PRELIMINARY REPORT ON THE IRRADIATION PARAMETERS FOR THE EBR-II COBRA-1A2 TEST - A. M. Ermi (Westinghouse Hanford Company) and M. L. Hamilton (Pacific Northwest Laboratory)[a]

OBJECTIVE

The objective of this effort was to report on the preliminary irradiation parameters (temperatures, fluences and dpa values) for the COBRA-1A2 test irradiated in the EBR-II. The report covers specimens irradiated in four B7A capsules from November 1992 to September 1994.

SUMMARY

The COBRA-1A2 test specimens were irradiated in the Experimental Breeder Reactor - II (EBR-II) during Runs 162 and 163 (as part of the COBRA-1A1 test), and during Runs 164 through 170. The four capsules in the COBRA-1A2 subassembly were irradiated for a total of 337.3 Effective Full Power Days (EFPD) at a nominal reactor power level of 62.5 MWt. The estimated mid-core total peak fast fluence was 6.85×10^{22} n/cm^2 (E > 0.111 MeV), and the estimated total peak displacements per atom was 32.6 dpa (in stainless steel). During reactor operation, the inlet coolant remained at 371°C while the calculated coolant outlet temperature was 441°C.

PROGRESS AND STATUS

Introduction

The COBRA-1A experiment was sponsored by the U.S. Neutron Interactive Materials Program (NIMS) and the Japanese Ministry of Education, Science and Culture (Monbusho). This test was part of an ongoing U.S./Japan collaborative program to study the effects of neutron irradiation on fusion reactor candidate materials.

The COBRA-1A subassembly, designated as X516, consisted of seven B7A capsules, and was irradiated in EBR-II core position 2B1. The seven capsules were divided into four high fluence capsules (B-388 through B-391) and three low fluence capsules (B-392 through B-394). The three low fluence capsules were discharged after Run 163 (the COBRA-1A1 irradiation), while the four high fluence capsules continued to be irradiated during Runs 164 through 170 (the COBRA-1A2 irradiation).

The COBRA-1A2 subassembly, designated as X516A, consisted of the four B7A capsules from COBRA-1A1, and three dummy capsules. This subassembly was also irradiated in core position 2B1. The location of position 2B1 in the EBR-II reactor grid is shown in Figure 1. The positions of the B7A specimen capsules and dummy capsules in subassembly X516A and their relative position to the core center are shown in Figure 2.

The four specimen capsules in the COBRA-1A2 subassembly consisted of three weeper capsules (B-388, B-389 and B-390) and one gas-gapped capsule (B-391). The weeper capsules were designed to expose the test specimens and specimen subcapsules to the reactor coolant. The gas-gapped capsule was

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[a]Operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

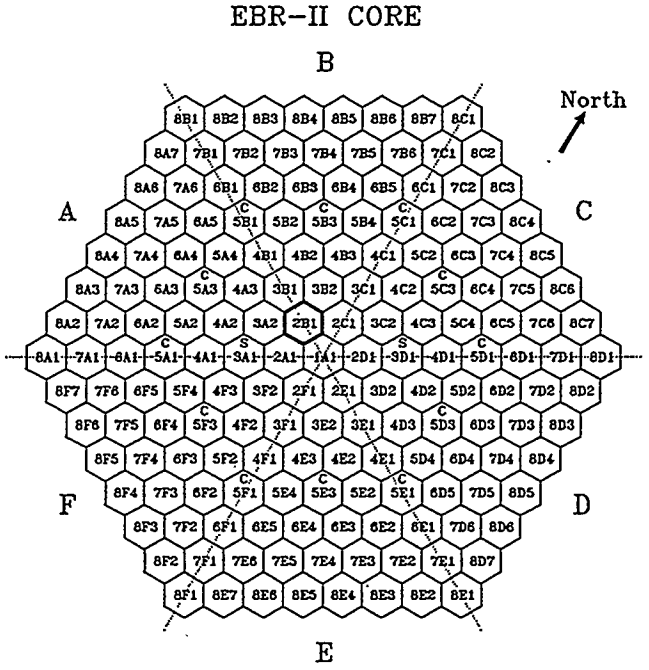

Figure 1. Location of Position 2B1 in the EBR-II Reactor Grid.

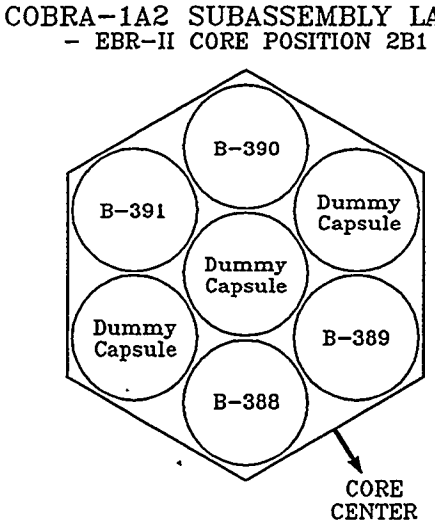

Figure 2. Position of COBRA-1A2 B7A Capsules in Subassembly X516A.

designed to irradiate one subcapsule (D05) at a goal temperature of 800°C. The remaining specimens in this capsule were designed to operate at temperatures close to the ambient coolant temperature. Baskets and subcapsules were used in all capsules to maintain the specimens at pre-determined positions. References 1 through 6 give more details on the test matrix, baskets, subcapsules, capsules, specimen loading and the overall experiment.

Summary of Reactor Conditions for EBR-II Runs 162 through 170

EBR-II Run 162 commenced on November 26, 1992, marking the beginning of the COBRA-1A irradiation. The seven COBRA-1A1 capsules remained in the reactor through Run 163 which ended on April 1, 1993. Following the long spring maintenance and refueling outage, the four COBRA-1A2 capsules continued the irradiation with Run 164, which commenced on June 4, 1993. The capsules remained in the reactor through Run 170, which ended on September 26, 1994.

There were five unscheduled reactor shutdown periods during the twenty-two month irradiation period. One was caused by severe winter storms that prevented required reactor crew changes. The other four were caused by various minor problems with operating systems or equipment. The power levels for EBR-II Runs 162 through 170 are shown in Figures 3 through 6, while reactor operations details for the nine runs are given in References 7 through 15. The reactor operation during the COBRA-1A irradiation is summarized in Table 1. The cumulative EFPD for the COBRA-1A2 specimens during Runs 162 through 170 was 337.3 EFPD (at a nominal full power level of 62.5 MWt).

Table 1. Summary of EBR-II Operation During the COBRA-1A Irradiation.

Run #	Start Date	End Date	Shutdown Remarks	Run EFPD*	Total EFPD*
162	Nov. 26, 1992	Jan. 20, 1993	Severe Winter Storms	55.44	55.44
	Jan. 30, 1993	Feb. 1, 1993	Scheduled End of Run		
163	Feb. 26, 1993	April 1, 1993	Scheduled End of Run	33.17	88.61
164	June 4, 1993	July 6, 1993	Scheduled End of Run	30.26	118.87
165	July 31, 1993	Oct. 7, 1993	Scheduled End of Run	66.00	184.87
166	Oct. 30, 1993	Nov. 6, 1993	Loss of Instrument Air	26.34	211.21
	Nov. 8, 1993	Dec. 1, 1993	Scheduled End of Run		
167	Dec. 23, 1993	Dec. 28, 1993	Loss of Control Rod Movement	30.67	241.88
	Jan. 8, 1994	Jan. 17, 1994	Loss of Coolant Flow		
	Jan. 19, 1994	Feb. 7, 1994	Scheduled End of Run		
168	Feb. 25, 1994	Mar. 5, 1994	Scheduled End of 1st Run	13.84	255.72
	Mar. 22, 1994	Mar. 30, 1994	Scheduled End of 2nd Run		
169	June 23, 1994	Aug. 9, 1994	Scheduled End of Run	46.54	302.26
170	Aug. 20, 1994	Aug. 31, 1994	Loss of Steam Pressure Control	35.00	337.26
	Sep. 2, 1994	Sep. 26, 1994	Scheduled End of Run		

*Note: Full Power was nominally 62.5 MWt

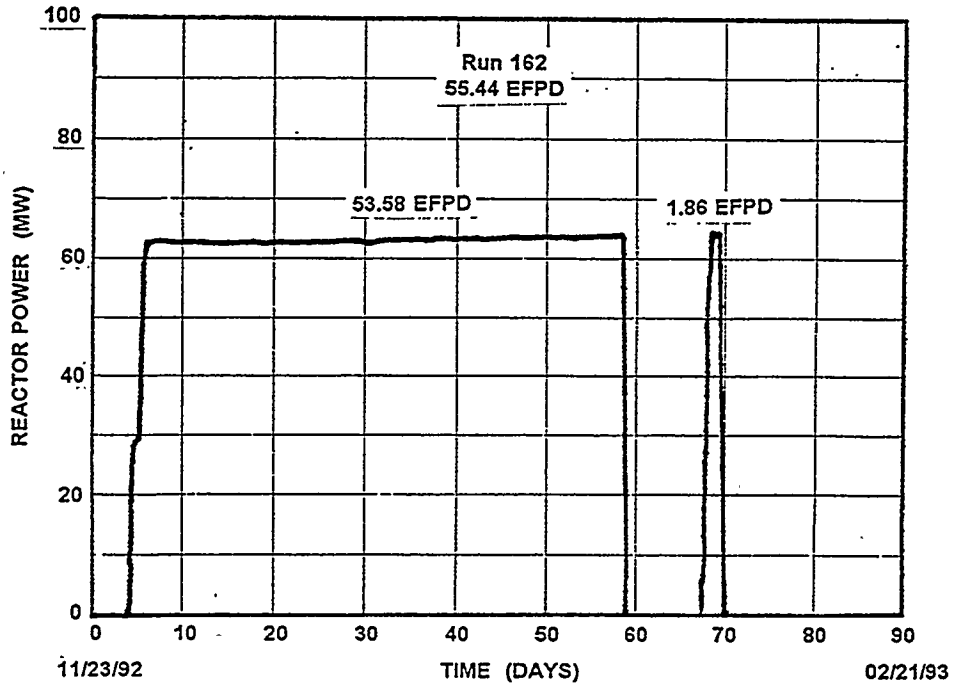

Figure 3. EBR-II Reactor Power During Run 162.

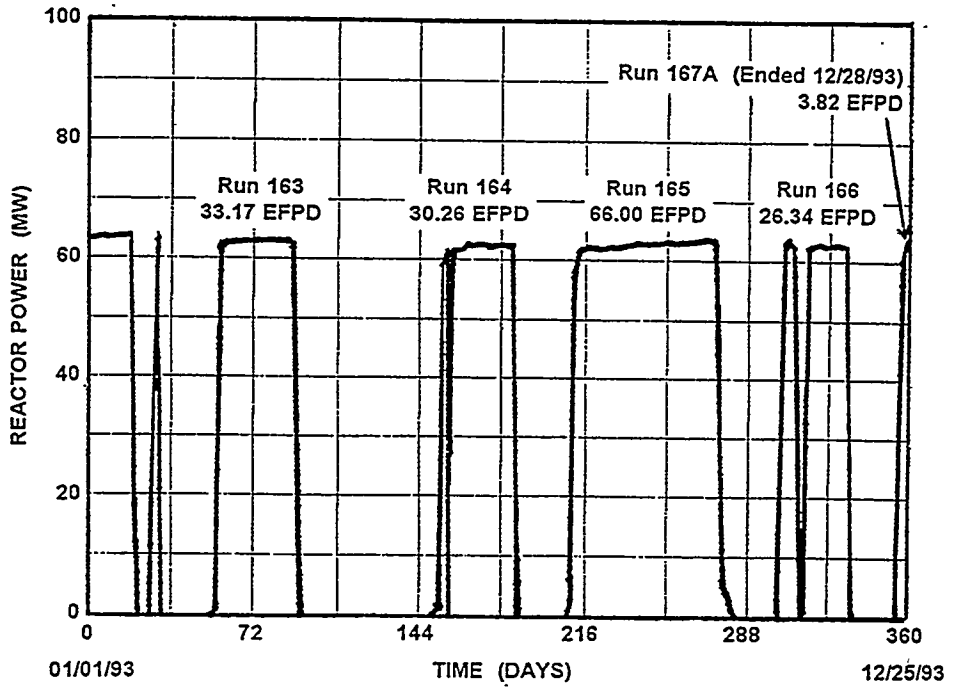

Figure 4. EBR-II Reactor Power During Runs 163 through 167A.

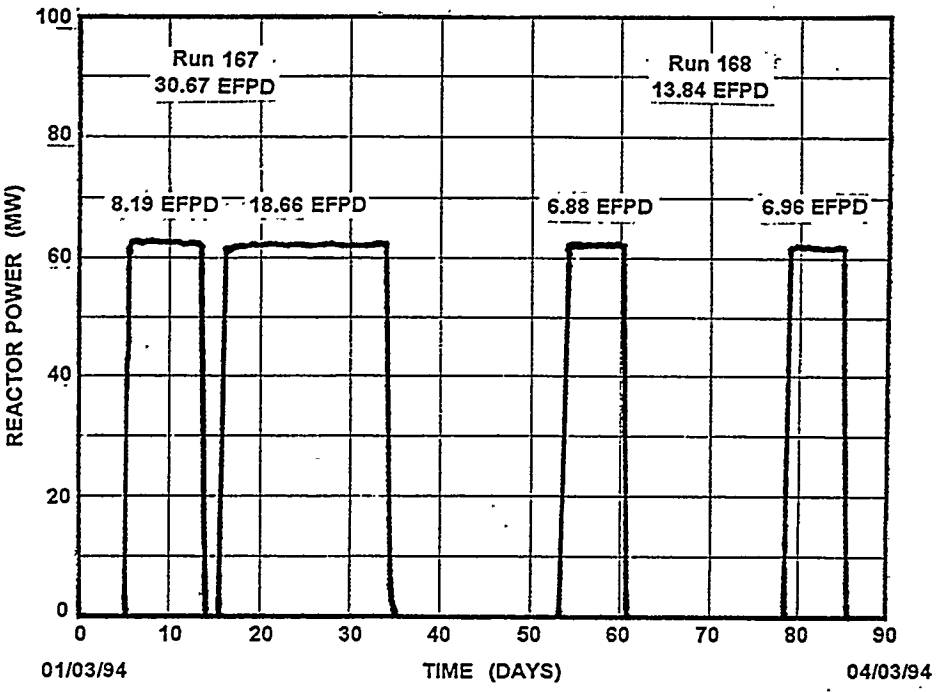

Figure 5. EBR-II Reactor Power During Runs 167B through 168.

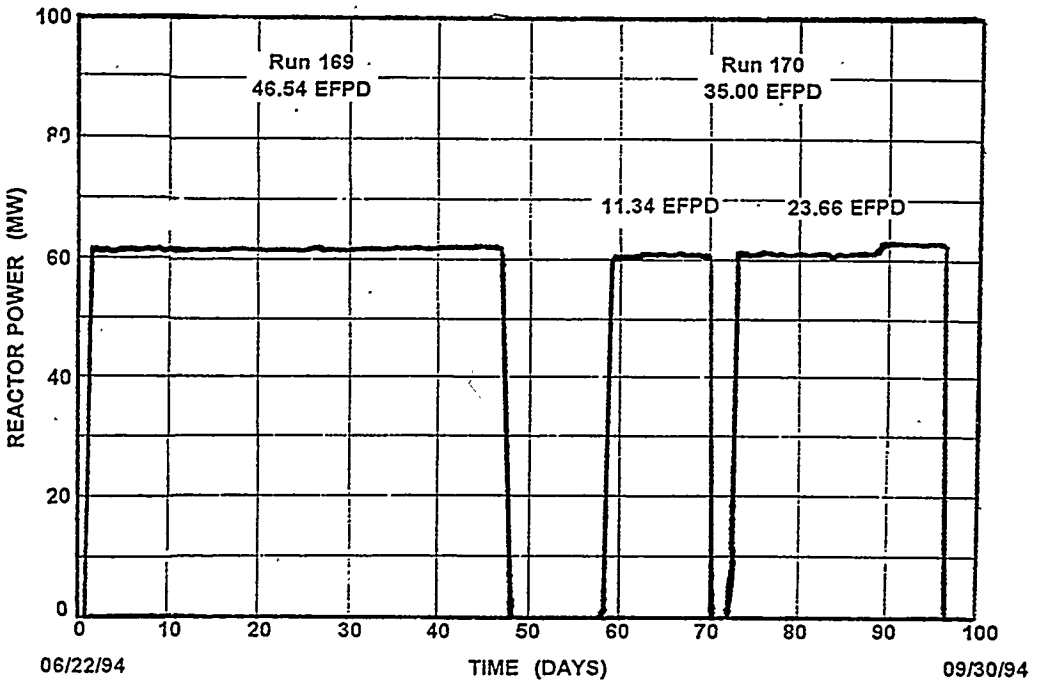

Figure 6. EBR-II Reactor Power During Runs 169 and 170.

Temperature Results

The B7A subassembly tests in EBR-II are uninstrumented, and therefore do not contain any active temperature monitoring devices. Thermal expansion difference monitors (TEDs) and silicon carbide (SiC) monitors were placed throughout the test to monitor peak temperatures in some baskets and subcapsules. However, it will be several months before the information from these temperature monitors are available. In the meantime, estimates of the temperatures, based on prior COBRA-1A1 experience, were used.

The capsules were designed to operate at specific irradiation temperatures based on various reactor and capsule parameters: nuclear heating, sodium coolant temperature, material compositions and mass distribution; for gas-gapped subcapsules, additional parameters are the gas-gap and conductivity of the gas.

The inlet coolant temperature remained constant during the irradiation of COBRA-1A. The inlet temperature was kept at 371°C during full power operation and during the short outages between runs. However, during the long maintenance and refueling outages in the springs of 1993 and 1994 (between Runs 163 and 164, and between Runs 168 and 169), the coolant temperature was lowered to approximately 177°C. It should also be noted that the COBRA-1A capsules were removed from the core between Runs 163 and 164 for the reconstitution of four COBRA-1A1 (X516) capsules into COBRA-1A2 (X516A).

The sodium outlet temperature for the COBRA-1A subassemblies depended on the reactor power and the heat generated from the adjacent subassemblies. The calculated outlet sodium temperature of 441°C was used for both COBRA-1A1 and COBRA-1A2.

The approximate mixed mean coolant temperature in the test assembly is given in Table 2. These temperatures were used to assign temperature values to the specimens in baskets in the weeper capsules B-388, B-389 and B-390 (baskets A03-A13, B03-B08, B10-B12, and C04-C10). For specimens in subcapsules in the weeper capsules (A01, A02, A14-A16, B01, B02, B09, and C01-C03), the assigned temperatures were 5-10°C higher. This was based on engineering judgement which took into account the core locations of the subcapsules in conjunction with encapsulation considerations (lower thermal conductivities of the gaseous bonding media).

Although capsule B-391 was gas-gapped, only subcapsule D05 was designed to operate at an elevated temperature. The remaining subcapsules (D01-D03) and basket (D04) were designed to operate close to the ambient sodium temperature, and were assigned values 5-20°C above the coolant temperature profile (for the same reasons as cited above). Subcapsule D05 was designed to operate at 800°C. However, based on a recent worst case analysis (Reference 16), the operating temperature of this subcapsule may have decreased by the end of the irradiation from 800°C to as low as 736°C. Since there is no way to assign a verifiable temperature to this subcapsule at present, the design temperature of 800°C was used in this preliminary report.

Dosimetry Results

Calculated mid-plane peak fast fluxes (E>0.111 MeV) for core position 2B1 were obtained from References 17-25, and are listed in Table 3. The peak fluences were then calculated based on the EFPD for each run.

Since the COBRA-1A2 dosimeter data have not been analyzed, flux profile information from Run 75D (Reference 26) and dosimetry results from a recent EBR-II test (Reference 27) were used to construct an estimated flux profile for a row 2 reactor position. Figure 7 shows the normalized flux curve.

Table 2. Calculated Mixed Mean Coolant Temperature for COBRA-1A.

Distance from Bottom of EBR-II Core		Mixed Mean Coolant Temperature (°C)
inches	mm	
0	0.0	375
1	25.4	377
2	50.8	379
3	76.2	381
4	101.6	384
5	127.0	387
6	152.4	390
7	177.8	393
8	203.2	396
9	228.6	399
10	254.0	401
11	279.4	403
12	304.8	405
13	330.2	407
14	355.6	409
15	381.0	411
16	406.4	413
17	431.8	415
18	457.2	417
19	482.6	418
20	508.0	421
21	533.4	423
22	558.8	425
23	584.2	427
24	609.6	429
25	635.0	431
26	660.4	432
27	685.8	433
28	711.2	434
29	736.6	435
30	762.0	436
31	787.4	437
32	812.8	438
33	838.2	439
34	863.6	440

Table 3. Estimated Mid-Core Peak Fast Fluxes and Fluences for COBRA-1A2.

EBR-II Run number	Calculated Mid-Core Fast Flux [E>0.111 MeV] ($n/cm^2/sec$)	Effective Full Power Days, EFPD (Days)	Estimated Mid-Core Fast Fluence [E>0.111 MeV] (n/cm^2)
162	2.357×10^{15}	55.44	1.13×10^{22}
163	2.321×10^{15}	33.17	0.67×10^{22}
164	2.327×10^{15}	30.26	0.61×10^{22}
165	2.341×10^{15}	66.00	1.33×10^{22}
166	2.320×10^{15}	26.34	0.53×10^{22}
167	2.355×10^{15}	30.67	0.62×10^{22}
168	2.379×10^{15}	13.84	0.28×10^{22}
169	2.376×10^{15}	46.54	0.96×10^{22}
170	2.384×10^{15}	35.00	0.72×10^{22}
Totals	2.351×10^{15}*	337.26	6.85×10^{22}

*Time-Averaged Value

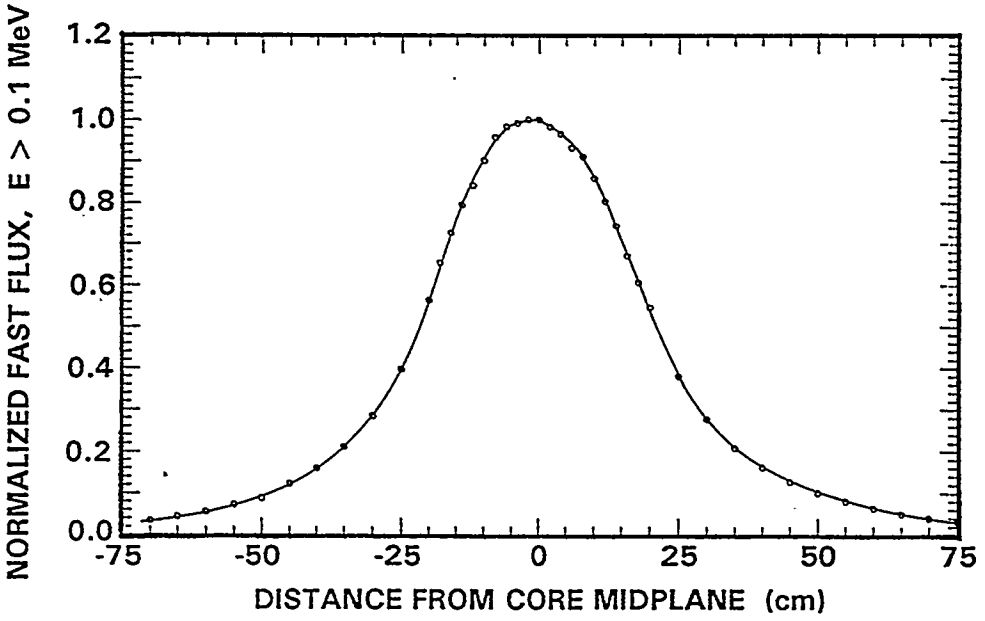

Figure 7. Estimated Normalized Flux Curve for an EBR-II Row 2 Position.

The estimated fast flux and fast fluence data along the vertical axis are given in Table 4. The values are based on the average mid-plane fast flux value from Table 3 and the normalized flux curve in Figure 7. Table 4 also gives the irradiation exposure in dpa (for stainless steel). The dpa values are based on dosimetry results (Reference 27), and a dpa per 10^{22} n/cm^2 profile for an EBR-II row 2 position.

Table 4. Estimated COBRA-1A2 Flux and Fluence Data.

Based on 337.3 EFPD for EBR-II Runs 162-170

VERTICAL DISTANCE FROM HORIZONTAL MIDPLANE [cm]	FAST FLUX, E>0.1 MeV [n/(cm^2-s)]	FAST FLUENCE, E>0.1 MeV [n/cm^2]	dpa per second	TOTAL dpa	dpa per (10^22 n/cm^2)
+75.00	7.35E+13	2.14E+21	2.47E-08	0.720	3.36
+70.00	9.27E+13	2.70E+21	3.12E-08	0.909	3.37
+65.00	1.16E+14	3.38E+21	3.94E-08	1.148	3.40
+60.00	1.49E+14	4.34E+21	5.07E-08	1.478	3.40
+55.00	1.88E+14	5.48E+21	6.48E-08	1.888	3.45
+50.00	2.36E+14	6.88E+21	8.27E-08	2.410	3.50
+45.00	2.99E+14	8.71E+21	1.06E-07	3.089	3.55
+40.00	3.81E+14	1.11E+22	1.39E-07	4.051	3.65
+35.00	4.90E+14	1.43E+22	1.86E-07	5.421	3.80
+30.00	6.50E+14	1.89E+22	2.54E-07	7.402	3.91
+25.00	8.93E+14	2.60E+22	3.66E-07	10.666	4.10
+20.00	1.29E+15	3.76E+22	5.54E-07	16.145	4.29
+18.00	1.43E+15	4.17E+22	6.33E-07	18.447	4.43
+16.00	1.58E+15	4.60E+22	7.18E-07	20.924	4.54
+14.00	1.75E+15	5.10E+22	8.17E-07	23.810	4.67
+12.00	1.89E+15	5.51E+22	8.99E-07	26.199	4.76
+10.00	2.02E+15	5.89E+22	9.67E-07	28.181	4.79
+8.00	2.14E+15	6.24E+22	1.02E-06	29.726	4.77
+6.00	2.20E+15	6.41E+22	1.05E-06	30.600	4.77
+4.00	2.27E+15	6.62E+22	1.08E-06	31.474	4.76
+2.00	2.31E+15	6.73E+22	1.10E-06	32.057	4.76
+0.00	2.35E+15	6.85E+22	1.12E-06	32.640	4.77
-2.00	2.35E+15	6.85E+22	1.12E-06	32.640	4.77
-4.00	2.33E+15	6.79E+22	1.11E-06	32.348	4.76
-6.00	2.31E+15	6.73E+22	1.10E-06	32.057	4.76
-8.00	2.25E+15	6.56E+22	1.07E-06	31.183	4.76
-10.00	2.12E+15	6.18E+22	1.01E-06	29.434	4.76
-12.00	1.98E+15	5.77E+22	9.39E-07	27.365	4.74
-14.00	1.87E+15	5.45E+22	8.74E-07	25.471	4.67
-16.00	1.71E+15	4.98E+22	7.78E-07	22.673	4.55
-18.00	1.54E+15	4.49E+22	6.82E-07	19.875	4.43
-20.00	1.33E+15	3.88E+22	5.74E-07	16.728	4.32
-25.00	9.33E+14	2.72E+22	3.83E-07	11.162	4.11
-30.00	6.67E+14	1.94E+22	2.61E-07	7.606	3.91
-35.00	4.95E+14	1.44E+22	1.88E-07	5.479	3.80
-40.00	3.75E+14	1.09E+22	1.37E-07	3.993	3.65
-45.00	2.87E+14	8.36E+21	1.02E-07	2.973	3.55
-50.00	2.06E+14	6.00E+21	7.21E-08	2.101	3.50
-55.00	1.70E+14	4.95E+21	5.84E-08	1.702	3.44
-60.00	1.29E+14	3.76E+21	4.39E-08	1.279	3.40
-65.00	1.01E+14	2.94E+21	3.42E-08	0.997	3.39
-70.00	7.88E+13	2.30E+21	2.65E-08	0.772	3.36

Flux and dpa profiles based on calculations and previous dosimetry.
dpa values are estimates for an Fe-18Cr-8Ni stainless steel.

COBRA-1A2 Damage Parameters

Combining the information from Table 3, Figure 7 and Reference 27 with the basket and subcapsule length information and the basket z-values, the fast fluence and dpa values for each basket and subcapsule were generated. Values were calculated for the tops, bottoms and middles of all baskets and subcapsules. The values were determined by linearly interpolation (on a semi-log scale) of flux and dpa rate curves. Tables 5, 6, 7, and 8 give the fluences and dpa values for each basket and subcapsule in capsules B-388, B-389, B-390 and B-391, respectively. Again note that the fluence values are for energies greater than 0.111 MeV, and the dpa values are for an Fe-18Cr-8-Ni stainless steel. Experimenters will need to apply an appropriate dpa correction factor for other materials.

The entire database listing for the COBRA-1A2 specimens has been generated and is available at PNL.[28] Also included are the COBRA-1A2 capsule loading diagrams showing all baskets and subcapsules, their relative stacking within each capsule, and various capsule, basket, subcapsule and specimen related information.

CONCLUSIONS

Preliminary irradiation parameters (temperatures, fluences and dpa values) for all test locations and specimens in COBRA-1A2 were reported. Additional details regarding the estimated irradiation conditions for individual specimens are available through PNL.

FUTURE WORK

A final report for the COBRA-1A2 test will be issued once the TED and SiC temperature monitors, and dosimetry from the four COBRA-1A2 capsules have been analyzed.

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Table 5. Estimated Irradiation Parameters for COBRA-1A2, Capsule B-388.

Based on 337.3 EFPD for EBR-II Runs 162-170

I.D.	Temp. °C*	Temp. Monitor	Program	Capsule Insert	Length (in)**	Z-Horizontal Midplane (in)#	Fast Fluence##	dpa in SS
A16	440	none	Fusion	Subcapsule	4.164	Top: +27.308 Mid: +25.398 Bot: +23.488	2.78E21 3.46E21 4.41E21	0.93 1.18 1.50
A15	432	none	Fusion	Subcapsule	4.164	Top: +19.067 Mid: +17.157 Bot: +15.247	7.41E21 9.34E21 1.18E22	2.61 3.34 4.36
A14	420	none	Fusion	Subcapsule	4.164	Top: +10.722 Mid: +8.812 Bot: +6.902	2.26E22 3.16E22 4.27E22	9.06 13.3 19.0
A13	406	none	Fusion	Basket	1.220	Top: +6.710 Mid: +6.110 Bot: +5.510	4.37E22 4.72E22 5.10E22	19.6 21.6 23.8
A12	404	none	Fusion	Basket	1.220	Top: +5.490 Mid: +4.890 Bot: +4.290	5.11E22 5.42E22 5.71E22	23.9 25.7 27.3
A11	401	none	Fusion	Basket	1.220	Top: +4.270 Mid: +3.670 Bot: +3.070	5.72E22 6.00E22 6.25E22	27.3 28.7 29.8
A10	399	none	Fusion	Basket	1.220	Top: +3.050 Mid: +2.450 Bot: +1.850	6.26E22 6.39E22 6.54E22	29.8 30.5 31.2
A09	395	none	Fusion	Basket	1.220	Top: +1.830 Mid: +1.230 Bot: +0.630	6.55E22 6.67E22 6.76E22	31.2 31.7 32.2
A08	392	none	Fusion	Basket	1.220	Top: +0.610 Mid: +0.010 Bot: -0.590	6.76E22 6.85E22 6.85E22	32.2 32.6 32.6
A07	388	none	Fusion	Basket	1.220	Top: -0.610 Mid: -1.210 Bot: -1.810	6.85E22 6.82E22 6.77E22	32.6 32.5 32.3
A06	384	none	Fusion	Basket	1.220	Top: -1.830 Mid: -2.430 Bot: -3.030	6.77E22 6.72E22 6.58E22	32.3 32.0 31.3
A05	381	none	Fusion	Basket	1.220	Top: -3.050 Mid: -3.650 Bot: -4.250	6.58E22 6.31E22 6.01E22	31.3 30.1 28.6
A04	378	none	Fusion	Basket	1.220	Top: -4.270 Mid: -4.870 Bot: -5.470	6.00E22 5.71E22 5.47E22	28.5 27.0 25.6
A03	376	TED(Inc)	Fusion	Basket	1.220	Top: -5.490 Mid: -6.090 Bot: -6.690	5.46E22 5.10E22 4.73E22	25.5 23.4 21.2
A02	377	none	Fusion	Subcapsule	2.464	Top: -11.882 Mid: -12.942 Bot: -14.002	1.92E22 1.64E22 1.40E22	7.52 6.30 5.29
A01	375	none	Fusion	Subcapsule	2.464	Top: -14.346 Mid: -15.406 Bot: -16.466	1.33E22 1.15E22 9.91E21	5.00 4.22 3.59

* Average Temperatures Based on Calculations and Coolant Profile
** Total Length Including Basket/Subcapsule Tops and Bottoms
\# Includes Only Specimen Region, Not Basket/Subcapsule Tops and Bottoms
Fluence Units: n/cm^2 [E>0.1 MeV]

Table 6. Estimated Irradiation Parameters for COBRA-1A2, Capsule B-389.

Based on 337.3 EFPD for EBR-II Runs 162-170

I.D.	Temp. °C*	Temp. Monitor	Program	Capsule Insert	Length (in)**	Z-Horizontal Midplane (in)#	Fast Fluence##	dpa in SS
B12	431	none	Dos.	Basket	1.300	Top: +19.214 Mid: +18.574 Bot: +17.934	7.28E21 7.86E21 8.49E21	2.56 2.77 3.01
B11	415	TED(Inc)	Temp/Dos	Basket	1.300	Top: +10.912 Mid: +10.272 Bot: +9.632	2.19E22 2.43E22 2.71E22	8.75 9.85 11.1
B10	407	none	Dos.	Basket	1.000	Top: +6.803 Mid: +6.313 Bot: +5.823	4.32E22 4.60E22 4.90E22	19.3 20.9 22.6
B09	410	SiC	Fusion	Subcapsule	3.664	Top: +5.631 Mid: +3.971 Bot: +2.311	5.02E22 5.87E22 6.42E22	23.3 28.1 30.7
B08	395	TED(Inc)	Fusion	Basket	1.940	Top: +2.119 Mid: +1.159 Bot: +0.199	6.47E22 6.68E22 6.82E22	30.9 31.8 32.5
B07	389	none	Fusion	Basket	1.940	Top: +0.179 Mid: -0.781 Bot: -1.741	6.82E22 6.85E22 6.78E22	32.5 32.6 32.3
B06	383	none	Fusion	Basket	1.940	Top: -1.761 Mid: -2.721 Bot: -3.681	6.78E22 6.65E22 6.30E22	32.3 31.7 30.0
B05	379	none	Fusion	Basket	1.940	Top: -3.701 Mid: -4.661 Bot: -5.621	6.29E22 5.80E22 5.38E22	29.9 27.5 25.1
B04	376	none	Fusion	Basket	1.100	Top: -5.641 Mid: -6.181 Bot: -6.721	5.37E22 5.05E22 4.71E22	25.0 23.1 21.1
B03	373	TED(Inc)	Fusion	Basket	1.300	Top: -10.410 Mid: -11.050 Bot: -11.690	2.47E22 2.21E22 1.98E22	9.99 8.82 7.79
B02	377	none	Fusion	Subcapsule	2.464	Top: -11.882 Mid: -12.942 Bot: -14.002	1.92E22 1.64E22 1.40E22	7.52 6.30 5.29
B01	375	none	Fusion	Subcapsule	2.464	Top: -14.346 Mid: -15.406 Bot: -16.466	1.33E22 1.15E22 9.91E21	5.00 4.22 3.59

* Average Temperatures Based on Calculations and Coolant Profile
** Total Length Including Basket/Subcapsule Tops and Bottoms
\# Includes Only Specimen Region, Not Basket/Subcapsule Tops and Bottoms
Fluence Units: n/cm^2 [E>0.1 MeV]

Table 7. Estimated Irradiation Parameters for COBRA-1A2, Capsule B-390.

Based on 337.3 EFPD for EBR-II Runs 162-170

I.D.	Temp. °C*	Temp. Monitor	Program	Capsule Insert	Length (in)**	Z-Horizontal Midplane (in)#	Fast Fluence##	dpa in SS
C10	405	TED(Inc)	Fusion	Basket	1.220	Top: +6.254 Mid: +5.654 Bot: +5.054	4.63E22 5.01E22 5.33E22	21.1 23.3 25.2
C09	403	none	Fusion	Basket	1.220	Top: +5.034 Mid: +4.434 Bot: +3.834	5.34E22 5.64E22 5.93E22	25.2 26.9 28.4
C08	401	none	Fusion	Basket	1.220	Top: +3.814 Mid: +3.214 Bot: +2.614	5.94E22 6.21E22 6.35E22	28.4 29.6 30.3
C07	397	none	Fusion	Basket	1.220	Top: +2.594 Mid: +1.994 Bot: +1.394	6.36E22 6.51E22 6.64E22	30.3 31.0 31.6
C06	394	none	Fusion	Basket	1.220	Top: +1.374 Mid: +0.774 Bot: +0.174	6.64E22 6.73E22 6.82E22	31.6 32.1 32.5
C05	390	none	Fusion	Basket	1.220	Top: +0.154 Mid: -0.446 Bot: -1.046	6.83E22 6.85E22 6.83E22	32.5 32.6 32.5
C04	386	none	Fusion	Basket	1.220	Top: -1.066 Mid: -1.666 Bot: -2.266	6.83E22 6.78E22 6.74E22	32.5 32.3 32.1
C03	388	none	Fusion	Subcapsule	9.424	Top: -2.458 Mid: -6.998 Bot: -11.538	6.71E22 4.54E22 2.04E22	31.9 20.2 8.02
C02	378	none	Fusion	Subcapsule	2.464	Top: -11.882 Mid: -12.942 Bot: -14.002	1.92E22 1.64E22 1.40E22	7.52 6.30 5.29
C01	375	none	Fusion	Subcapsule	2.464	Top: -14.346 Mid: -15.406 Bot: -16.466	1.33E22 1.15E22 9.91E21	5.00 4.22 3.59

* Average Temperatures Based on Calculations and Coolant Profile
** Total Length Including Basket/Subcapsule Tops and Bottoms
\# Includes Only Specimen Region, Not Basket/Subcapsule Tops and Bottoms
Fluence Units: n/cm^2 [E>0.1 MeV]

Table 8. Estimated Irradiation Parameters for COBRA-1A2, Capsule B-391.

Based on 337.3 EFPD for EBR-II Runs 162-170

I.D.	Temp. °C*	Temp. Monitor	Program	Capsule Insert	Length (in)**	Z-Horizontal Midplane (in)#	Fast Fluence##	dpa in SS
D05	800	SiC	Fusion	Subcapsule	5.170	Top: +4.108 Mid: +1.695 Bot: -0.718	5.80E22 6.58E22 6.85E22	27.7 31.3 32.6
D04	405	none	Dos.	Basket	1.000	Top: -1.460 Mid: -1.950 Bot: -2.440	6.80E22 6.76E22 6.71E22	32.4 32.2 32.0
D03	395	none	Fusion	Subcapsule	9.250	Top: -2.800 Mid: -7.086 Bot: -11.372	6.63E22 4.49E22 2.09E22	31.6 19.9 8.29
D02	378	none	Fusion	Subcapsule	2.464	Top: -11.882 Mid: -12.942 Bot: -14.002	1.92E22 1.64E22 1.40E22	7.52 6.30 5.29
D01	375	none	Fusion	Subcapsule	2.464	Top: -14.346 Mid: -15.406 Bot: -16.466	1.33E22 1.15E22 9.91E21	5.00 4.22 3.59

* Average Temperatures Based on Calculations and Coolant Profile
** Total Length Including Basket/Subcapsule Tops and Bottoms
\# Includes Only Specimen Region, Not Basket/Subcapsule Tops and Bottoms
Fluence Units: n/cm^{-2} [E>0.1 MeV]