

Neutronics Calculations for EBR-II Run 137E

Nuclear Science and Engineering Division

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ABSTRACT

Neutronics calculations were performed for EBR-II Run 137E using MC²-3/TWODANT, DIF3D, and PERSENT codes. Parameters required for system safety analysis such as the reactivity feedback coefficients and core power distribution were evaluated. The detailed results are provided in the accompanying Excel spreadsheet Run_137E_Neutronics_Results.xls. This report describes the core model of EBR-II at the beginning of Run 137E, the computation methodology, and how to interpret the results listed in the Excel spreadsheet.

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1 Introduction

Neutronics calculations were performed for EBR-II Run 137E to evaluate the reactivity feedback coefficients and the axial and radial core power distributions. The detailed results are organized in the accompanying Excel spreadsheet Run_137E_Neutronics_Results.xls for system analyses of the SHRT-35, SHRT-37, SHRT-39, SHRT-41, and SHRT-45 tests. Although these five tests were performed at different times within Run 137E, the neutronics calculations were performed at the beginning of Run 137E. This is mainly due to the lack of a detailed power history and the small amount of energy generated during Run 137E. Depletion during Run 137E is expected to have a negligible effect on the reactivity feedback coefficients and power distribution.

This report briefly describes the EBR-II core at the beginning of Run 137E in Section 2. In Section 3, the methodology and computer codes employed for these calculations are described. Section 4 provides a detailed description of the model and an interpretation of the results contained in the accompanying spreadsheet.

2 EBR-II Run 137E Description

The EBR-II core operated at a maximum of 60 MWth during Run 137E. Figure 2.1 presents the core-loading pattern for Run 137E [1]. There are a total of 637 subassemblies loaded in EBR-II during Run 137E:

- 68 standard driver subassemblies,
- 13 half-worth driver subassemblies,
- 9 experimental subassemblies,
- 6 dummy subassemblies,
- 8 high-worth control subassemblies,
- 2 safety subassemblies,
- 201 reflector subassemblies, and
- 330 blanket subassemblies.

The subassembly pitch is 5.89 cm at room temperature. A regular driver subassembly contains 91 fuel pins, while a half-worth driver subassembly contains 46 fuel pins and 45 steel pins. A blanket subassembly contains 19 fuel pins. Both the control and safety subassemblies contain 61 fuel pins placed in the inner duct. The control subassemblies loaded in Run 137E are all high-worth control subassemblies with 7 B₄C pins placed above the fuel region. The detail subassembly design and dimensions can be found in the Appendix of Reference 2.

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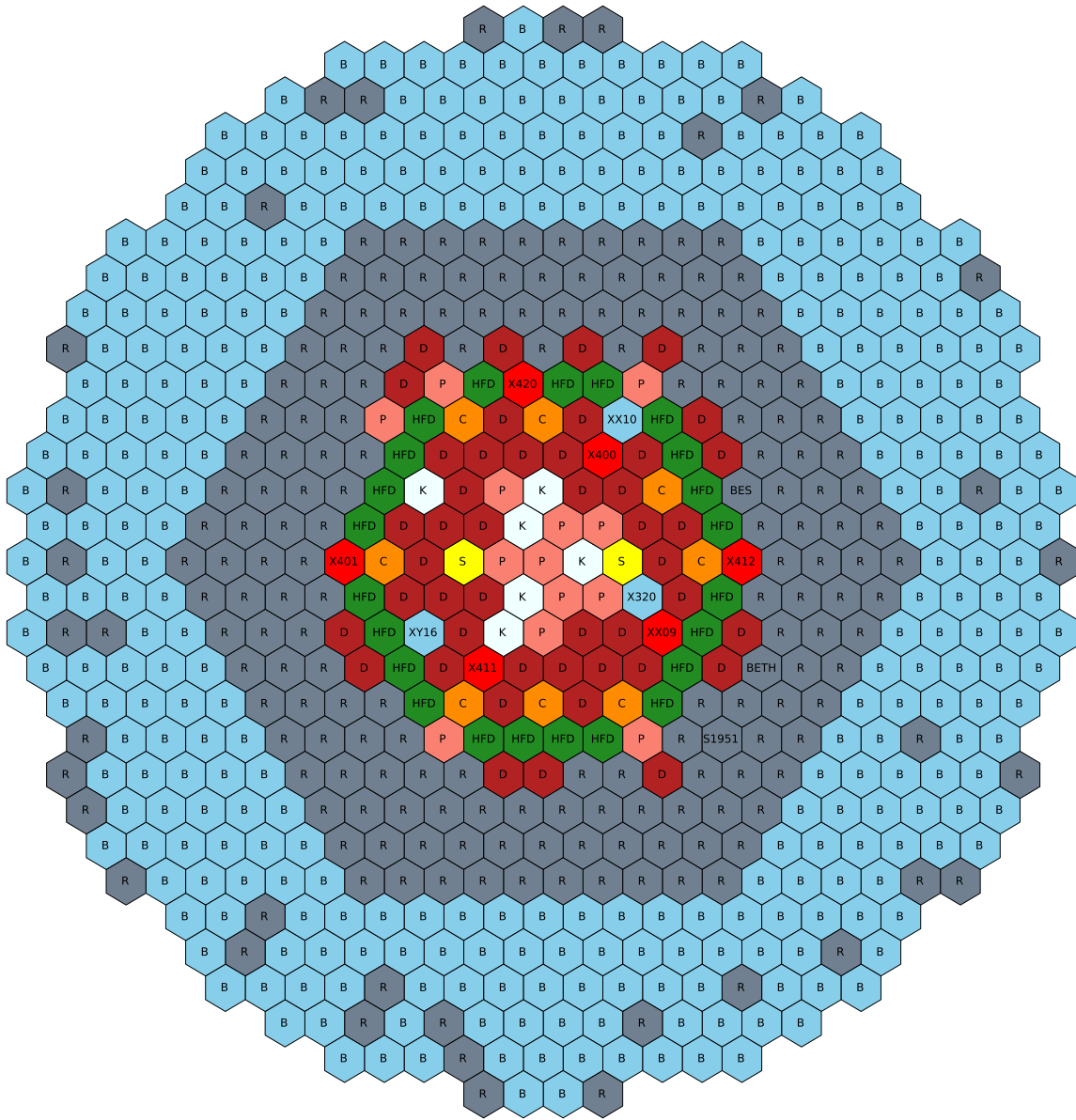


Figure 2.1. EBR-II Run 137E Core-Loading Pattern

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Fuel compositions at the beginning of Run 137E are provided in the spreadsheet for subassemblies containing fissile material (driver, half-worth driver, control, safety, blanket, X402A, X400, X401, X412, XX09, and X411). The fuel compositions provided correspond to room temperature. Except for the blanket subassemblies, the fuel compositions account for 6.88% axial swelling. U-Fs (5 wt% Fs) fuel was used in all the fuel subassemblies except for the blankets, which used depleted Uranium fuel. The composition of Fs can be found in Table 3.2.2 of Reference [3]. The composition of the lumped fission products LFP35, LFP38, LFP39, LFP40, and LFP41 corresponding to the fission products produced from U-235, U-238, Pu-239, Pu-240, and Pu-241 fission, and are listed in Appendix A. The fuel composition is provided in three axial segments with equal length for all driver, half-worth driver, control, safety, X402A, X400, X401, X412, XX09, and X411 subassemblies. For the blanket subassemblies, the fuel composition is provided in three axial segments with different lengths: 55.9 cm, 36.6 cm, and 47.1 cm from bottom to top.

In this report and the accompanying neutronics Excel spreadsheet, the grid locations are identified using the EBR-II neutronics convention, which employed three coordinates (row, edge, position) to label a grid location as illustrated in Figure 2.2. For example, C201 refers to the grid location in row 3 and position 1 along edge 2. In the convention used in Reference 2, C201 would refer to the subassembly in the 3B1 position.

The control and safety subassembly were partially inserted in the core at the beginning of Run 137E.

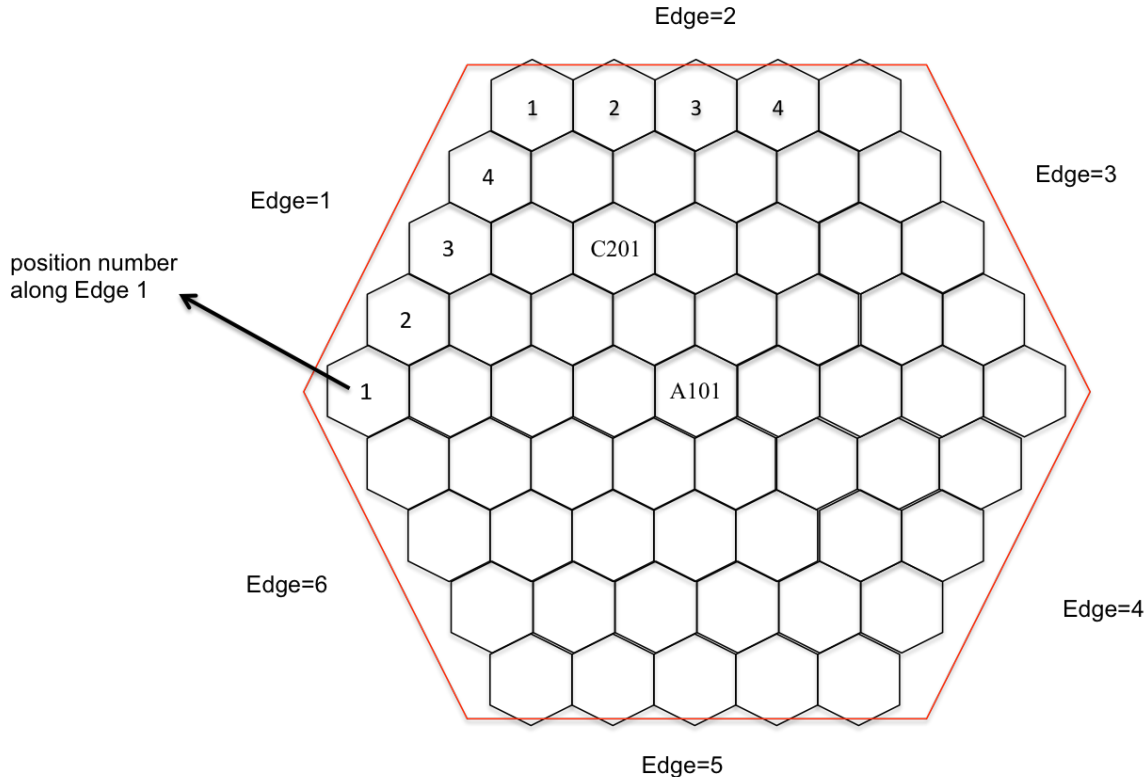


Figure 2.2. EBR-II Convention for Grid Location Identification

3 Methodology

The Argonne National Laboratory neutronics tool suite was employed to evaluate the neutronic parameters and reactivity feedback coefficients. MC²-3/TWODANT [4] was used to generate neutron and photon cross-sections, neutron flux to photon source conversion matrix, and neutron and photon KERMA factors. The cross-section generation followed a 2-step MC²-3 calculation. The first step was performed with 2-dimensional RZ transport TWODANT model using a 1041-group neutron cross-section library to solve for the neutron flux spectrum for different regions in EBR-II. In the second step, the flux spectrum obtained from the first step was used to condense the neutron library to 33 groups, and this condensed neutron cross-section set was used in a DIF3D-VARIANT [5] calculation. This 2-step cross section generation procedure was performed for five different EBR-II cores: normal core (i.e. no perturbation), core with fuel temperature doubled, 10% sodium voided core, 99% sodium voided core with normal fuel temperatures, and 99% sodium voided core with doubled fuel temperatures.

DIF3D-VARIANT was employed to evaluate the power distribution in the EBR-II core. The hexagonal-Z model of DIF3D-VARIANT was employed with a P3 angular approximation. The power distribution calculation was performed in three steps. In the first step, the neutron flux was calculated and a photon source was generated using the GAMSOR module of DIF3D. In the second step, the photon source was used to evaluate the photon flux distribution. The neutron flux from step 1 and photon flux from step 2 were multiplied by the corresponding KERMA factors in the final step to determine the power distribution Run 137E.

For evaluation of the control and safety worth curves, two series of DIF3D-VARIANT calculations were performed where k_{eff} was evaluated at different control and safety subassembly insertion positions. One series of calculations varied the control subassembly insertion position while maintaining the safety subassembly insertion position. The other series of calculations performed the opposite calculation where the safety subassembly insertion position was varied while the control subassembly insertion position was maintained.

DIF3D-VARIANT was also employed to evaluate the neutron flux profile for two reference cases, which served as the base cases for evaluating the reactivity feedback coefficients with perturbation theory. One of the two reference cases is the normal EBR-II core model without any perturbation. Based on this case, the Doppler, sodium density, fuel density, and structural density reactivity feedback coefficients were evaluated by PERSENT [6] using first-order perturbation theory. The other reference case modeled an EBR-II core with 99% sodium voided. This served as the base case for calculating the voided Doppler reactivity feedback coefficients. The perturbed cases for evaluating these reactivity feedback coefficients are described in more detail in Table 3.1.

In addition to being used for evaluating reactivity feedback coefficients, PERSENT was also used to evaluate the effective delayed neutron fraction, β_{eff} , and the decay constants for 6 delayed neutron precursor groups.

Table 3.1. Description of Perturbed Cases for Reactivity Feedback Calculations

Reactivity feedback	Description
Fuel Doppler	Base case: Unperturbed EBR-II core Perturbed case: Fuel temperature doubled in the driver, half-worth driver, safety, control, and fueled experimental subassemblies.
Fuel Density	Base case: Unperturbed EBR-II core Perturbed case: Fuel density reduced by 1% in the driver, half-worth driver, safety, control, and fueled experimental subassemblies.
Steel Density	Base case: Unperturbed EBR-II core Perturbed case: Structural density reduced by 1% in the driver, half-worth driver, safety, control, and fueled experimental subassemblies.
Sodium Density	Base case: Unperturbed EBR-II core Perturbed case: Sodium density reduced by 10% everywhere.
Voided Fuel Doppler	Base case: Sodium density reduced by 99% everywhere with 99% sodium voided cross-section. Perturbed case: 99% sodium voided cross-section with fuel temperature doubled in the driver, half-worth driver, safety, control and fueled experimental subassemblies.

4 Modeling and Results

The EBR-II core model for the neutronics calculation consisted of 7 different axial discretization schemes for the different subassembly types: driver, blanket, dummy, reflector, safety, control, and XX10 subassemblies. A thermal expansion of 0.685% was applied uniformly to all subassemblies in the core. The bottom tip of the lower reflector region of a regular MARK-IIA driver was selected as the zero position. Tables 4.1-4.7 list the axial mesh used to discretize each subassembly type in the neutronics model. The label listed in the second column of these tables combined with the grid location identification label discussed in Figure 2.2 was used to name the DIF3D-VARIANT regions. Using this naming convention, the exact location in the EBR-II core of a DIF3D-VARIANT region can be easily extracted. For example, region C201G is located in grid location C201 (row 3, position 1 along edge 2).

The experimental subassemblies X402A, X400, X401, X412, XX09, and X411 used the same axial discretization as that of a regular driver subassembly. For the experimental subassemblies XY16 and X320C, the axial discretization for the dummy subassemblies was used.

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Table 4.1. Driver and Half-Worth Driver Subassemblies Axial Mesh Configuration

Zone	Label	Upper bound (cm)
Lower shield	A	18.540
	B	27.930
	C	37.320
	D	47.870
	E	55.703
Lower grid	F	58.420
Bottom fuel	G	61.495
	H	64.570
	I	67.645
	J	70.720
Middle fuel	K	73.795
	L	79.945
	M	83.020
Top fuel	N	86.095
	O	89.170
	P	92.245
	Q	95.320
Gas plenum	R	97.967
	S	102.880
	T	110.440
	U	118.000
Upper grid	V	121.720
Upper shield	W	129.135
	X	136.550
	Y	146.755
	Z	156.965

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Table 4.2. Blanket Subassemblies Axial Mesh Configuration

Zone	Label	Upper bound (cm)
Lower reflector	A	2.100
Bottom fuel	B	18.540
	C	37.320
	D	58.420
Middle fuel	E	70.720
	F	83.020
	G	95.320
Top fuel	H	118.000
	I	136.550
	J	142.760
Upper shield	K	146.755
	L	156.965

Table 4.3. Dummy Subassemblies Axial Mesh Configuration

Zone	Label	Upper bound (cm)
Lower shield	A	4.227
Dummy	B	55.703
	C	58.420
	D	70.720
	E	83.020
	F	95.320
	G	118.000
	H	121.720
	I	136.550
J	156.965	

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Table 4.4. Reflector Subassemblies Axial Mesh Configuration

Zone	Label	Upper bound (cm)
Reflector	A	58.420
	B	95.320
	C	118.000
	D	156.965

Table 4.5. Safety Subassemblies Axial Mesh Configuration

Zone	Label	Upper bound (cm)
Lower shield	B	8.920
	C	18.540
	D	26.178
	E	35.681
Lower grid	F	38.398
Bottom fuel	G	41.473
	H	44.548
	I	47.870
	J	50.698
Middle fuel	K	53.853
	L	58.420
	M	62.998
Top fuel	N	66.073
	O	69.148
	P	72.223
	Q	75.298
Gas plenum	R	78.093
	S	83.020
	T	90.418
	U	97.967
Upper grid	V	101.698
Upper shield	W	109.113
	X	116.528
	Y	126.733
	Z	136.550

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	A	156.965
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Table 4.6. Control Subassemblies Axial Mesh Configuration

Zone	Label	Upper bound (cm)
Lower shield	C	7.820
	D	15.641
	E	23.461
Lower grid	F	26.178
Bottom fuel	G	29.253
	H	32.328
	I	35.681
	J	38.398
Middle fuel	K	41.473
	L	47.870
	M	50.698
Top fuel	N	53.853
	O	56.928
	P	61.495
	Q	62.998
Gas plenum	R	78.093
	S	81.648
Poison	T	86.095
	U	97.967
	V	104.308
	W	121.720
Upper shield	X	124.718
	Y	131.628
	Z	156.965

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Table 4.7. XX10 Axial Mesh Configuration

Zone	Label	Upper bound (cm)
Lower shield	A	18.540
	B	27.930
	C	37.320
	D	47.870
	E	55.703
Lower grid	F	58.420
XX10 steel pin region	G	61.495
	H	64.570
	I	67.645
	J	70.720
	K	73.795
	L	79.945
	M	83.020
	N	86.095
	O	89.170
	P	92.245
	Q	95.320
	R	97.967
	S	102.880
T	110.440	
U	118.000	
Upper grid	V	121.720
Upper shield	W	129.135
	X	136.550
	Y	146.755
	Z	156.965

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There were several differences in the control subassembly model compared to the actual control subassembly axial configuration. These changes were made due to a limitation of the finite element method (VARIANT), which requires mesh sizes to be greater than 1 or 2 cm in order to obtain a converged solution. The changes made include adjusting the bottom fuel height from 12.30 cm to 12.22 cm and reducing the height of the poison region by 0.53 cm. These changes were made on control subassemblies to avoid adjusting the axial mesh for driver subassemblies and were considered to have a negligible effect on the reactivity feedbacks.

The results are summarized in Table 4.8 for β_{eff} and reactivity feedback coefficient, in Figure 4.1 for the control and safety subassembly worth curves, and in Figure 4.2 for power generation in first 7 rows of the core. The control and safety subassembly insertions were measured as the distance between the bottom of the fuel region of a regular driver subassembly and that of the control or safety subassembly.

The detailed region-wise data are provided in the spreadsheet that is accompanies this report. The spreadsheet contains the axial discretization for each type of subassemblies (driver, blanket, dummy, reflector, control, safety, and XX10). It also contains the total power (neutron plus photon) distribution in the core, the region-wise reactivity feedback coefficients (fuel Doppler, fuel density, steel density, sodium density, and voided fuel Doppler), the delayed neutron fractions and decay constants of the six-group precursors, control and safety subassembly worth curves, and the composition at the beginning of Run 137E.

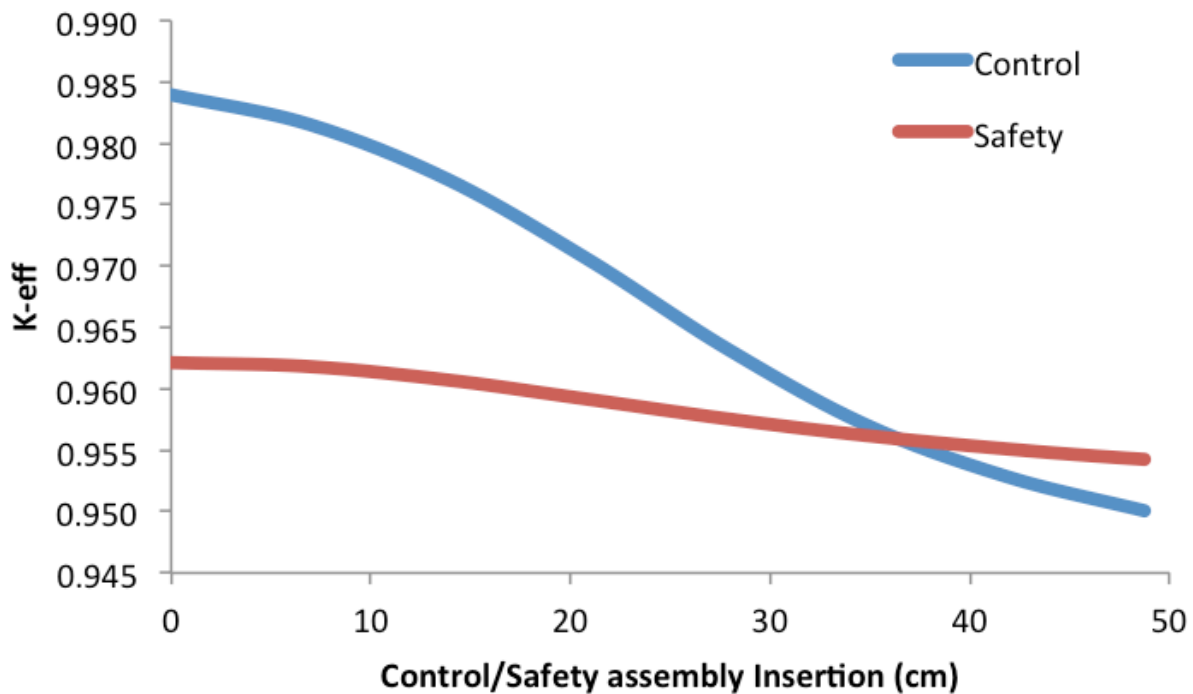


Figure 4.1. Control and Safety Subassembly Worth Curve

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Table 4.8. β_{eff} and Reactivity Feedback Coefficients

Parameters	Value (pcm)
β_{eff}	699
Fuel Doppler	-30.1
Fuel Density	-541
Steel Density	-29.6
Sodium Density	-695
Voided Fuel Doppler	-22.1

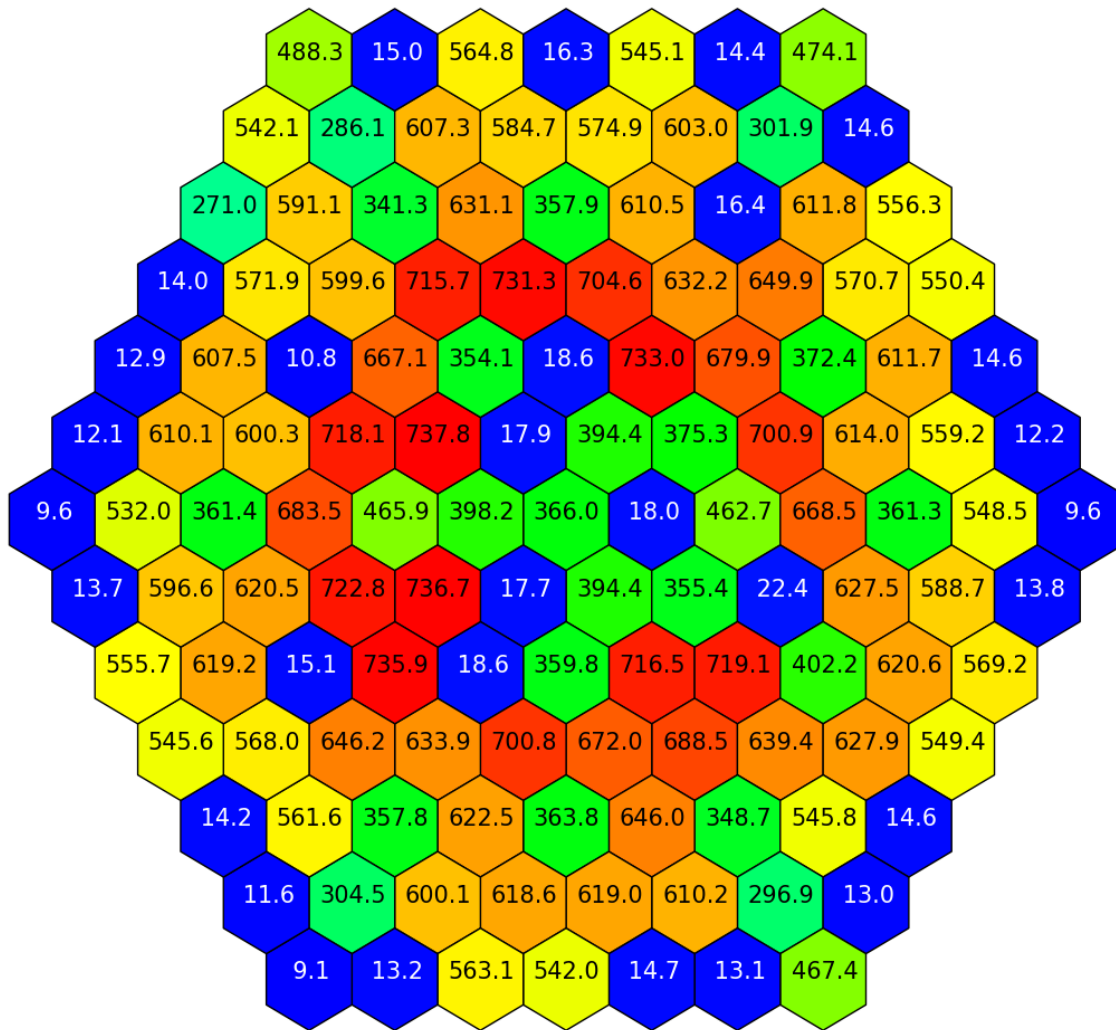


Figure 4.2. Power (kW) Generation in Subassemblies of Inner 7 Rows of EBR-II Core at Beginning of Run 137E

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5 References

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6 Appendix A. Lumped Fission Product Compositions

Isotopes	LFP35	LFP38	LFP39	LFP40	LFP41
Ge-73	5.23995E-06	2.06001E-06	7.05988E-06	3.09000E-06	4.78000E-06
Ge-74	1.18999E-05	2.77002E-06	1.73597E-05	7.84000E-06	1.12600E-05
Ge-76	1.75758E-04	8.00005E-06	5.80590E-05	4.09100E-05	5.63100E-05
As-75	3.52997E-05	4.62003E-06	2.54796E-05	1.70500E-05	2.81600E-05
Se-76	5.47995E-09	5.60004E-11	4.84991E-08	1.37000E-08	6.87000E-09
Se-77	3.18077E-04	3.30102E-05	1.26918E-04	1.07860E-04	9.69300E-05
Se-78	5.71175E-04	1.12221E-04	2.29286E-04	2.22110E-04	1.84160E-04
Se-80	1.75954E-03	4.27413E-04	9.25064E-04	7.11070E-04	6.49440E-04
Se-82	3.40051E-03	2.13773E-03	2.17716E-03	1.72793E-03	1.42755E-03
Br-79	9.08562E-04	3.26732E-04	6.07699E-04	4.16930E-04	3.58640E-04
Kr-80	1.14999E-09	3.75002E-11	3.38994E-08	7.01000E-09	1.65000E-09
Kr-82	1.42999E-06	1.22001E-07	1.12998E-05	3.26000E-06	1.01000E-06
Kr-86	1.94679E-02	1.29645E-02	7.88978E-03	6.26201E-03	5.99304E-03
Rb-86	4.37996E-07	2.80002E-08	4.72992E-06	9.06000E-07	2.18000E-07
Sr-86	6.73994E-11	1.37001E-12	1.00000E-08	3.17000E-10	3.71000E-11
Sr-88	3.49440E-02	2.02805E-02	1.32970E-02	9.74526E-03	9.88938E-03
Nb-94	9.20992E-10	3.71002E-11	1.00998E-07	1.72000E-08	1.56000E-09
Mo-94	1.00000E-12	1.00000E-13	7.68986E-12	6.22000E-13	2.25000E-14
Cd-108	1.00000E-12	1.00000E-12	7.37987E-10	4.37000E-11	2.44000E-11
Cd-116	3.40037E-04	3.93143E-04	6.03559E-04	6.48270E-04	9.69280E-04
Sn-116	1.15999E-10	1.43001E-12	3.17994E-09	1.48000E-10	7.92000E-11
Sn-119	3.50197E-04	3.97203E-04	5.50160E-04	5.85550E-04	8.23890E-04
Sn-120	3.52917E-04	3.87132E-04	5.56890E-04	6.70710E-04	8.65050E-04
Sn-122	4.04077E-04	4.10733E-04	6.98318E-04	7.59810E-04	9.46470E-04
Sn-124	6.29815E-04	4.64483E-04	1.20621E-03	1.09807E-03	1.11948E-03
Sn-126	9.73552E-04	5.40723E-04	2.63366E-03	2.69768E-03	2.22637E-03
Sb-126	7.91993E-07	6.82004E-08	1.43397E-05	8.00000E-06	5.52000E-06
Te-122	1.21999E-08	2.33001E-10	7.19987E-07	1.44000E-07	3.42000E-08

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Te-123	1.42999E-10	7.01004E-13	2.66995E-08	4.18000E-09	6.15000E-10
Te-124	3.49997E-06	1.34001E-07	1.50997E-06	7.18000E-07	1.15300E-05
I-130	1.70999E-07	4.06003E-14	2.89295E-05	1.89000E-06	4.45000E-12
Xe-128	1.00000E-12	1.00000E-12	3.24994E-14	1.00000E-12	1.00000E-12
Xe-136	6.21534E-02	6.97892E-02	6.94008E-02	6.62763E-02	6.67232E-02
Cs-136	1.17279E-04	9.60006E-06	1.23092E-03	5.36180E-04	1.51770E-04
Ba-136	6.00000E-08	1.48001E-09	4.73000E-06	7.20000E-07	9.00000E-08
Pr-142	1.56999E-11	7.46005E-13	1.15998E-08	1.53000E-09	5.67000E-11
Nd-142	1.00000E-12	1.00000E-12	4.01993E-13	2.29000E-14	1.00000E-12
Gd-152	4.90996E-13	2.30001E-14	1.13998E-09	5.90000E-11	6.53000E-12
Gd-160	1.13199E-05	3.54402E-05	1.60327E-04	1.93970E-04	3.96910E-04
Tb-160	1.11999E-10	1.89001E-11	1.80997E-07	4.06000E-08	1.37000E-08
Dy-160	1.19999E-14	1.00000E-12	1.83997E-10	1.00000E-10	2.25000E-12
Dy-161	3.32997E-06	1.21501E-05	8.64885E-05	1.18690E-04	2.34070E-04
Dy-162	5.76995E-07	3.40002E-06	6.14089E-05	6.86400E-05	1.17880E-04
Dy-163	9.61992E-08	2.04001E-06	3.14694E-05	2.16700E-05	5.22800E-05
Dy-164	5.76995E-08	1.25001E-06	1.79297E-05	1.16400E-05	3.31300E-05
Ho-165	2.30998E-08	7.66005E-07	8.96984E-06	5.70000E-06	1.53800E-05
Er-166	9.61992E-09	5.67004E-07	6.34989E-06	3.03000E-06	6.21000E-06
Er-167	3.84997E-09	4.35003E-07	2.66995E-06	1.82000E-06	3.11000E-06
Br-81	2.28000E-03	8.62090E-04	1.41870E-03	1.17770E-03	9.23750E-04
Kr-83	5.76530E-03	3.95860E-03	3.15500E-03	2.25720E-03	2.03430E-03
Kr-84	1.03070E-02	8.25580E-03	4.98670E-03	3.87210E-03	3.56810E-03
Rb-85	1.36380E-02	7.43060E-03	6.04180E-03	4.33500E-03	4.46550E-03
Rb-87	2.54380E-02	1.62550E-02	1.04330E-02	8.55550E-03	8.01990E-03
Y-89	4.37370E-02	2.76110E-02	1.72530E-02	1.40990E-02	1.28220E-02
Sr-90	5.46500E-02	3.24700E-02	2.04840E-02	1.79880E-02	1.55090E-02
Zr-90	8.89990E-13	1.75000E-14	1.00000E-06	1.00000E-07	7.55000E-13
Zr-91	5.73340E-02	4.03950E-02	2.51650E-02	2.19040E-02	1.92880E-02
Zr-92	5.84600E-02	4.31250E-02	3.03770E-02	2.68030E-02	2.39440E-02
Zr-93	6.25400E-02	4.91330E-02	3.82570E-02	3.51080E-02	2.98100E-02

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Zr-94	6.30020E-02	4.61010E-02	4.23310E-02	3.93120E-02	3.30580E-02
Mo-95	6.43200E-02	5.14050E-02	4.67140E-02	4.43820E-02	3.79200E-02
Zr-96	6.20230E-02	6.01740E-02	4.85290E-02	4.73120E-02	4.29330E-02
Mo-96	1.20000E-06	1.04000E-07	3.37390E-05	2.20900E-05	1.73000E-06
Mo-97	6.00290E-02	5.56250E-02	5.29720E-02	5.16560E-02	4.45870E-02
Mo-98	5.92370E-02	5.94500E-02	5.63300E-02	5.50140E-02	4.79910E-02
Tc-99	5.94310E-02	6.16830E-02	5.98250E-02	5.93090E-02	5.52900E-02
Mo-100	6.29830E-02	6.69740E-02	6.54400E-02	6.81140E-02	5.96040E-02
Ru-100	2.37000E-08	1.56000E-09	1.92000E-06	5.30000E-07	4.91000E-08
Ru-101	5.12430E-02	6.20910E-02	6.66980E-02	6.47990E-02	6.49090E-02
Ru-102	4.35900E-02	6.44740E-02	6.73180E-02	6.66720E-02	6.86560E-02
Rh-103	3.24390E-02	6.27530E-02	6.82890E-02	6.61330E-02	6.50800E-02
Ru-104	2.07240E-02	5.03600E-02	6.58460E-02	6.83960E-02	7.30640E-02
Pd-104	7.31990E-11	7.43010E-12	8.44990E-08	9.75000E-09	1.50000E-09
Pd-105	1.19630E-02	4.05130E-02	5.36100E-02	5.58450E-02	6.58340E-02
Ru-106	5.32390E-03	2.48970E-02	4.36320E-02	5.09280E-02	6.24410E-02
Pd-106	1.00000E-20	1.00000E-20	2.20000E-05	4.20000E-06	1.90000E-06
Pd-107	3.02330E-03	1.44590E-02	3.22100E-02	3.92760E-02	4.90670E-02
Pd-108	1.30820E-03	6.01420E-03	2.00270E-02	2.79520E-02	3.54200E-02
Ag-109	8.15450E-04	2.52140E-03	1.03630E-02	1.74620E-02	2.35300E-02
Pd-110	6.49140E-04	1.40760E-03	6.47320E-03	9.41010E-03	1.39960E-02
Cd-110	8.86990E-14	1.00000E-20	1.00000E-20	1.00000E-20	1.00000E-20
Cd-111	4.25770E-04	7.12150E-04	3.57010E-03	4.87210E-03	6.44580E-03
Cd-112	3.77120E-04	5.59010E-04	1.88920E-03	2.27970E-03	3.17790E-03
Cd-113	3.22330E-04	4.55720E-04	1.26170E-03	1.47830E-03	2.10750E-03
Cd-114	3.22940E-04	3.92570E-04	9.42630E-04	9.11210E-04	1.17390E-03
In-115	3.27280E-04	3.62730E-04	7.86440E-04	5.91710E-04	1.05320E-03
Sn-117	3.68190E-04	3.77320E-04	6.98700E-04	6.37520E-04	8.80450E-04
Sn-118	3.36320E-04	4.31760E-04	5.98630E-04	5.89950E-04	8.33580E-04
Sb-121	3.68110E-04	3.69270E-04	6.30870E-04	6.80340E-04	9.15940E-04
Sb-123	4.40630E-04	4.45340E-04	7.68080E-04	8.69400E-04	1.01770E-03

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Sb-125	6.80290E-04	4.85240E-04	1.77840E-03	8.92890E-04	1.51120E-03
Te-125	1.08000E-13	5.37000E-10	1.64000E-11	3.25000E-12	9.88000E-13
I-127	3.06250E-03	1.36250E-03	5.00840E-03	4.17470E-03	3.32100E-03
Te-128	5.04500E-03	2.86090E-03	8.78990E-03	6.93440E-03	6.58790E-03
I-129	8.35160E-03	1.01130E-02	1.45100E-02	1.14950E-02	1.16720E-02
Te-130	1.79460E-02	1.91370E-02	2.45100E-02	2.03090E-02	1.86300E-02
Xe-130	1.78000E-07	4.24000E-14	3.01700E-05	1.97000E-06	4.64000E-12
Xe-131	3.21950E-02	3.29080E-02	3.87840E-02	3.52000E-02	3.36240E-02
Xe-132	4.67100E-02	5.14750E-02	5.32940E-02	5.04200E-02	4.70990E-02
Cs-133	6.72360E-02	6.76100E-02	6.97090E-02	6.91970E-02	6.45930E-02
Xe-134	7.66670E-02	7.60950E-02	7.38220E-02	7.48610E-02	7.54460E-02
Cs-134	5.04000E-08	6.46000E-09	6.62990E-06	1.19000E-06	2.49000E-07
Ba-134	1.89000E-12	1.05000E-13	1.00000E-08	1.65000E-10	1.62000E-11
Xe-135	6.60110E-02	6.96760E-02	7.54190E-02	7.43920E-02	7.06890E-02
Cs-135	2.10000E-06	4.00000E-07	1.25200E-04	3.31000E-05	7.50000E-06
Cs-137	6.22140E-02	6.05250E-02	6.58460E-02	6.55750E-02	6.38660E-02
Ba-137	9.00000E-07	1.00000E-07	5.51000E-05	1.55000E-05	2.40000E-06
Ba-138	6.68050E-02	5.76250E-02	6.12650E-02	6.44920E-02	6.14730E-02
Ce-140	5.97790E-02	5.81530E-02	5.33310E-02	5.50540E-02	5.30610E-02
Pr-141	5.94910E-02	5.33650E-02	5.14710E-02	5.01540E-02	5.07530E-02
Ce-142	5.54210E-02	4.58580E-02	4.75430E-02	4.88990E-02	4.63420E-02
Nd-143	5.73120E-02	4.62210E-02	4.34190E-02	4.43680E-02	4.67120E-02
Nd-144	5.26870E-02	4.54800E-02	3.67290E-02	3.96210E-02	4.17110E-02
Nd-145	3.77570E-02	3.80900E-02	3.00410E-02	3.07510E-02	3.32670E-02
Nd-146	2.92140E-02	3.44570E-02	2.46000E-02	2.55310E-02	2.80580E-02
Pm-147	2.13890E-02	2.59270E-02	1.99060E-02	2.20290E-02	2.22420E-02
Sm-147	1.00000E-20	1.00000E-20	2.26000E-13	1.00000E-20	1.00000E-20
Sm-148	4.67000E-10	2.27000E-11	1.53000E-07	1.69000E-08	2.34000E-09
Sm-149	1.03700E-02	1.62530E-02	1.24110E-02	1.33520E-02	1.45860E-02
Nd-150	6.85810E-03	1.27350E-02	9.94630E-03	1.08490E-02	1.23030E-02
Sm-150	2.51000E-07	3.29000E-08	2.22800E-05	4.44000E-06	1.12000E-06

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Sm-151	4.11990E-03	7.99400E-03	7.84930E-03	8.50480E-03	9.11270E-03
Eu-151	9.54990E-12	1.00000E-20	6.78990E-11	2.67000E-12	1.83000E-13
Sm-152	2.70850E-03	5.30230E-03	6.26690E-03	6.51100E-03	7.31910E-03
Eu-152	4.68000E-13	2.19000E-14	1.09000E-09	5.62000E-11	6.22000E-12
Eu-153	1.67060E-03	4.14790E-03	4.25840E-03	5.14600E-03	5.50600E-03
Sm-154	7.23180E-04	2.16280E-03	2.67200E-03	3.09570E-03	3.81330E-03
Eu-154	6.21000E-10	8.25010E-11	4.71990E-07	5.33000E-08	1.26000E-08
Gd-154	2.58000E-14	1.00000E-20	1.00000E-09	1.00000E-10	8.23000E-13
Eu-155	3.94720E-04	1.41520E-03	2.08820E-03	2.35510E-03	3.35850E-03
Gd-155	1.33000E-12	8.04010E-14	5.23990E-09	3.40000E-10	5.22000E-11
Gd-156	2.02590E-04	7.60340E-04	1.54750E-03	1.73940E-03	2.44250E-03
Gd-157	1.05830E-04	4.13750E-04	1.06140E-03	1.30280E-03	1.62830E-03
Gd-158	6.49390E-05	1.84870E-04	6.56560E-04	7.77830E-04	1.11950E-03
Tb-159	3.00700E-05	8.61910E-05	3.85460E-04	3.59050E-04	6.51340E-04



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