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RERTR-9 Irradiation Summary Report

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Approved by:

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SUMMARY

The RERTR-9 experiment was designed to test the effect of modified fuel/clad interfaces in monolithic fuel plates and to demonstrate that the addition of Si to the matrix material in dispersion plates continued to be effective at high loading (~8.5 g U/cc). Several monolithic fuel plates were fabricated by Hot Isostatic Pressing (HIP) and Friction Bonding (FB) with thin layers of Si inserted and by HIP with a Zr diffusion barrier between the fuel and cladding. Si was applied to the interface by thermal spray of Al-Si mixtures and by the insertion of thin Si-rich Al alloy foil between the fuel/clad interface. The dispersion fuel plates were fabricated by semi-standard rolling techniques (the reduction by rolling was lowered to limit fabrication defects). Matrix materials consisted of Al-Si alloys and mixtures with various levels of Si.

The following report summarizes the life of the RERTR-9A/B experiment through end of irradiation, including as-run neutronic analysis, thermal analysis and hydraulic testing results.

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TABLES

ACRONYMS

Al	aluminum
ATR	Advanced Test Reactor
EFPD	effective full power days
FB	friction bonding
FSW	friction stir weld
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-9 Irradiation Summary Report

1. EXPERIMENT SUMMARY

The RERTR-9A/B 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-9A/B Experiment Matrix is shown in Table 1.

The RERTR-9 experiment was designed to test the effect of modified fuel/clad interfaces in monolithic fuel plates and to demonstrate that the addition of Si to the matrix material in dispersion plates continued to be effective at high loading (~8.5 g U/cc). Several monolithic fuel plates were fabricated by Hot Isostatic Pressing (HIP) and Friction Bonding (FB) with thin layers of Si inserted and by HIP with a Zr diffusion barrier between the fuel and cladding. Si was applied to the interface by thermal spray of Al-Si mixtures and by the insertion of thin Si-rich Al alloy foil between the fuel/clad interface. The dispersion fuel plates were fabricated by semi-standard rolling techniques (the reduction by rolling was lowered to limit fabrication defects). Matrix materials consisted of Al-Si alloys and mixtures with various levels of Si.[1]

Table 1. RERTR-9A/B experiment matrix loading diagram.[1]

RERTR-9A/B Experiment Matrix				
Capsule	**Column 1**	**Column 2**	**Column 3**	**Column 4**
A-Top	A1 Blank **DUM09**	A2 U-7MO AL-4043 8 g-U/cc **R3R078**	A3 Blank **DUM10**	A4 U-10Mo FSW **L1F22C**
A-Bottom	A5 U-10Mo FSW **L1F27C**	A6 U-10Mo Al-4043 Layer HIP **L1P03A**	A7 U-7Mo Al + 2 Si 8 g-U/cc **R4R028**	A8 U-10Mo FSW **L1F29C**
B-Top	B1 U-10Mo Al-Si .005” TS FSW **L1F34T**	B2 U-10MO FSW **L1F330**	B3 U-10Mo Al-4030 HIP **L1P05A**	B4 U-10Mo Al-Si 0.010” TS FSW **L1F37T**
B-Bottom	B5 U-10Mo Zr barrier HIP **L1P09T**	B6 U-7Mo Al-2Si 8.5 g-U/cc **R2R088**	B7 U-7Mo Al-3.5Si 8.5 g-U/cc **R6R018**	B8 U-10Mo Al-Si .005” TS HIP **L1P07T**
C-Top	C1 U-10Mo FSW **L1F26C**	C2 U-7Mo Al-4043 8 g-U/cc **R3R108**	C3 U-7Mo Al + 2 Si 8 g-U/cc **R2R078**	C4 U-10Mo FSW **L1F28C**
C-Bottom	C5 U-10Mo FSW **L1F32C**	C6 U-10Mo Al-4043 Layer HIP **L1P04A**	C7 U-7Mo Al + 2 Si 8 g-U/cc **R4R018**	C8 U-10Mo FSW **L1F24C**
D-Top	D1 U-10Mo Al-Si 0.005” TS FSW **L1F35T**	D2 U-7Mo Al-3.5Si 8.5 g-U/cc **R6R048**	D3 U-10Mo Al-4043 HIP **L1P06A**	D4 U-10Mo Al-Si 0.010” TS FSW **L1F36T**
D-Bottom	D5 U-10Mo Zr barrier HIP **L1P10T**	D6 U-7Mo Al-2Si 8.5 g-U/cc **R2R118**	D7 U-7Mo Al-3.5Si 8.5 g-U/cc **R6R038**	D8 U-10Mo Al-Si 0.005” TS HIP **L1P08T**

2. CONSTITUENT MASSES AND DENSITIES

Table 2. Constituent masses and densities for RERTR-9A/B plates.[2,3]

Fuel Plate ID	Fuel Plate #	Fuel Constituent Masses			Constituent Densities		
		Total-U (g)	U-235 (g)	Mo (g)	Total U Density (g/cc)	U-235 Density (g/cc)	Mo (g/cc)
A1	Blank	--	--	--	--	--	--
A2	R3R078	6.990	3.106	0.525	8.062	3.582	0.606
A3	Blank	--	--	--	--	--	--
A4	L1F22C	5.842	3.396	0.652	15.293	8.890	1.707
A5	L1F27C	5.750	3.306	0.640	15.333	8.816	1.707
A6	L1P03A	6.091	3.548	0.676	15.304	8.915	1.698
A7	R4R028	7.122	3.164	0.536	7.958	3.535	0.599
A8	L1F29C	5.813	3.362	0.649	15.297	8.847	1.708
B1	L1F34T	5.895	3.465	0.654	14.723	8.654	1.633
B2	L1F330	5.494	3.202	0.609	14.496	5.148	0.979
B3	L1P05A	5.663	3.301	0.628	14.600	8.511	1.619
B4	L1F37T	5.898	3.474	0.658	15.286	9.003	1.705
B5	L1P09T	5.963	3.350	0.632	13.939	7.831	1.477
B6	R2R088	6.021	3.501	0.453	7.460	4.338	0.561
B7	R6R018	6.030	3.506	0.453	7.566	4.399	0.568
B8	L1P07T	5.729	3.366	0.635	14.431	8.479	1.599
C1	L1F26C	5.829	3.352	0.649	15.299	8.798	1.703
C2	R3R108	7.026	3.122	0.529	8.039	3.572	0.605
C3	R2R078	7.090	3.150	0.533	7.984	3.547	0.600
C4	L1F28C	5.907	3.417	0.660	15.303	8.852	1.710
C5	L1F32C	5.878	3.398	0.655	15.033	8.691	1.675
C6	L1P04A	5.873	3.421	0.652	15.334	8.932	1.702
C7	R4R018	7.064	3.139	0.532	8.018	3.563	0.604
C8	L1F24C	5.720	3.324	0.638	15.294	8.888	1.706
D1	L1F35T	5.672	3.334	0.630	14.623	8.595	1.624
D2	R6R048	6.045	3.515	0.454	7.633	4.438	0.573
D3	L1P06A	5.826	3.396	0.646	14.432	8.412	1.600
D4	L1F36T	5.870	3.450	0.651	15.629	9.186	1.733
D5	L1P10T	5.494	3.233	0.611	13.507	7.948	1.502
D6	R2R118	5.986	3.480	0.450	7.511	4.366	0.565
D7	R6R038	6.052	3.519	0.455	7.593	4.415	0.571
D8	L1P08T	5.738	3.383	0.638	14.831	8.744	1.649

3. EXPERIMENT HARDWARE

The experiment hardware configuration is identical to that used in the RERTR-7A, -7B, and -8 experiments. A list of irradiation hardware drawings used for analysis is given in Table 3.

Table 3. RERTR-9 irradiation hardware drawing list.[1,4]

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[4], (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[4] 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.

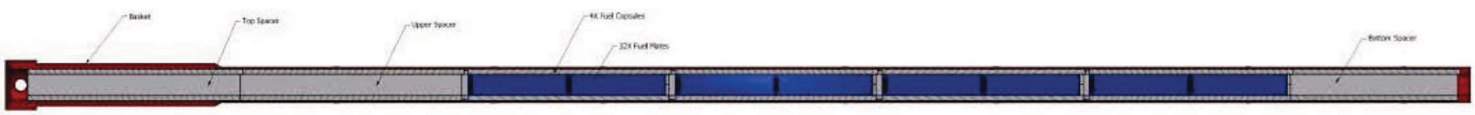

Figure 1 RERTR miniplate irradiation Assembly.[4]

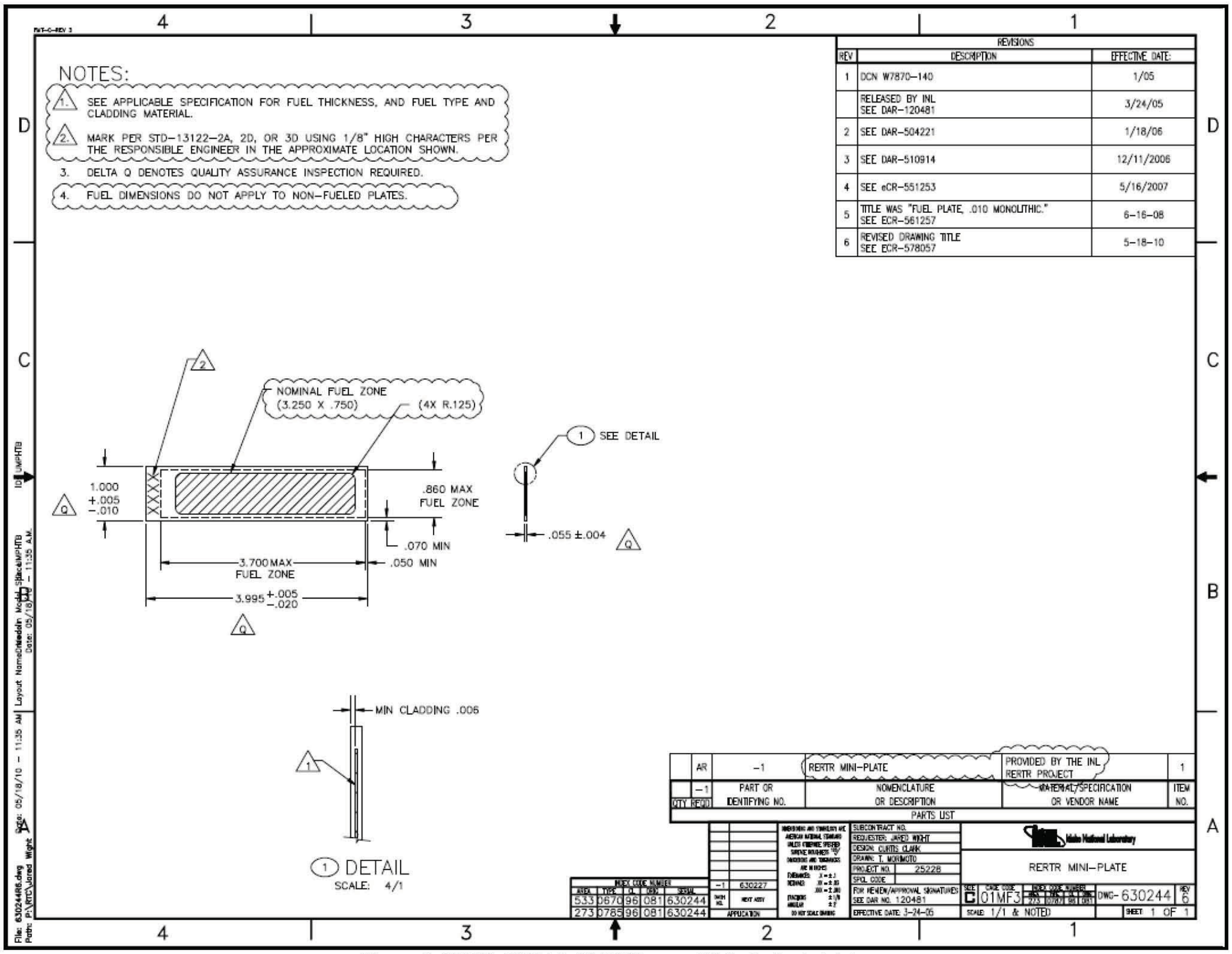

Figure 2. DWG-630244: RERTR monolithic fuel miniplate.

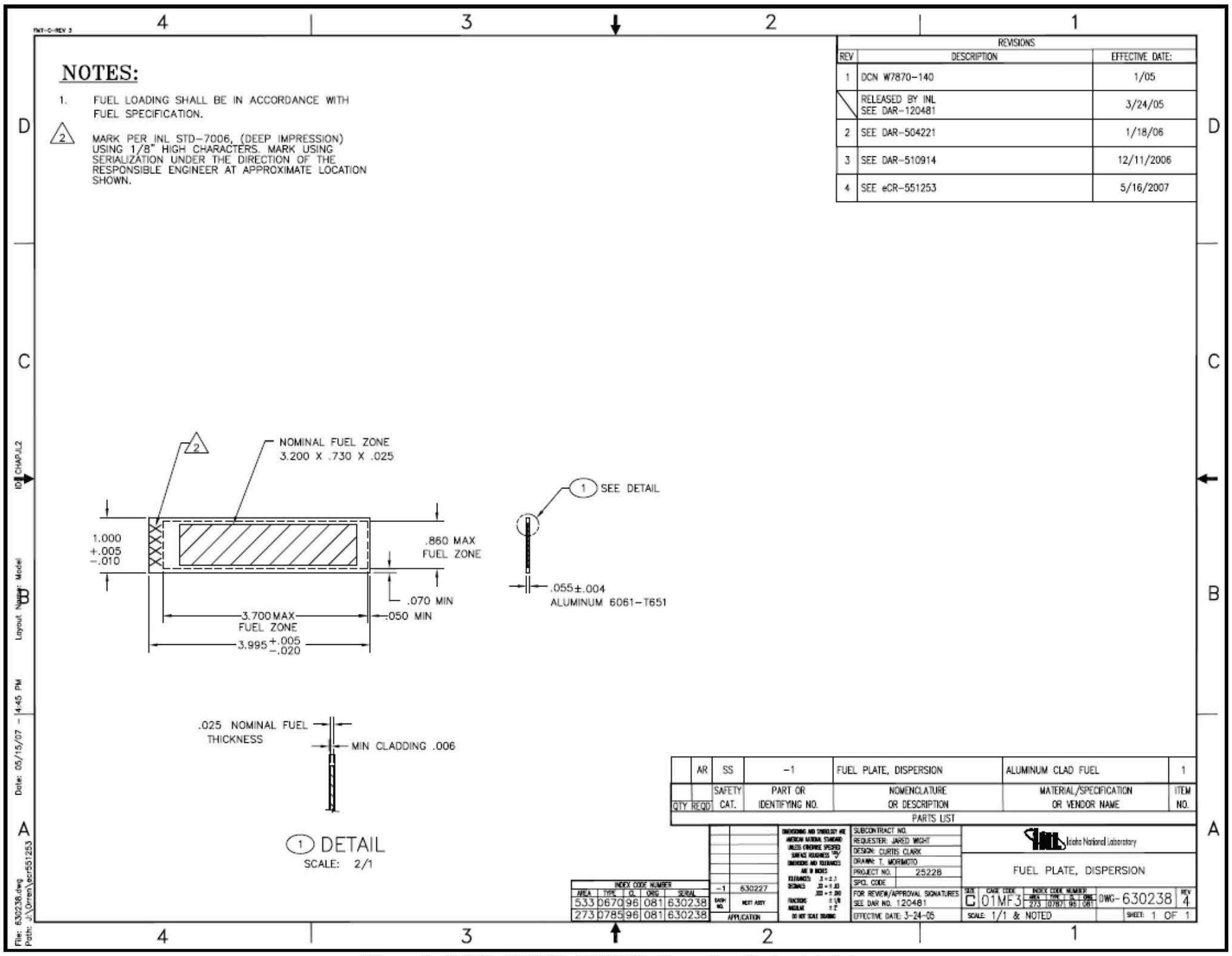

Figure 3. DWG-630238: RERTR dispersion fuel miniplate.

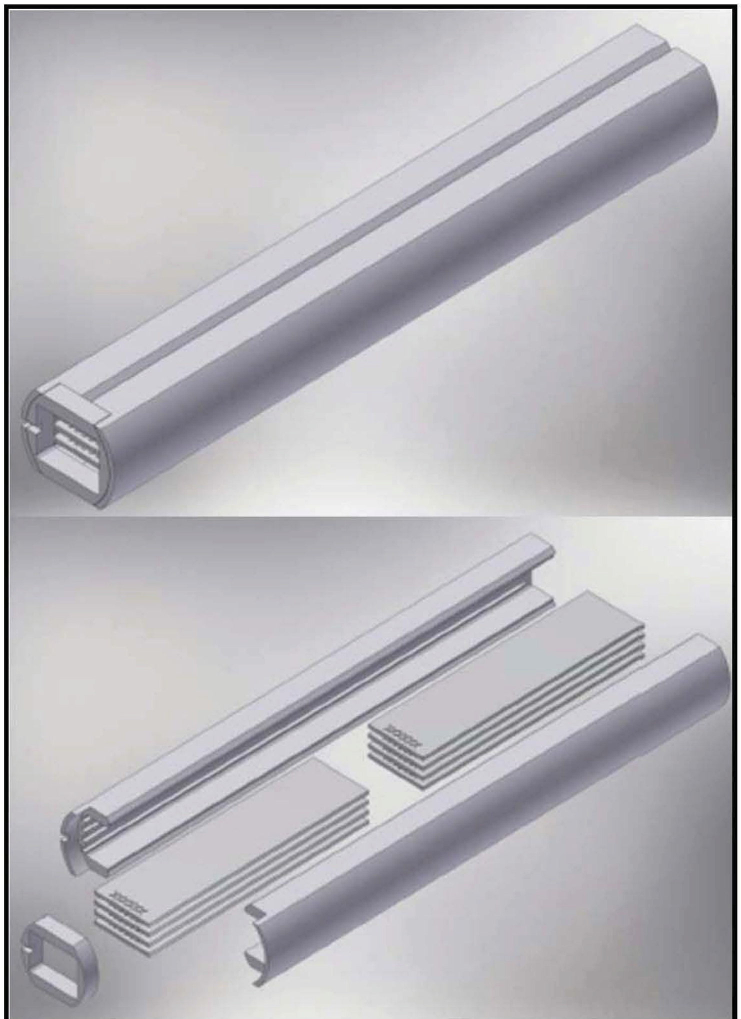

Figure 4. RERTR capsule assembly.[4]

4. IRRADIATION HISTORY

The RERTR-9A test assembly was irradiated in Cycles 139A and 140A. The RERTR-9B test assembly was irradiated in Cycles 140A, 140B, and 141A. The RERTR-9A/B test assembly is the combined 9A and 9B test assemblies, which were irradiated in Cycle 140A. These experiments were irradiated in the large-B position B-11. The power of this position 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 139A ran for 51.6 EFPDs at 24.0 MW, Cycle 140A ran for 46.5 EFPDs at 23.1 MW, Cycle 140B ran for 35.7 EFPDs at 22.6 MW, and Cycle 141A ran for 32.4 EFPDs at 22.8 MW. There was a Mid-Cycle SCRAM during Cycle 139A with duration of 3 days and Cycle 140B with duration of 8 days. This information is tabulated in Table 4.

Table 4. Irradiation history.

ATR CYCLE	RERTR-9A/B Test ID	RERTR-9 Capsules Irradiated	Dates Irradiated	Cycle EFPDs	Mid-Cycle Scram Decay Days	Post-Cycle Decay Days	South Lobe Source Power (MW)
139A	RERTR-9A	A,C	02/26/2007 – 04/21/2007	51.6	3	65	24.0
140A	RERTR-9A/B	A,B,C,D	10/16/2007 – 12/01/2007	46.5	--	15	22.6
140B	RERTR-9B	B,D	12/16/2007 – 01/26/2008	35.7	8	10	22.8
141A	RERTR-9B	B,D	02/05/2008 – 03/06/2008	32.4	--	55	23.1

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%.[5] 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 139A, 140A, 140B, and 141A are shown in Table 6. The average plate power and burnup for time intervals 02 through 04 for each cycle are shown in Table 7 through Table 10. 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	139A (days)	140A (days)	140B (days)	141A (days)
01	1.00E-4	1.00E-4	1.00E-4	1.00E-4
02	18	18	12	15
03	20	18	12	10
04	13.5	10.5	11	7
05	1.00E-3	1.00E-3	1.00E-3	1.00E-3
EFPDs	51.50	46.50	35.00	32.00

Table 6. End of cycle average plate power and burnup.

Fuel Plate ID	Fuel Plate #	Cycle 139A			Cycle 140A			Cycle 140B			Cycle 141A		
		Fission Power Density (W/cc)	Heat Flux (W/cm^2)	U-235 Burnup U-235/U-235$_{initial}$ (%)	Fission Power Density (W/cc)	Heat Flux (W/cm^2)	U-235 Burnup U-235/U-235$_{initial}$ (%)	Fission Power Density (W/cc)	Heat Flux (W/cm^2)	U-235 Burnup U-235/U-235$_{initial}$ (%)	Fission Power Density (W/cc)	Heat Flux (W/cm^2)	U-235 Burnup U-235/U-235$_{initial}$ (%)
A1	BLANK	--	--	--	--	--	--	--	--	--	--	--	--
A2	R3R078	6566.45	208.48	13.75%	6971.73	221.35	26.21%	--	--	--	--	--	--
A3	BLANK	--	--	--	--	--	--	--	--	--	--	--	--
A4	L1F22C	13199.76	167.64	10.54%	15555.59	197.56	20.53%	--	--	--	--	--	--
A5	L1F27C	11989.51	152.27	10.07%	13532.82	171.87	19.96%	--	--	--	--	--	--
A6	L1P03A	10514.44	133.53	8.17%	12353.59	156.89	16.24%	--	--	--	--	--	--
A7	R4R028	5283.18	167.74	11.09%	6190.00	196.53	21.75%	--	--	--	--	--	--
A8	L1F29C	16861.72	214.14	13.78%	19306.36	245.19	26.50%	--	--	--	--	--	--
B1	L1F34T	--	--	--	22642.93	287.57	16.41%	21569.64	273.93	27.98%	20166.07	256.11	37.33%
B2	L1F330	--	--	--	18994.60	241.23	14.27%	18357.43	233.14	24.87%	17573.45	223.18	33.58%
B3	L1P05A	--	--	--	19851.32	252.11	14.22%	19362.74	245.91	25.01%	18550.41	235.59	33.83%
B4	L1F37T	--	--	--	24898.01	316.20	16.54%	23310.94	296.05	28.98%	21620.74	274.58	38.65%
B5	L1P09T	--	--	--	22861.90	290.35	17.34%	21582.65	274.10	29.31%	20000.33	254.00	38.93%
B6	R2R088	--	--	--	10793.23	274.15	14.35%	10442.32	265.23	24.96%	10013.80	254.35	33.76%
B7	R6R018	--	--	--	10949.42	278.12	14.32%	10686.13	271.43	25.14%	10232.18	259.90	34.02%
B8	L1P07T	--	--	--	24763.80	314.50	17.40%	23305.65	295.98	30.19%	21411.85	271.93	40.17%
C1	L1F26C	19328.18	245.47	16.77%	21151.90	268.63	32.76%	--	--	--	--	--	--
C2	R3R108	6554.49	208.11	14.62%	7682.82	243.93	28.96%	--	--	--	--	--	--
C3	R2R078	6607.01	209.77	14.57%	7869.32	249.85	28.89%	--	--	--	--	--	--
C4	L1F28C	19991.84	253.90	16.82%	23076.60	293.85	32.68%	--	--	--	--	--	--
C5	L1F32C	18967.92	240.89	16.14%	20906.06	265.51	31.55%	--	--	--	--	--	--
C6	L1P04A	16504.22	209.60	13.90%	19304.78	245.17	27.58%	--	--	--	--	--	--
C7	R4R018	6432.94	204.25	14.25%	7694.48	255.30	28.14%	--	--	--	--	--	--
C8	L1F24C	19146.65	243.16	16.40%	22180.02	281.69	32.01%	--	--	--	--	--	--
D1	L1F35T	--	--	--	210122.81	266.86	15.57%	19999.04	253.99	26.67%	18695.01	237.43	35.64%
D2	R6R048	--	--	--	9859.68	250.44	13.01%	9738.73	247.36	22.72%	9404.22	238.87	30.82%
D3	L1P06A	--	--	--	18978.21	241.02	13.09%	18619.02	236.46	23.08%	17871.46	226.97	31.30%
D4	L1F36T	--	--	--	23198.21	294.62	15.49%	21939.67	278.63	27.30%	20424.65	259.39	36.51%
D5	L1P10T	--	--	--	18055.33	229.30	13.70%	17260.71	219.21	23.57%	16328.68	207.37	31.62%
D6	R2R118	--	--	--	8627.27	219.13	11.34%	8363.95	212.44	19.85%	8135.36	206.64	26.99%
D7	R6R038	--	--	--	8938.50	277.04	11.30%	8652.50	219.77	19.92%	8421.68	213.91	27.09%
D8	L1P08T	--	--	--	20176.74	256.24	13.51%	18990.23	241.18	23.90%	17922.68	227.62	32.10%

Table 7. Average plate power and burnup for Cycle 139A.

Fuel Plate ID	Fuel Plate #	Cycle 139A 02			Cycle 139A 03			Cycle 139A 04		
		Fission Power Density (W/cc)	Heat Flux (W/cm^2)	U-235 Burnup U-235/U-235$_{initial}$ (%)	Fission Power Density (W/cc)	Heat Flux (W/cm^2)	U-235 Burnup U-235/U-235$_{initial}$ (%)	Fission Power Density (W/cc)	Heat Flux (W/cm^2)	U-235 Burnup U-235/U-235$_{initial}$ (%)
A1	BLANK	--	--	--	--	--	--	--	--	--
A2	R3R078	6069.22	192.70	4.70%	6341.53	201.34	9.99%	6566.45	208.48	13.75%
A3	BLANK	--	--	--	--	--	--	--	--	--
A4	L1F22C	12061.62	153.18	3.56%	12655.78	160.73	7.62%	13199.76	167.64	10.54%
A5	L1F27C	11549.74	146.68	3.51%	11608.20	147.42	7.36%	11989.51	152.27	10.07%
A6	L1P03A	9825.95	124.79	2.79%	10004.15	127.05	5.94%	10514.44	133.53	8.17%
A7	R4R028	5088.20	161.55	3.92%	5055.59	160.51	8.11%	5283.18	167.74	11.09%
A8	L1F29C	16142.18	205.01	4.79%	16325.77	207.34	10.05%	16861.72	214.14	13.78%
B1	L1F34T	--	--	--	--	--	--	--	--	--
B2	L1F330	--	--	--	--	--	--	--	--	--
B3	L1P05A	--	--	--	--	--	--	--	--	--
B4	L1F37T	--	--	--	--	--	--	--	--	--
B5	L1P09T	--	--	--	--	--	--	--	--	--
B6	R2R088	--	--	--	--	--	--	--	--	--
B7	R6R018	--	--	--	--	--	--	--	--	--
B8	L1P07T	--	--	--	--	--	--	--	--	--
C1	L1F26C	21209.88	269.37	6.28%	19483.37	247.44	12.52%	19328.18	245.47	16.77%
C2	R3R108	7114.93	225.90	5.48%	6502.15	206.44	10.87%	6554.49	208.11	14.62%
C3	R2R078	7074.22	224.61	5.43%	6546.69	207.86	10.86%	6607.01	209.77	14.57%
C4	L1F28C	21450.52	272.42	6.21%	19950.69	253.37	12.51%	19991.84	253.90	16.82%
C5	L1F32C	20487.15	260.19	5.93%	19194.56	243.77	12.04%	18967.92	240.89	16.14%
C6	L1P04A	17564.56	223.07	5.12%	16405.85	208.35	10.33%	16504.22	209.60	13.90%
C7	R4R018	6807.73	216.15	5.22%	6408.72	203.48	10.60%	6432.94	204.25	14.25%
C8	L1F24C	20211.99	256.69	6.06%	18929.24	240.40	12.21%	19146.65	243.16	16.40%
D1	L1F35T	--	--	--	--	--	--	--	--	--
D2	R6R048	--	--	--	--	--	--	--	--	--
D3	L1P06A	--	--	--	--	--	--	--	--	--
D4	L1F36T	--	--	--	--	--	--	--	--	--
D5	L1P10T	--	--	--	--	--	--	--	--	--
D6	R2R118	--	--	--	--	--	--	--	--	--
D7	R6R038	--	--	--	--	--	--	--	--	--
D8	L1P08T	--	--	--	--	--	--	--	--	--

Table 8. Average plate power and burnup for Cycle 140A.

Fuel Plate ID	Fuel Plate #	Cycle 140A 02 Fission Power Density (W/cc)	Cycle 140A 02 Heat Flux (W/cm^2)	Cycle 140A 02 U-235 Burnup $U\text{-}235/U\text{-}235_{initial}$ (%)	Cycle 140A 03 Fission Power Density (W/cc)	Cycle 140A 03 Heat Flux (W/cm^2)	Cycle 140A 03 U-235 Burnup $U\text{-}235/U\text{-}235_{initial}$ (%)	Cycle 140A 04 Fission Power Density (W/cc)	Cycle 140A 04 Heat Flux (W/cm^2)	Cycle 140A 04 U-235 Burnup $U\text{-}235/U\text{-}235_{initial}$ (%)
A1	BLANK	--	--	--	--	--	--	--	--	--
A2	R3R078	6883.41	218.55	18.76%	6503.18	206.48	23.39%	6971.73	221.35	26.21%
A3	BLANK	--	--	--	--	--	--	--	--	--
A4	L1F22C	14198.81	180.32	14.46%	13608.27	172.83	18.25%	15555.59	197.56	20.53%
A5	L1F27C	13927.49	176.88	14.06%	12996.01	165.05	17.81%	13532.82	171.87	19.96%
A6	L1P03A	12002.08	152.43	11.40%	11245.58	142.82	14.41%	12353.59	156.89	16.24%
A7	R4R028	5945.54	188.77	15.35%	5531.76	175.63	19.34%	6190.00	196.53	21.75%
A8	L1F29C	18445.90	234.26	18.89%	17088.73	217.03	23.64%	19306.36	245.19	26.50%
B1	L1F34T	25153.80	319.45	6.79%	22645.88	287.60	12.92%	22642.93	287.57	16.41%
B2	L1F330	19931.74	253.13	5.85%	18054.82	229.30	11.18%	18994.60	241.23	14.27%
B3	L1P05A	20426.41	259.42	5.82%	18479.02	234.68	11.12%	19851.32	252.11	14.22%
B4	L1F37T	25268.53	320.91	6.82%	22760.59	289.06	12.93%	24898.01	316.20	16.54%
B5	L1P09T	26095.49	331.41	7.30%	23035.57	292.55	13.73%	22861.90	290.35	17.34%
B6	R2R088	11399.64	289.55	5.89%	10319.01	262.10	11.27%	10793.23	274.15	14.35%
B7	R6R018	11414.60	289.93	5.88%	10250.11	260.35	11.25%	10949.42	278.12	14.32%
B8	L1P07T	26086.84	331.30	7.23%	23126.46	293.71	13.62%	24763.80	314.50	17.40%
C1	L1F26C	24535.04	311.59	23.48%	21526.14	273.38	29.44%	21151.90	268.63	32.76%
C2	R3R108	8298.19	263.47	20.53%	7420.24	235.59	25.86%	7682.82	243.93	28.96%
C3	R2R078	8414.74	267.17	20.56%	7456.96	236.76	25.85%	7869.32	249.85	28.89%
C4	L1F28C	24673.39	313.35	23.44%	21700.65	275.60	29.33%	23076.60	293.07	32.68%
C5	L1F32C	23709.12	301.11	22.57%	21053.89	267.38	28.32%	20906.06	265.51	31.55%
C6	L1P04A	20770.74	263.79	19.57%	18620.96	236.49	24.64%	19304.78	245.17	27.58%
C7	R4R018	8087.30	256.77	19.98%	7206.64	228.81	25.15%	7694.48	244.30	28.14%
C8	L1F24C	23431.22	297.58	22.93%	20641.89	262.15	28.66%	22180.02	281.69	32.01%
D1	L1F35T	22892.98	290.74	6.41%	20587.43	261.46	12.22%	21012.81	266.86	15.57%
D2	R6R048	10269.74	260.85	5.27%	9330.88	237.00	10.20%	9859.68	250.44	13.01%
D3	L1P06A	19167.42	243.43	5.34%	17481.73	222.02	10.22%	18978.21	241.02	13.09%
D4	L1F36T	23284.00	295.71	6.33%	21161.15	268.75	12.08%	23198.21	294.62	15.49%
D5	L1P10T	19298.48	245.09	5.61%	17557.13	222.98	10.73%	18055.33	229.30	13.70%
D6	R2R118	8779.25	222.99	4.55%	8015.48	203.59	8.85%	8627.27	219.13	11.34%
D7	R6R038	8759.70	222.50	4.50%	8016.06	203.61	8.75%	8938.50	227.04	11.30%
D8	L1P08T	19633.78	249.35	5.45%	17963.40	228.14	10.49%	20176.74	256.24	13.51%

Table 9. Average plate power and burnup for Cycle 140B.

Fuel Plate ID	Fuel Plate #	Cycle 140B 02			Cycle 140B 03			Cycle 140B 04		
		Fission Power Density (W/cc)	Heat Flux (W/cm^2)	U-235 Burnup $U\text{-}235/U\text{-}235_{initial}$ (%)	Fission Power Density (W/cc)	Heat Flux (W/cm^2)	U-235 Burnup $U\text{-}235/U\text{-}235_{initial}$ (%)	Fission Power Density (W/cc)	Heat Flux (W/cm^2)	U-235 Burnup $U\text{-}235/U\text{-}235_{initial}$ (%)
A1	BLANK	--	--	--	--	--	--	--	--	--
A2	R3R078	--	--	--	--	--	--	--	--	--
A3	BLANK	--	--	--	--	--	--	--	--	--
A4	L1F22C	--	--	--	--	--	--	--	--	--
A5	L1F27C	--	--	--	--	--	--	--	--	--
A6	L1P03A	--	--	--	--	--	--	--	--	--
A7	R4R028	--	--	--	--	--	--	--	--	--
A8	L1F29C	--	--	--	--	--	--	--	--	--
B1	L1F34T	20416.82	259.29	20.03%	22039.50	279.90	23.96%	21569.64	273.93	27.98%
B2	L1F330	16856.94	214.08	17.56%	18633.15	236.64	21.19%	18357.43	233.14	24.87%
B3	L1P05A	17285.00	219.52	17.46%	19626.12	249.25	21.16%	19362.74	245.91	25.01%
B4	L1F37T	20531.95	260.76	20.20%	24276.12	308.31	24.52%	23310.94	296.05	28.98%
B5	L1P09T	20619.73	261.87	21.13%	22173.45	281.60	25.20%	21582.65	274.10	29.31%
B6	R2R088	9602.12	243.89	17.66%	10554.15	268.08	21.32%	10442.32	265.23	24.96%
B7	R6R018	9559.97	242.82	17.65%	10790.47	274.08	21.34%	10686.13	271.43	25.14%
B8	L1P07T	20697.23	262.85	21.17%	24338.78	309.10	25.63%	23305.65	295.98	30.19%
C1	L1F26C	--	--	--	--	--	--	--	--	--
C2	R3R108	--	--	--	--	--	--	--	--	--
C3	R2R078	--	--	--	--	--	--	--	--	--
C4	L1F28C	--	--	--	--	--	--	--	--	--
C5	L1F32C	--	--	--	--	--	--	--	--	--
C6	L1P04A	--	--	--	--	--	--	--	--	--
C7	R4R018	--	--	--	--	--	--	--	--	--
C8	L1F24C	--	--	--	--	--	--	--	--	--
D1	L1F35T	18855.26	239.46	19.05%	20296.95	257.77	22.86%	19999.04	253.99	26.67%
D2	R6R048	8752.85	222.32	16.01%	9639.34	244.84	19.35%	9738.73	247.36	22.72%
D3	L1P06A	16434.94	208.72	16.10%	18531.35	235.35	19.53%	18619.02	236.46	23.08%
D4	L1F36T	19217.06	244.06	18.95%	22759.19	289.04	22.99%	21939.67	278.63	27.30%
D5	L1P10T	16077.44	204.18	16.82%	17415.43	221.18	20.17%	17260.71	219.21	23.57%
D6	R2R118	7544.62	191.63	14.00%	8424.42	213.98	16.86%	8363.95	212.44	19.85%
D7	R6R038	7512.15	190.81	13.85%	8658.32	219.92	16.80%	8652.50	219.77	19.92%
D8	L1P08T	16317.77	207.24	16.48%	19604.60	248.98	20.10%	18990.23	241.18	23.90%

Table 10. Average plate power and burnup for Cycle 141A.

Fuel Plate ID	Fuel Plate No.	Cycle 141A 02			Cycle 141A 03			Cycle 141A 04		
		Fission Power Density (W/cc)	Heat Flux (W/cm^2)	U-235 Burnup U-235/U-235$_{initial}$ (%)	Fission Power Density (W/cc)	Heat Flux (W/cm^2)	U-235 Burnup U-235/U-235$_{initial}$ (%)	Fission Power Density (W/cc)	Heat Flux (W/cm^2)	U-235 Burnup U-235/U-235$_{initial}$ (%)
A1	BLANK	--	--	--	--	--	--	--	--	--
A2	R3R078	--	--	--	--	--	--	--	--	--
A3	BLANK	--	--	--	--	--	--	--	--	--
A4	L1F22C	--	--	--	--	--	--	--	--	--
A5	L1F27C	--	--	--	--	--	--	--	--	--
A6	L1P03A	--	--	--	--	--	--	--	--	--
A7	R4R028	--	--	--	--	--	--	--	--	--
A8	L1F29C	--	--	--	--	--	--	--	--	--
B1	L1F34T	19665.45	249.75	32.41%	18977.36	241.01	35.32%	20166.07	256.11	37.33%
B2	L1F330	16755.09	212.79	29.03%	16266.93	206.59	31.69%	17573.45	223.18	33.58%
B3	L1P05A	17543.36	222.80	29.19%	17017.92	216.13	31.96%	18550.41	235.59	33.83%
B4	L1F37T	20493.12	260.26	33.62%	19750.13	250.83	36.60%	21620.74	274.58	38.65%
B5	L1P09T	19754.40	250.88	33.93%	18820.34	239.02	36.89%	20000.33	254.00	38.93%
B6	R2R088	9626.33	244.51	29.13%	9313.52	236.56	31.85%	10013.80	254.35	33.76%
B7	R6R018	9711.84	246.68	29.40%	9373.19	238.08	32.12%	10232.18	259.90	34.02%
B8	L1P07T	20657.89	262.36	35.02%	19622.58	249.21	38.10%	21411.85	271.93	40.17%
C1	L1F26C	--	--	--	--	--	--	--	--	--
C2	R3R108	--	--	--	--	--	--	--	--	--
C3	R2R078	--	--	--	--	--	--	--	--	--
C4	L1F28C	--	--	--	--	--	--	--	--	--
C5	L1F32C	--	--	--	--	--	--	--	--	--
C6	L1P04A	--	--	--	--	--	--	--	--	--
C7	R4R018	--	--	--	--	--	--	--	--	--
C8	L1F24C	--	--	--	--	--	--	--	--	--
D1	L1F35T	18110.94	230.01	30.95%	17558.55	222.99	33.74%	18695.01	237.43	35.64%
D2	R6R048	8731.70	221.79	26.51%	8668.97	220.19	29.07%	9404.22	238.87	30.82%
D3	L1P06A	16596.76	210.78	26.96%	16344.06	207.57	29.52%	17871.46	226.97	31.30%
D4	L1F36T	19223.24	244.14	31.70%	18626.64	236.56	34.58%	20424.65	259.39	36.51%
D5	L1P10T	15505.92	196.93	27.41%	15266.62	193.89	29.90%	16328.68	207.37	31.62%
D6	R2R118	7520.33	191.02	23.22%	7471.79	189.78	25.45%	8135.36	206.64	26.99%
D7	R6R038	7669.62	194.81	23.30%	7655.14	194.44	25.55%	8421.68	213.91	27.09%
D8	L1P08T	16582.98	210.60	27.79%	16288.42	206.86	30.36%	17922.68	227.62	32.10%

5.2 Gradients

The MCNP-calculated power gradients 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 5 and Figure 6 depict the power gradient in the transverse direction and Figure 7 and Figure 8 depict the power gradient in the axial direction.

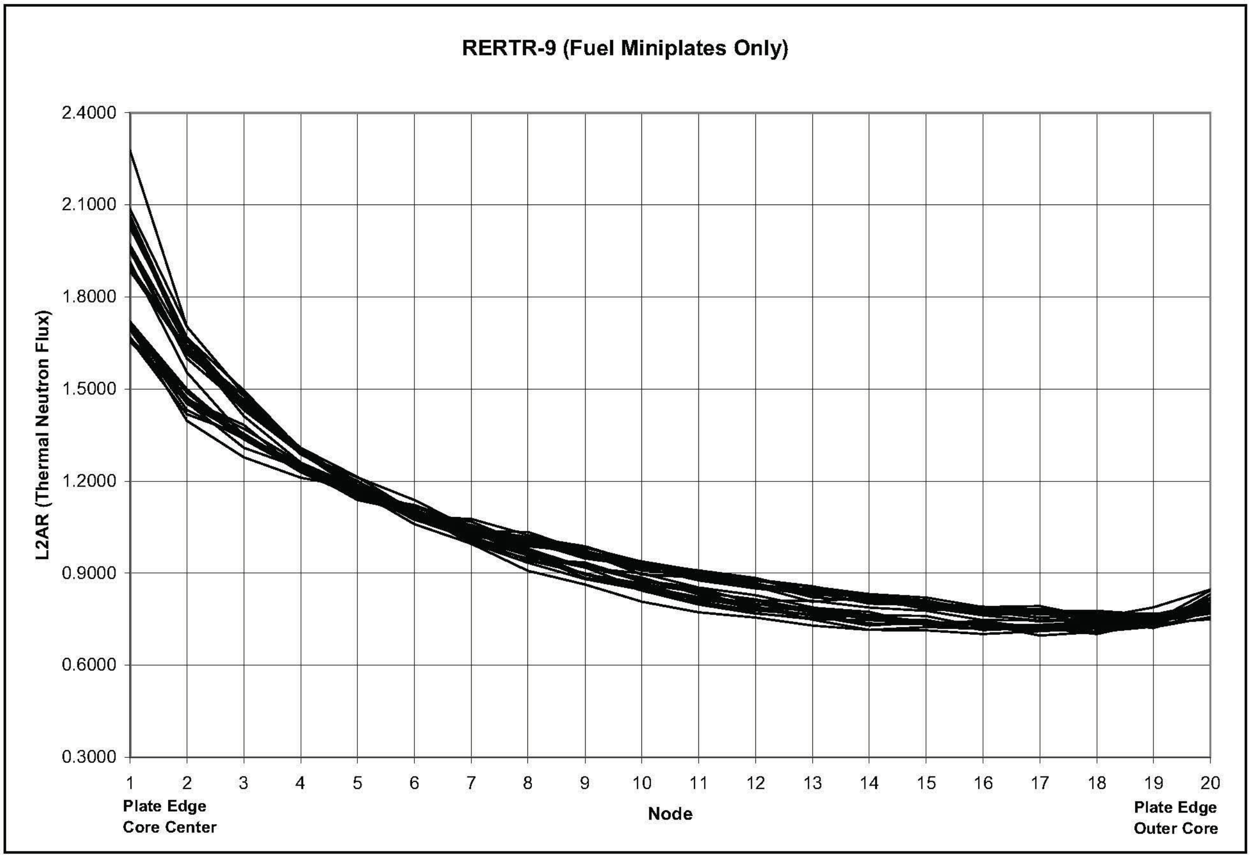

Figure 5. RERTR-9 fuel miniplates thermal neutron flux L2ARs in transverse direction.[6]

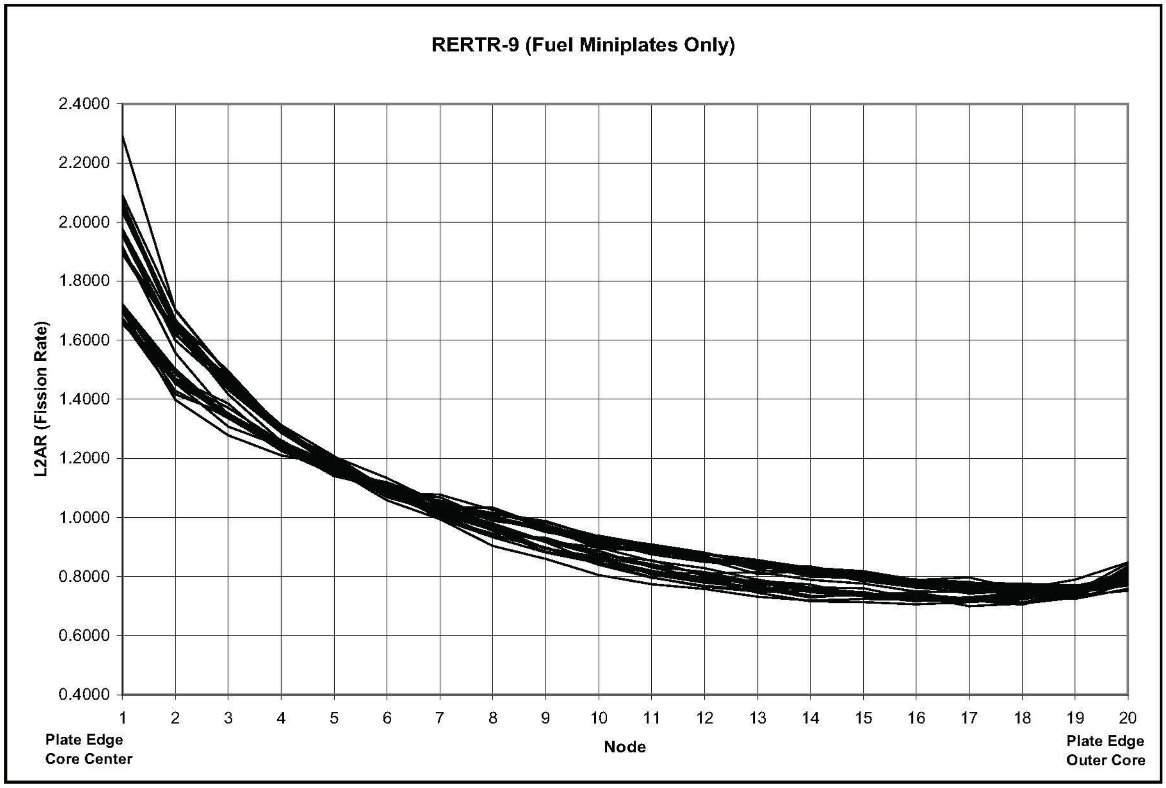

Figure 6. RERTR-9 fuel miniplates fission rate L2ARs in transverse direction.[6]

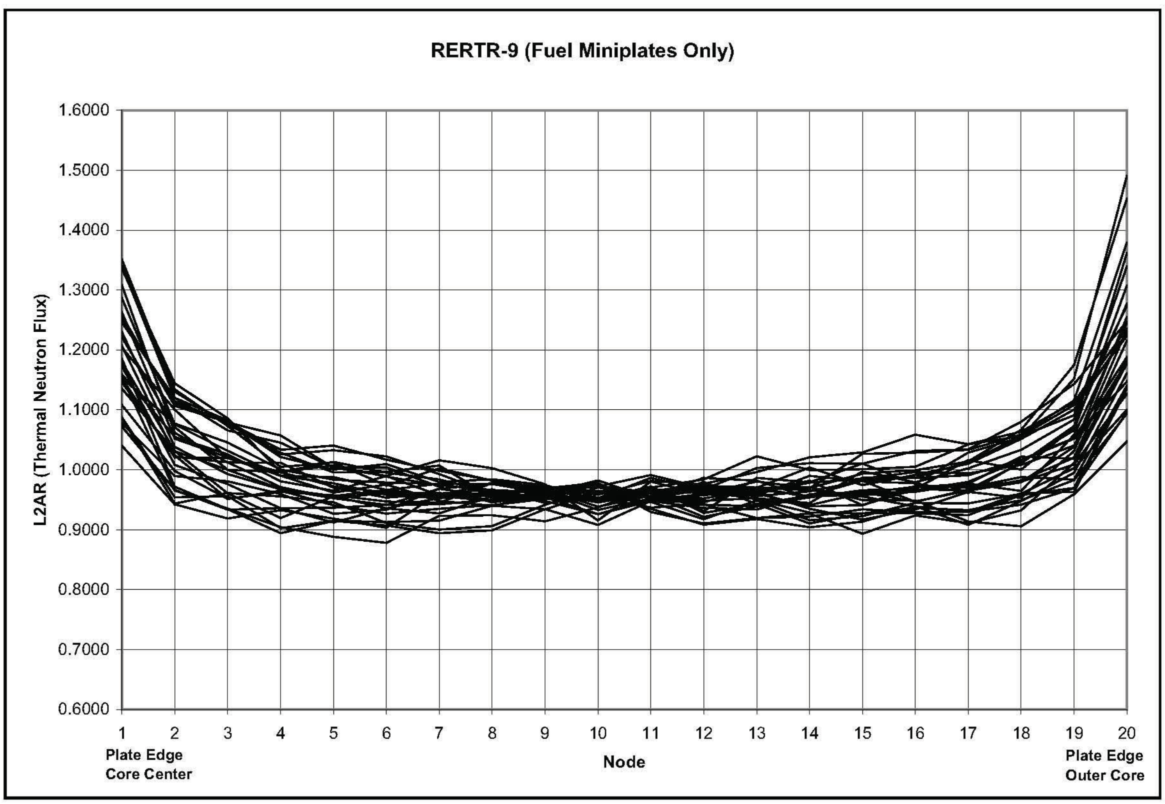

Figure 7. RERTR-9 fuel miniplates thermal neutron flux L2ARs in axial direction.[6]

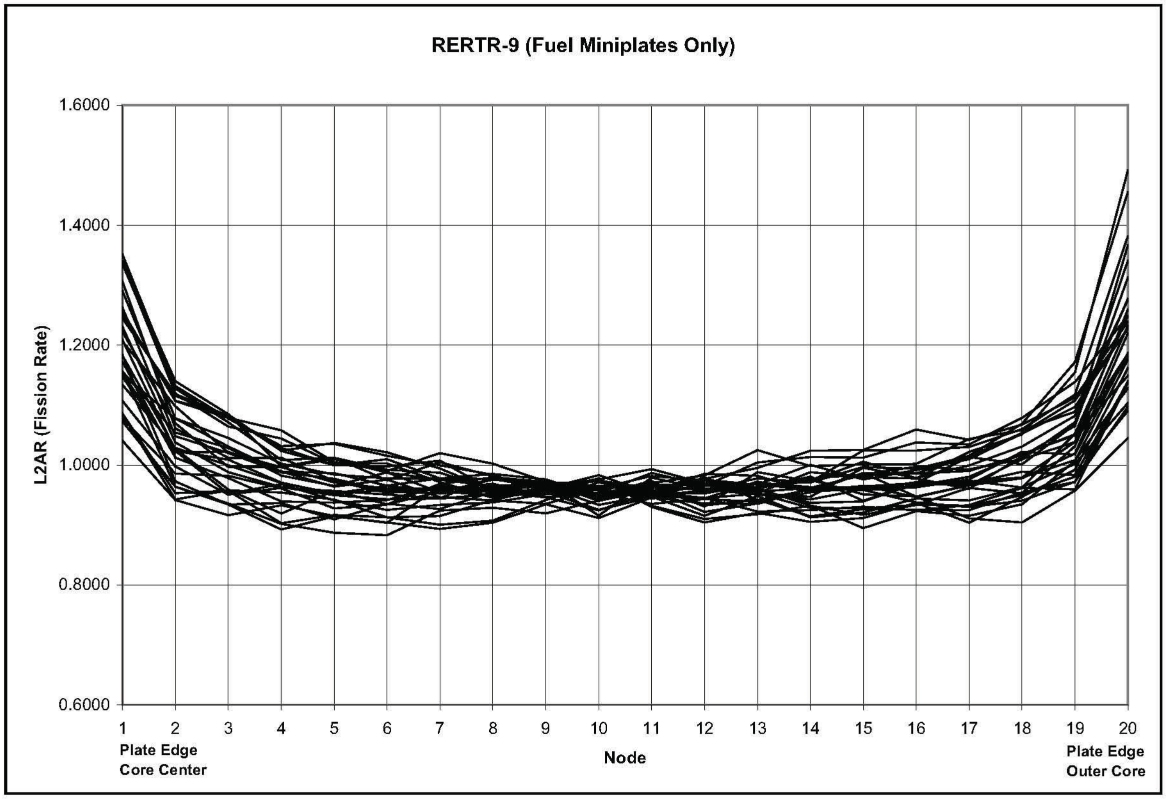

Figure 8. RERTR-9 fuel miniplates fission rate L2ARs in axial direction.[6]

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 11.

Table 11. 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 MCNP-calculated heat flux, nominal coolant flow rate and ABAQUS were used to calculate the coolant and plate surface temperatures.

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 9 through Figure 12.

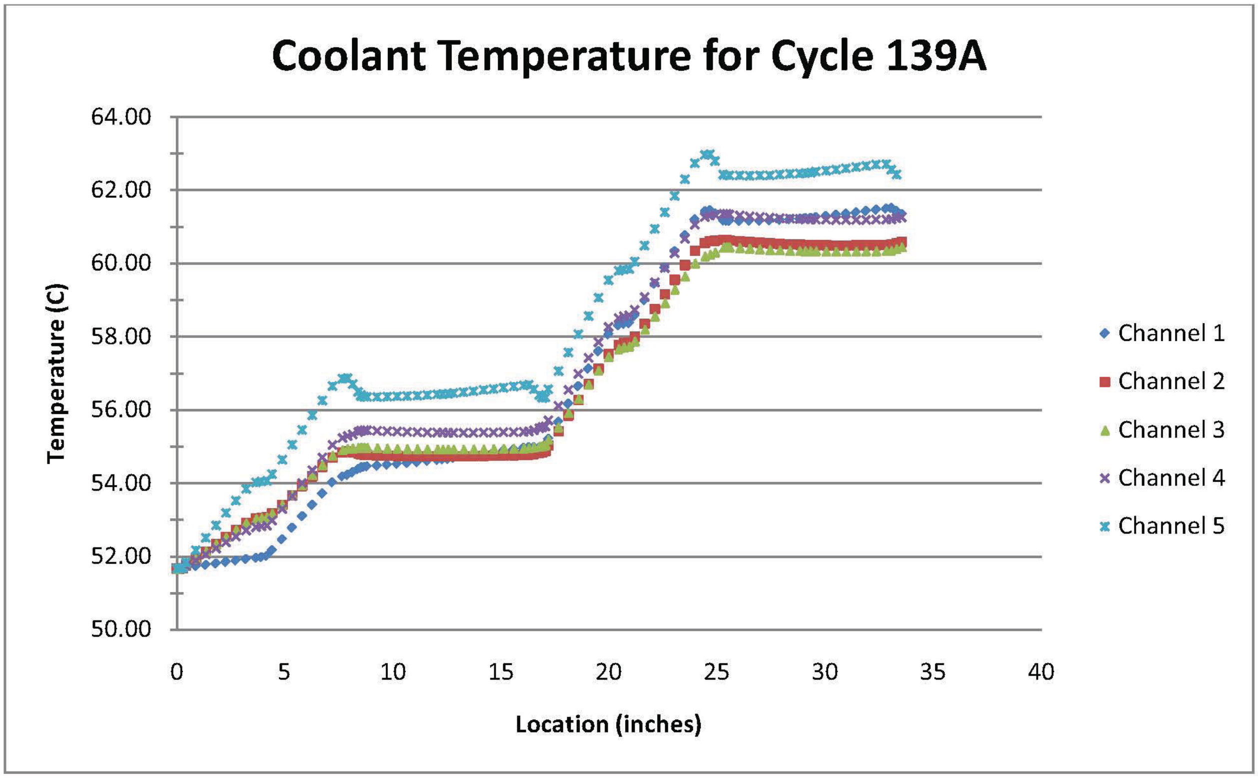

Figure 9. Coolant temperature as a function of location along the test assembly for Cycle 139A.

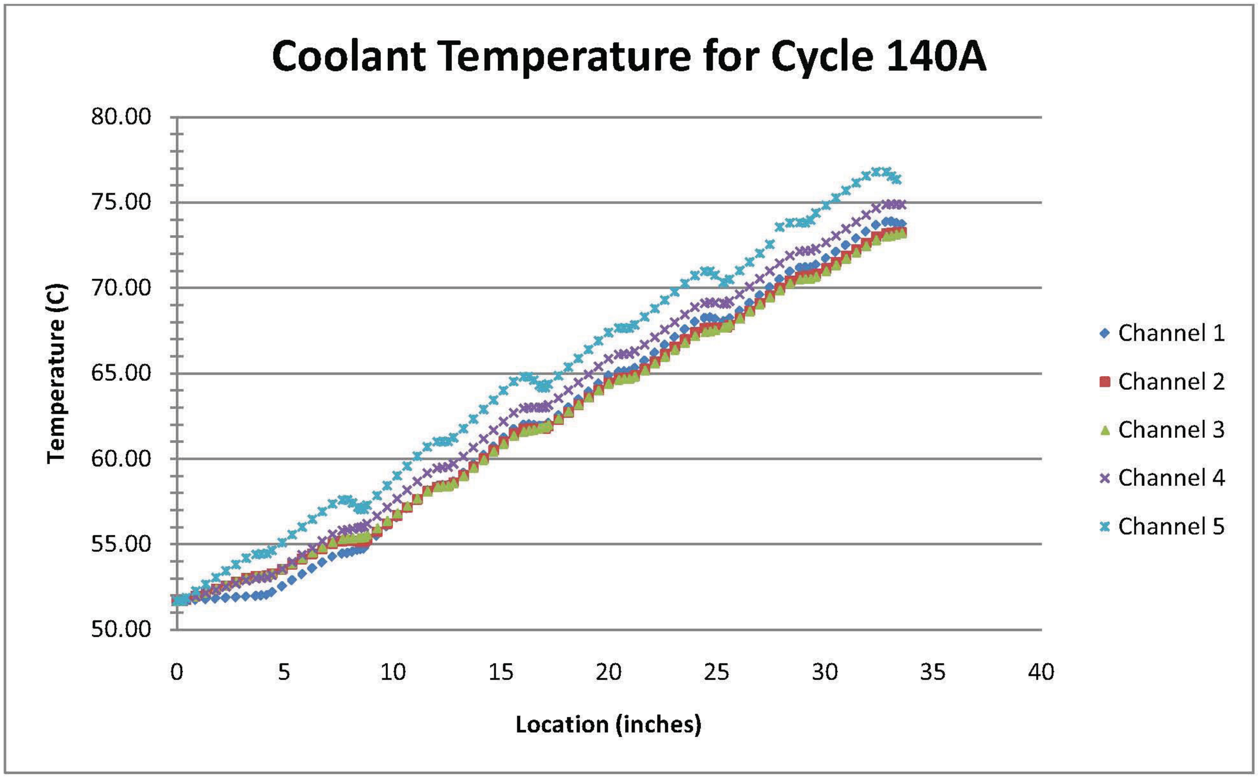

Figure 10. Coolant temperature as a function of location along the test assembly for Cycle 140A.

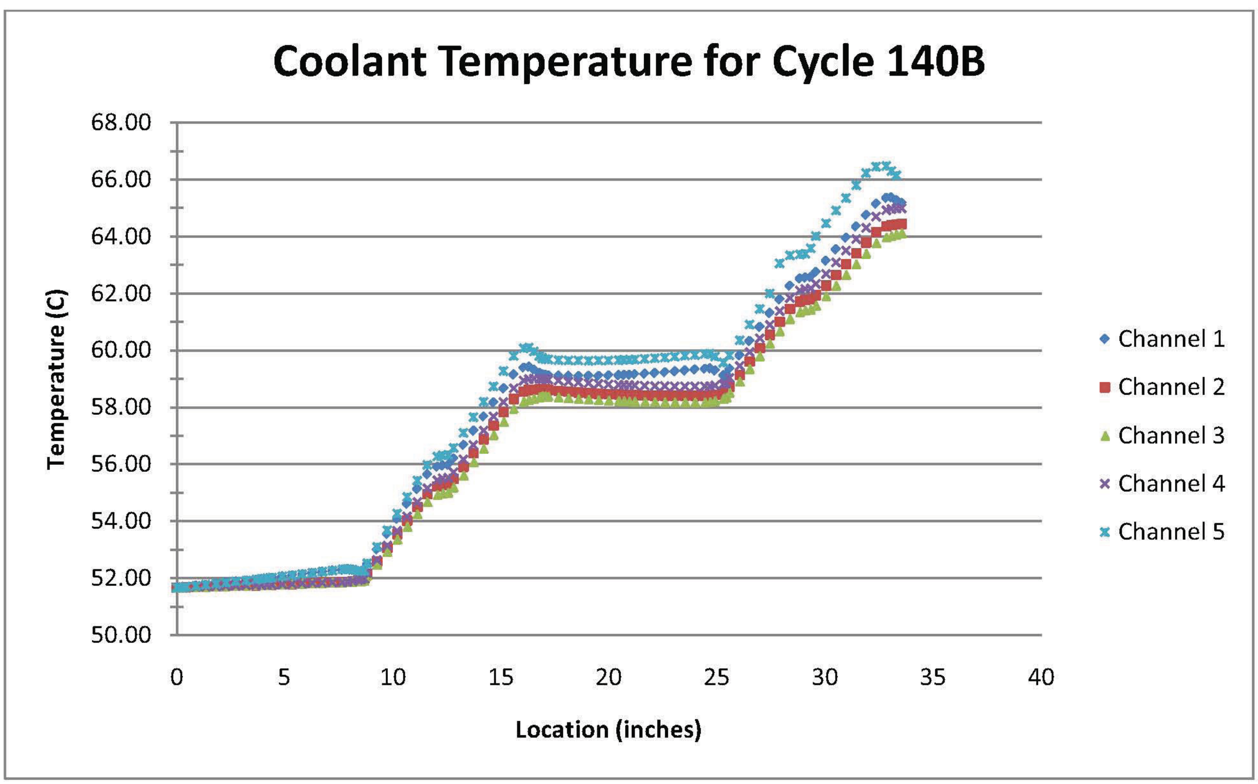

Figure 11. Coolant temperature as a function of location along the test assembly for Cycle 140B.

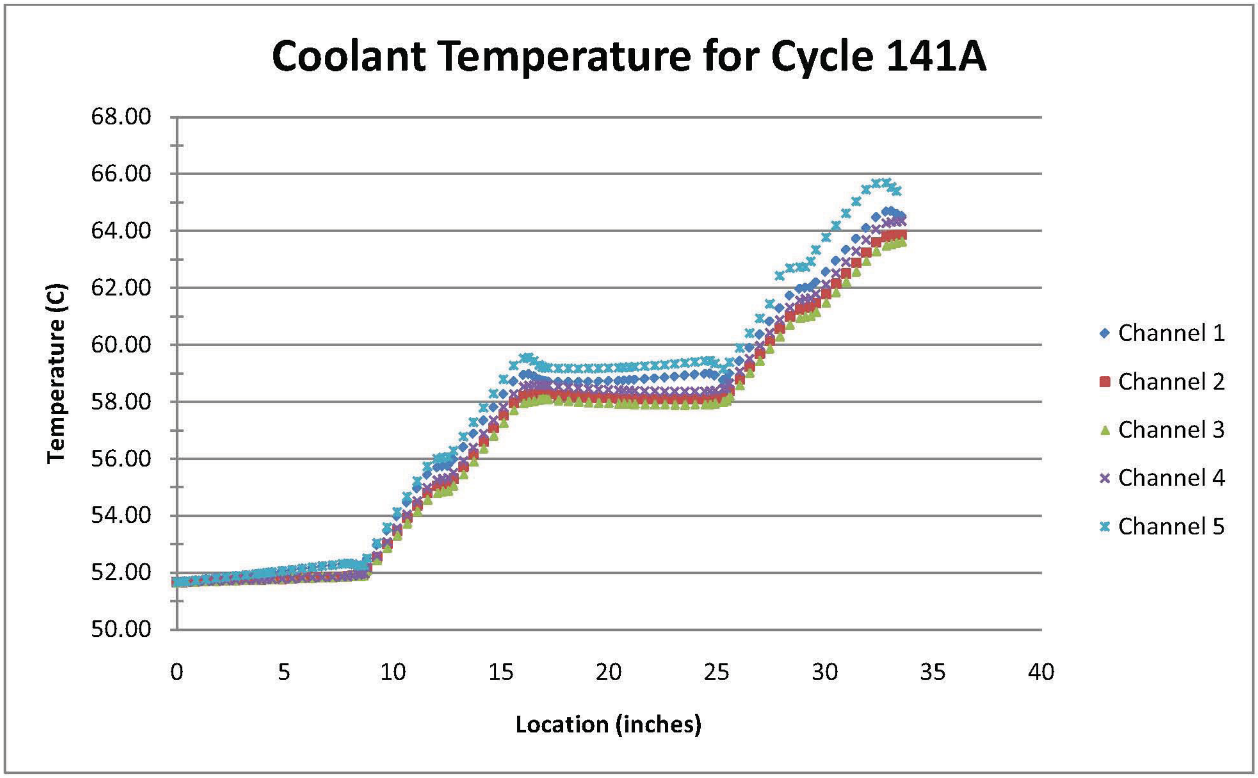

Figure 12. Coolant temperature as a function of location along the test assembly for Cycle 141A.

7.2 Plate Surface Temperature

The maximum, minimum, and average plate temperatures for each cycle are provided in Table 12 through Table 15.

Table 12. Plate surface temperatures for Cycle 139A.

Fuel Plate ID	Fuel Plate #	Maximum	Minimum	Average
A1	Blank	66.6	52.1	53.6
A2	R3R078	87.3	52.9	70.7
A3	Blank	67.6	52.1	53.8
A4	L1F22C	83.7	52.8	68.7
A5	L1F27C	81.7	52.7	67.5
A6	L1P03A	77.6	54.2	66.6
A7	R4R028	82.9	53.2	68.6
A8	L1F29C	92.7	54.5	73.6
B1	Blank	57.1	54.8	55.4
B2	Blank	56.7	55.0	55.5
B3	Blank	57.0	55.2	55.7
B4	Blank	58.0	55.7	56.5
B5	Blank	58.5	55.1	55.7
B6	Blank	58.1	55.1	55.7
B7	Blank	58.4	55.3	56.0
B8	Blank	59.3	55.9	56.8
C1	L1F26C	98.4	56.6	78.3
C2	R3R108	90.5	56.4	74.8
C3	R2R078	91.2	56.6	75.2
C4	L1F28C	100.7	57.6	79.7
C5	L1F32C	100.1	59.3	79.8
C6	L1P04A	92.7	59.0	76.6
C7	R4R018	92.5	59.1	76.5
C8	L1F24C	101.6	60.2	80.9
D1	Blank	63.3	60.7	61.5
D2	Blank	62.4	60.5	61.0
D3	Blank	62.9	60.6	61.3
D4	Blank	64.1	61.5	62.4
D5	Blank	64.5	60.9	61.8
D6	Blank	63.7	60.6	61.3
D7	Blank	64.0	60.8	61.6
D8	Blank	65.2	61.7	62.7

Table 13. Plate surface temperatures for Cycle 140A.

Fuel Plate ID	Fuel Plate #	Maximum	Minimum	Average
A1	Blank	68.2	52.1	53.7
A2	R3R078	89.1	52.9	71.8
A3	Blank	71.0	52.1	54.0
A4	L1F22C	88.5	52.9	71.2
A5	L1F27C	84.9	52.7	69.2
A6	L1P03A	81.4	54.4	68.6
A7	R4R028	87.4	53.3	70.9
A8	L1F29C	97.7	54.8	76.2
B1	L1F34T	104.5	56.4	81.2
B2	L1F330	95.3	56.4	77.4
B3	L1P05A	97.5	56.7	78.5
B4	L1F37T	110.3	57.5	84.5
B5	L1P09T	107.6	59.4	83.6
B6	R2R088	102.4	59.2	81.6
B7	R6R018	103.7	59.5	82.4
B8	L1P07T	112.9	60.7	86.8
C1	L1F26C	107.0	62.2	85.2
C2	R3R108	100.7	62.0	82.6
C3	R2R078	102.5	62.5	83.6
C4	L1F28C	112.2	63.7	88.3
C5	L1F32C	109.0	65.3	87.1
C6	L1P04A	103.3	65.0	84.8
C7	R4R018	104.2	65.4	85.3
C8	L1F24C	113.2	66.8	89.9
D1	L1F35T	111.5	68.0	90.1
D2	R6R048	106.4	67.8	88.1
D3	L1P06A	106.2	68.2	88.1
D4	L1F36T	117.2	69.7	93.6
D5	L1P10T	108.5	71.0	89.7
D6	R2R118	104.4	70.8	88.1
D7	R6R038	106.7	71.1	89.3
D8	L1P08T	114.4	72.7	93.4

Table 14. Plate surface temperatures for Cycle 140B.

Fuel Plate ID	Fuel Plate #	Maximum	Minimum	Average
A1	Blank	54.0	52.1	52.6
A2	Blank	53.6	52.1	52.5
A3	Blank	53.6	52.1	52.5
A4	Blank	54.0	52.1	52.6
A5	Blank	55.5	52.2	52.9
A6	Blank	55.1	52.2	52.7
A7	Blank	55.1	52.2	52.7
A8	Blank	55.5	52.2	52.9
B1	L1F34T	100.6	54.0	78.2
B2	L1F330	92.0	53.6	74.4
B3	L1P05A	93.8	53.6	75.3
B4	L1F37T	104.0	54.1	79.9
B5	L1P09T	103.3	56.9	80.3
B6	R2R088	98.7	56.4	78.4
B7	R6R018	99.8	56.4	79.0
B8	L1P07T	106.9	57.1	82.2
C1	Blank	60.9	58.6	59.3
C2	Blank	60.1	58.2	58.8
C3	Blank	60.2	58.3	59.0
C4	Blank	61.2	58.9	59.7
C5	Blank	62.3	58.8	59.6
C6	Blank	61.6	58.4	59.1
C7	Blank	61.7	58.5	59.2
C8	Blank	62.6	59.1	60.0
D1	L1F35T	102.9	60.4	82.2
D2	R6R048	98.8	59.8	80.6
D3	L1P06A	97.6	59.9	80.0
D4	L1F36T	106.9	60.8	84.4
D5	L1P10T	100.1	63.1	81.8
D6	R2R118	96.2	62.6	80.1
D7	R6R038	97.6	62.7	80.8
D8	L1P08T	104.1	63.6	83.9

Table 15. Plate surface temperatures for Cycle 141A.

Fuel Plate ID	Fuel Plate #	Maximum	Minimum	Average
A1	Blank	54.0	52.1	52.6
A2	Blank	53.6	52.1	52.5
A3	Blank	53.6	52.1	52.5
A4	Blank	54.0	52.1	52.6
A5	Blank	55.5	52.2	52.9
A6	Blank	55.1	52.2	52.7
A7	Blank	55.1	52.2	52.7
A8	Blank	55.5	52.2	52.9
B1	L1F34T	97.9	53.9	76.8
B2	L1F330	90.5	53.6	73.6
B3	L1P05A	92.3	53.6	74.5
B4	L1F37T	100.8	54.0	78.3
B5	L1P09T	100.1	57.8	78.6
B6	R2R088	97.0	56.2	77.5
B7	R6R018	98.0	56.3	78.0
B8	L1P07T	103.1	56.9	80.2
C1	Blank	60.6	58.3	59.0
C2	Blank	59.8	58.0	58.5
C3	Blank	60.0	58.1	58.7
C4	Blank	60.9	58.6	59.3
C5	Blank	62.1	58.5	59.3
C6	Blank	61.3	58.2	58.8
C7	Blank	61.5	58.2	58.9
C8	Blank	62.3	58.8	59.6
D1	L1F35T	100.1	60.0	80.6
D2	R6R048	97.3	59.5	79.7
D3	L1P06A	95.9	59.6	79.0
D4	L1F36T	103.7	60.4	82.6
D5	L1P10T	97.9	62.6	80.4
D6	R2R118	95.0	62.2	79.3
D7	R6R038	96.3	62.3	79.9
D8	L1P08T	101.6	63.0	82.4

8. REFERENCES

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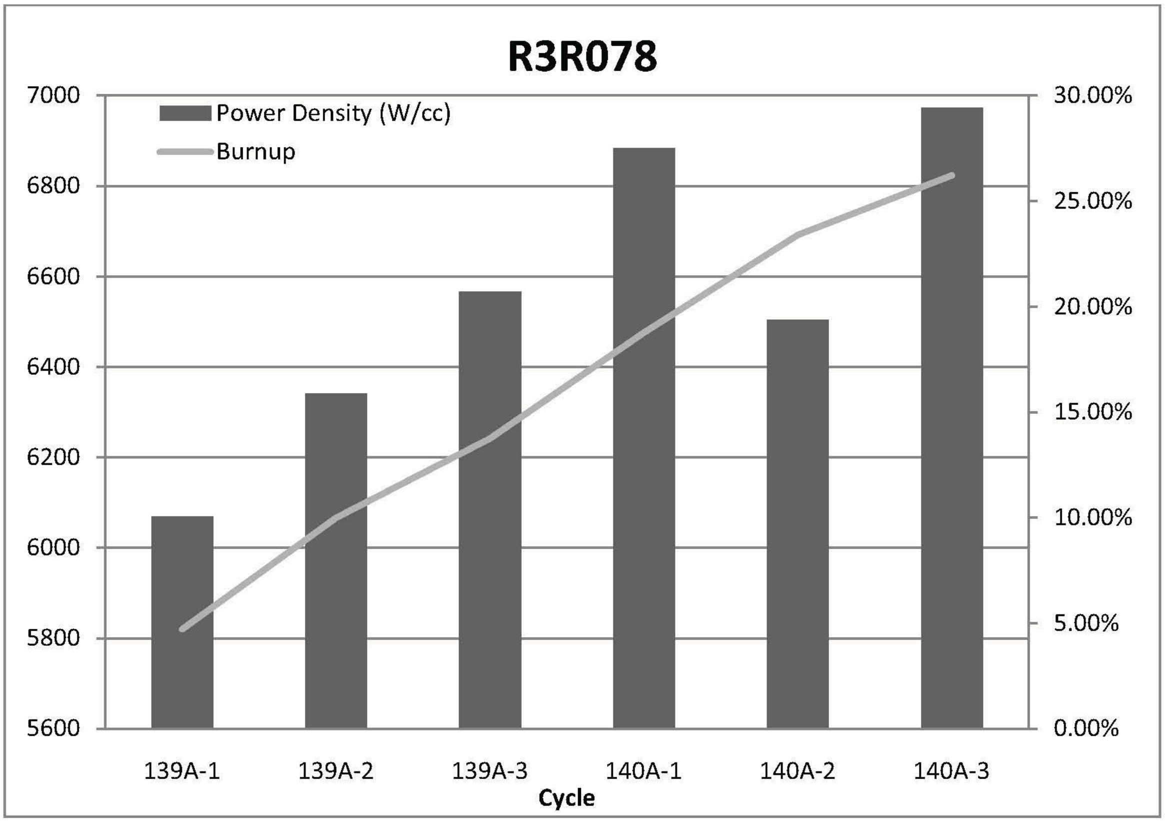
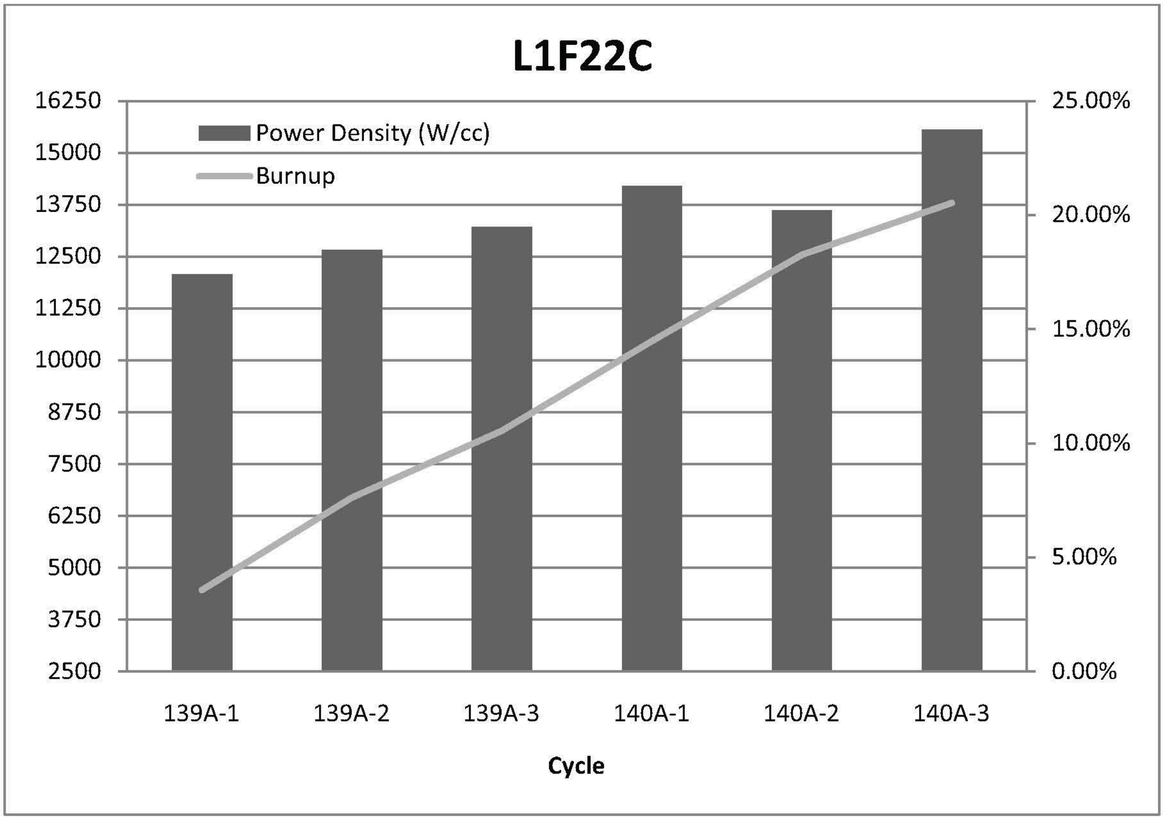
Appendix A

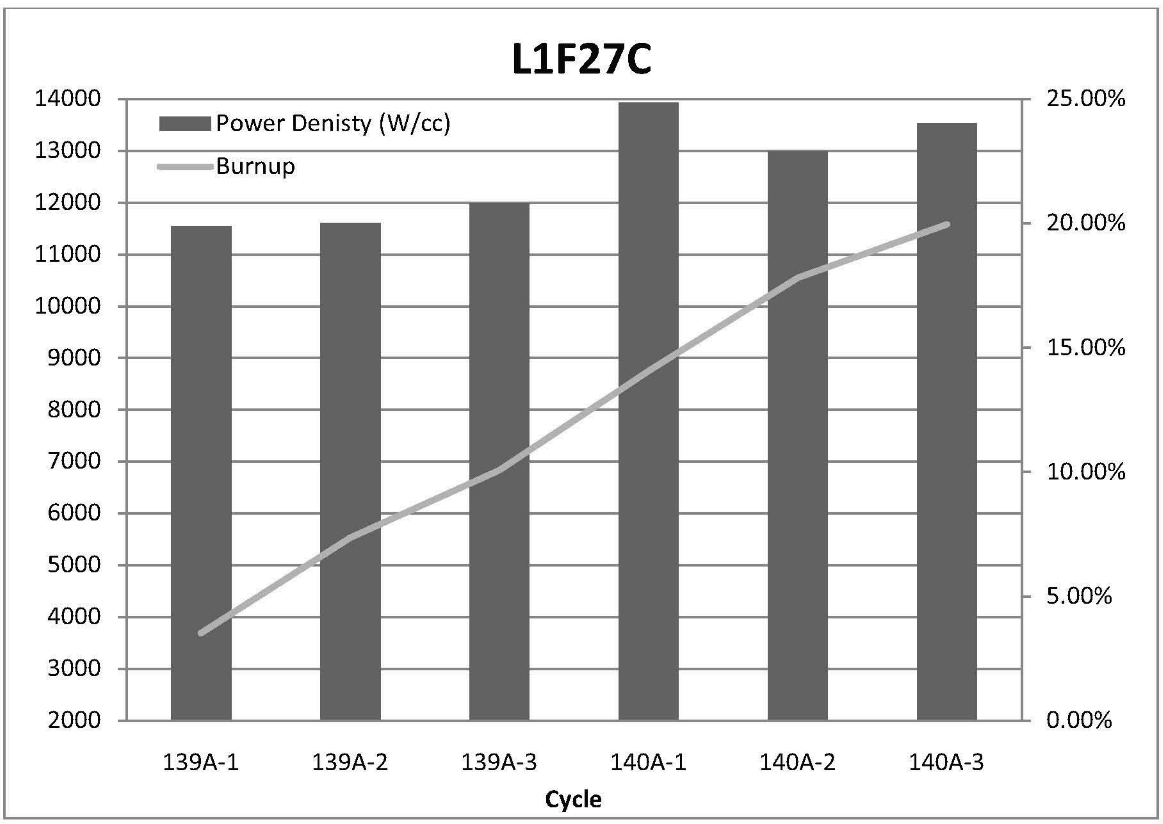
Individual Plate Power and Burnup Plots

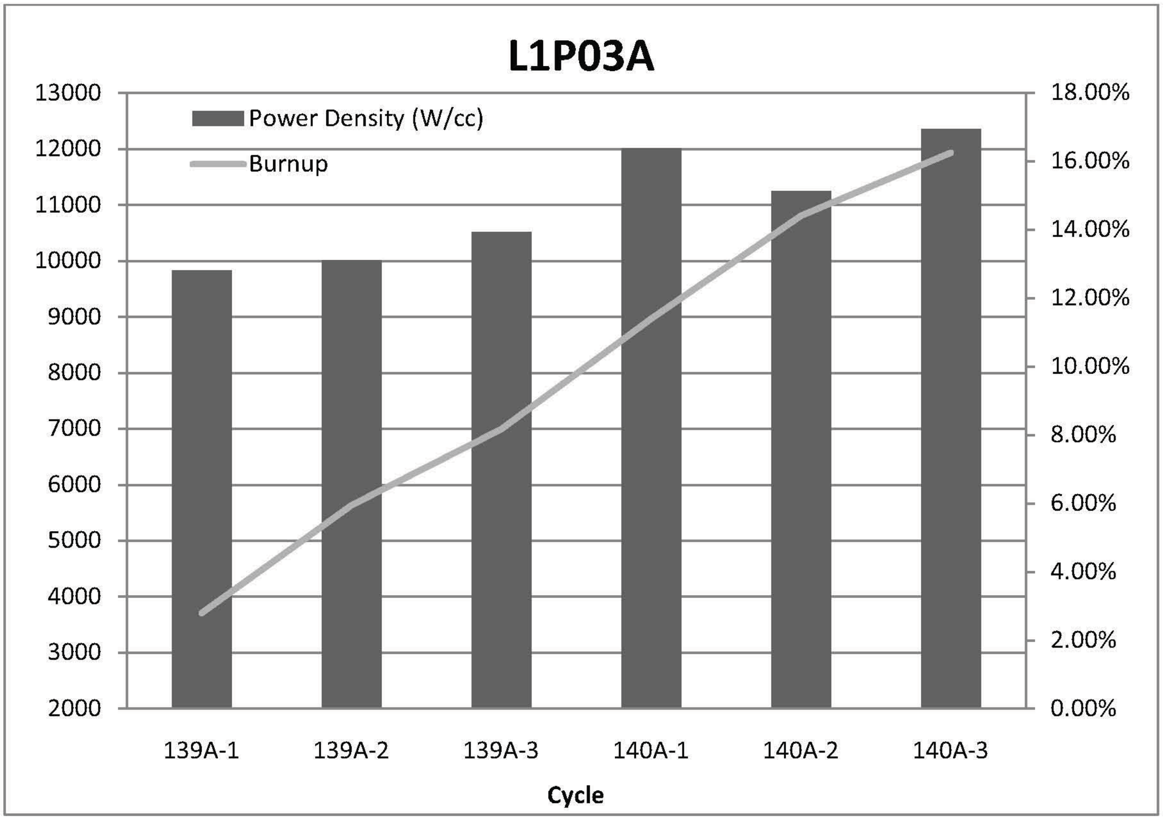
Appendix A
Individual Plate Power and Burnup Plots

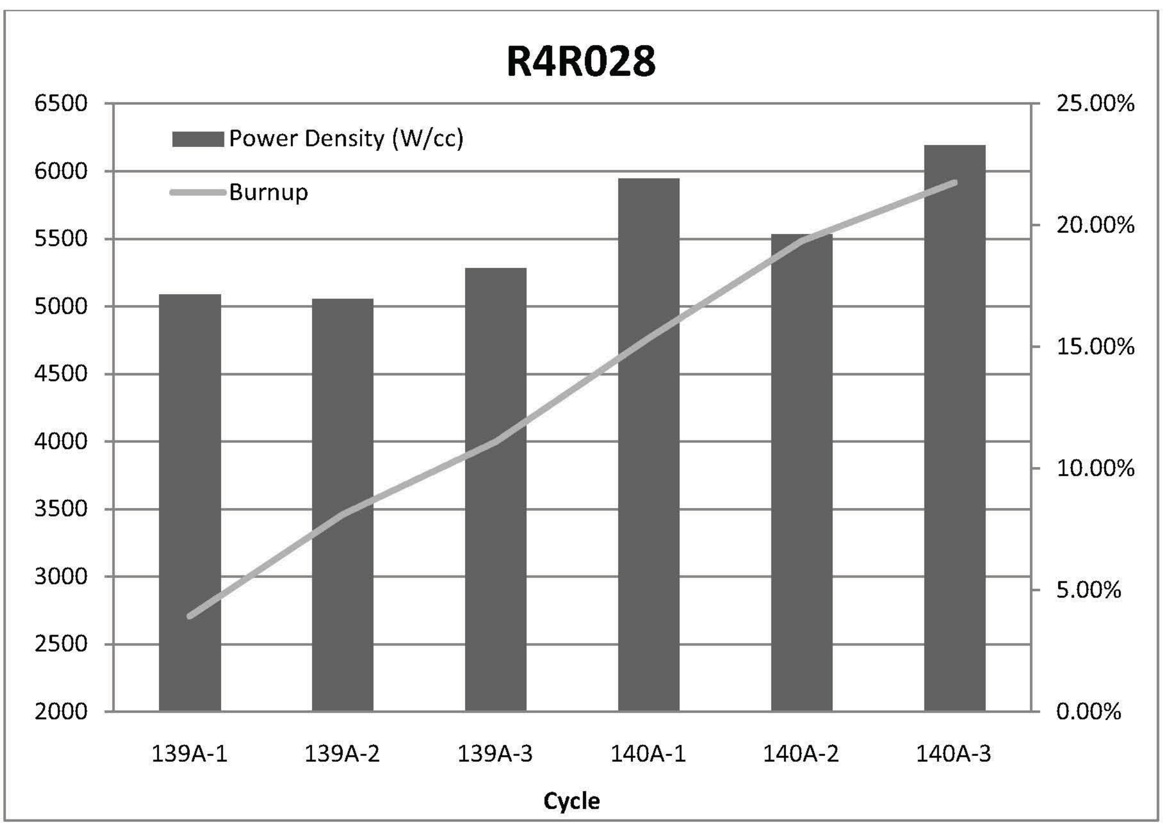
A-1. RERTR-9A

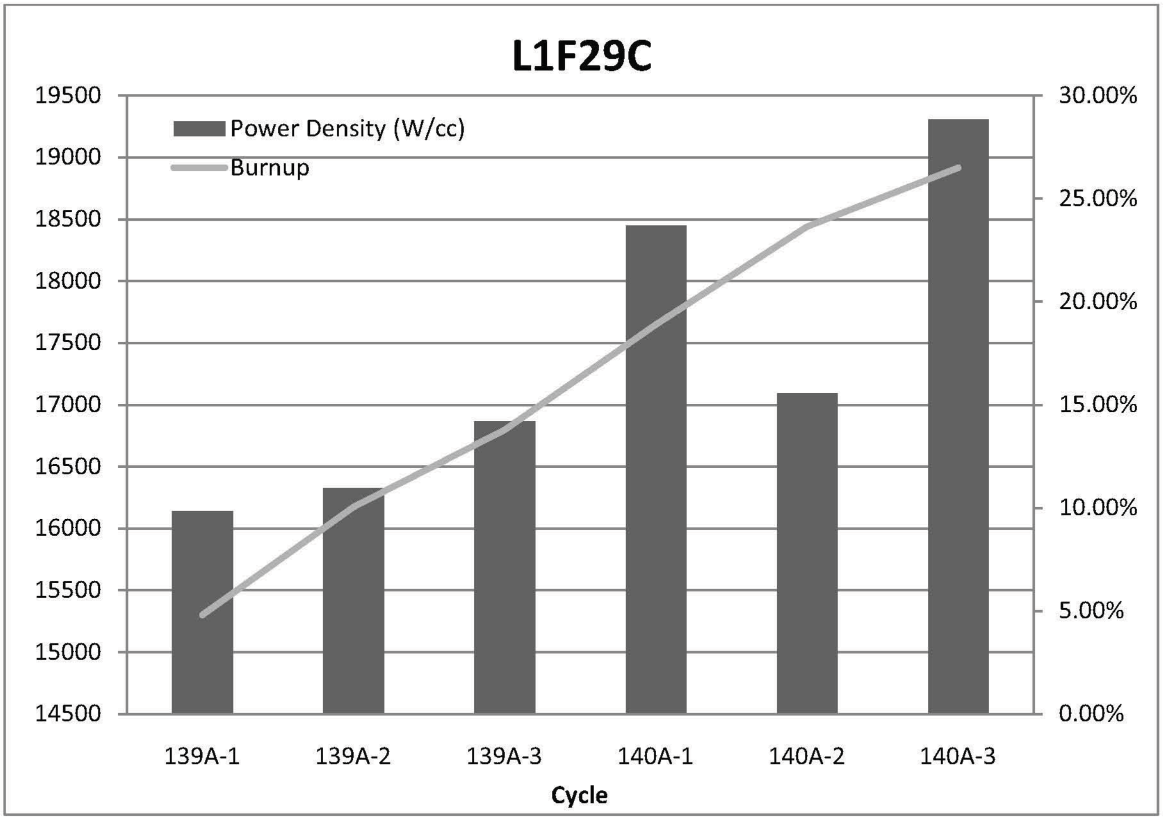


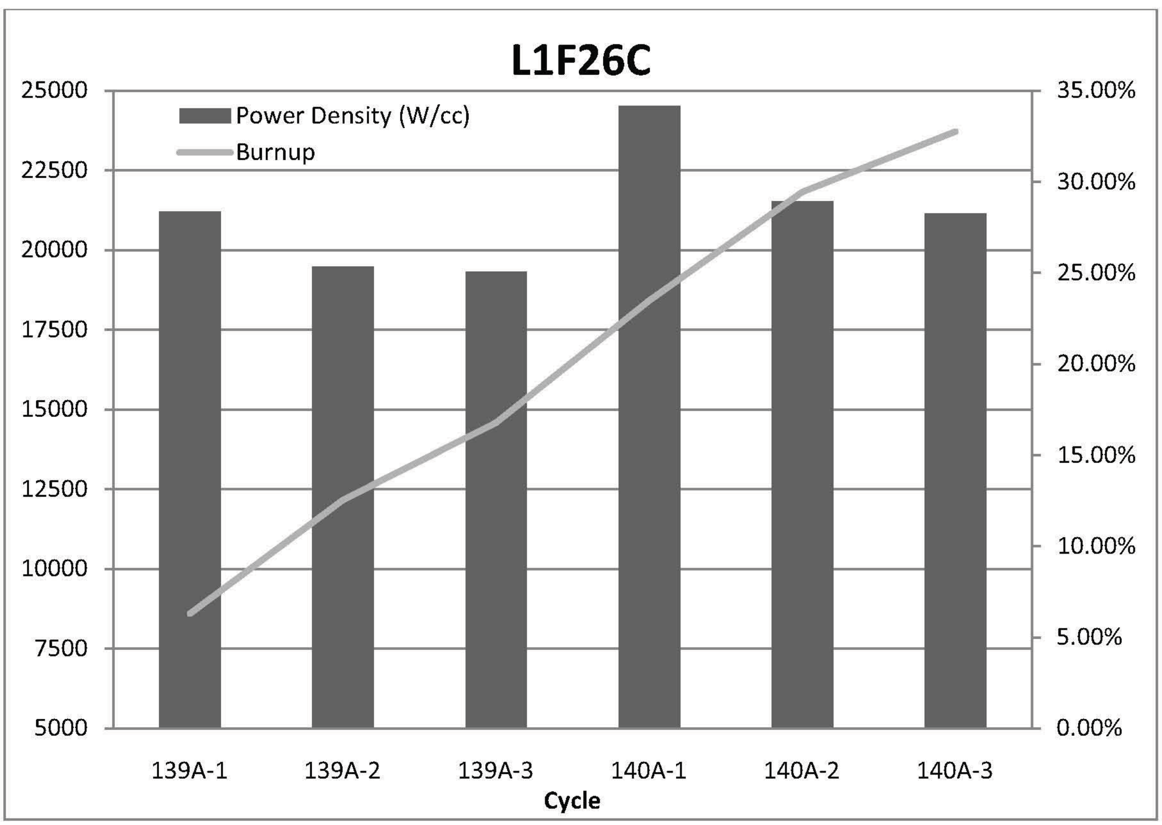

L1F22C
Power Density (W/cc)
Burnup
16250
15000
13750
12500
11250
10000
8750
7500
6250
5000
3750
2500
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
139A-1
139A-2
139A-3
140A-1
140A-2
140A-3
Cycle

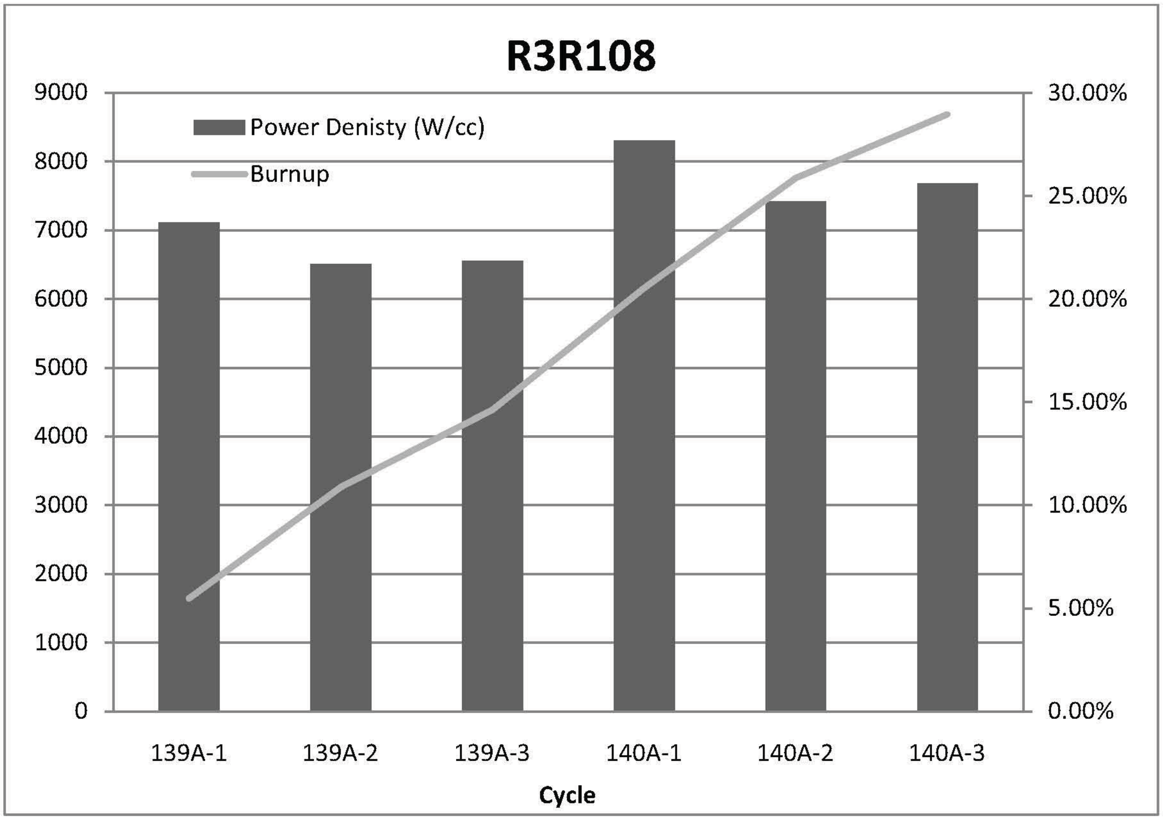

L1F27C
Power Denisty (W/cc)
Burnup
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
139A-1
139A-2
139A-3
140A-1
140A-2
140A-3
Cycle

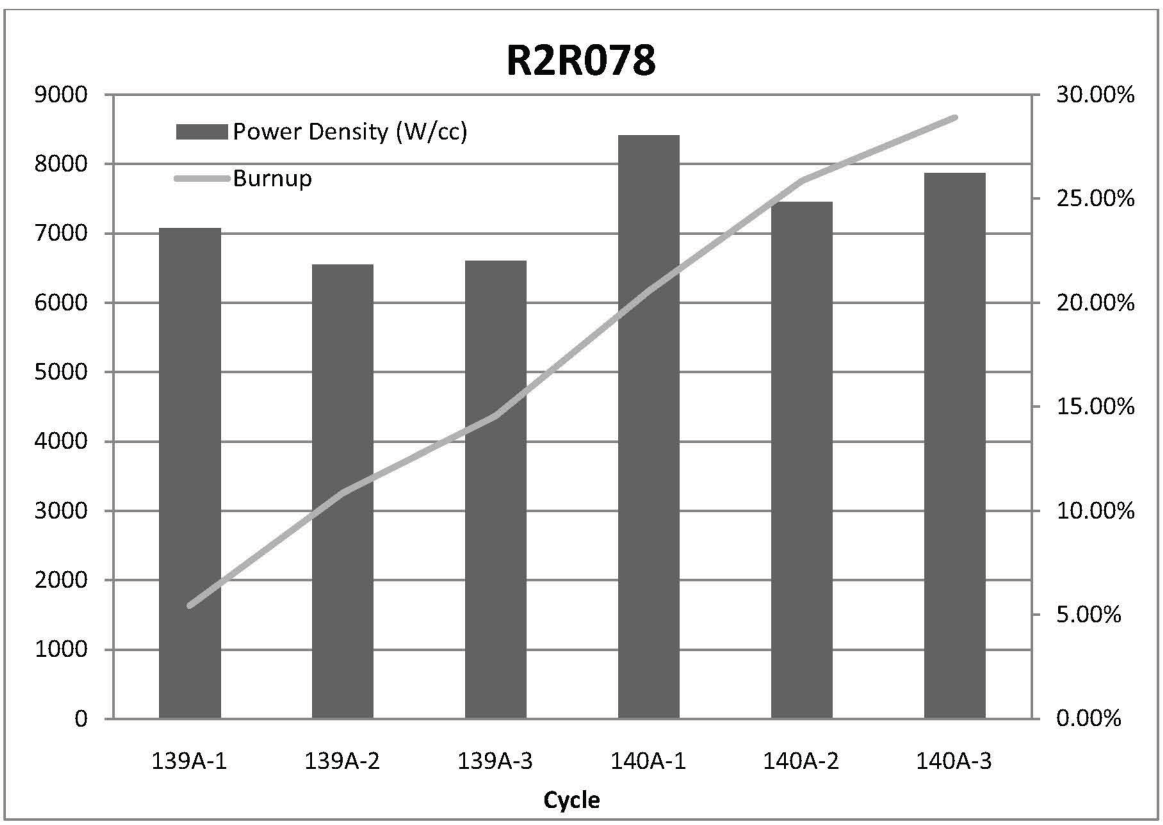

L1P03A
Power Density (W/cc)
Burnup
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
18.00%
16.00%
14.00%
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
139A-1
139A-2
139A-3
140A-1
140A-2
140A-3
Cycle

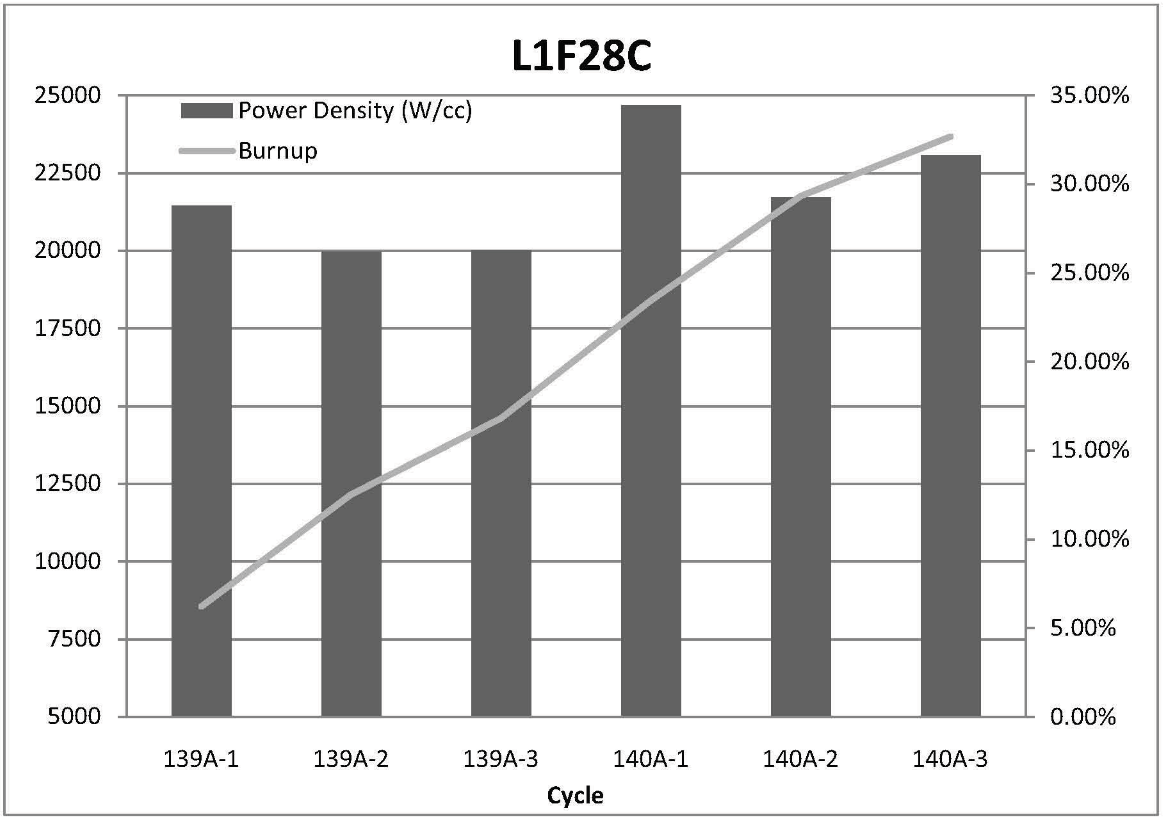

R4R028
Power Density (W/cc)
Burnup
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
139A-1
139A-2
139A-3
140A-1
140A-2
140A-3
Cycle


L1F29C
Power Density (W/cc)
Burnup
19500
19000
18500
18000
17500
17000
16500
16000
15500
15000
14500
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
139A-1
139A-2
139A-3
140A-1
140A-2
140A-3
Cycle

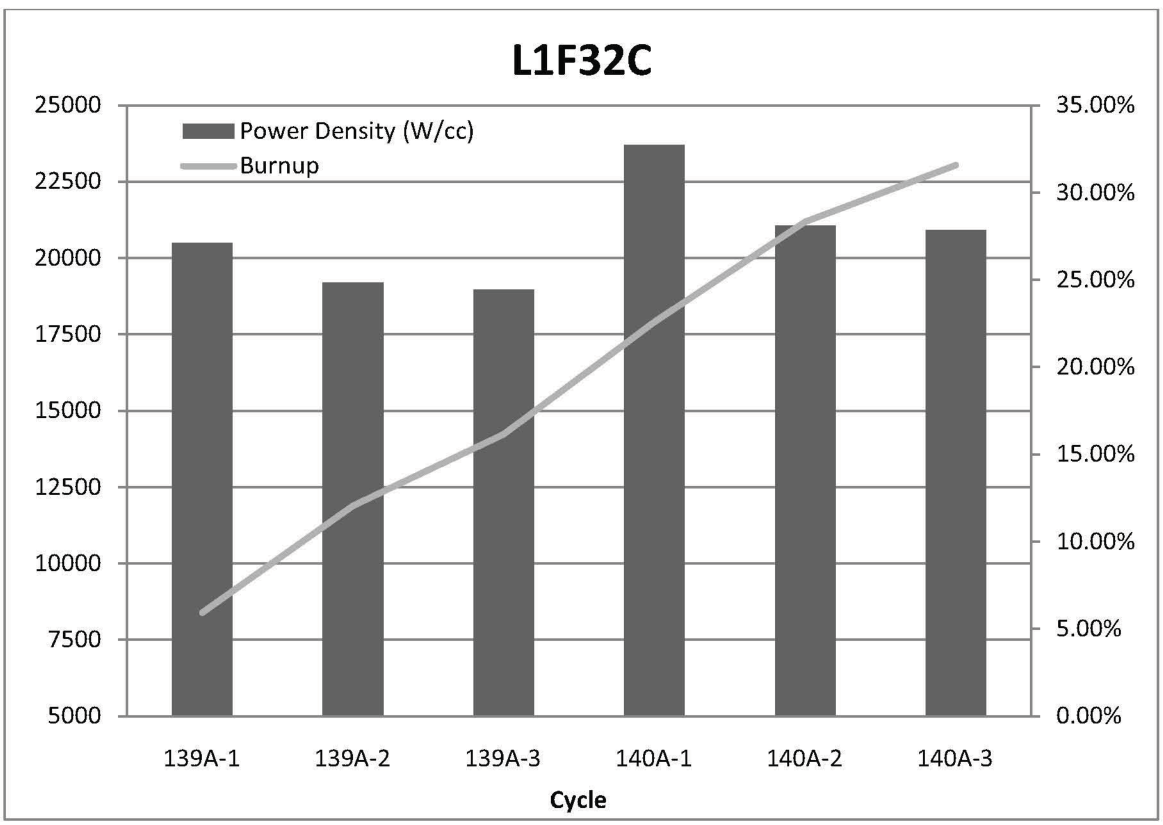

L1F26C
Power Density (W/cc)
Burnup
25000
22500
20000
17500
15000
12500
10000
7500
5000
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
139A-1
139A-2
139A-3
140A-1
140A-2
140A-3
Cycle


R3R108
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Power Denisty (W/cc)
Burnup
139A-1
139A-2
139A-3
140A-1
140A-2
140A-3
Cycle

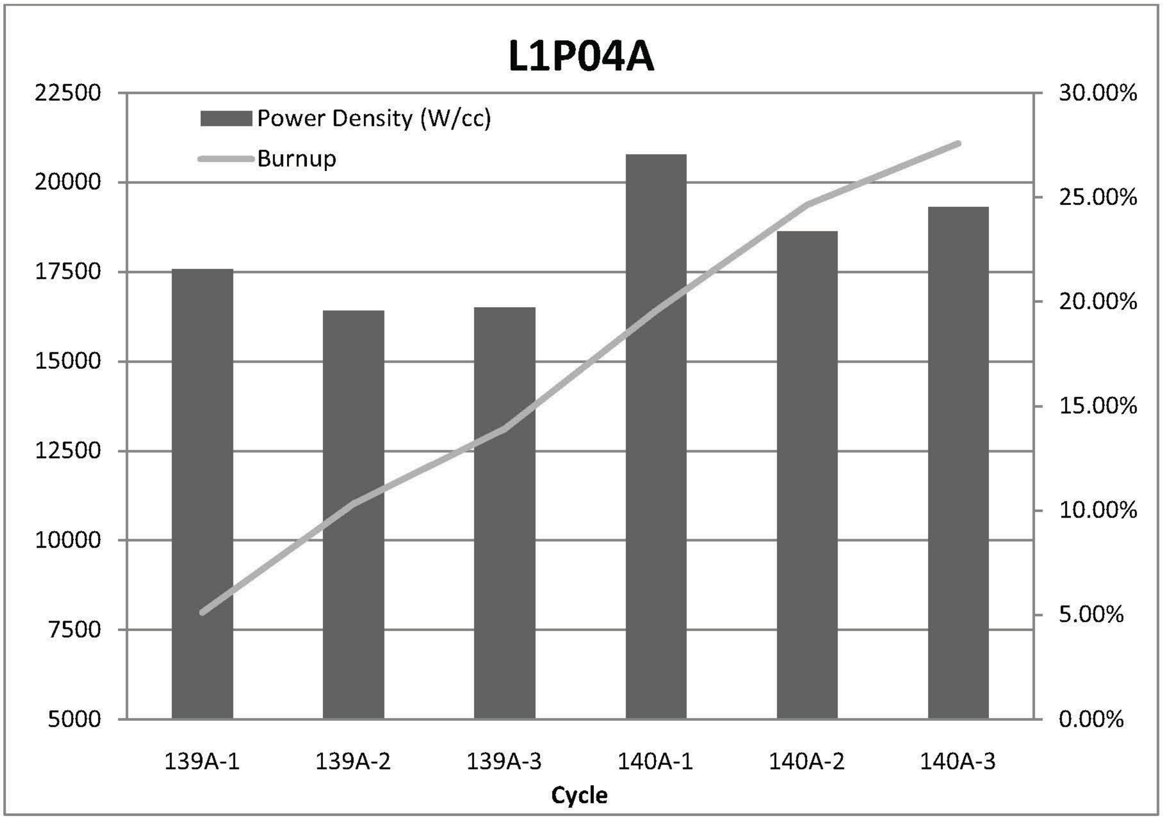

R2R078
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Power Density (W/cc)
Burnup
139A-1
139A-2
139A-3
140A-1
140A-2
140A-3
Cycle



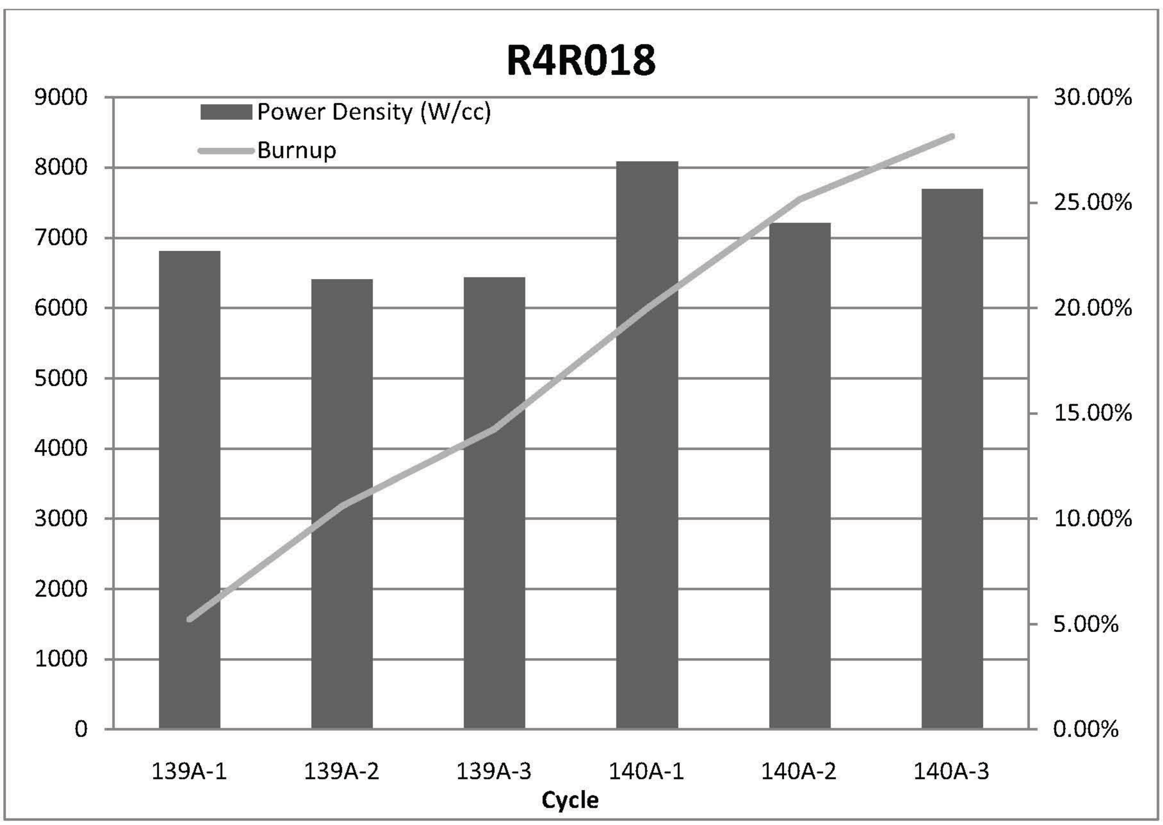
L1F28C
25000
22500
20000
17500
15000
12500
10000
7500
5000
Power Density (W/cc)
Burnup
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
139A-1
139A-2
139A-3
140A-1
140A-2
140A-3
Cycle



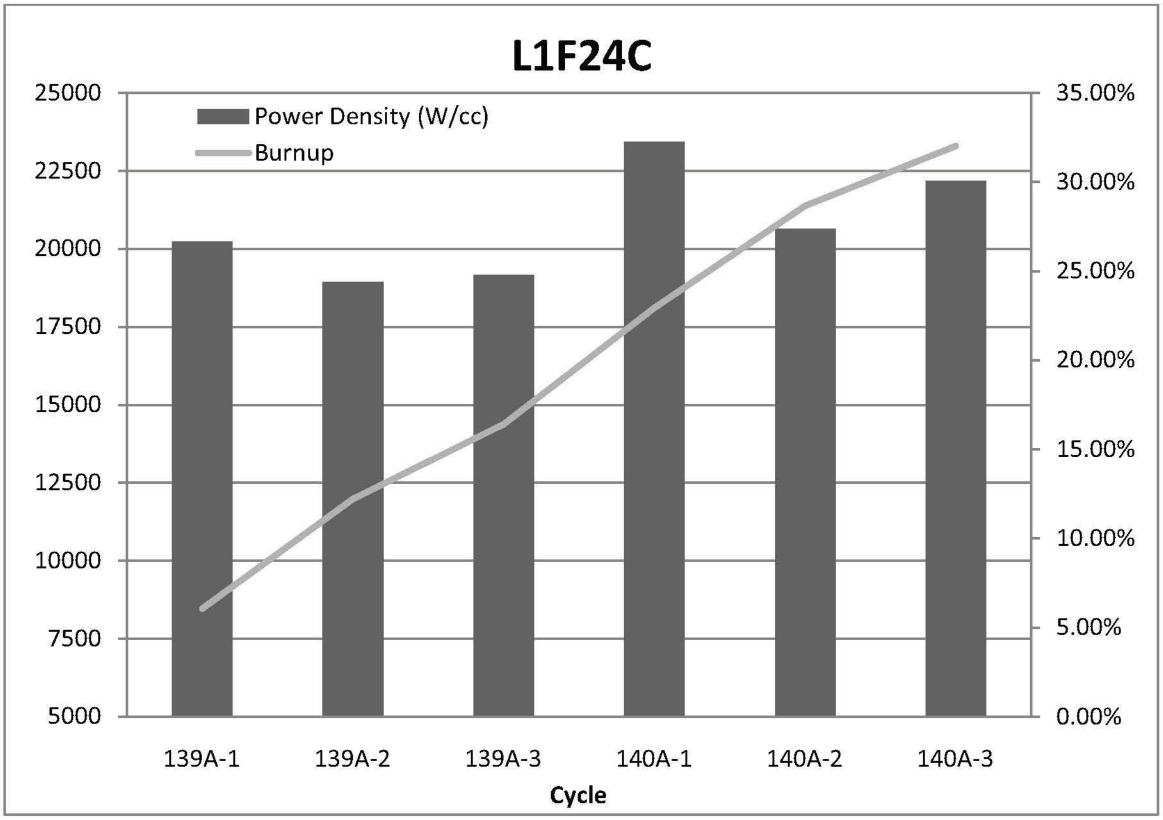
L1F32C
25000
22500
20000
17500
15000
12500
10000
7500
5000
Power Density (W/cc)
Burnup
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
139A-1
139A-2
139A-3
140A-1
140A-2
140A-3
Cycle



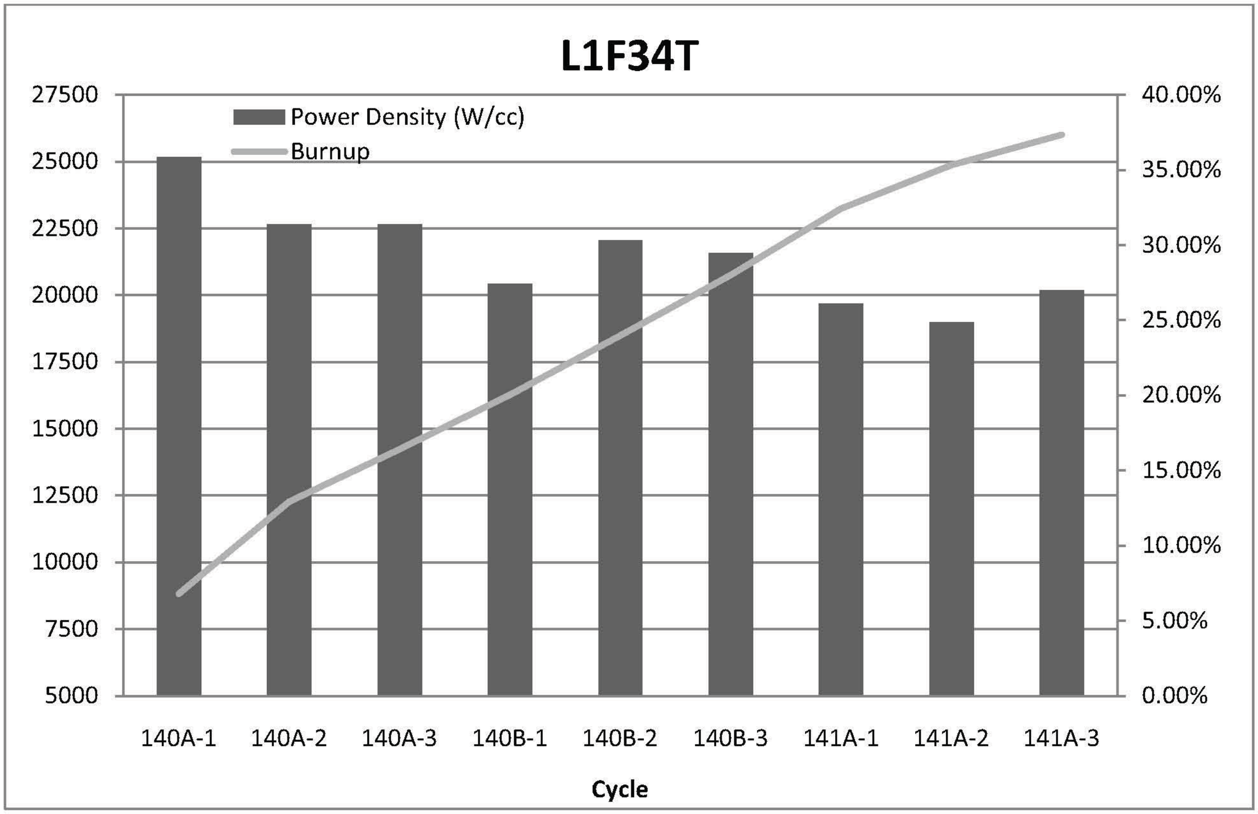
L1P04A
Power Density (W/cc)
Burnup
22500
20000
17500
15000
12500
10000
7500
5000
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
139A-1
139A-2
139A-3
140A-1
140A-2
140A-3
Cycle

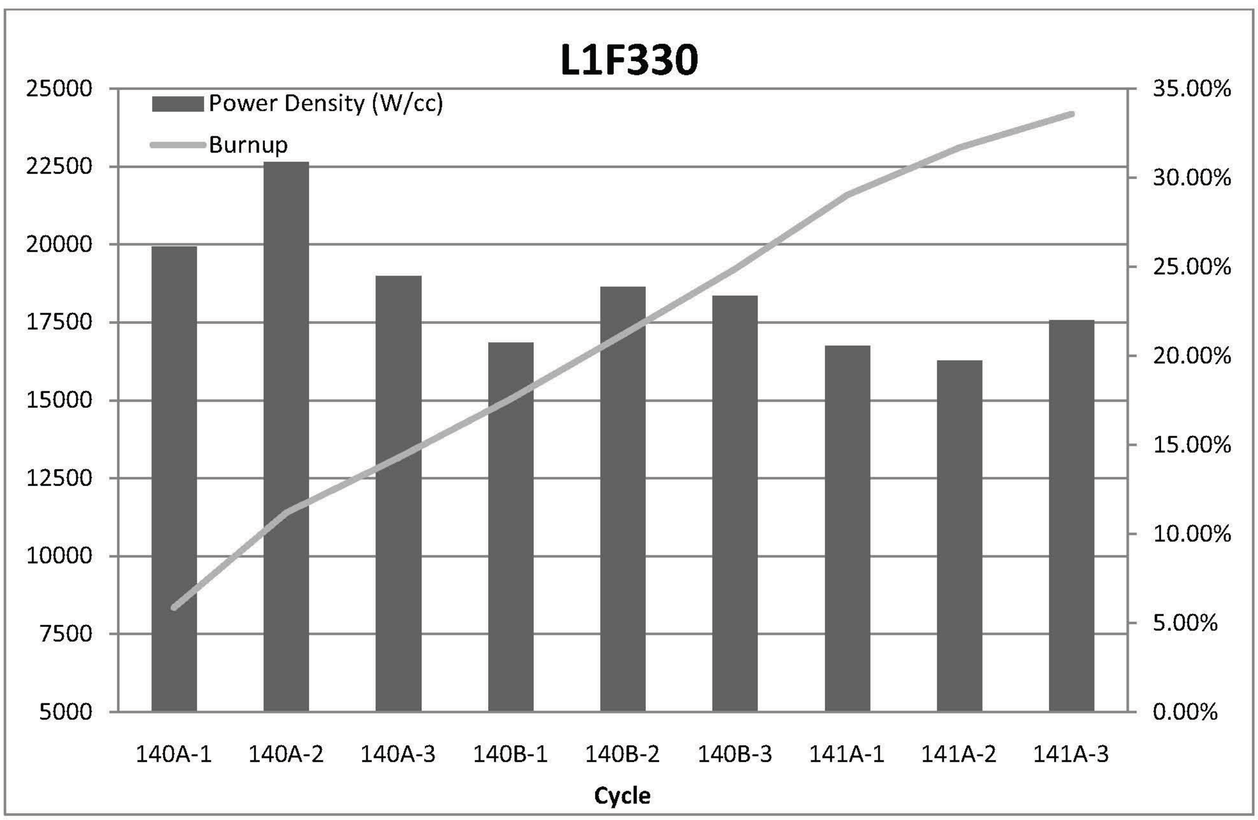


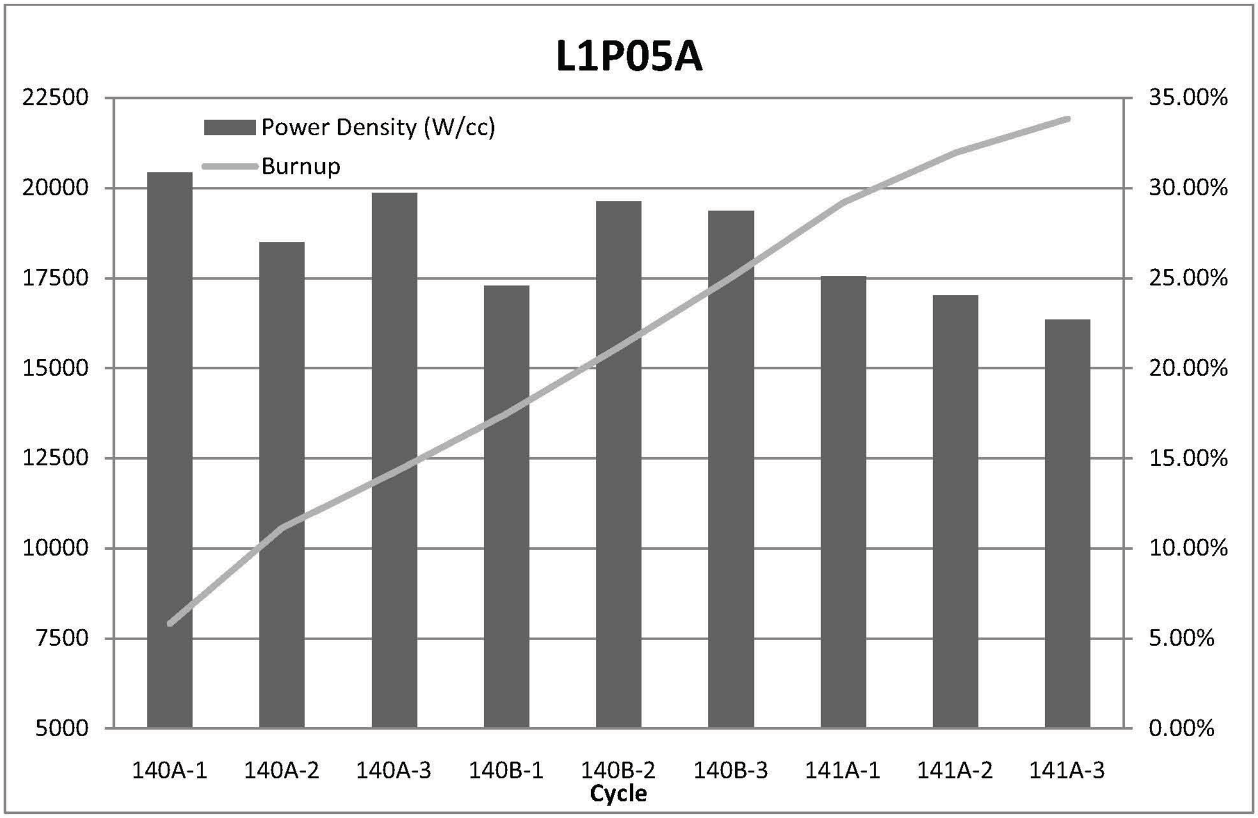
R4R018
Power Density (W/cc)
Burnup
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
139A-1
139A-2
139A-3
140A-1
140A-2
140A-3
Cycle

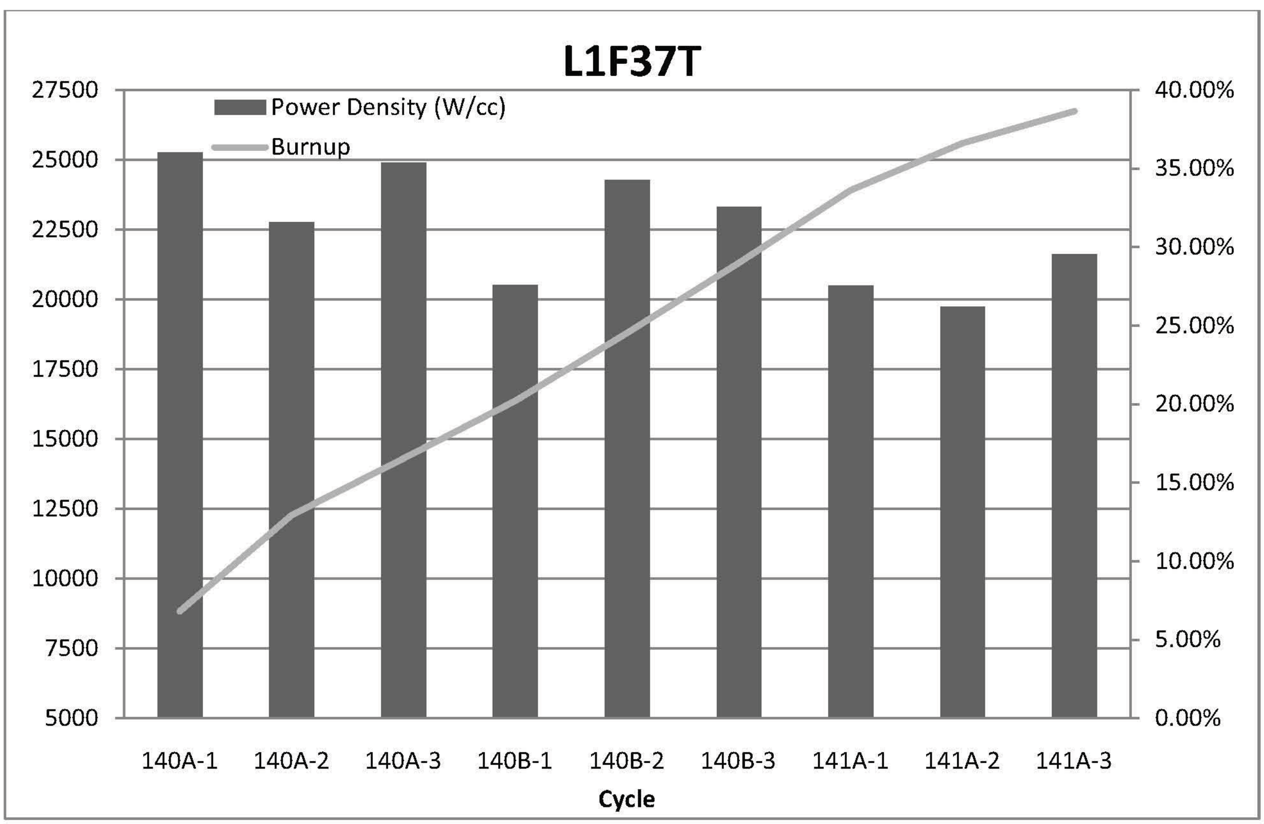

L1F24C
25000
22500
20000
17500
15000
12500
10000
7500
5000
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Power Density (W/cc)
Burnup
139A-1
139A-2
139A-3
140A-1
140A-2
140A-3
Cycle

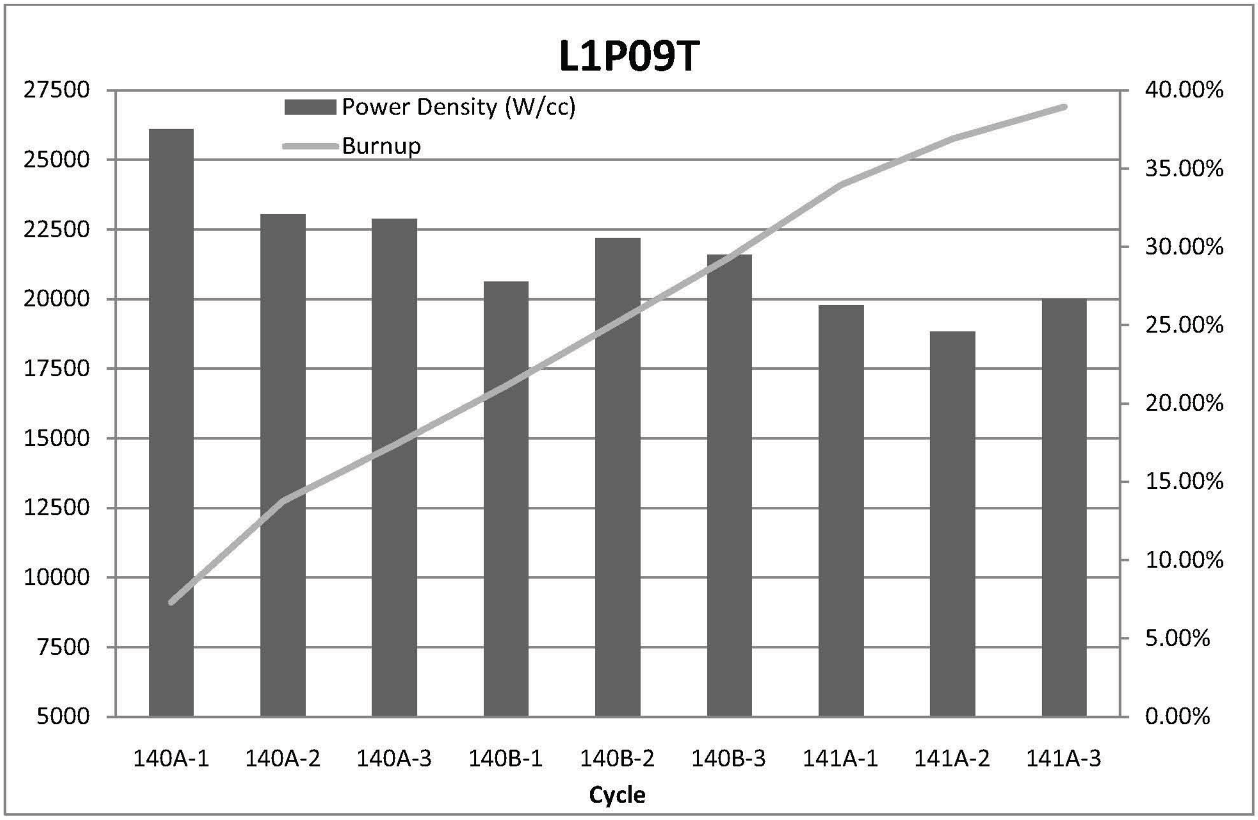
A-2. RERTR-9B

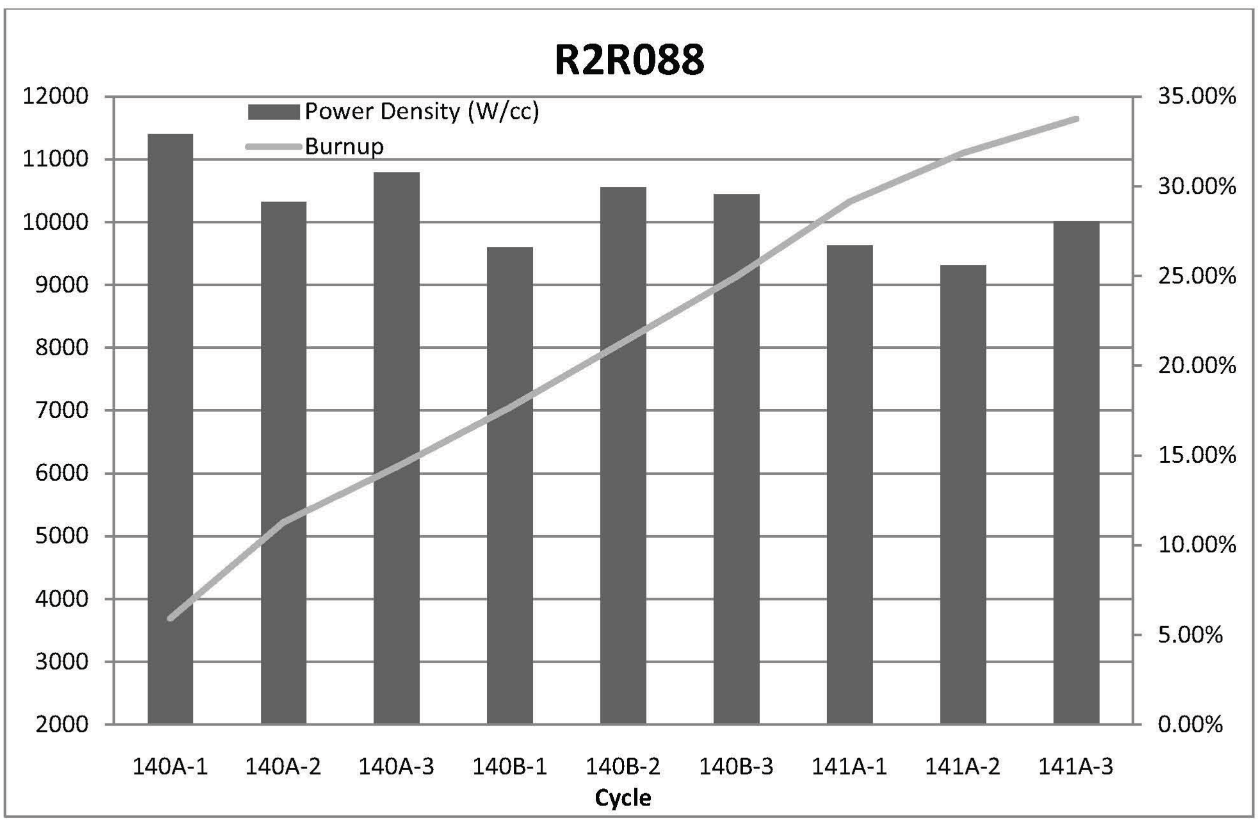

L1F34T
Power Density (W/cc)
Burnup
27500
25000
22500
20000
17500
15000
12500
10000
7500
5000
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1
140A-2
140A-3
140B-1
140B-2
140B-3
141A-1
141A-2
141A-3
Cycle

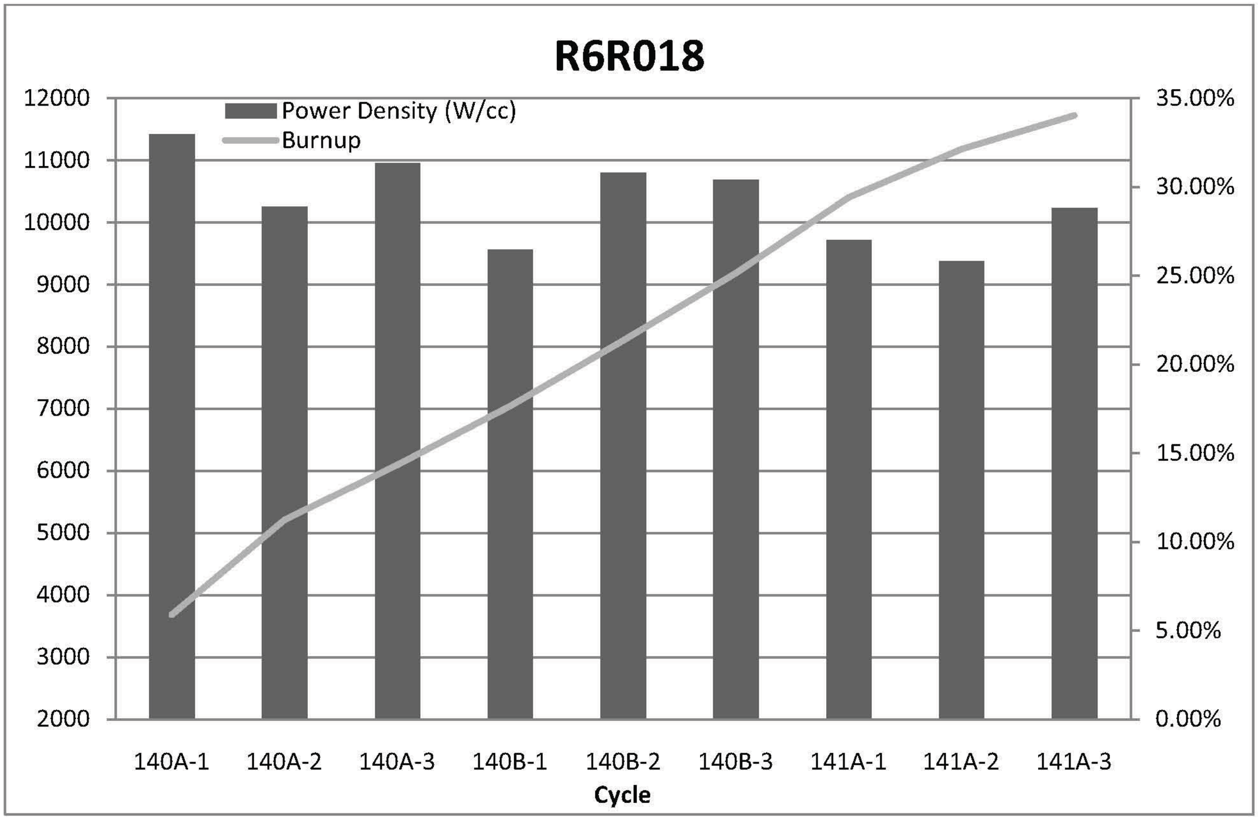

L1F330
Power Density (W/cc)
Burnup
25000
22500
20000
17500
15000
12500
10000
7500
5000
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1
140A-2
140A-3
140B-1
140B-2
140B-3
141A-1
141A-2
141A-3
Cycle

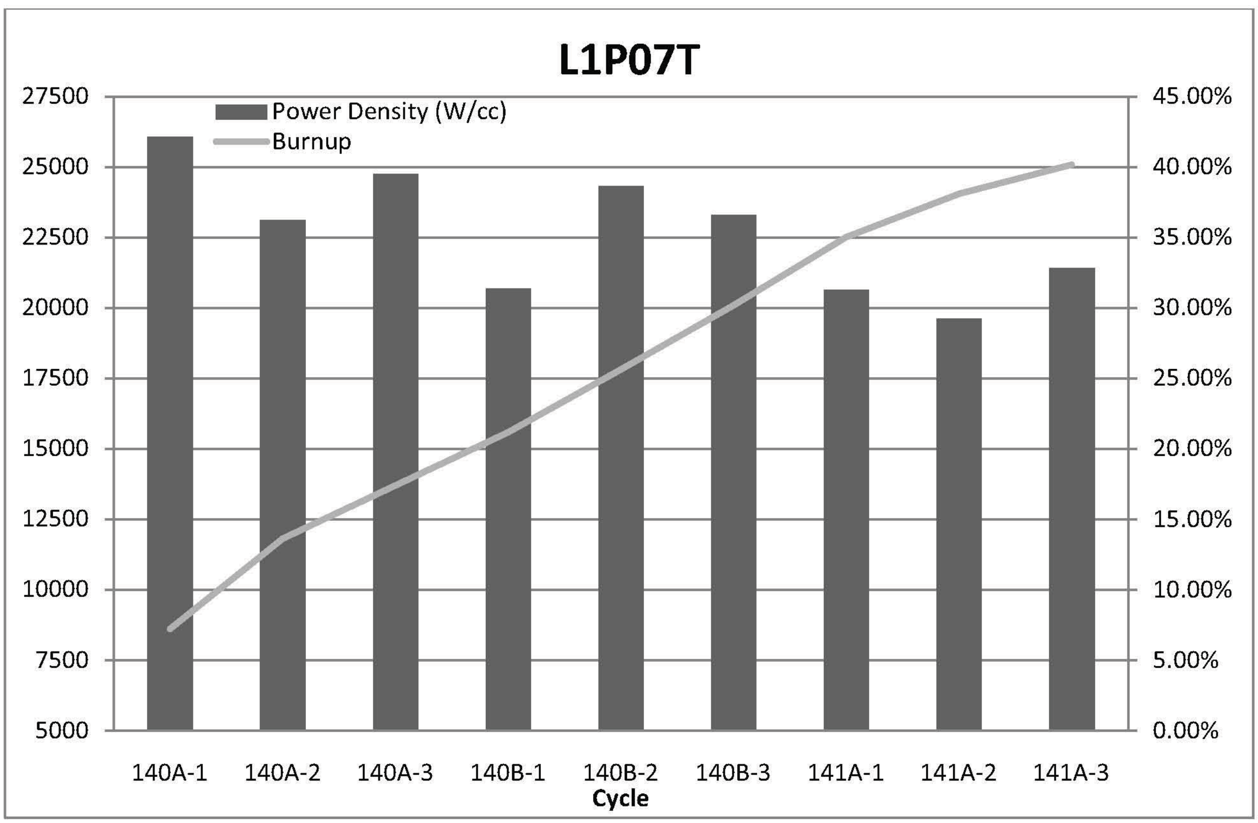

L1P05A
Power Density (W/cc)
Burnup
22500
20000
17500
15000
12500
10000
7500
5000
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1 140A-2 140A-3 140B-1 140B-2 140B-3 141A-1 141A-2 141A-3
Cycle

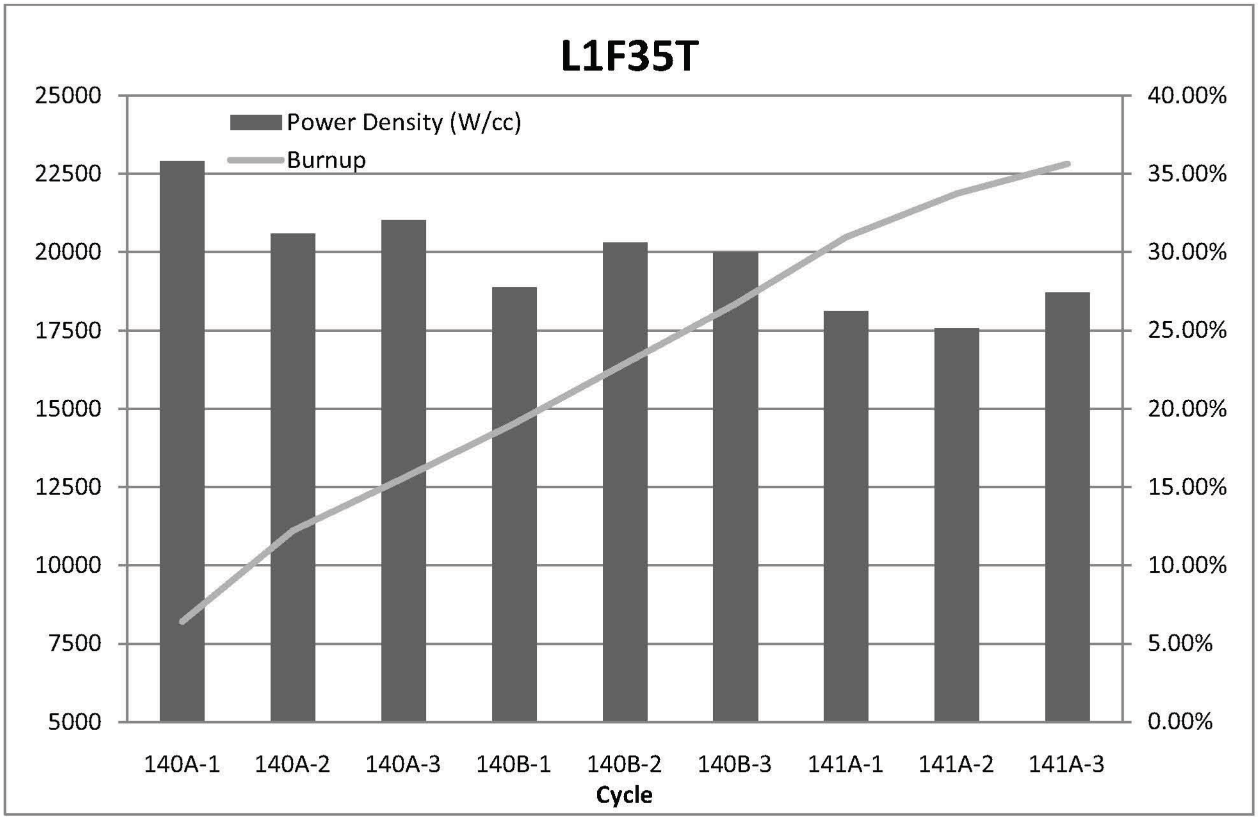

L1F37T
Power Density (W/cc)
Burnup
27500
25000
22500
20000
17500
15000
12500
10000
7500
5000
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1 140A-2 140A-3 140B-1 140B-2 140B-3 141A-1 141A-2 141A-3
Cycle

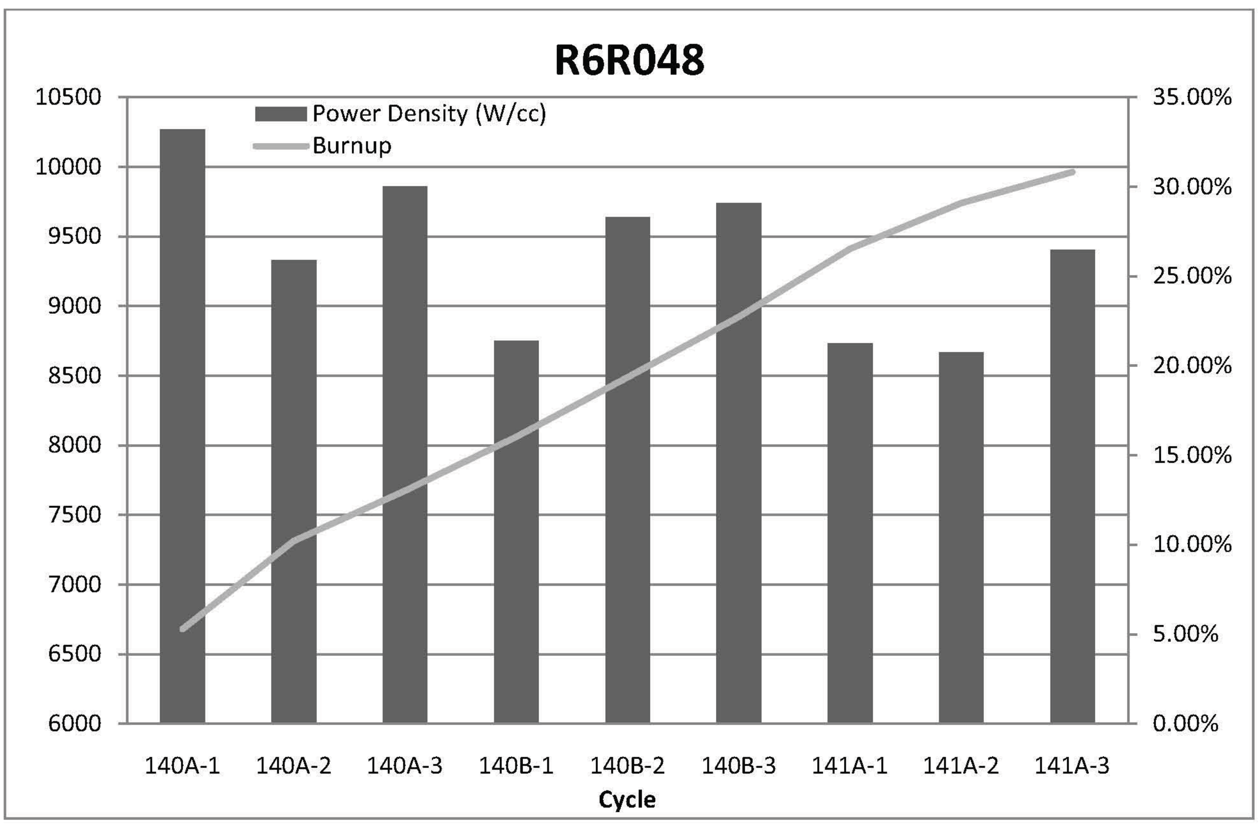

L1P09T
Power Density (W/cc)
Burnup
27500
25000
22500
20000
17500
15000
12500
10000
7500
5000
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1
140A-2
140A-3
140B-1
140B-2
140B-3
141A-1
141A-2
141A-3
Cycle

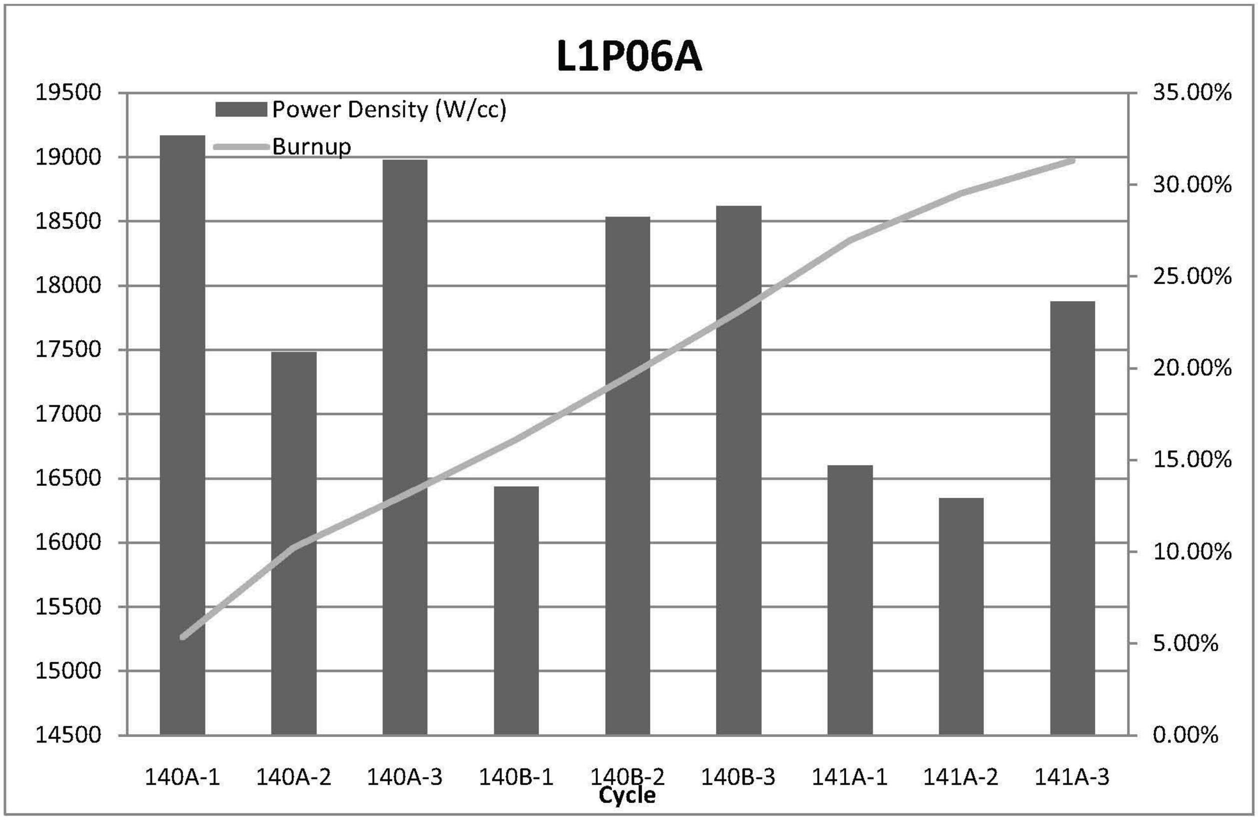

R2R088
Power Density (W/cc)
Burnup
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1
140A-2
140A-3
140B-1
140B-2
140B-3
141A-1
141A-2
141A-3
Cycle

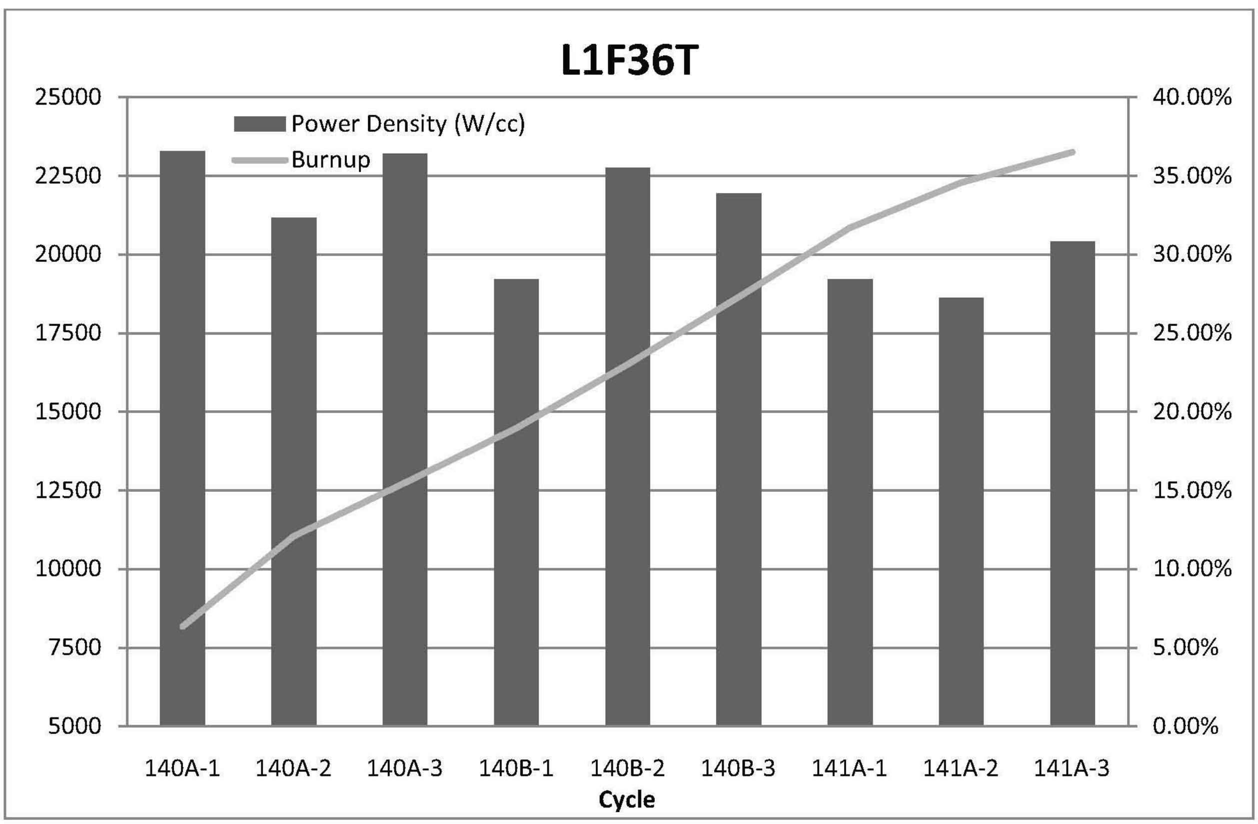

R6R018
Power Density (W/cc)
Burnup
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1
140A-2
140A-3
140B-1
140B-2
140B-3
141A-1
141A-2
141A-3
Cycle

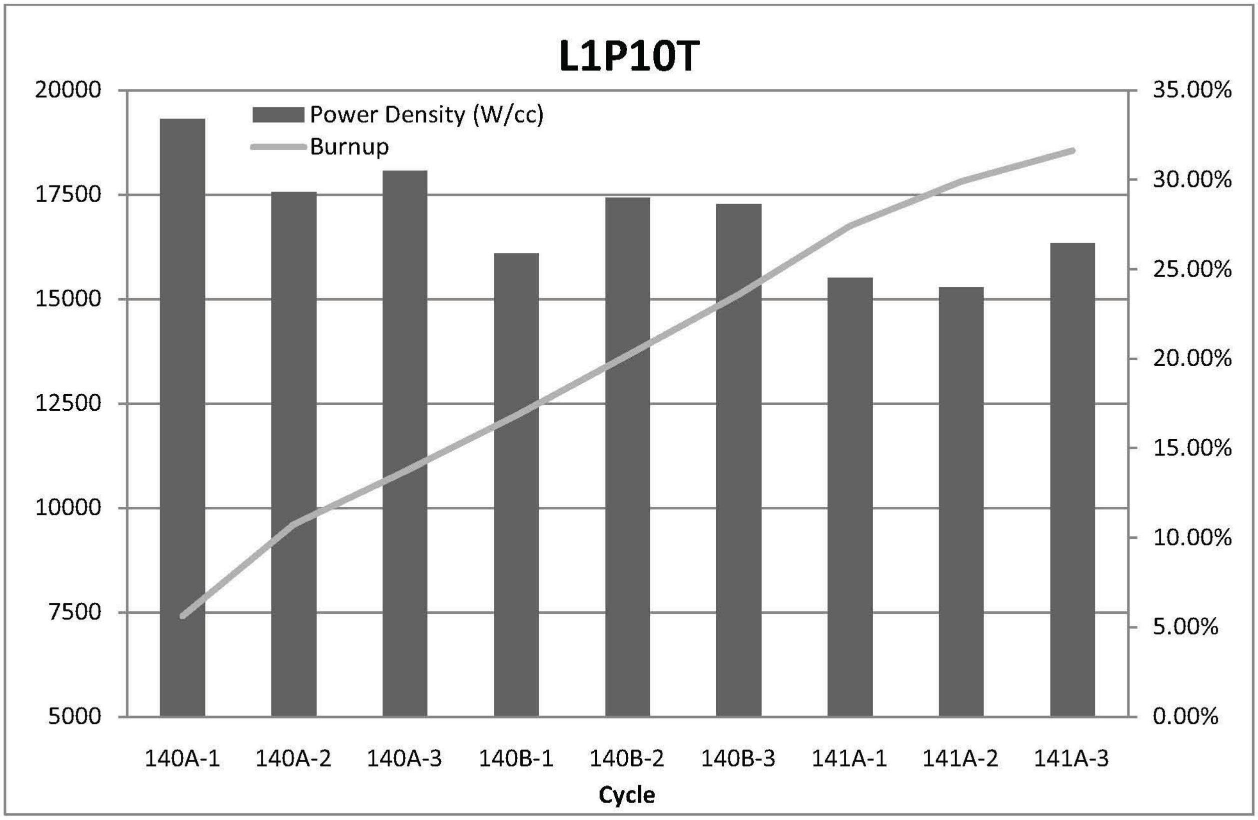

L1P07T
Power Density (W/cc)
Burnup
27500
25000
22500
20000
17500
15000
12500
10000
7500
5000
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1
140A-2
140A-3
140B-1
140B-2
140B-3
141A-1
141A-2
141A-3
Cycle

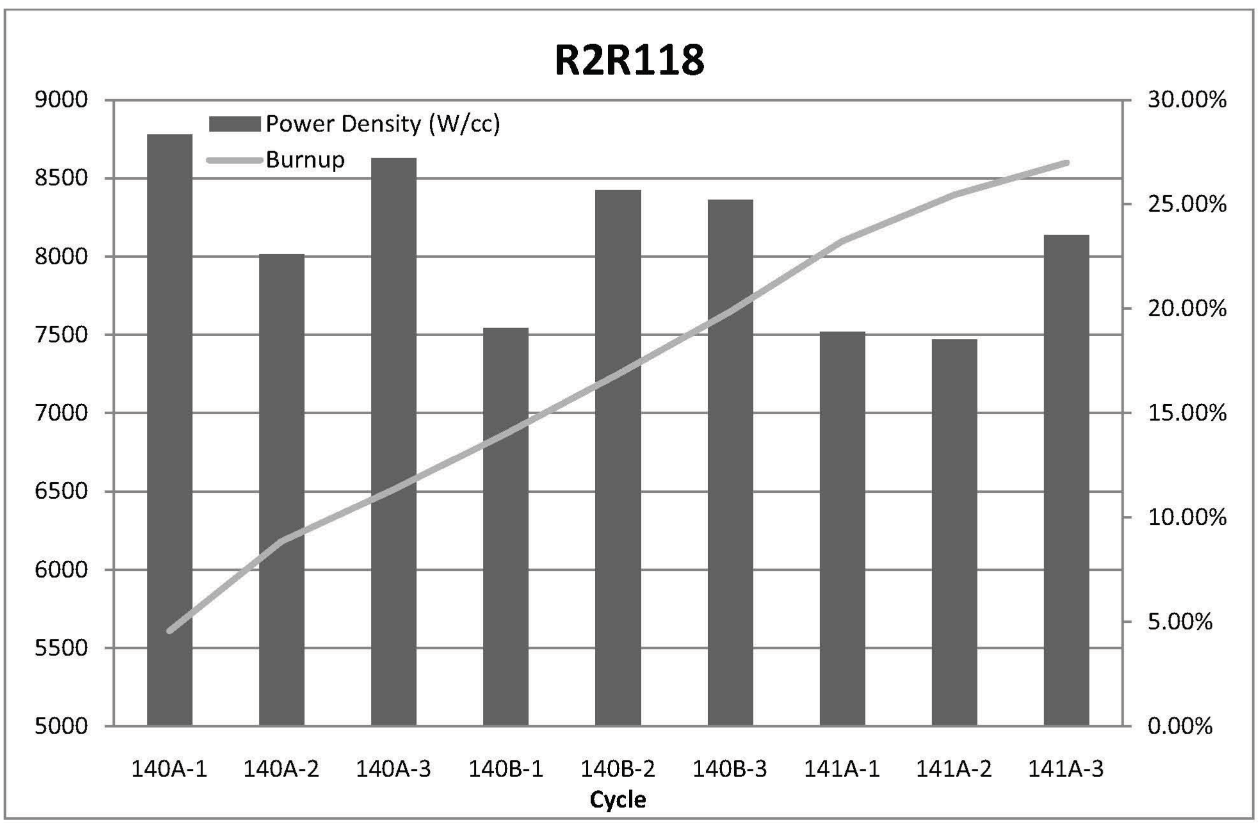

L1F35T
Power Density (W/cc)
Burnup
25000
22500
20000
17500
15000
12500
10000
7500
5000
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1
140A-2
140A-3
140B-1
140B-2
140B-3
141A-1
141A-2
141A-3
Cycle

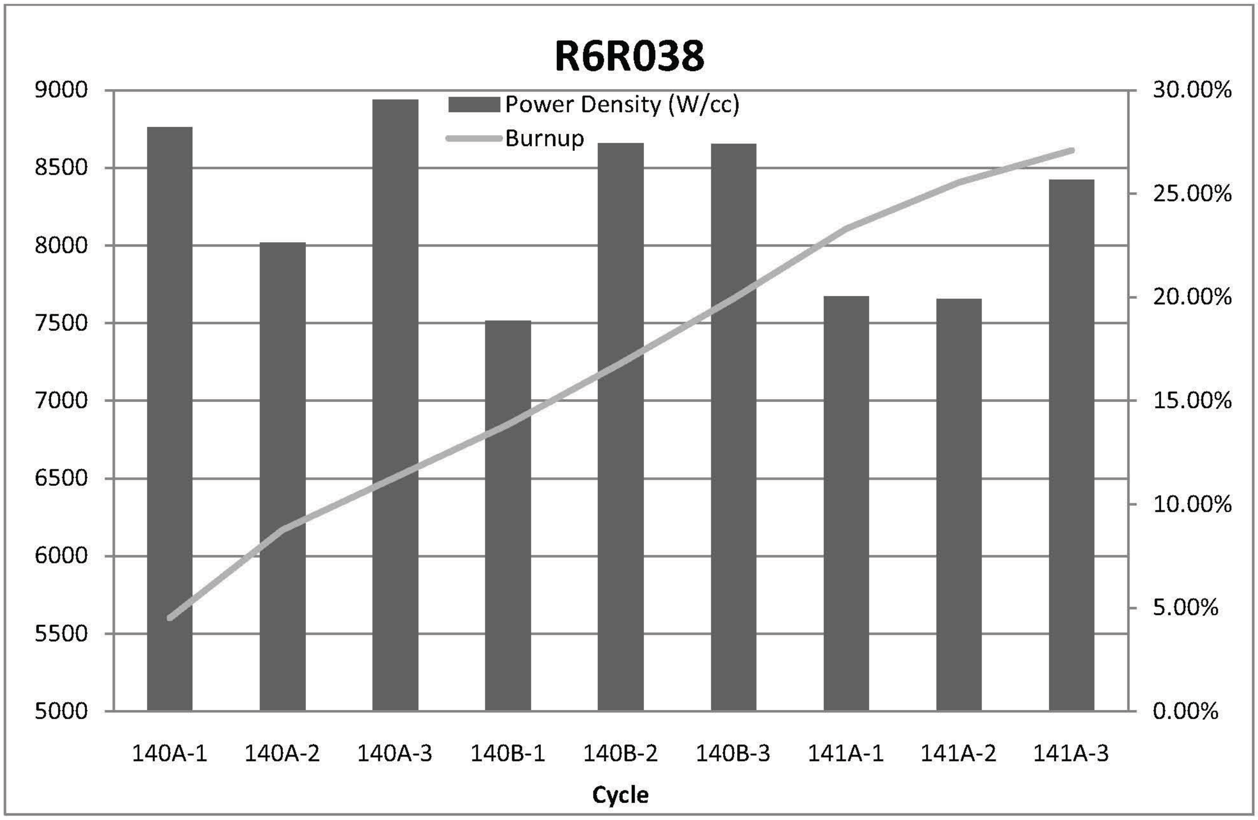

R6R048
Power Density (W/cc)
Burnup
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1
140A-2
140A-3
140B-1
140B-2
140B-3
141A-1
141A-2
141A-3
Cycle

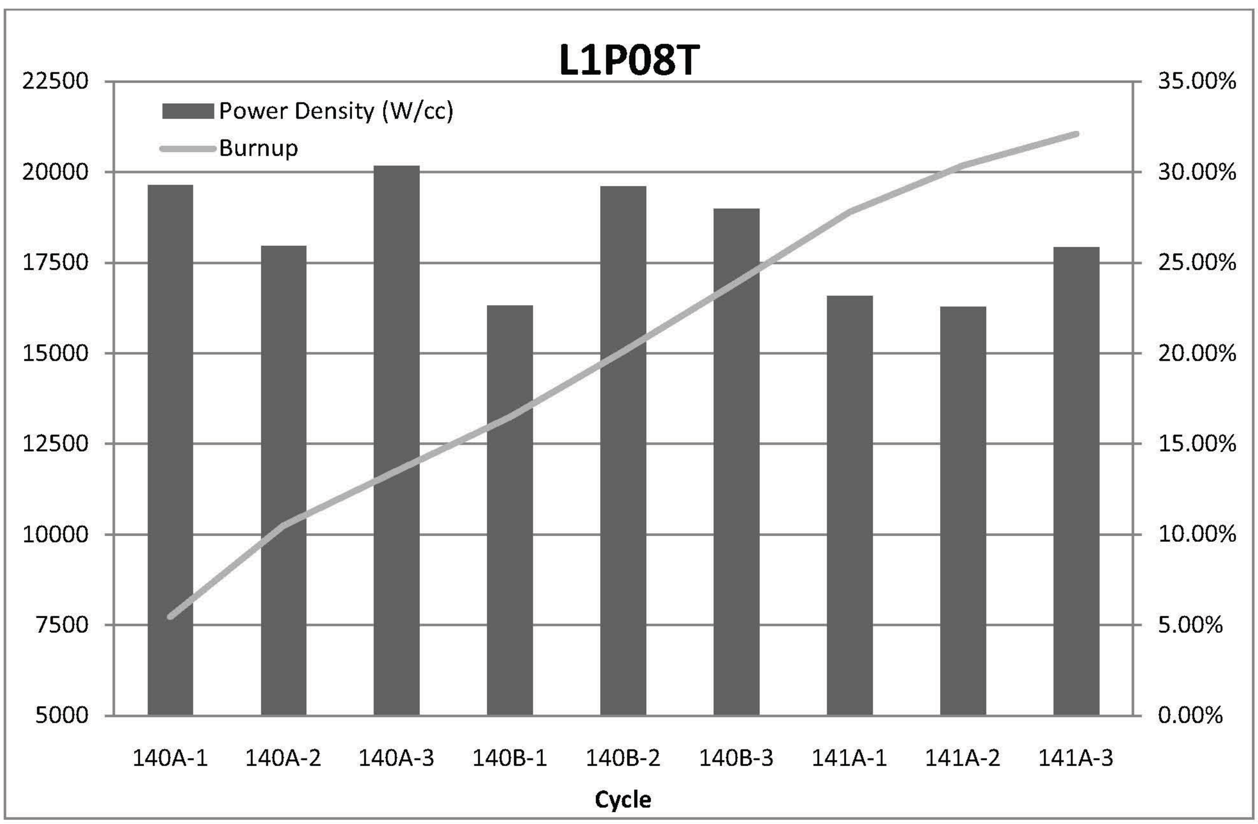

L1P06A
Power Density (W/cc)
Burnup
19500
19000
18500
18000
17500
17000
16500
16000
15500
15000
14500
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1 140A-2 140A-3 140B-1 140B-2 140B-3 141A-1 141A-2 141A-3
Cycle


L1F36T
Power Density (W/cc)
Burnup
25000
22500
20000
17500
15000
12500
10000
7500
5000
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1 140A-2 140A-3 140B-1 140B-2 140B-3 141A-1 141A-2 141A-3
Cycle


L1P10T
Power Density (W/cc)
Burnup
20000
17500
15000
12500
10000
7500
5000
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1
140A-2
140A-3
140B-1
140B-2
140B-3
141A-1
141A-2
141A-3
Cycle


R2R118
Power Density (W/cc)
Burnup
9000
8500
8000
7500
7000
6500
6000
5500
5000
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1
140A-2
140A-3
140B-1
140B-2
140B-3
141A-1
141A-2
141A-3
Cycle


R6R038
Power Density (W/cc)
Burnup
9000
8500
8000
7500
7000
6500
6000
5500
5000
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1
140A-2
140A-3
140B-1
140B-2
140B-3
141A-1
141A-2
141A-3
Cycle


L1P08T
Power Density (W/cc)
Burnup
22500
20000
17500
15000
12500
10000
7500
5000
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
140A-1
140A-2
140A-3
140B-1
140B-2
140B-3
141A-1
141A-2
141A-3
Cycle