Neutron Fluences for EBR-II Reflector Assemblies U9902, U9003, U9005, U9006 and U9027

Preliminary Sponsor Report

Nuclear Engineering Division

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September 30, 2014

September 30, 2014

To: D. L. Porter

INL

From: K. N. Grimm

ANL

Subject: Neutron Fluences for EBR-II Reflector Assemblies U9902, U9003, U9005, U9006 and U9027

Introduction

There are currently five complete Experimental Breeder Reactor No. 2 (EBR-II) reflector assemblies being stored in the Hot Fuel Examination Facility (HFEF) pits at Idaho National Laboratory (INL); these are reflector assemblies U9902, U9003, U9005, U9006 and U9027.

Reflector assembly U9027 was fabricated with a 12% cold-worked Type 316 steel can and Type 304 steel blocks, while the other assemblies had Type 304 steel cans and blocks.

There has been interest at INL in using these irradiated reflector (steel) assemblies to correlate observed material damage to exposure (fluence, i.e., flux times time), and to do this, spatial neutron fluence levels for each of these reflector assemblies needs to be known.

The irradiation histories of these five reflector assemblies, in terms of EBR-II grid positions and Run cycles, are shown in Table 1. This data was obtained from the "SASBLY" file in the EBR-II Physics Analysis Database (PADB) which gives positional and run information for each assembly irradiated in the EBR-II. Except for short-term storage in the blanket region (position 13D8), all relevant reflector assemblies were irradiated in either EBR-II hex-row 9 or 10.

Table 1: EBR-II Reflector Assembly Histories.

Reflector Assembly	Grid Position	First Run	Last Run
U9902	9C2*	103A	144A
U9003	10A9	108A	167C
	13D8	168A	168A
U9005	10B9	107C	168A
U9006	10C2	107C	168A
	13D8	168B	169A
U9027	10B1	135A	144A
	10D5	145A	170A

* Read 9C2 as EBR-II Row 9 - Sector C - Position 2 (in Sector C)

The use of these reflector materials for damage research requires knowledge of irradiation conditions, including irradiation time, total and fast ($E > 0.1 \text{ MeV}$) neutron flux at various axial and radial positions for each reflector assembly listed above.

To get a more accurate picture of the damage in an assembly, also needed are fluences (fast and total) for each of the six axial blocks that makeup an EBR-II reflector assembly. Finally, since these assemblies were in the outer rows of the reactor where flux gradients are high, radial damage gradients across the assemblies are important.

Shown in Figure 1 is a sketch of the reflector assembly parts (six blocks) of interest.

Figure 1. EBR-II Reflector Assembly Blocks.

Shown in Table 2 are the heights of each of the six hexagonal blocks. From Figure 1 it is seen that the center of Block 3 is at, or near, the core centerline.

Table 2. EBR-II Reflector Block Heights.

Block	Height, in	Height, cm
1	15.562	39.527
2	9.578	24.328
3	9.578	24.328
4	9.578	24.328
5	8.562	21.747
6	8.562	21.747
Total	61.420	156.007

EBR-II Reactor Description and Irradiation History

The EBR-II reactor had a hexagonal grid structure containing sixteen rows of assemblies (rows 15 and 16 were not complete rows), with each 60-degree section of the hexagonal grid-structure given the letter assignment A-F. How assemblies are positioned in the EBR-II hexagonal grid (sector, row and position in row) is shown in Figure 2.

Figure 2. EBR-II Sector Assignments, Row Numbers and Position in Sector Terminology.

The EBR-II irradiation history consisted of 170 different runs from August 1, 1964 through September 30, 1994, each of which may contain one or more sub-run(s). For example, EBR-II Run 139 was composed of five sub-runs (Run 139A through Run139E).

Shown in Figures 3 and 4 are the individual-run energy deposition (Mega-Watt-day, MWD) and the cumulative thermal energy deposition for all EBR-II runs and sub-runs (1-170). Notice the large energy-deposition differences between the early and late runs. For the five reflector assemblies under consideration, only EBR-II Runs after Run 103A are relevant.

Figure 3. Reactor Energy Deposition (MWD) for all EBR-II Runs (1-170).

Figure 4. Cumulative Reactor Energy Deposition (MWD) for all EBR-II Runs (1-170).

The effective time duration (in days) for a particular run can be determined by dividing the energy deposition for a run (in MWD) by the nominal power level of EBR-II (i.e., 62.5 MWt). Even if the actual power level is larger or smaller, using the effective time duration and the nominal power level of 62.5 MWt gives the correct number of megawatt-days.

Shown in Table 4 are the run dates, numerical energy depositions (in MWD) and effective run times for all EBR-II Runs. The “change” MWD values in Table 3 are what have been plotted in Figure 3. Except for the run energy deposition (in MWD) and effective run times (in days), this data was obtained directly from the Argonne National Laboratory (ANL) EBR-II Physics Analysis Database (PADB).

Table 3. EBR-II Irradiation History (@62.5 MWt per run).

EBR-II Run No.	Starting Date	Ending Date	Energy Deposition, MWD			Effective Run Time, days
			Starting	Ending	Change	
1	080164*	082364	0.00E+00	3.43E+02	343	5.49
2	100264	101964	3.43E+02	7.05E+02	362	5.79
3	031565	041065	7.05E+02	1.28E+03	575	9.20
4	042465	050465	1.28E+03	1.63E+03	351	5.62
5	051065	052165	1.63E+03	2.00E+03	372	5.95
6	052465	062565	2.00E+03	2.50E+03	499	7.98
7	072965	081565	2.50E+03	2.93E+03	425	6.80
8	090765	091965	2.93E+03	3.32E+03	393	6.29
9	101365	102165	3.32E+03	3.67E+03	345	5.52
10	102865	110765	3.67E+03	3.98E+03	315	5.04
11	111865	112765	3.98E+03	4.28E+03	300	4.80
12	113065	121165	4.28E+03	4.75E+03	470	7.52
13	121765	122465	4.75E+03	5.05E+03	300	4.80
14	011066	012266	5.05E+03	5.57E+03	520	8.32
15	032866	041466	5.57E+03	6.37E+03	795	12.72
16	041766	050866	6.37E+03	7.14E+03	775	12.40
17	051166	052366	7.14E+03	7.62E+03	475	7.60
18	052666	061566	7.62E+03	8.48E+03	867	13.87
19	062766	062966	8.48E+03	8.57E+03	89	1.42
20	071966	080766	8.57E+03	9.27E+03	699	11.18
21	081266	082766	9.27E+03	9.38E+03	110	1.76
22	102066	111466	9.38E+03	1.09E+04	1545	24.72
23	111666	120366	1.09E+04	1.16E+04	690	11.04
24	120666	123166	1.16E+04	1.22E+04	630	10.08
25	051767	081767	1.22E+04	1.38E+04	1561	24.98
26A	092267	092967	1.38E+04	1.39E+04	87	1.39
26B	101167	112067	1.39E+04	1.49E+04	1029	16.46
26C	112267	121267	1.49E+04	1.55E+04	619	9.90
27A	20268	22968	1.55E+04	1.58E+04	283	4.53
27B	030168	030568	1.58E+04	1.60E+04	177	2.83
27C	030768	031168	1.60E+04	1.61E+04	62	0.99
27D	033068	040668	1.61E+04	1.63E+04	286	4.58
27E	040768	041168	1.63E+04	1.64E+04	90	1.44
27F	041368	041668	1.64E+04	1.65E+04	68	1.09
27G	041768	041968	1.65E+04	1.66E+04	49	0.78

27H	042568	050268	1.66E+04	1.68E+04	206	3.30
27I	050368	050668	1.68E+04	1.69E+04	96	1.54
28A	050968	051368	1.69E+04	1.70E+04	154	2.46
28B	051568	052768	1.70E+04	1.73E+04	303	4.85
28C	052968	061568	1.73E+04	1.80E+04	669	10.70
29A	062668	070568	1.80E+04	1.82E+04	188	3.01
29B	070968	071168	1.82E+04	1.82E+04	24	0.38
29C	071568	072268	1.82E+04	1.84E+04	205	3.28
29D	072568	081668	1.84E+04	1.91E+04	710	11.36
30A	082168	090568	1.91E+04	1.98E+04	652	10.43
30B	090768	091168	1.98E+04	1.99E+04	166	2.66
30C	091168	091568	1.99E+04	2.00E+04	52	0.83
30D	091768	092168	2.00E+04	2.01E+04	79	1.26
30E	092268	092568	2.01E+04	2.01E+04	79	1.26
31A	093068	100468	2.01E+04	2.02E+04	89	1.42
31B	101168	101868	2.02E+04	2.04E+04	159	2.54
31C	101968	102268	2.04E+04	2.05E+04	84	1.34
31D	102668	110368	2.05E+04	2.08E+04	372	5.95
31E	110468	110468	2.08E+04	2.08E+04	0	0.00
31F	110568	111468	2.08E+04	2.13E+04	413	6.61
31G	111568	111768	2.13E+04	2.14E+04	111	1.78
32A	112768	121768	2.14E+04	2.22E+04	852	13.63
32B	121868	122468	2.22E+04	2.25E+04	249	3.98
32C	122568	122768	2.25E+04	2.25E+04	72	1.15
32D	122868	010269	2.25E+04	2.28E+04	224	3.58
33A	022569	032969	2.28E+04	2.34E+04	600	9.60
33B	040769	042269	2.34E+04	2.39E+04	576	9.22
34A	042569	051369	2.39E+04	2.48E+04	822	13.15
34B	051469	052169	2.48E+04	2.51E+04	310	4.96
35A	052969	062669	2.51E+04	2.63E+04	1202	19.23
36A	063069	072069	2.63E+04	2.71E+04	800	12.80
36B	072269	073169	2.71E+04	2.75E+04	400	6.40
37A	080269	083069	2.75E+04	2.87E+04	1196	19.14
38A	091069	092869	2.87E+04	2.94E+04	770	12.32
38B	100369	101669	2.94E+04	3.00E+04	600	9.60
39A	121669	011070	3.00E+04	3.08E+04	771	12.34
39B	011470	011970	3.08E+04	3.10E+04	185	2.96
39C	011970	012870	3.10E+04	3.14E+04	415	6.64
40A	013170	021070	3.14E+04	3.19E+04	443	7.09
40B	021070	030170	3.19E+04	3.28E+04	924	14.78
41A	030570	032570	3.28E+04	3.37E+04	961	15.38
41B	032770	040170	3.37E+04	3.39E+04	157	2.51
42A	041870	051870	3.39E+04	3.52E+04	1344	21.50

43A	052670	062370	3.52E+04	3.66E+04	1350	21.60
44A	062670	071570	3.66E+04	3.75E+04	900	14.40
44B	072570	080470	3.75E+04	3.79E+04	451	7.22
45A	080970	082370	3.79E+04	3.86E+04	645	10.32
45B	082670	091070	3.86E+04	3.93E+04	705	11.28
46A	092070	100670	3.93E+04	4.00E+04	751	12.02
46B	100870	102270	4.00E+04	4.08E+04	799	12.78
47A	102870	111570	4.08E+04	4.18E+04	975	15.60
47B	030271	031371	4.18E+04	4.23E+04	505	8.08
48A	033171	040271	4.23E+04	4.23E+04	19	0.30
48B	040371	040471	4.23E+04	4.24E+04	60	0.96
48C	040671	042071	4.24E+04	4.31E+04	726	11.62
48D	042271	050471	4.31E+04	4.38E+04	650	10.40
48E	050671	050771	4.38E+04	4.38E+04	12	0.19
49A	051871	051971	4.38E+04	4.39E+04	64	1.02
49B	052071	053171	4.39E+04	4.44E+04	590	9.44
49C	060371	060871	4.44E+04	4.47E+04	274	4.38
49D	061071	061071	4.47E+04	4.47E+04	5	0.08
49E	061471	061571	4.47E+04	4.47E+04	13	0.21
49F	062071	063071	4.47E+04	4.53E+04	565	9.04
50A	070471	070571	4.53E+04	4.54E+04	62	0.99
50B	070671	070771	4.54E+04	4.54E+04	11	0.18
50C	070871	071171	4.54E+04	4.54E+04	72	1.15
50D	071171	071371	4.54E+04	4.55E+04	70	1.12
50E	071371	071471	4.55E+04	4.55E+04	26	0.42
50F	071671	072971	4.55E+04	4.63E+04	777	12.43
50G	080371	080371	4.63E+04	4.63E+04	0	0.00
50H	080671	081571	4.63E+04	4.69E+04	546	8.74
51A	082771	091071	4.69E+04	4.75E+04	646	10.34
51B	091271	091271	4.75E+04	4.75E+04	0	0.00
51C	092071	100871	4.75E+04	4.84E+04	908	14.53
52A	102071	102771	4.84E+04	4.88E+04	411	6.58
52B	102871	102971	4.88E+04	4.88E+04	5	0.08
52C	102971	111771	4.88E+04	5.00E+04	1134	18.14
53A	121371	121571	5.00E+04	5.00E+04	73	1.17
53B	121671	121871	5.00E+04	5.02E+04	135	2.16
53C	121871	122171	5.02E+04	5.03E+04	138	2.21
53D	122371	122771	5.03E+04	5.05E+04	226	3.62
53E	122871	011472	5.05E+04	5.15E+04	979	15.66
54A	020572	030172	5.15E+04	5.30E+04	1522	24.35
55A	031272	032672	5.30E+04	5.38E+04	800	12.80
55B	032872	040772	5.38E+04	5.44E+04	567	9.07
56A	070172	070272	5.44E+04	5.44E+04	3	0.05

56B	070372	070372	5.44E+04	5.44E+04	0	0.00
56C	070572	080372	5.44E+04	5.60E+04	1550	24.80
57A	081372	090772	5.60E+04	5.74E+04	1426	22.82
58A	091472	092572	5.74E+04	5.80E+04	651	10.42
58B	092772	100372	5.80E+04	5.84E+04	333	5.33
58C	100472	101472	5.84E+04	5.89E+04	566	9.06
59B	102372	111972	5.89E+04	6.05E+04	1552	24.83
60A	121372	011073	6.05E+04	6.20E+04	1550	24.80
61A	011573	012973	6.20E+04	6.28E+04	773	12.37
61B	013173	021973	6.28E+04	6.36E+04	777	12.43
62A	022473	031373	6.36E+04	6.45E+04	941	15.06
62B	031673	031673	6.45E+04	6.45E+04	3	0.05
62C	031773	031873	6.45E+04	6.46E+04	72	1.15
62D	031973	032873	6.46E+04	6.51E+04	524	8.38
62E	033073	033173	6.51E+04	6.51E+04	16	0.26
63A	061773	071373	6.51E+04	6.66E+04	1492	23.87
64A	071673	081273	6.66E+04	6.82E+04	1535	24.56
65A	082273	090673	6.82E+04	6.90E+04	801	12.82
65B	090873	091373	6.90E+04	6.92E+04	233	3.73
65C	091473	092173	6.92E+04	6.96E+04	418	6.69
66A	092773	092873	6.96E+04	6.96E+04	11	0.18
66B	093073	100373	6.96E+04	6.97E+04	35	0.56
66C	100573	101073	6.97E+04	6.99E+04	242	3.87
66D	101173	101273	6.99E+04	6.99E+04	15	0.24
66E	101473	101773	6.99E+04	7.01E+04	166	2.66
66F	101973	102573	7.01E+04	7.04E+04	354	5.66
66G	102673	110773	7.04E+04	7.12E+04	715	11.44
67A	111573	112673	7.12E+04	7.18E+04	647	10.35
67B	113073	121373	7.18E+04	7.25E+04	734	11.74
68A	121873	122173	7.25E+04	7.26E+04	101	1.62
68B	122373	122473	7.26E+04	7.27E+04	9	0.14
68C	122473	122573	7.27E+04	7.27E+04	8	0.13
68D	122573	122673	7.27E+04	7.27E+04	28	0.45
68E	122773	123073	7.27E+04	7.29E+04	184	2.94
68F	010174	010674	7.29E+04	7.30E+04	160	2.56
68G	010874	012674	7.30E+04	7.41E+04	1037	16.59
69A	020274	020374	7.41E+04	7.41E+04	10	0.16
69B	020774	030474	7.41E+04	7.56E+04	1540	24.64
70A	030774	032574	7.56E+04	7.67E+04	1045	16.72
70B	032774	040974	7.67E+04	7.74E+04	747	11.95
71A	060674	070674	7.74E+04	7.91E+04	1666	26.66
71B	071174	071174	7.91E+04	7.91E+04	0	0.00
72A	071774	081074	7.91E+04	8.06E+04	1474	23.58

73A	082174	092474	8.06E+04	8.27E+04	2099	33.58
74A	101174	102774	8.27E+04	8.36E+04	978	15.65
74B	103074	103074	8.36E+04	8.36E+04	9	0.14
74C	103174	103174	8.36E+04	8.36E+04	5	0.08
74D	110174	110174	8.36E+04	8.37E+04	13	0.21
74E	110374	111974	8.37E+04	8.46E+04	945	15.12
74F	112074	112274	8.46E+04	8.47E+04	138	2.21
74G	112474	120574	8.47E+04	8.54E+04	637	10.19
75A	121474	122774	8.54E+04	8.61E+04	773	12.37
75B	122974	122974	8.61E+04	8.62E+04	2	0.03
75C	123074	010775	8.62E+04	8.66E+04	442	7.07
75D	011075	012075	8.66E+04	8.72E+04	582	9.31
75E	012175	012275	8.72E+04	8.72E+04	46	0.74
75F	012375	012375	8.72E+04	8.72E+04	1	0.02
75G	012475	012475	8.72E+04	8.72E+04	2	0.03
75H	012575	012575	8.72E+04	8.72E+04	2	0.03
75I	012675	013075	8.72E+04	8.75E+04	279	4.46
75J	013175	021075	8.75E+04	8.81E+04	574	9.18
76A	022175	022675	8.81E+04	8.83E+04	263	4.21
76B	022875	030475	8.83E+04	8.85E+04	191	3.06
76C	030575	030675	8.85E+04	8.86E+04	41	0.66
76D	030775	031575	8.86E+04	8.90E+04	446	7.14
76E	031675	031675	8.90E+04	8.90E+04	3	0.05
76F	031975	033175	8.90E+04	8.98E+04	733	11.73
77A	042975	052075	8.98E+04	9.10E+04	1248	19.97
77B	052275	062575	9.10E+04	9.30E+04	2028	32.45
77C	062675	070975	9.30E+04	9.37E+04	653	10.45
78A	071675	072275	9.37E+04	9.40E+04	310	4.96
78B	072375	090275	9.40E+04	9.65E+04	2502	40.03
78C	090475	090475	9.65E+04	9.65E+04	0	0.00
79A	091175	102675	9.65E+04	9.93E+04	2809	44.94
80A	112275	112875	9.93E+04	9.96E+04	311	4.98
80B	120375	011576	9.96E+04	1.02E+05	2584	41.34
81A	012276	021176	1.02E+05	1.03E+05	1151	18.42
81B	021576	031676	1.03E+05	1.05E+05	1757	28.11
82A	041576	050676	1.05E+05	1.06E+05	1264	20.22
82B	050776	060176	1.06E+05	1.08E+05	1519	24.30
83A	060476	062176	1.08E+05	1.09E+05	1046	16.74
83B	062276	063076	1.09E+05	1.09E+05	468	7.49
83C	063076	072276	1.09E+05	1.11E+05	1313	21.01
84A	073076	083076	1.11E+05	1.13E+05	1868	29.89
84B	083176	091776	1.13E+05	1.14E+05	1016	16.26
85A	092576	103076	1.14E+05	1.16E+05	1970	31.52

85B	103176	111476	1.16E+05	1.16E+05	844	13.50
86A	112176	010277	1.16E+05	1.19E+05	2639	42.22
86B	010477	010877	1.19E+05	1.19E+05	211	3.38
87A	011677	011977	1.19E+05	1.19E+05	204	3.26
87B	012377	021377	1.19E+05	1.21E+05	1328	21.25
87C	021777	021777	1.21E+05	1.21E+05	3	0.05
87D	021877	030777	1.21E+05	1.22E+05	1017	16.27
88A	040777	041677	1.22E+05	1.22E+05	504	8.06
88B	041777	050377	1.22E+05	1.23E+05	980	15.68
88C	050677	051777	1.23E+05	1.24E+05	653	10.45
88D	051877	061577	1.24E+05	1.26E+05	1673	26.77
89A	061977	062077	1.26E+05	1.26E+05	26	0.42
89B	062177	072577	1.26E+05	1.28E+05	2102	33.63
89C	072677	072777	1.28E+05	1.28E+05	38	0.61
89D	072877	073077	1.28E+05	1.28E+05	127	2.03
89E	073177	080877	1.28E+05	1.28E+05	463	7.41
90A	081577	081677	1.28E+05	1.28E+05	19	0.30
90B	081977	083177	1.28E+05	1.29E+05	755	12.08
90C	090177	090777	1.29E+05	1.29E+05	306	4.90
90D	090777	100177	1.29E+05	1.31E+05	1458	23.33
91A	100977	101477	1.31E+05	1.31E+05	289	4.62
91B	101577	102277	1.31E+05	1.32E+05	427	6.83
91C	102377	111877	1.32E+05	1.33E+05	1567	25.07
91D	111977	112877	1.33E+05	1.34E+05	528	8.45
92A	120377	121577	1.34E+05	1.34E+05	643	10.29
92B	121677	122377	1.34E+05	1.35E+05	416	6.66
92C	122477	011578	1.35E+05	1.36E+05	1385	22.16
93A	012178	012678	1.36E+05	1.36E+05	321	5.14
93B	012878	031278	1.36E+05	1.39E+05	2707	43.31
94A	041478	041678	1.39E+05	1.39E+05	109	1.74
94B	041778	042678	1.39E+05	1.40E+05	560	8.96
94C	042878	051278	1.40E+05	1.41E+05	855	13.68
94D	051278	051478	1.41E+05	1.41E+05	65	1.04
94E	051478	051978	1.41E+05	1.41E+05	251	4.02
94F	052078	052278	1.41E+05	1.41E+05	118	1.89
94G	052278	052378	1.41E+05	1.41E+05	30	0.48
94H	052478	052478	1.41E+05	1.41E+05	1	0.02
94I	052578	060578	1.41E+05	1.42E+05	635	10.16
95A	061178	061578	1.42E+05	1.42E+05	165	2.64
95B	061678	062378	1.42E+05	1.42E+05	425	6.80
95C	062478	062478	1.42E+05	1.42E+05	32	0.51
95D	062578	062578	1.42E+05	1.42E+05	11	0.18
95E	062678	071178	1.42E+05	1.43E+05	899	14.38

95F	071178	071778	1.43E+05	1.44E+05	206	3.30
95G	071778	072078	1.44E+05	1.44E+05	163	2.61
95H	072178	073178	1.44E+05	1.44E+05	610	9.76
96A	080778	081578	1.44E+05	1.45E+05	467	7.47
96B	081678	081778	1.45E+05	1.45E+05	22	0.35
96C	081878	082278	1.45E+05	1.45E+05	240	3.84
96D	082378	082878	1.45E+05	1.45E+05	301	4.82
96E	082978	082978	1.45E+05	1.45E+05	1	0.02
96F	083078	092478	1.45E+05	1.47E+05	1583	25.33
97A	093078	093078	1.47E+05	1.47E+05	3	0.05
97B	100178	100178	1.47E+05	1.47E+05	2	0.03
97C	100378	100378	1.47E+05	1.47E+05	13	0.21
97D	100478	100578	1.47E+05	1.47E+05	35	0.56
97E	100678	101678	1.47E+05	1.48E+05	589	9.42
97F	101678	110778	1.48E+05	1.49E+05	1325	21.20
97G	110778	111378	1.49E+05	1.49E+05	308	4.93
98A	111878	010379	1.49E+05	1.52E+05	2762	44.19
99A	010979	020179	1.52E+05	1.53E+05	1395	22.32
99B	020379	020479	1.53E+05	1.53E+05	48	0.77
99C	020579	021179	1.53E+05	1.54E+05	368	5.89
99D	021279	021379	1.54E+05	1.54E+05	8	0.13
99E	021479	022279	1.54E+05	1.54E+05	525	8.40
100A	030479	030679	1.54E+05	1.54E+05	100	1.60
100B	030979	032779	1.54E+05	1.55E+05	1063	17.01
100C	032879	033079	1.55E+05	1.56E+05	45	0.72
100D	033179	041579	1.56E+05	1.57E+05	975	15.60
101A	051679	060579	1.57E+05	1.58E+05	1242	19.87
101B	060679	062579	1.58E+05	1.59E+05	1192	19.07
102A	070479	070979	1.59E+05	1.59E+05	275	4.40
102B	071079	071079	1.59E+05	1.59E+05	8	0.13
102C	071279	071679	1.59E+05	1.59E+05	223	3.57
102D	071779	081579	1.59E+05	1.61E+05	1762	28.19
102E	081679	082079	1.61E+05	1.61E+05	245	3.92
103A	082779	090479	1.61E+05	1.62E+05	453	7.25
103B	090679	100679	1.62E+05	1.64E+05	1824	29.18
104A	101279	102079	1.64E+05	1.64E+05	449	7.18
104B	102079	120379	1.64E+05	1.67E+05	2436	38.98
105A	120879	121079	1.67E+05	1.67E+05	80	1.28
105B	121179	121179	1.67E+05	1.67E+05	0	0.00
105C	121279	012780	1.67E+05	1.69E+05	2590	41.44
106A	020280	021780	1.69E+05	1.70E+05	805	12.88
106B	022180	032380	1.70E+05	1.72E+05	1756	28.10
107A	042780	050880	1.72E+05	1.72E+05	585	9.36

107B	051080	060280	1.72E+05	1.74E+05	1300	20.80
107C	060380	060980	1.74E+05	1.74E+05	301	4.82
107D	061080	061280	1.74E+05	1.74E+05	120	1.92
107E	061380	061680	1.74E+05	1.74E+05	156	2.50
108A	062180	062480	1.74E+05	1.74E+05	118	1.89
108B	062580	072480	1.74E+05	1.76E+05	1667	26.67
108C	072580	080480	1.76E+05	1.77E+05	560	8.96
108D	080580	081180	1.77E+05	1.77E+05	340	5.44
109A	081680	100580	1.77E+05	1.80E+05	2849	45.58
110A	101280	120880	1.80E+05	1.83E+05	3165	50.64
111A	121580	121980	1.83E+05	1.83E+05	186	2.98
111B	121980	012681	1.83E+05	1.85E+05	2113	33.81
112A	020281	032281	1.85E+05	1.86E+05	1096	17.54
112B	032481	032581	1.86E+05	1.86E+05	18	0.29
112C	032681	032681	1.86E+05	1.86E+05	1	0.02
112D	032681	032781	1.86E+05	1.86E+05	11	0.18
113A	050481	061181	1.86E+05	1.88E+05	1911	30.58
113B	061281	061781	1.88E+05	1.89E+05	239	3.82
113C	061881	062281	1.89E+05	1.89E+05	217	3.47
114A	063081	071381	1.89E+05	1.90E+05	706	11.30
114B	071481	072981	1.90E+05	1.90E+05	794	12.70
114C	073081	081781	1.90E+05	1.91E+05	988	15.81
115A	082081	091681	1.91E+05	1.93E+05	1496	23.94
115B	091781	100381	1.93E+05	1.94E+05	929	14.86
116A	101081	110481	1.94E+05	1.95E+05	1377	22.03
116B	110481	111181	1.95E+05	1.95E+05	355	5.68
116C	111181	120781	1.95E+05	1.97E+05	1424	22.78
117A	121381	012282	1.97E+05	1.99E+05	2240	35.84
118A	020882	021482	1.99E+05	1.99E+05	307	4.91
118B	021682	022382	1.99E+05	2.00E+05	387	6.19
118C	022482	032682	2.00E+05	2.02E+05	1718	27.49
119A	051082	070682	2.02E+05	2.04E+05	2914	46.62
119B	070782	071282	2.04E+05	2.05E+05	257	4.11
120A	071882	090782	2.05E+05	2.08E+05	2870	45.92
121A	092382	102582	2.08E+05	2.09E+05	1765	28.24
122A	110182	112982	2.09E+05	2.10E+05	727	11.63
123A	013183	020383	2.10E+05	2.10E+05	80	1.28
123B	020483	020683	2.10E+05	2.10E+05	81	1.30
123C	021183	040483	2.10E+05	2.13E+05	2564	41.02
124A	040783	053183	2.13E+05	2.16E+05	3025	48.40
125A	072283	072683	2.16E+05	2.16E+05	204	3.26
125B	072683	080383	2.16E+05	2.16E+05	444	7.10
125C	080483	090983	2.16E+05	2.18E+05	1939	31.02

126A	091883	110783	2.18E+05	2.21E+05	2764	44.22
127A	111783	112483	2.21E+05	2.22E+05	368	5.89
127B	112683	010484	2.22E+05	2.24E+05	2228	35.65
127C	010584	012384	2.24E+05	2.25E+05	1010	16.16
128A	013184	020984	2.25E+05	2.25E+05	486	7.78
128B	021084	021084	2.25E+05	2.25E+05	3	0.05
128C	021084	021384	2.25E+05	2.25E+05	155	2.48
128D	030884	040984	2.25E+05	2.27E+05	1800	28.80
128E	041184	041384	2.27E+05	2.27E+05	66	1.06
129A	051784	052184	2.27E+05	2.27E+05	136	2.18
129B	052284	052484	2.27E+05	2.27E+05	69	1.10
129C	052584	062084	2.27E+05	2.29E+05	1061	16.98
129D	062384	071284	2.29E+05	2.30E+05	1040	16.64
129E	071384	072384	2.30E+05	2.30E+05	298	4.77
130A	080384	091484	2.30E+05	2.32E+05	2301	36.82
130B	091484	092784	2.32E+05	2.33E+05	688	11.01
130C	092884	100184	2.33E+05	2.33E+05	120	1.92
131A	100784	102484	2.33E+05	2.34E+05	965	15.44
131B	102484	111984	2.34E+05	2.35E+05	1441	23.06
131C	111984	120384	2.35E+05	2.36E+05	762	12.19
131D	121084	121284	2.36E+05	2.36E+05	114	1.82
132A	122184	021185	2.36E+05	2.39E+05	2937	46.99
132B	021285	021585	2.39E+05	2.39E+05	114	1.82
133A	022185	040685	2.39E+05	2.42E+05	2473	39.57
133B	040785	041285	2.42E+05	2.42E+05	208	3.33
134A	051385	052185	2.42E+05	2.42E+05	131	2.10
134B	052485	061485	2.42E+05	2.43E+05	1127	18.03
134C	061585	070785	2.43E+05	2.44E+05	1164	18.62
135A	071885	072385	2.44E+05	2.45E+05	212	3.39
135B	072385	072585	2.45E+05	2.45E+05	71	1.14
135C	072585	082685	2.45E+05	2.47E+05	1825	29.20
135D	082785	091685	2.47E+05	2.48E+05	1132	18.11
135E	091785	092085	2.48E+05	2.48E+05	106	1.70
136A	093085	101085	2.48E+05	2.48E+05	545	8.72
136B	101285	101485	2.48E+05	2.48E+05	111	1.78
136C	101585	110885	2.48E+05	2.50E+05	1398	22.37
136D	110985	111285	2.50E+05	2.50E+05	128	2.05
137A	112185	112285	2.50E+05	2.50E+05	20	0.32
137B	112385	011386	2.50E+05	2.53E+05	2970	47.52
137C	011486	011886	2.53E+05	2.53E+05	152	2.43
137D	012586	013186	2.53E+05	2.53E+05	189	3.02
137E	020386	021386	2.53E+05	2.53E+05	143	2.29
138A	022086	032686	2.53E+05	2.55E+05	1917	30.67

138B	032886	040386	2.55E+05	2.56E+05	177	2.83
138C	040586	041086	2.56E+05	2.56E+05	240	3.84
139A	051686	061286	2.56E+05	2.57E+05	1509	24.14
139B	061386	071586	2.57E+05	2.59E+05	1839	29.42
139C	071686	071686	2.59E+05	2.59E+05	3	0.05
139D	071686	071786	2.59E+05	2.59E+05	6	0.10
139E	071786	072186	2.59E+05	2.59E+05	161	2.58
140A	072886	072986	2.59E+05	2.59E+05	69	1.10
140B	073086	091586	2.59E+05	2.62E+05	2707	43.31
141A	092286	111786	2.62E+05	2.65E+05	3267	52.27
141B	112286	120186	2.65E+05	2.66E+05	483	7.73
141C	120286	121086	2.66E+05	2.66E+05	284	4.54
142A	121686	020587	2.66E+05	2.69E+05	3075	49.20
142B	020587	020987	2.69E+05	2.69E+05	150	2.40
143A	021587	040987	2.69E+05	2.73E+05	3219	51.50
144A	051987	082487	2.73E+05	2.78E+05	5865	93.84
145A	082887	110287	2.78E+05	2.82E+05	4011	64.18
146A	110887	111987	2.82E+05	2.83E+05	437	6.99
146B	112087	020888	2.83E+05	2.88E+05	4921	78.74
147A	021188	040188	2.88E+05	2.91E+05	3062	48.99
148A	051488	052288	2.91E+05	2.91E+05	473	7.57
148B	052588	080788	2.91E+05	2.96E+05	4613	73.81
149A	081688	110188	2.96E+05	3.01E+05	4697	75.15
150A	111188	111488	3.01E+05	3.01E+05	120	1.92
150B	111688	020189	3.01E+05	3.06E+05	4774	76.38
151A	021589	031789	3.06E+05	3.07E+05	1871	29.94
151B	031889	040689	3.07E+05	3.09E+05	1161	18.58
152A	102389	103089	3.09E+05	3.09E+05	51	0.82
152B	103189	110689	3.09E+05	3.09E+05	359	5.74
152C	112189	010990	3.09E+05	3.11E+05	2132	34.11
152D	011090	012090	3.11E+05	3.12E+05	579	9.26
153A	012690	040190	3.12E+05	3.16E+05	4031	64.50
154A	051990	052590	3.16E+05	3.16E+05	148	2.37
154B	052790	053090	3.16E+05	3.16E+05	172	2.75
154C	053190	062290	3.16E+05	3.17E+05	1333	21.33
154D	062290	062390	3.17E+05	3.17E+05	5	0.08
154E	062790	062890	3.17E+05	3.17E+05	15	0.24
154F	062990	092190	3.17E+05	3.22E+05	5037	80.59
155A	092990	111390	3.22E+05	3.25E+05	2766	44.26
155B	111590	120690	3.25E+05	3.26E+05	1281	20.50
156A	122090	122190	3.26E+05	3.26E+05	0	0.00
156B	122390	032991	3.26E+05	3.32E+05	5899	94.38
157A	052091	052391	3.32E+05	3.32E+05	91	1.46

157C	061591	062091	3.32E+05	3.33E+05	258	4.13
157D	073091	082191	3.33E+05	3.34E+05	1354	21.66
157H	083091	090391	3.34E+05	3.34E+05	176	2.82
157J	092391	110191	3.34E+05	3.36E+05	1978	31.65
158A	112791	012092	3.36E+05	3.40E+05	3302	52.83
158B	012192	012292	3.40E+05	3.40E+05	19	0.30
159A	030492	030992	3.40E+05	3.40E+05	200	3.20
159B	031192	031392	3.40E+05	3.40E+05	74	1.18
160A	062492	090192	3.40E+05	3.43E+05	3322	53.15
160B	090292	090992	3.43E+05	3.43E+05	360	5.76
160C	091092	091692	3.43E+05	3.44E+05	282	4.51
161A	100392	110892	3.44E+05	3.46E+05	1933	30.93
162A	112692	020193	3.46E+05	3.49E+05	3465	55.44
163A	022693	040193	3.49E+05	3.51E+05	2073	33.17
164A	060493	070693	3.51E+05	3.53E+05	1891	30.26
165A	072993	100793	3.53E+05	3.57E+05	4125	66.00
166A	103093	120193	3.57E+05	3.59E+05	1646	26.34
167A	122393	122893	3.59E+05	3.59E+05	239	3.82
167B	010894	011794	3.59E+05	3.60E+05	512	8.19
167C	011894	020794	3.60E+05	3.61E+05	1166	18.66
168A	022594	030594	3.61E+05	3.61E+05	430	6.88
168B	032294	033094	3.61E+05	3.62E+05	435	6.96
169A	062294	080994	3.62E+05	3.65E+05	2909	46.54
170A	081994	092794	3.65E+05	3.67E+05	2188	35.01
170B	093094	093094	3.67E+05	3.67E+05	0	0.00

* Read 080164 as August 01, 1964

For the time period under consideration for the reflector assemblies shown in Table 1, the enriched region (core) is located in Rows 1-6, while Row 7 is a transition row which may contain both enriched assemblies and radial reflector assemblies. Rows 8-10 generally contain radial reflector assemblies and Rows 10-16 typically contain radial blanket assemblies. (Control assemblies are in Row 5, whereas safety assemblies are in Row 3.)

Radial reflector assemblies contain six block sections; the total height of all the blocks is 156.0 cm (61.42 inches) (see Table 2). Radial blanket assemblies contain 19 cylindrical elements; each radial blanket element contains 139.7 cm (55 inches) of depleted uranium.

Shown in Figure 5 are axial flux shapes in an enriched region row (Row 1), axial shapes in radial reflector rows 8-10 and an axial shape in a radial blanket (Row 14) assembly; this axial data was obtained from an EBR-II Run 155A calculation using the REBUS fuel cycle analysis code with a whole-core Hex-Z nodal transport theory flux solution and 28-group ENDF/B Version 5 cross sections. Superimposed on the axial flux shapes in Figure 5 are the axial regions for an enriched assembly (lower structure [L/STR], lower

reflector [L/REFL], lower grid [L/GRID], core, plenum, upper grid [U/GRID] and upper reflector [U/REFL]).

Figure 5. Axial Flux Shapes in EBR-II Run 155A.

As seen from Figure 5, the enriched regions have the most peaked axial flux; this axial peaking decreases as assemblies get further from the core center.

In published EBR-II run reports generated by ANL-East for the EBR-II, two midplane neutron flux parameters are reported for each EBR-II assembly in a particular grid loading, the total and fast flux (flux with energy greater than 0.11 MeV). The total fluence is the total flux times the effective irradiation time and the fast fluence is the fast flux times the effective irradiation time.

Shown in Figure 6 are the axial fast flux percentage profiles for two reflector grid positions of interest (9C2 and 10C2) and the core center (1A1); this data is from the above mentioned EBR-II Run 155A calculation. The spectrum for the core center is only shown here to show how much the spectrum can change with grid position.

Figure 6. Axial Fast Flux Percentage Profiles in EBR-II Run 155A.

As seen from Figure 6, the axial fast flux percentage is similar for the two reflector positions, while the core center has a much harder spectrum.

Reflector-Specific Assembly Histories

Shown in Figures 7-11 are the run energy depositions as seen by the reflector assemblies under consideration (from Table 1) for EBR-II runs greater than Run 103A.

Figure 7. Reactor Energy Deposition for EBR-II Reflector U9902.

Figure 8. Reactor Energy Deposition for EBR-II Reflector U9003.

Figure 9. Reactor Energy Deposition for EBR-II Reflector U9005.

Figure 10. Reactor Energy Deposition for EBR-II Reflector U9006.

Figure 11. Reactor Energy Deposition for EBR-II Reflector U9027.

Reflector Assembly Block-Specific Fluences

Run reports were issued for each major run in the EBR-II reactor irradiation history. These run reports contained an assembly location hex-grid-plot, assembly-dependent midplane hex-grid-plots for flow rate, several isotopic reaction rates, uranium and iron heating rates, total and fast neutron fluxes. In addition, an individual-assembly total energy deposition rate hex-grid-plot was also part of the run report. Using the run reports issued for the EBR-II reactor and summing the subassembly-dependent midplane fluxes times the appropriate effective run-times, the core-midplane

fast and total fluence values for the relevant reflector assemblies, shown in Figure 12, were obtained; the values used to produce this bar-chart are given in Table 4.

Figure 12. Midplane Total and Fast Fluence for EBR-II Reflectors U9902, U9003, U9005, U9006 and U9027.

Table 4. EBR-II Reflector Core-Midplane Fast and Total Fluences.

Reflector Assembly	Core-Midplane Fluence, 10^{23} n/cm ²		Percentage Fast
	Fast	Total	
U9902	0.7816	1.357	57.61
U9003	0.8257	1.522	54.25
U9005	0.8143	1.534	53.08
U9006	0.8192	1.542	53.13
U9027	0.6639	1.139	58.28

There has been one major assumption used in generating the fluence values in Figure 12 and Table 4. As mentioned above, for each reactor run, there may be several sub-runs. While not true for all runs, generally, midplane calculated quantities were only published for one of the sub-runs since all sub-runs for a particular run were similar. Therefore, one assumption that was made here was that the published information for a chosen sub-run was applicable to all the sub-runs within a given run classification. Furthermore, if results were published for more than one sub-run, the sub-run with the longest irradiation time was chosen as the representative run history for that particular run.

Given in Table 1 were all the relevant grid positions for the reflector assemblies under consideration. Shown in Figure 13 are the relative block-center fluence values for the six blocks for each of the grid positions under consideration; this axial data was obtained from an EBR-II Run 155A Hex-Z neutronics calculation. The block-center data in Figure 13 was assumed equal to the calculated axial position value nearest a block center. As

seen from Figure 13, the relative block fluence levels are roughly the same for each grid position under consideration. Thus, it was assumed that the relative fluence for a particular block is independent of grid position.

Figure 13. Relative Fluence Values for EBR-II Reflector Blocks in Run 155A.

Shown in Figure 14 are the Run 155A block-center-to-midplane total and fast fluence factors (these are the average of the values for each block in Figure 13); the corresponding numeric values are shown in Table 5. Also shown in Figure 14 are the corresponding center-to-midplane total flux factors for EBR-II Run 105A. Axial results are only shown for these two EBR-II runs because this was the only detailed energy and spatial Hex-Z data that was readily available for the EBR-II run history (greater than Run 103A) under consideration.

Figure 14. Block Center-to-Midplane Fluence Factors for EBR-II Reflector Blocks in Runs 155A and 105A.

Table 5. Center-to-Midplane Factors for each Reflector Block in Runs 155A and 105A.

Block	Center-to-Midplane Factors		
	155A Flux	105A Flux	155A Fast Flux
1	0.1636	0.1636	0.1066
2	0.6443	0.7021	0.5696
3	1.0000	1.0000	1.0000
4	0.7505	0.7469	0.7030
5	0.3033	0.2350	0.2340
6	0.0841	0.0671	0.0562

As seen from Figure 14, the EBR-II center-to-midplane flux factors are relatively stable for runs after Run 100; this is not surprising since the reflector was relatively unchanged after Run 100. Most of the differences seen in this data between Runs 105A and Run 155A values is most likely due to calculated flux points not being exactly at block center locations (i.e., the data shown is the calculated point nearest the block centers). Since center-to-midplane factors are quite similar for EBR-II runs 105A and 155A, arbitrarily, it has been assumed that the flux factors for Run 155A are applicable to all runs after Run 100. Furthermore, it has also been assumed that the fast flux factors from Run 155A are applicable to all runs after Run 100.

The factors shown in Figure 14 and Table 5 are used in the following way. The fluence (total or fast) at the center of each block is found by multiplying the core-midplane fluences in Table 4 by the center-to-midplane total and fast flux factors shown in Table 5. This gives the fluence at the physical center of each block.

Shown in Figure 15 (and Table 6) are the Run 155A total and fast flux factors needed to convert the block-center fluence to the block-average fluence (i.e., axially-averaged over the whole block).

Figure 15. Block Average-to-Center Fluence Factors for EBR-II Reflector Blocks in Run 155A.

Table 6. Average-to-Center Factors for each Reflector Block in Run 155A.

Block	Average-to-Center Factor	
	155A Flux	155A Fast Flux
1	1.096	1.160
2	0.963	0.970
3	0.941	0.926
4	0.942	0.935
5	1.282	1.385
6	1.026	1.056

Like the core-midplane to block-center values shown previously, the block-center to block-average total and fast flux factors generated using Run 155A values was assumed applicable to all runs after Run 100.

Using the core-midplane fluences from Table 4 and the conversion factors in Tables 5 and 6, the total and fast fluences in Tables 7 - 10 were obtained.

Table 7. Block-Center Total Fluence for Reflectors U9902, U9003, U9005, U9006 and U9027.

Block	Block-Center Total Fluence, 10^{23} n/cm ²				
	U9902	U9003	U9005	U9006	U9027
1	0.2220	0.2490	0.2510	0.2522	0.1864
2	0.8742	0.9806	0.9883	0.9934	0.7339
3	1.3568	1.5220	1.5340	1.5418	1.1390
4	1.0183	1.1423	1.1513	1.1572	0.8549
5	0.4115	0.4616	0.4652	0.4676	0.3455
6	0.1140	0.1279	0.1289	0.1296	0.0957

Table 8. Block-Average Total Fluence for Reflectors U9902, U9003, U9005, U9006 and U9027.

Block	Block-Average Total Fluence, 10^{23} n/cm ²				
	U9902	U9003	U9005	U9006	U9027
1	0.2434	0.2730	0.2751	0.2765	0.2043
2	0.8421	0.9446	0.9521	0.9569	0.7070
3	1.2767	1.4322	1.4435	1.4509	1.0719
4	0.9589	1.0756	1.0841	1.0897	0.8050
5	0.5276	0.5919	0.5965	0.5996	0.4430
6	0.1170	0.1313	0.1323	0.1330	0.0982

Table 9. Block-Center Fast Fluence for Reflectors U9902, U9003, U9005, U9006 and U9027.

Block	Block-Center Fast Fluence, 10^{23} n/cm ²				
	U9902	U9003	U9005	U9006	U9027
1	0.0833	0.0880	0.0868	0.0873	0.0708
2	0.4452	0.4704	0.4639	0.4667	0.3782
3	0.7816	0.8257	0.8143	0.8192	0.6639
4	0.5495	0.5805	0.5725	0.5759	0.4667
5	0.1829	0.1932	0.1906	0.1917	0.1554
6	0.0439	0.0464	0.0457	0.0460	0.0373

Table 10. Block-Average Fast Fluence for Reflectors U9902, U9003, U9005, U9006 and U9027.

Block	Block-Average Fast Fluence, 10^{23} n/cm^2				
	U9902	U9003	U9005	U9006	U9027
1	0.0974	0.1029	0.1015	0.1021	0.0827
2	0.4320	0.4564	0.4501	0.4528	0.3670
3	0.7242	0.7650	0.7544	0.7590	0.6151
4	0.5138	0.5428	0.5352	0.5385	0.4364
5	0.2534	0.2676	0.2639	0.2655	0.2152
6	0.0464	0.0490	0.0483	0.0486	0.0394

Radial Fluence Gradients in EBR-II Reflector Assemblies

The above fluences are block-center and block-average values; they do not give any indications as to radial-fluence gradients within a block.

The EBR-II core-assembly geometry is hexagonal, thus the distance between any given assemblies in a particular sector and the core center can be very different. Shown in Figure 16 are the distances between a corner assembly and the core center plus the distance from an assembly in the middle of the “flats” portion of the row to the core center. (The distances shown in Figure 16 are in units of the assembly pitch [P].) As seen from Figure 16, for a given row, the “mid-flats” assemblies are closer to the core than the corner assemblies. [Equation fits are also shown in Figure 16; the 0.866 value in the “mid-flats” equation is a constant which comes from cosine (30 degrees) = sine (60 degrees) = 0.866.]

Figure 16. Distance to Assembly Center for EBR-II Rows.

From Figure 16 it is seen that the mid-flats position is closer to the core center than a corner position, therefore it should have a higher flux level. For example, since the flux

changes radially by $\sim 1/R^2$ (where R is the radius), the results shown in Figure 16 for row 9 implies that a “mid-flats” flux in row 9 is about 1.33 times a row 9 corner flux. (Row nine is the second full row of reflectors in a standard EBR-II configuration and is one of the rows in which a required reflector assembly [U9902] is located.)

The midplane fluxes for all assemblies in EBR-II Run 155A reflector-row 9 sector A, displayed in Figure 17, shows the oscillatory behavior suggested in Figure 16. (All other sector fluxes are similar to the Sector A values.)

Figure 17. Row 9 Sector A Midplane Fluxes in EBR-II Run 155A.

Using the fluxes in Figure 17, the “mid-flats” flux in row 9 is about 1.37 times the corner flux; approximately the same value suggested above using only geometrical factors.

Shown in Figure 18 are the fluence gradients across blocks that are in a corner position in rows 8-10 of Run 155A. (Fluence gradients were determined by linear interpolation of center-point values.) As seen in Figure 18, except for Block 6, the fluence drop across a Row 8 corner assembly is about 20-25%, the fluence drop across a Row 9 corner assembly is about 24-28% and the fluence drop across a Row 10 corner assembly is about 30-33%. These fluence drops were determined for Run 155A fluences, but they should be similar for all runs. These indicate, except for Block 6, the further out an assembly is from the center of the core, the larger the fluence gradient across the assembly. The non-conformity of Block 6 is most likely due to its relatively large distance from the core centerline.

Figure 18. Fluence Gradients for EBR-II Corner Assemblies in Run 155A.

The fluence drops across the center of Block 3 for a corner and “mid-flats” position are shown in Figure 19 for Run 155A assemblies. (The “mid-flats” values shown were for an assembly at the center-point between two corner-assemblies.) [The Block 3 (~ midplane) corner values shown in Figure 19 are the Block 3 values from Figure 18.]

Figure 19. Fluence Gradients for EBR-II Midplane Corner & Flats Assemblies.

The fluence drops are somewhat lower for a “mid-flats” assembly, but they are in the same “ball-park” as the corner assembly changes. This discrepancy between corner and “mid-flats” fluence gradients is due to corner assemblies being further from the core center.

The fluence drops shown in Figures 18 and 19 should also apply to fast fluences because the fast flux percentages of adjacent assemblies are almost the same (see Figure 6).

Summary

There are currently five complete EBR-II reflector assemblies being stored in the Hot Fuel Examination Facility (HFEF) pits at INL; these are reflector assemblies U9902, U9003, U9005, U9006 and U9027. An EBR-II reflector assembly consists of six steel (304SS) blocks inside a hexcan; each block varies in height between 21.74 cm (8.562 inches) and 39.527 cm (15.562 inches).

INL would like to use these steel reflector assemblies to study damage in irradiated assemblies. To do this, the total and fast ($E > 0.1 \text{ MeV}$) neutron fluence of each of these assemblies have to be determined.

Using flux results from EBR-II Run Reports and assembly irradiation histories, the midplane total and fast fluences shown in Table 10 were obtained. (Table 11 is identical to Table 4.)

Table 11. EBR-II Reflector Core-Midplane Fast and Total Fluences.

Reflector Assembly	Core-Midplane Fluence, 10^{23} n/cm^2		Percentage Fast
	Fast	Total	
U9902	0.7816	1.357	57.61
U9003	0.8257	1.522	54.25
U9005	0.8143	1.534	53.08
U9006	0.8192	1.542	53.13
U9027	0.6639	1.139	58.28

To convert midplane fluences to block-center values, multiply the midplane values in Table 11 by the factors shown in Table 12. (The center of Block 3 is very close to, if not equal to, the reactor midplane position.)

Table 12. Center-to-Midplane Factors for each Reflector Block.

Block	Center-to-Midplane Factors	
	Flux	Fast Flux
1	0.1636	0.1066
2	0.6443	0.5696
3	1.0000	1.0000
4	0.7505	0.7030
5	0.3033	0.2340
6	0.0841	0.0562

To convert block-center fluences to block-average values, multiply the block-center values by the factors shown in Table 13.

Table 13. Average-to-Center Factors for each Reflector Block.

Block	Average-to-Center Factor	
	Flux	Fast Flux
1	1.096	1.160
2	0.963	0.970
3	0.941	0.926
4	0.942	0.935
5	1.282	1.385
6	1.026	1.056

The block-center and block-average total and fast fluences for each block and reflector assembly were given previously in Tables 7-10, but are repeated in this summary as Tables 14-17.

Table 14. Block-Center Total Fluence for Reflectors U9902, U9003, U9005, U9006 and U9027.

Block	Block-Center Total Fluence, 10^{23} n/cm ²				
	U9902	U9003	U9005	U9006	U9027
1	0.2220	0.2490	0.2510	0.2522	0.1864
2	0.8742	0.9806	0.9883	0.9934	0.7339
3	1.3568	1.5220	1.5340	1.5418	1.1390
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5	0.4115	0.4616	0.4652	0.4676	0.3455
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Table 15. Block-Average Total Fluence for Reflectors U9902, U9003, U9005, U9006 and U9027.

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	U9902	U9003	U9005	U9006	U9027
1	0.2434	0.2730	0.2751	0.2765	0.2043
2	0.8421	0.9446	0.9521	0.9569	0.7070
3	1.2767	1.4322	1.4435	1.4509	1.0719
4	0.9589	1.0756	1.0841	1.0897	0.8050
5	0.5276	0.5919	0.5965	0.5996	0.4430
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Table 16. Block-Center Fast Fluence for Reflectors U9902, U9003, U9005, U9006 and U9027.

Block	Block-Center Fast Fluence, 10^{23} n/cm ²				
	U9902	U9003	U9005	U9006	U9027
1	0.0833	0.0880	0.0868	0.0873	0.0708
2	0.4452	0.4704	0.4639	0.4667	0.3782
3	0.7816	0.8257	0.8143	0.8192	0.6639
4	0.5495	0.5805	0.5725	0.5759	0.4667
5	0.1829	0.1932	0.1906	0.1917	0.1554
6	0.0439	0.0464	0.0457	0.0460	0.0373

Table 17. Block-Average Fast Fluence for Reflectors U9902, U9003, U9005, U9006 and U9027.

Block	Block-Average Fast Fluence, 10^{23} n/cm ²				
	U9902	U9003	U9005	U9006	U9027
1	0.0974	0.1029	0.1015	0.1021	0.0827
2	0.4320	0.4564	0.4501	0.4528	0.3670
3	0.7242	0.7650	0.7544	0.7590	0.6151
4	0.5138	0.5428	0.5352	0.5385	0.4364
5	0.2534	0.2676	0.2639	0.2655	0.2152
6	0.0464	0.0490	0.0483	0.0486	0.0394

Radial fluence gradients were also determined for assemblies in corner and “mid-flats” positions. Except for Block 6, the fluence drop across a Row 8 corner assembly varies between 20-25%, the fluence drop across a Row 9 corner assembly varies between 24-28% and the fluence drop across a Row 10 corner assembly is varies between 30-33% (see Figures 18). The midplane, corner and “mid-flats” fluence changes for EBR-II rows 8-10 were presented in Figure 19; the “flats” fluence drops were somewhat smaller than the equivalent-row corner position values, most likely because they were closer to the core center.

Finally, for the assemblies considered, the fast flux (or fluence) drop should be similar to the corresponding total flux drop.

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