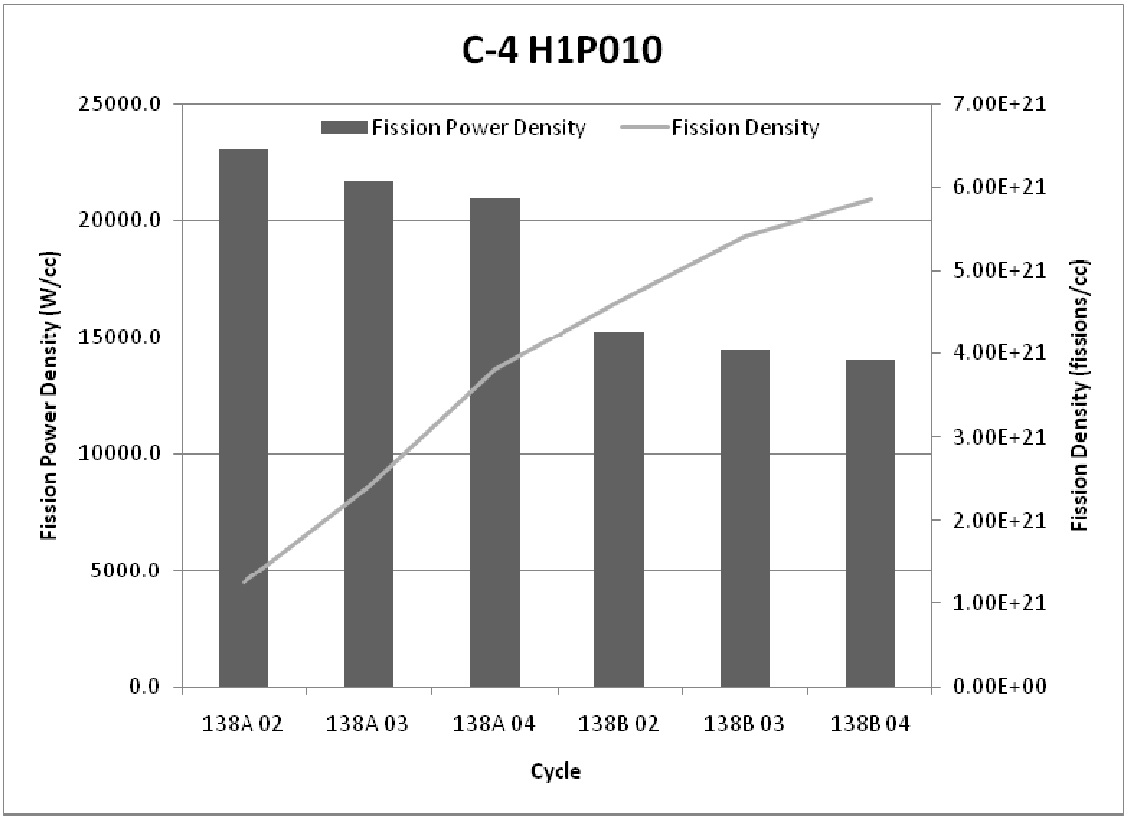
Cycle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Fission Density
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Fission Density (fissions/cc)
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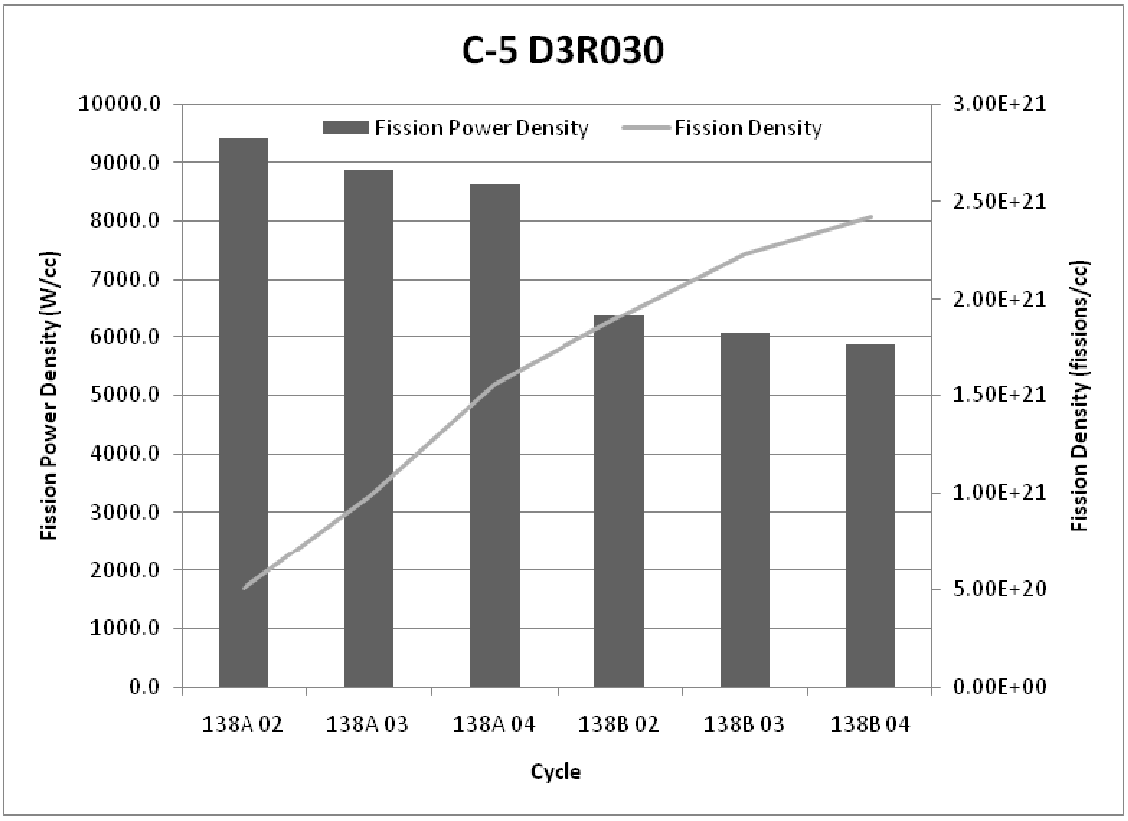
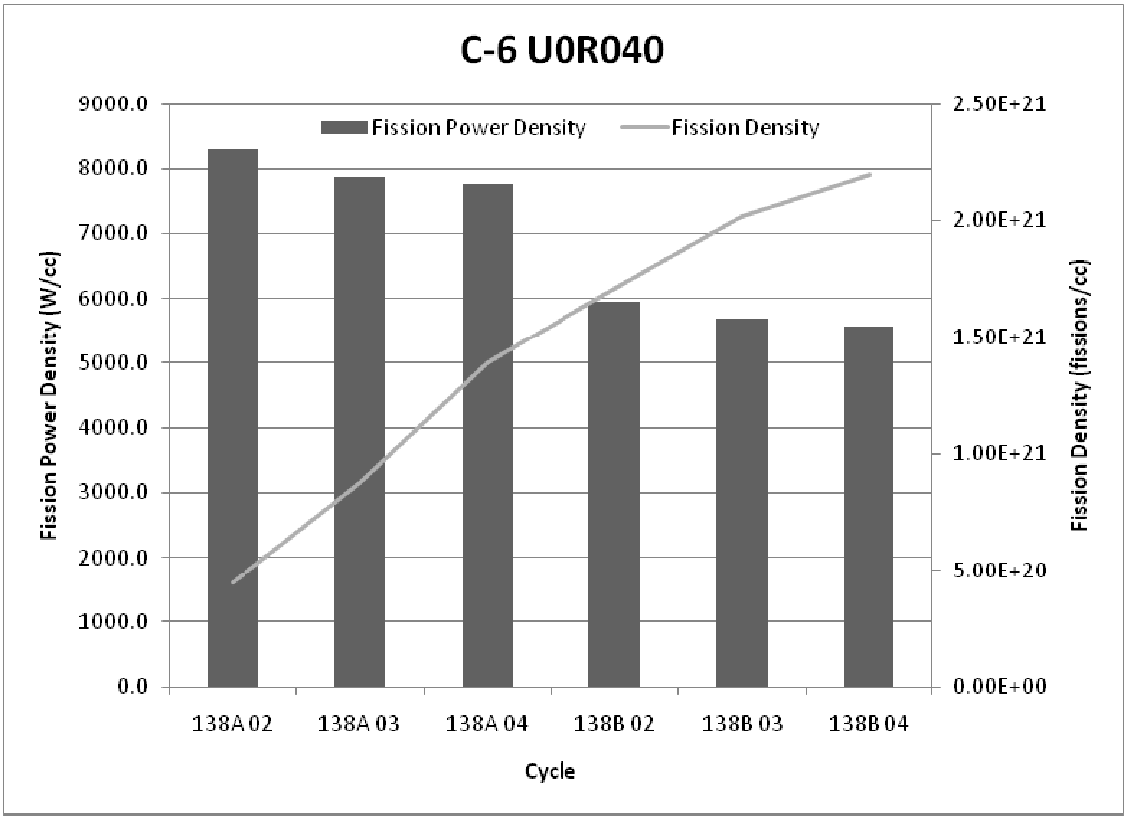
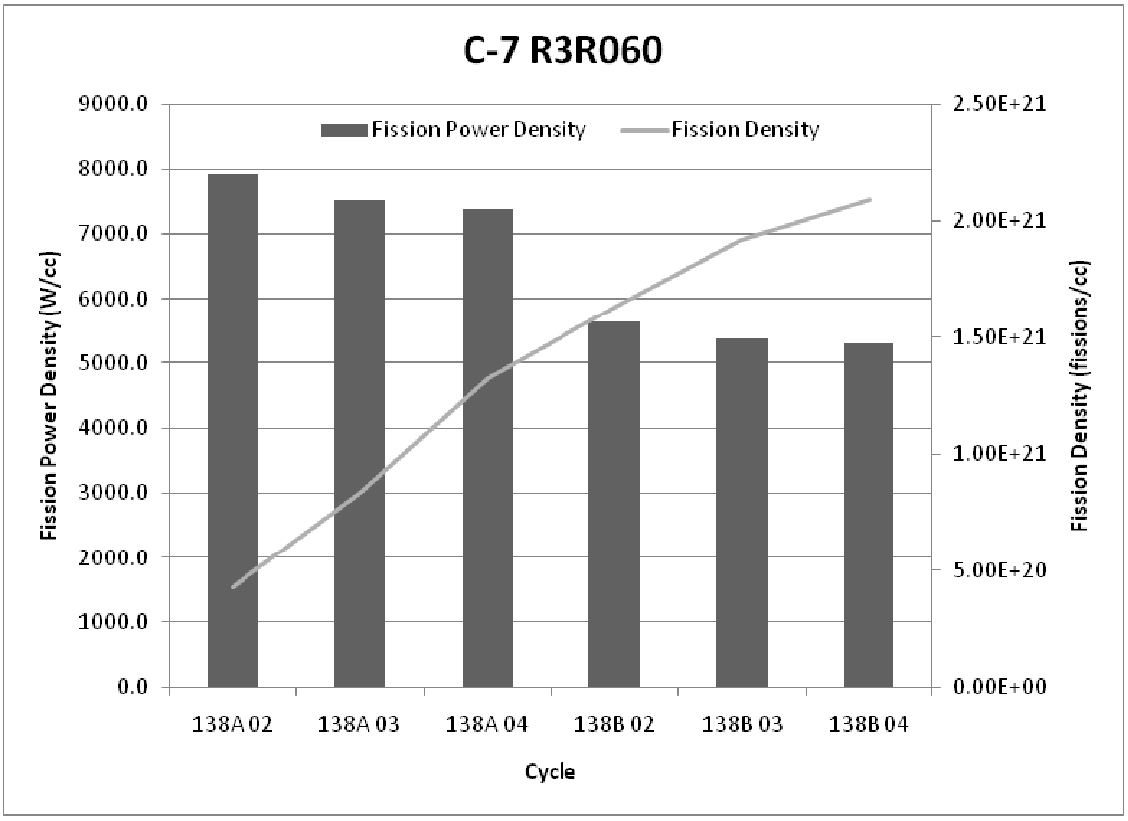
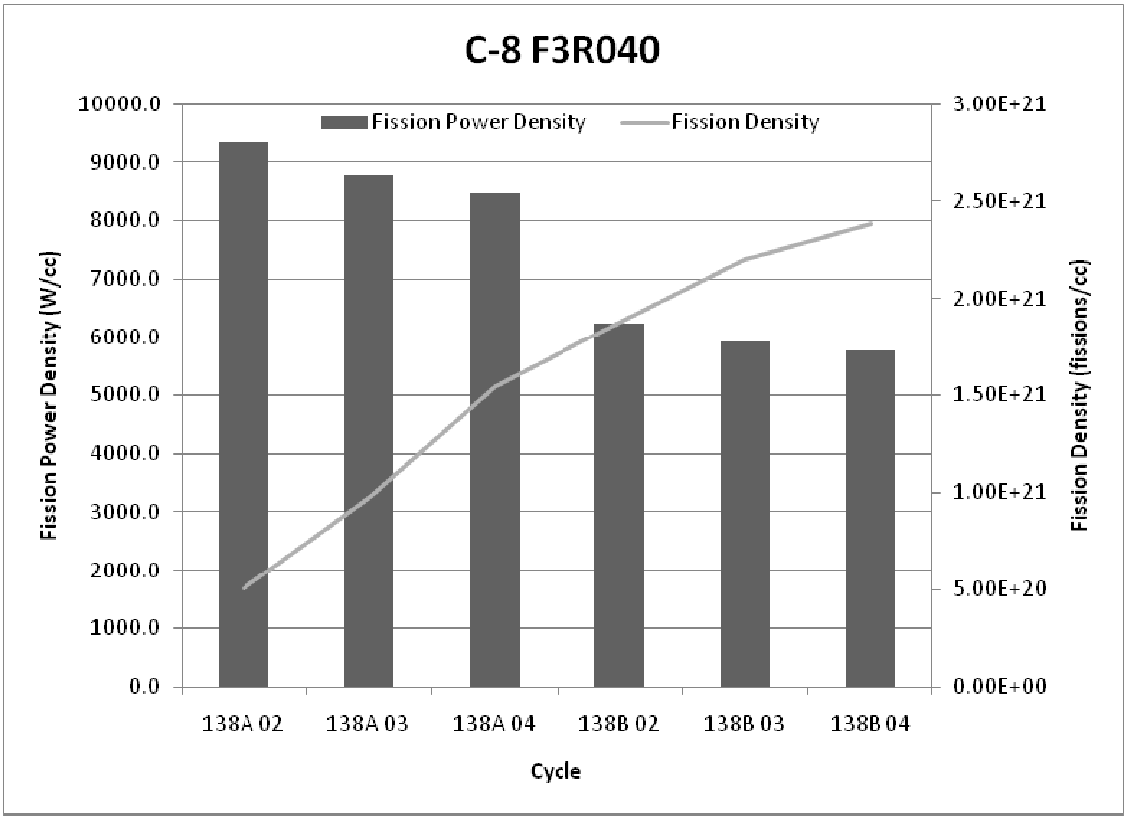
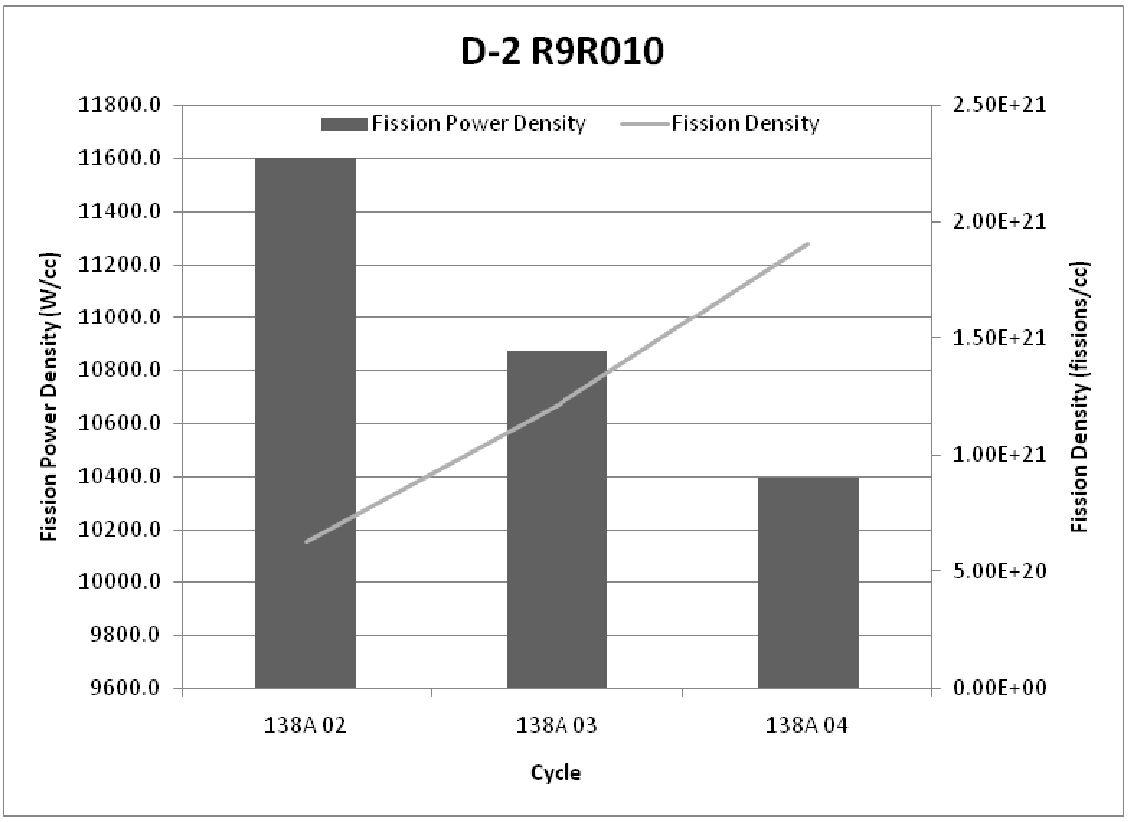
138A 03
138A 04
138B 02
138B 03
138B 04
Cycle


C-5 D3R030
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
10000.0
9000.0
8000.0
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
0.00E+00
138A 02
138A 03
138A 04
138B 02
138B 03
138B 04
Cycle


C-6 U0R040
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
9000.0
8000.0
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
0.00E+00
138A 02
138A 03
138A 04
138B 02
138B 03
138B 04
Cycle


C-7 R3R060
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
9000.0
8000.0
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
0.00E+00
138A 02
138A 03
138A 04
138B 02
138B 03
138B 04
Cycle


C-8 F3R040
Fission Power Density
Fission Density
Fission Power Density (W/cc)
Fission Density (fissions/cc)
10000.0
9000.0
8000.0
7000.0
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
3.00E+21
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
0.00E+00
138A 02
138A 03
138A 04
138B 02
138B 03
138B 04
Cycle


D-2 R9R010
Fission Power Density
Fission Density
11800.0
11600.0
11400.0
11200.0
11000.0
10800.0
10600.0
10400.0
10200.0
10000.0
9800.0
9600.0
Fission Power Density (W/cc)
2.50E+21
2.00E+21
1.50E+21
1.00E+21
5.00E+20
0.00E+00
Fission Density (fissions/cc)
138A 02
138A 03
138A 04
Cycle

Appendix B

Local-To-Average Ratio Gradient Tables

Table B- 1 RERTR-8 thermal neutron flux local to average ratio (L2AR) in transverse direction (from core center plate edge to outer plate edge)[4]

ID	Fuel Phase	Fuel Type	Core Center Edge Position 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Outer Edg 20
A-1	U_3Si_2	disp	1.75	1.47	1.32	1.22	1.18	1.09	1.02	0.99	0.97	0.93	0.90	0.85	0.85	0.82	0.79	0.77	0.78	0.74	0.74	0.81
A-2	U-10Mo	mono	1.97	1.60	1.48	1.32	1.22	1.14	1.00	0.97	0.91	0.85	0.84	0.81	0.77	0.73	0.73	0.73	0.70	0.71	0.73	0.78
A-3	U-7Mo-1Ti	disp	2.05	1.65	1.46	1.32	1.18	1.08	1.03	0.97	0.91	0.85	0.83	0.79	0.76	0.74	0.71	0.72	0.73	0.70	0.73	0.79
A-4	U-7Mo-2Zr	disp	1.73	1.46	1.30	1.23	1.18	1.11	1.02	1.00	0.97	0.91	0.87	0.87	0.82	0.83	0.81	0.77	0.78	0.78	0.78	0.79
A-5	--	blank	1.25	1.24	1.20	1.17	1.16	1.14	1.10	1.08	1.05	1.01	0.98	0.95	0.93	0.91	0.89	0.85	0.82	0.79	0.76	0.72
A-6	--	blank	1.28	1.25	1.21	1.19	1.15	1.14	1.11	1.10	1.04	1.01	0.98	0.96	0.94	0.90	0.88	0.84	0.82	0.78	0.73	0.68
A-7	--	blank	1.27	1.24	1.22	1.19	1.16	1.13	1.10	1.09	1.05	1.02	1.00	0.96	0.94	0.90	0.87	0.85	0.80	0.77	0.74	0.69
A-8	--	blank	1.25	1.24	1.22	1.18	1.14	1.12	1.09	1.07	1.05	1.02	0.99	0.96	0.93	0.92	0.89	0.85	0.82	0.78	0.76	0.72
B-1	--	blank	1.27	1.23	1.21	1.18	1.16	1.11	1.10	1.06	1.04	1.02	1.01	0.97	0.95	0.91	0.88	0.85	0.82	0.78	0.75	0.71
B-2	--	blank	1.27	1.24	1.22	1.16	1.17	1.15	1.13	1.09	1.04	1.02	0.99	0.97	0.94	0.89	0.88	0.83	0.81	0.77	0.74	0.69
B-3	--	blank	1.28	1.24	1.23	1.20	1.17	1.14	1.10	1.08	1.04	1.02	1.00	0.95	0.93	0.90	0.87	0.85	0.80	0.77	0.75	0.70
B-4	--	blank	1.26	1.22	1.20	1.19	1.15	1.12	1.10	1.08	1.05	1.02	0.98	0.97	0.94	0.92	0.89	0.84	0.83	0.79	0.76	0.71
B-5	U-12Mo w/BorAl	mono	1.47	1.32	1.26	1.19	1.15	1.11	1.08	1.04	1.00	1.00	0.96	0.93	0.88	0.85	0.85	0.84	0.80	0.76	0.77	0.75
B-6	--	blank	1.39	1.34	1.28	1.23	1.18	1.14	1.10	1.06	1.01	0.98	0.96	0.92	0.90	0.88	0.84	0.82	0.79	0.75	0.73	0.70
B-7	--	blank	1.33	1.28	1.24	1.22	1.17	1.13	1.11	1.08	1.05	1.01	0.99	0.93	0.91	0.90	0.86	0.83	0.79	0.76	0.72	0.70
B-8	--	blank	1.30	1.29	1.23	1.20	1.17	1.12	1.07	1.06	1.03	1.01	0.98	0.95	0.92	0.91	0.88	0.85	0.81	0.77	0.75	0.72
C-1	U-10Mo	mono	1.67	1.44	1.35	1.24	1.18	1.10	1.04	1.01	0.95	0.91	0.91	0.88	0.84	0.82	0.82	0.79	0.78	0.75	0.76	0.77
C-2	U-8Mo	mono	1.89	1.62	1.44	1.30	1.20	1.11	1.05	0.99	0.90	0.87	0.83	0.81	0.79	0.74	0.74	0.73	0.73	0.73	0.75	0.78
C-3	U-10Mo	mono	1.86	1.59	1.44	1.29	1.19	1.14	1.04	0.99	0.90	0.89	0.87	0.82	0.77	0.76	0.74	0.72	0.72	0.72	0.75	0.78
C-4	U-12Mo	mono	1.67	1.46	1.35	1.24	1.15	1.13	1.06	0.98	0.96	0.91	0.90	0.85	0.83	0.82	0.79	0.78	0.79	0.76	0.77	0.77
C-5	U-7Mo-1Ti	disp	1.79	1.50	1.33	1.25	1.15	1.09	1.04	0.98	0.97	0.91	0.88	0.85	0.82	0.80	0.79	0.79	0.76	0.73	0.77	0.81
C-6	U_3Si_2	disp	2.07	1.68	1.47	1.29	1.18	1.07	1.01	0.94	0.88	0.85	0.82	0.78	0.77	0.74	0.75	0.70	0.71	0.73	0.75	0.82
C-7	U-7Mo	disp	2.00	1.65	1.44	1.31	1.17	1.08	1.03	0.98	0.89	0.85	0.82	0.79	0.78	0.76	0.71	0.71	0.73	0.73	0.75	0.81
C-8	U-7Mo-2Zr	disp	1.75	1.50	1.33	1.25	1.15	1.08	1.05	0.98	0.95	0.91	0.89	0.86	0.83	0.80	0.79	0.78	0.78	0.76	0.77	0.79
D-1	--	blank	1.42	1.36	1.27	1.19	1.14	1.10	1.06	1.03	1.01	0.96	0.94	0.92	0.91	0.89	0.86	0.83	0.81	0.78	0.77	0.75
D-2	U-7Mo	disp	1.64	1.37	1.27	1.20	1.15	1.09	1.06	1.01	1.01	0.96	0.91	0.90	0.88	0.85	0.83	0.80	0.78	0.76	0.74	0.78
D-3	--	blank	1.42	1.38	1.31	1.22	1.18	1.13	1.07	1.05	1.03	0.97	0.93	0.92	0.89	0.85	0.83	0.80	0.80	0.77	0.73	0.71
D-4	--	blank	1.33	1.31	1.26	1.21	1.17	1.12	1.09	1.06	1.04	1.00	0.96	0.93	0.92	0.88	0.86	0.83	0.79	0.78	0.74	0.72
D-5	--	blank	1.27	1.22	1.21	1.17	1.16	1.12	1.09	1.06	1.07	1.02	0.99	0.97	0.94	0.92	0.88	0.85	0.81	0.78	0.76	0.71
D-6	--	blank	1.28	1.26	1.23	1.19	1.16	1.12	1.11	1.09	1.05	1.01	1.00	0.96	0.93	0.91	0.87	0.84	0.80	0.77	0.73	0.69
D-7	--	blank	1.29	1.26	1.24	1.21	1.17	1.12	1.10	1.08	1.05	1.01	0.96	0.94	0.93	0.91	0.88	0.84	0.80	0.77	0.73	0.69
D-8	--	blank	1.28	1.25	1.21	1.20	1.14	1.12	1.10	1.07	1.04	1.00	0.99	0.96	0.94	0.91	0.88	0.85	0.82	0.79	0.75	0.71

Table B- 2 RERTR-8 thermal neutron flux local to average ratio (L2AR) in axial direction (from core center plate edge to outer plate edge)[4]

ID	Fuel Phase	Fuel Type	Core Center Edge Position 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Outer Edg 20
A-1	U_3Si_2	disp	1.07	0.94	0.94	0.93	0.90	0.91	0.91	0.95	0.95	0.94	0.96	0.98	0.99	0.98	1.02	1.01	1.05	1.07	1.18	1.33
A-2	U-10Mo	mono	1.16	0.97	0.90	0.91	0.89	0.90	0.90	0.91	0.94	0.95	0.95	0.95	1.01	0.96	0.99	0.98	1.05	1.06	1.15	1.47
A-3	U-7Mo-1Ti	disp	1.19	0.95	0.91	0.91	0.89	0.87	0.92	0.91	0.92	0.90	0.93	0.95	0.99	1.00	1.01	1.02	1.04	1.08	1.17	1.44
A-4	U-7Mo-2Zr	disp	1.08	0.94	0.92	0.91	0.90	0.88	0.93	0.93	0.96	0.96	0.94	0.97	0.98	1.01	1.02	1.05	1.06	1.10	1.14	1.34
A-5	--	blank	0.90	0.90	0.91	0.93	0.95	0.95	0.96	0.98	0.99	1.02	1.01	1.01	1.02	1.04	1.04	1.03	1.08	1.08	1.07	1.14
A-6	--	blank	0.88	0.90	0.92	0.93	0.94	0.93	0.96	0.99	0.98	1.01	1.03	1.01	1.04	1.03	1.05	1.05	1.07	1.08	1.09	1.10
A-7	--	blank	0.90	0.91	0.92	0.92	0.96	0.95	0.96	0.97	0.99	0.99	1.02	1.04	1.04	1.02	1.03	1.05	1.06	1.07	1.11	1.09
A-8	--	blank	0.93	0.92	0.94	0.96	0.97	0.95	0.96	0.96	0.98	0.98	1.02	1.01	1.05	1.04	1.03	1.01	1.04	1.07	1.09	1.09
B-1	--	blank	0.97	0.98	1.00	0.99	0.99	0.98	0.98	0.99	1.00	0.97	1.01	1.03	1.00	1.00	1.01	1.02	1.01	1.03	1.02	1.02
B-2	--	blank	0.99	0.98	0.99	0.98	0.97	0.96	0.98	0.98	1.00	1.01	1.00	1.00	1.00	1.02	1.03	1.00	1.00	1.02	1.03	1.04
B-3	--	blank	0.96	0.96	0.95	0.99	0.99	0.96	0.97	0.98	0.98	1.00	1.02	1.01	1.02	1.02	1.02	1.03	1.02	1.03	1.02	1.04
B-4	--	blank	0.98	0.98	0.98	0.99	0.98	0.99	0.97	0.97	0.99	1.01	1.02	1.02	1.02	1.01	1.02	1.02	1.02	1.01	1.03	1.02
B-5	U-12Mo w/BorAl	mono	1.03	0.98	0.97	0.98	0.97	0.97	0.97	0.97	1.00	0.98	0.99	0.98	0.99	0.98	1.01	1.00	1.02	1.03	1.07	1.12
B-6	--	blank	1.04	1.02	0.97	0.98	0.98	0.95	0.98	0.98	0.99	0.98	0.99	0.98	0.98	0.99	1.00	1.00	1.03	1.02	1.03	1.12
B-7	--	blank	0.98	1.01	1.02	0.97	0.99	0.97	0.99	0.98	0.99	0.99	1.01	0.97	0.99	0.99	1.01	1.01	1.03	1.03	1.03	1.05
B-8	--	blank	0.97	0.98	0.98	0.98	0.97	0.94	0.99	0.98	0.97	1.00	0.99	1.00	1.00	1.03	1.02	1.02	1.03	1.04	1.05	1.06
C-1	U-10Mo	mono	1.20	1.11	1.02	1.00	1.00	0.99	0.98	0.96	0.97	0.95	0.96	0.97	0.95	0.94	0.94	0.97	0.97	0.99	1.01	1.12
C-2	U-8Mo	mono	1.28	1.08	1.04	0.99	0.96	0.98	0.96	0.95	0.94	0.95	0.96	0.96	0.93	0.95	0.93	0.95	0.96	0.99	1.03	1.20
C-3	U-10Mo	mono	1.31	1.06	1.02	1.00	0.97	0.95	0.98	0.96	0.95	0.94	0.95	0.98	0.97	0.92	0.91	0.94	0.97	0.95	1.03	1.22
C-4	U-12Mo	mono	1.16	1.07	1.05	0.99	0.98	0.99	0.97	0.96	0.97	0.96	0.98	0.97	0.96	0.98	0.95	0.98	0.96	0.98	0.99	1.13
C-5	U-7Mo-1Ti	disp	1.19	1.02	1.01	1.00	1.00	0.96	0.98	0.97	0.97	0.96	0.96	0.96	0.95	0.96	0.96	0.95	0.97	1.01	1.01	1.22
C-6	U_3Si_2	disp	1.27	1.06	0.99	0.99	0.98	0.96	0.97	0.95	0.96	0.93	0.93	0.92	0.93	0.94	0.96	0.95	0.96	0.96	1.06	1.31
C-7	U-7Mo	disp	1.29	1.05	1.02	0.98	0.97	0.96	0.95	0.96	0.96	0.95	0.92	0.93	0.93	0.94	0.95	0.96	0.96	0.96	1.06	1.30
C-8	U-7Mo-2Zr	disp	1.17	1.05	1.02	0.98	0.99	0.99	0.95	0.97	0.96	0.96	0.95	0.95	0.95	0.94	0.96	0.95	0.97	1.02	1.06	1.20
D-1	--	blank	1.13	1.10	1.07	1.05	1.01	1.03	1.03	1.03	1.00	0.97	0.99	0.97	0.99	0.96	0.95	0.96	0.93	0.93	0.93	0.99
D-2	U-7Mo	disp	1.16	1.08	1.05	1.05	1.04	0.99	1.02	0.99	0.98	0.98	0.97	0.97	0.95	0.96	0.96	0.95	0.94	0.96	0.96	1.04
D-3	--	blank	1.15	1.07	1.07	1.06	1.03	1.00	1.00	0.99	0.99	0.97	0.99	0.96	0.95	0.94	0.96	0.96	0.94	0.97	0.98	1.03
D-4	--	blank	1.10	1.08	1.09	1.03	1.03	1.02	1.02	1.00	0.98	0.98	0.99	0.97	0.97	0.98	0.95	0.96	0.94	0.96	0.97	1.00
D-5	--	blank	1.08	1.05	1.04	1.03	1.06	1.05	1.03	1.02	1.01	0.99	0.99	0.99	0.98	0.97	0.95	0.96	0.97	0.96	0.94	0.92
D-6	--	blank	1.07	1.08	1.07	1.04	1.02	1.03	1.04	1.00	1.02	1.01	0.99	0.96	1.00	0.96	0.97	0.96	0.97	0.95	0.94	0.91
D-7	--	blank	1.06	1.04	1.06	1.02	1.05	1.03	1.04	1.03	1.01	0.99	1.00	0.99	0.99	0.98	0.95	0.97	0.96	0.95	0.94	0.93
D-8	--	blank	1.06	1.06	1.06	1.05	1.01	1.03	1.02	1.01	1.02	1.00	1.00	0.98	0.97	0.98	0.96	0.98	0.96	0.96	0.93	0.95

Table B- 3 RERTR-8 fission rate tally local to average ratio (L2AR) in transverse direction (from core center plate edge to outer plate edge)[4]

ID	Fuel Phase	Fuel Type	Core Center Edge Position 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Outer Edg 20
A-1	U_3Si_2	disp	1.76	1.47	1.32	1.22	1.17	1.09	1.02	0.99	0.97	0.92	0.90	0.85	0.85	0.82	0.79	0.77	0.78	0.74	0.75	0.81
A-2	U-10Mo	mono	1.98	1.60	1.49	1.32	1.22	1.14	1.00	0.97	0.91	0.84	0.84	0.81	0.77	0.73	0.73	0.73	0.70	0.71	0.73	0.78
A-3	U-7Mo-1Ti	disp	2.06	1.65	1.46	1.32	1.18	1.08	1.02	0.97	0.90	0.85	0.83	0.79	0.76	0.74	0.71	0.72	0.73	0.70	0.73	0.80
A-4	U-7Mo-2Zr	disp	1.73	1.46	1.30	1.23	1.18	1.10	1.02	1.00	0.97	0.91	0.87	0.87	0.82	0.83	0.81	0.77	0.78	0.78	0.78	0.79
A-5	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
A-6	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
A-7	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
A-8	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-1	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-2	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-3	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-4	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-5	U-12Mo w/BorAl	mono	1.47	1.32	1.26	1.19	1.15	1.10	1.08	1.05	1.00	1.00	0.96	0.92	0.88	0.85	0.85	0.84	0.80	0.76	0.77	0.75
B-6	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-7	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-8	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
C-1	U-10Mo	mono	1.68	1.44	1.35	1.24	1.17	1.10	1.04	1.01	0.95	0.91	0.91	0.88	0.84	0.81	0.82	0.79	0.78	0.75	0.76	0.77
C-2	U-8Mo	mono	1.90	1.63	1.44	1.31	1.20	1.11	1.05	0.99	0.90	0.86	0.83	0.81	0.79	0.74	0.74	0.73	0.73	0.73	0.75	0.78
C-3	U-10Mo	mono	1.86	1.59	1.44	1.29	1.19	1.14	1.04	0.99	0.90	0.89	0.86	0.82	0.76	0.76	0.74	0.72	0.73	0.73	0.75	0.78
C-4	U-12Mo	mono	1.67	1.46	1.35	1.24	1.15	1.13	1.06	0.98	0.96	0.91	0.89	0.85	0.83	0.83	0.79	0.79	0.79	0.76	0.77	0.77
C-5	U-7Mo-1Ti	disp	1.80	1.50	1.33	1.24	1.15	1.08	1.03	0.98	0.97	0.91	0.88	0.85	0.82	0.80	0.79	0.79	0.76	0.74	0.77	0.81
C-6	U_3Si_2	disp	2.08	1.68	1.47	1.28	1.17	1.08	1.01	0.94	0.87	0.85	0.81	0.78	0.76	0.74	0.75	0.70	0.71	0.73	0.75	0.83
C-7	U-7Mo	disp	2.01	1.65	1.44	1.31	1.16	1.08	1.03	0.98	0.89	0.85	0.82	0.79	0.78	0.75	0.71	0.71	0.73	0.73	0.76	0.82
C-8	U-7Mo-2Zr	disp	1.76	1.50	1.33	1.24	1.15	1.08	1.05	0.98	0.95	0.91	0.89	0.86	0.83	0.80	0.80	0.77	0.78	0.76	0.78	0.79
D-1	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-2	U-7Mo	disp	1.65	1.37	1.27	1.20	1.16	1.09	1.06	1.01	1.01	0.96	0.91	0.90	0.88	0.85	0.83	0.80	0.78	0.76	0.75	0.78
D-3	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-4	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-5	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-6	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-7	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-8	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table B- 4 RERTR-8 fission rate tally local to average ratio (L2AR) in axial direction (from core center plate edge to outer plate edge)[4]

ID	Fuel Phase	Fuel Type	Core Center Edge Position 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Outer Edg 20
A-1	U_3Si_2	disp	1.07	0.94	0.94	0.93	0.90	0.91	0.91	0.95	0.95	0.94	0.96	0.99	1.00	0.98	1.02	1.01	1.05	1.07	1.17	1.34
A-2	U-10Mo	mono	1.16	0.97	0.90	0.91	0.89	0.90	0.90	0.91	0.94	0.95	0.95	0.95	1.01	0.96	0.99	0.97	1.05	1.07	1.15	1.47
A-3	U-7Mo-1Ti	disp	1.19	0.95	0.91	0.91	0.89	0.87	0.92	0.91	0.92	0.89	0.93	0.95	0.98	0.99	1.01	1.02	1.05	1.09	1.17	1.45
A-4	U-7Mo-2Zr	disp	1.07	0.94	0.91	0.91	0.90	0.89	0.94	0.93	0.95	0.96	0.95	0.97	0.98	1.01	1.01	1.05	1.06	1.10	1.14	1.35
A-5	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
A-6	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
A-7	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
A-8	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-1	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-2	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-3	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-4	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-5	U-12Mo w/BorAl	mono	1.03	0.98	0.97	0.98	0.97	0.97	0.97	0.97	0.99	0.98	0.99	0.98	0.98	0.98	1.01	1.00	1.02	1.03	1.07	1.12
B-6	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-7	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
B-8	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
C-1	U-10Mo	mono	1.20	1.11	1.02	1.00	1.00	0.98	0.98	0.96	0.98	0.95	0.96	0.97	0.95	0.94	0.94	0.97	0.97	0.99	1.01	1.12
C-2	U-8Mo	mono	1.28	1.08	1.03	1.00	0.97	0.98	0.95	0.95	0.94	0.95	0.96	0.96	0.93	0.94	0.93	0.95	0.96	0.98	1.03	1.21
C-3	U-10Mo	mono	1.31	1.06	1.02	1.00	0.98	0.95	0.98	0.97	0.95	0.94	0.95	0.98	0.97	0.92	0.91	0.93	0.96	0.96	1.04	1.21
C-4	U-12Mo	mono	1.16	1.07	1.05	0.99	0.98	0.99	0.97	0.96	0.98	0.96	0.99	0.97	0.96	0.98	0.95	0.98	0.96	0.98	0.99	1.13
C-5	U-7Mo-1Ti	disp	1.19	1.02	1.01	1.00	1.00	0.96	0.98	0.97	0.97	0.96	0.96	0.96	0.95	0.96	0.95	0.94	0.97	1.01	1.01	1.22
C-6	U_3Si_2	disp	1.28	1.06	0.99	0.99	0.98	0.96	0.97	0.95	0.97	0.93	0.93	0.93	0.93	0.94	0.96	0.95	0.96	0.96	1.06	1.31
C-7	U-7Mo	disp	1.29	1.05	1.02	0.97	0.97	0.96	0.95	0.96	0.96	0.95	0.92	0.93	0.93	0.94	0.95	0.96	0.95	0.96	1.06	1.31
C-8	U-7Mo-2Zr	disp	1.17	1.05	1.02	0.99	0.98	0.99	0.94	0.97	0.95	0.96	0.95	0.94	0.95	0.94	0.96	0.95	0.97	1.02	1.06	1.21
D-1	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-2	U-7Mo	disp	1.17	1.08	1.05	1.05	1.04	0.99	1.02	0.99	0.98	0.97	0.97	0.97	0.96	0.97	0.96	0.94	0.94	0.96	0.95	1.04
D-3	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-4	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-5	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-6	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-7	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-8	--	blank	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--