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**Analysis of Weapons-Grade MOX
VVER-1000 Benchmarks with
HELIOS and KENO**

**J. C. Gehin
C. Dourougie
M. B. Emmett
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Fissile Materials Disposition Program

**MANAGED AND OPERATED BY
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Computational Physics and Engineering Division

**ANALYSIS OF WEAPONS-GRADE MOX VVER-1000
BENCHMARKS WITH HELIOS AND KENO**

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Prepared by the
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CALCULATION OF THE RUSSIAN VVER-1000 BENCHMARKS WITH HELIOS AND KENO

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ABSTRACT

Calculations of computational benchmark problems for the disposition of weapons-grade mixed-oxide fuel in VVER-1000 reactors have been performed with the HELIOS fuel assembly analysis code. The benchmarks cover pin cell, single fuel assembly, and multiassembly structures with several different fuel types, moderator densities, and boron content for operational and off-normal conditions. Fuel depletion is performed to a burnup of 60 MWd/kg. The detailed results have been tabulated for multiplication factors, macroscopic and microscopic cross sections, reaction rates, fuel isotopics, and fission distributions. Additional results are given for a preliminary analysis of a multiassembly variant using the KENO Monte Carlo code with cross sections from HELIOS.

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1. INTRODUCTION

As part of the effort to eliminate surplus weapons plutonium, the options for burning the material in commercial power reactors will be analyzed. In Russia, a primary candidate for the disposition is the VVER-1000 reactor. To ensure that our existing calculational methods and data can accurately model VVER-1000 reactors with mixed-oxide (MOX) fuel of high-grade plutonium ($>90\%$ ^{239}Pu), benchmarking is required. Recently, many computational and experimental benchmarks have been analyzed¹ in Russia. The computational benchmarks were formulated for detailed comparisons of calculational methods and data. This report documents the results of these benchmarks using the HELIOS^{2,3} fuel assembly analysis code.

The goal of this work is to perform calculations of the VVER-1000 computational benchmarks for direct comparison of the methods in use at Oak Ridge National Laboratory (ORNL) with those in use in Russia. The purpose of this benchmarking is to ensure that the U.S. and Russian methods agree early in the process so that fewer problems arise in the design and analysis process.

The benchmark specifications consist of a total of 20 calculational variants. The geometry of these variants includes single pin cells, single fuel assemblies, and a multiassembly structure for investigation of UO_2 and MOX interface issues. Several fuel materials representing UO_2 , weapons-grade (WG) MOX, and reactor-grade (RG) MOX are considered. The conditions are typical of operation and off-normal states. Fuel depletion of 60 MWd/kg is performed for several of the variants. A detailed description of the benchmark specifications is given in Chap. 2.

Calculations of the VVER benchmark variants were performed at ORNL using the HELIOS fuel assembly analysis code. The HELIOS code is very flexible and allows for precise modeling of benchmark problems. A discussion of the models and methods is presented in Chap. 3. The final calculational results are presented in Chap. 4.

Preliminary calculations of one of the multiassembly configurations were also performed with the KENO⁴ Monte Carlo code with cross sections from HELIOS. The results of these calculations are given in Chap. 5. A final discussion of the work is presented in Chap. 6.

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2. BENCHMARK SPECIFICATIONS

Two sets of benchmark variants were formulated by the Russian participants in the joint U.S./Russian Federation plutonium disposition program. The first set¹ covered different aspects of UO_2 and MOX in VVER-1000 reactors in normal operating conditions. The second set⁵ was formulated to cover off-normal conditions and provide for a comparison of kinetics parameters. Specifications for these benchmark problems were formulated by the Russian participants in the joint U.S./Russian Federation plutonium disposition program. The following specifications are a combination of these two sets of benchmark variants.

2.1 MATERIAL SPECIFICATIONS

Material specifications for the different fuel materials, cladding, absorbers, and moderators are given in Table 2.1. The fuel materials include fresh UO_2 (FU1), fresh WG MOX (FU2), and RG MOX (FU10); spent UO_2 (FU3 and FU4) and WG MOX (FU11); fresh MOX with individual plutonium isotopes (FU7–FU9); and WG MOX with different plutonium contents for graded fuel designs (FU12–FU14). The cladding material is zirconium (CL1), and the absorber material is B_4C (ABS). Six different types of moderator materials differing in density and boron concentration are given (MOD1–MOD6).

2.2 GEOMETRY SPECIFICATIONS

The geometry consists of different basic cell types (fuel, absorber, central tube, and guide tube), a standard VVER-1000 hexagonal assembly with 331 cell locations, and a multiassembly structure formed by two different assembly types. The cell types are presented in Table 2.2. Each cell type consists of concentric cylinders of materials in a hexagonal region. The assembly configuration, referred to as the K331 assembly, is shown in Fig. 2.1. The flat-to-flat dimension of the "container" zone is 23.6 cm, which represents the interassembly spacing. The multiassembly structure (MK2) is formed by an infinite array of two assembly types (K1 and K2), as shown in Fig. 2.2. The resulting ratio of K2 to K1 assemblies is 3:1. Note that the container zone shown in Fig. 2.1 is intended only to represent the assembly pitch; there is no physical container surrounding the VVER-1000 assemblies.

2.3 STATE SPECIFICATIONS

The specification of the temperatures, moderator density and boron content, absorber presence, and fission product (FP) poisoning is indicated by the different states. For these benchmark problems, twelve states are used, as presented in Table 2.3. Fuel burnup calculations are performed with State 1 only, and the remaining states are used for branch calculations (for every 10-MWd/kg step). The power density for the burnup calculations is 108 MW/m^3 taken over the entire volume (fuel, cladding, moderator, etc.).

2.4 CALCULATIONAL VARIANTS

The variants to be calculated consist of different combinations of the material, geometric, and state specifications given previously. The specific variants are presented in Tables 2.4 and 2.5. The first set of variants (V1–V14) represent standard operating conditions, while the second set (V15–V20) represent off-normal and accident conditions.

2.5 PARAMETERS TO BE CALCULATED

The parameters to be calculated are variant-dependent and consist of the following quantities:

- (a) The k_{eff} or critical buckling, k_0 (ratio of neutron production to neutron absorption).
- (b) Migration area, M^2 .
- (c) Concentrations of ^{235}U , ^{236}U , ^{238}U , ^{238}Pu , ^{239}Pu , ^{240}Pu , ^{241}Pu , ^{242}Pu , ^{135}Xe , ^{149}Sm , and total concentrations of FPs in fuel (for assembly geometry type in cells numbered 1, 29, and 72 in Fig. 2.1).
- (d) Concentrations of ^{241}Am , $^{242\text{m}}\text{Am}$, ^{243}Cm , and ^{244}Cm in fuel.
- (e) Pin-by-pin power (fission) distribution.
- (f) Neutron flux in the cell and the ratio of the neutron flux in the fuel, cladding, and moderator regions to that of the cell.
- (g) One-group macroscopic cross sections (Σ_a , Σ_f , $\nu\Sigma_f$) averaged over the cell (for the assembly geometry types in cells numbered 1, 29, and 72 in Fig. 2.1).
- (h) Fuel-averaged, one-group microscopic cross sections (σ_a and $\nu\sigma_f$) of ^{235}U , ^{238}U , ^{238}Pu , ^{239}Pu , ^{240}Pu , ^{241}Pu , ^{242}Pu , ^{135}Xe , ^{149}Sm , and total FPs and relative reactions for these nuclides in the cell (for the assembly geometry type in cells numbered 1, 29, and 72).
- (i) Real and effective delayed neutron fractions (β and β_{eff}).
- (j) Prompt neutron lifetime (Λ).

The particular parameters to be computed for each variant are indicated in Tables 2.4–2.6. Note that for the variants that require burnup, items (a–d) are to be provided at every 2 MWd/kg for State 1 and every 10 MWd/kg for the remaining states. Items (e–h) are to be provided at every 10 MWd/kg.

Table 2.1. Material specifications

Material	Description	Isotope	Content (atoms/b·cm)	Isotope	Content (atoms/b·cm)	Isotope	Content (atoms/b·cm)	Isotope	Content (atoms/b·cm)
FU1	Fresh uranium fuel	²³⁵ U	8.7370×10^{-4}	²³⁸ U	1.8744×10^{-2}	¹⁶ O	3.9235×10^{-2}		
FU2	Fresh MOX fuel	²³⁵ U	3.8393×10^{-5}	²³⁹ Pu	6.5875×10^{-4}	²⁴¹ Pu	7.0246×10^{-6}	¹⁶ O	4.1707×10^{-2}
		²³⁸ U	1.8917×10^{-2}	²⁴⁰ Pu	4.2323×10^{-5}				
FU3	Spent uranium fuel without fission products	²³⁵ U	3.7843×10^{-4}	²³⁸ Pu	6.7254×10^{-6}	²⁴² Pu	4.7576×10^{-6}	²⁴² Cm	1.2582×10^{-7}
		²³⁶ U	8.6365×10^{-5}	²³⁹ Pu	1.3111×10^{-4}	²⁴¹ Am	4.9491×10^{-7}	²⁴³ Cm	2.0629×10^{-9}
		²³⁸ U	1.8327×10^{-2}	²⁴⁰ Pu	3.6233×10^{-5}	^{242m} Am	7.9194×10^{-9}	²⁴⁴ Cm	1.2387×10^{-7}
		²³⁷ Np	2.4823×10^{-5}	²⁴¹ Pu	2.1701×10^{-5}	²⁴³ Am	6.6925×10^{-7}	¹⁶ O	3.9235×10^{-2}
		²³⁹ Np	1.8332×10^{-6}						
FU4	Spent uranium fuel with fission products	²³⁵ U	3.7843×10^{-4}	²⁴¹ Pu	2.1701×10^{-5}	⁹⁵ Mo	3.3720×10^{-5}	¹⁴⁵ Nd	1.9975×10^{-5}
		²³⁶ U	8.6365×10^{-5}	²⁴² Pu	4.7576×10^{-6}	⁹⁹ Tc	3.3320×10^{-5}	¹⁴⁷ Pm	6.1574×10^{-6}
		²³⁸ U	1.8327×10^{-2}	²⁴¹ Am	4.9491×10^{-7}	¹⁰¹ Ru	3.1134×10^{-5}	¹⁵¹ Sm	3.0757×10^{-7}
		²³⁷ Np	2.4823×10^{-5}	^{242m} Am	7.9194×10^{-9}	¹⁰³ Rh	1.8890×10^{-5}	¹⁵² Sm	2.6842×10^{-6}
		²³⁸ Pu	6.7254×10^{-6}	²⁴³ Am	6.6925×10^{-7}	¹⁰⁹ Ag	2.2037×10^{-6}	¹⁵³ Eu	2.4801×10^{-6}
		²³⁹ Np	1.8332×10^{-6}	²⁴² Cm	1.2582×10^{-7}	¹³¹ Xe	1.4255×10^{-5}	¹⁵⁵ Eu	9.6857×10^{-8}
		²³⁹ Pu	1.3111×10^{-4}	²⁴³ Cm	2.0629×10^{-9}	¹³³ Cs	3.5974×10^{-5}	¹⁵⁴ Eu	5.1189×10^{-7}
		²⁴⁰ Pu	3.6233×10^{-5}	²⁴⁴ Cm	1.2387×10^{-7}	¹⁴³ Nd	2.6692×10^{-5}	¹⁶ O	3.9235×10^{-2}
FU7	Fresh MOX fuel with ²³⁹ Pu only	²³⁵ U	3.8393×10^{-5}	²³⁸ U	1.8917×10^{-2}	²³⁹ Pu	6.5875×10^{-4}	¹⁶ O	4.1707×10^{-2}
FU8	Fresh MOX fuel with ²⁴⁰ Pu only	²³⁵ U	3.8393×10^{-5}	²³⁸ U	1.8917×10^{-2}	²⁴⁰ Pu	4.2323×10^{-5}	¹⁶ O	4.1707×10^{-2}
FU9	Fresh MOX fuel with ²⁴¹ Pu only	²³⁵ U	3.8393×10^{-5}	²³⁸ U	1.8917×10^{-2}	²⁴¹ Pu	6.6577×10^{-4}	¹⁶ O	4.1707×10^{-2}
FU10	Fresh MOX fuel (RG)	²³⁵ U	5.0000×10^{-5}	²³⁹ Pu	1.1600×10^{-3}	²⁴¹ Pu	1.9000×10^{-4}	²⁴¹ Am	2.5000×10^{-5}
		²³⁸ U	2.2100×10^{-2}	²⁴⁰ Pu	4.9000×10^{-4}	²⁴² Pu	1.0500×10^{-4}	¹⁶ O	4.6300×10^{-2}
		²³⁸ Pu	3.0000×10^{-5}						

Table 2.1. Material specifications (continued)

Material	Description	Isotope	Content (atoms/b·cm)	Isotope	Content (atoms/b·cm)	Isotope	Content (atoms/b·cm)	Isotope	Content (atoms/b·cm)
FU11	Spent plutonium fuel with fission products	²³⁵ U	1.9990×10^{-5}	²⁴¹ Pu	7.6080×10^{-5}	⁹⁵ Mo	1.3470×10^{-5}	¹⁴⁵ Nd	8.4160×10^{-6}
		²³⁶ U	3.5520×10^{-6}	²⁴² Pu	1.7300×10^{-5}	⁹⁹ Tc	1.6610×10^{-5}	¹⁴⁷ Pm	2.8310×10^{-6}
		²³⁸ U	1.8480×10^{-2}	²⁴¹ Am	2.6120×10^{-6}	¹⁰¹ Ru	1.7120×10^{-5}	¹⁵¹ Sm	3.4630×10^{-7}
		²³⁷ Np	2.0710×10^{-6}	^{242m} Am	4.4530×10^{-8}	¹⁰³ Rh	1.5060×10^{-5}	¹⁵² Sm	2.0600×10^{-6}
		²³⁹ Np	2.0200×10^{-6}	²⁴³ Am	3.2580×10^{-6}	¹⁰⁹ Ag	3.4130×10^{-6}	¹⁵³ Eu	2.0570×10^{-6}
		²³⁸ Pu	1.1180×10^{-6}	²⁴² Cm	6.2890×10^{-7}	¹³¹ Xe	8.1400×10^{-6}	¹⁵⁴ Eu	5.1640×10^{-7}
		²³⁹ Pu	3.2190×10^{-4}	²⁴³ Cm	1.4150×10^{-8}	¹³³ Cs	1.8250×10^{-5}	¹⁵⁵ Eu	8.8120×10^{-8}
		²⁴⁰ Pu	1.4640×10^{-4}	²⁴⁴ Cm	8.0640×10^{-7}	¹⁴³ Nd	1.1490×10^{-5}	¹⁶ O	4.1707×10^{-2}
FU12	MOX fuel of type 1 in zoned fuel assembly	²³⁵ U	3.7918×10^{-5}	²³⁹ Pu	8.7697×10^{-4}	²⁴¹ Pu	9.3516×10^{-6}	¹⁶ O	4.1707×10^{-2}
		²³⁸ U	1.8683×10^{-2}	²⁴⁰ Pu	5.6343×10^{-5}				
FU13	MOX fuel of type 2 in zoned fuel assembly	²³⁵ U	3.8786×10^{-5}	²³⁹ Pu	4.7835×10^{-4}	²⁴¹ Pu	5.1009×10^{-6}	¹⁶ O	4.1707×10^{-2}
		²³⁸ U	1.9111×10^{-2}	²⁴⁰ Pu	3.0733×10^{-5}				
FU14	MOX fuel of type 3 in zoned fuel assembly	²³⁵ U	3.8959×10^{-5}	²³⁹ Pu	3.9862×10^{-4}	²⁴¹ Pu	4.2507×10^{-6}	¹⁶ O	4.1707×10^{-2}
		²³⁸ U	1.9196×10^{-2}	²⁴⁰ Pu	2.5610×10^{-5}				
CL1	Cladding	Zr	4.2300×10^{-2}						
MOD1	Hot moderator with 0.6 g/kg of natural boron	H	4.7830×10^{-2}	¹⁶ O	2.3910×10^{-2}	¹⁰ B	4.7344×10^{-6}	¹¹ B	1.9177×10^{-5}
MOD2	Hot moderator without boron	H	4.7830×10^{-2}	¹⁶ O	2.3910×10^{-2}				
MOD3	Cold moderator with 0.6 g/kg of natural boron	H	6.6940×10^{-2}	¹⁶ O	3.3470×10^{-2}	¹⁰ B	6.6262×10^{-6}	¹¹ B	2.6839×10^{-5}
MOD4	Hot moderator of low density	H	1.3390×10^{-2}	¹⁶ O	6.6900×10^{-3}				
MOD5	Cold moderator without natural boron	H	6.6940×10^{-2}	¹⁶ O	3.3470×10^{-2}				
MOD6	Hot moderator with 1.2 g/kg of boron	H	4.7830×10^{-2}	¹⁶ O	2.3910×10^{-2}	¹⁰ B	9.4688×10^{-6}	¹¹ B	3.8354×10^{-5}

Table 2.2. Cell types

Cell type	Description	Cell cylindrical zone specifications ^a		
		Number	Description ^b	Outer radius (cm)
G1	Fuel cell	1	Fuel (FUn)	0.386
		2	Clad (CL1)	0.4582
G2	Central tube cell	1	Coolant (MODn)	0.45
		2	Structure (CL1)	0.51277
G3	Absorber cell	1	Coolant (MODn)	0.35
		2	Clad (CL1)	0.41
		3	Absorber (ABS)	0.545
		4	Clad (CL1)	0.6323
G4	Guide tube cell	1	Coolant (MODn)	0.545
		2	Structure (CL1)	0.6323

^aAll cell types are surrounded by a moderator/coolant region with a hexagonal shape and a flat-to-flat dimension of 1.275 cm.

^bValues in parentheses refer to information in Table 2.1.

Table 2.3. State parameters

State	Fuel temperature (K)	Nonfuel temperature (K)	Moderator material	Cell type 3 ^a	¹³⁵ Xe and ¹⁴⁹ Sm FPs ^b	Buckling (cm ⁻²)
S1	1027	579	MOD1	G4	Present	0.003
S2	1027	579	MOD1	G3	Present	0.003
S3	1027	579	MOD2	G4	None	0.003
S4	1027	579	MOD1	G4	Present	0.003
S5	579	579	MOD1	G4	None	0.003
S6	300	300	MOD3	G4	None	0.003
S7	1027	579	MOD2	G4	None	0.0
S8	2000	579	MOD2	G4	None	0.0
S9	1027	579	MOD4	G4	None	0.0
S10	1027	579	MOD6	G4	None	0.0
S11	1027	579	MOD2	G4	None	Critical
S12	300	300	MOD5	G4	None	Critical

^aSee Fig. 2.1.

^b¹³⁵Xe and ¹⁴⁹Sm number densities are 9.4581×10^{-9} and 7.3667×10^{-8} atoms/(b-cm), respectively, at zero burnup and equilibrium values at other burnups.

Table 2.4. Specification of pin cell variants

Variant	Description ^a	Fuel material ^b	States ^c	Maximum burnup (MWd/kg)	Parameters to compute ^d
V1	UO ₂ pin cell	FU1	S1, S3–S6	60	(a)–(h)
V2	MOX pin cell	FU2	S1, S3–S6	60	(a)–(h)
V3	Spent UO ₂ pin cell, no FPs	FU3	S1, S3–S6	0	(a)–(h)
V4	Spent UO ₂ pin cell, with FPs	FU4	S1, S3–S6	0	(a)–(h)
V7	MOX pin cell with ²³⁹ Pu only	FU7	S1, S3–S6	0	(a)–(h)
V8	MOX pin cell with ²⁴⁰ Pu only	FU8	S1, S3–S6	0	(a)–(h)
V9	MOX pin cell with ²⁴¹ Pu only	FU9	S1, S3–S6	0	(a)–(h)
V10	Reactor MOX pin cell	FU10	S1, S3–S6	60	(a)–(h)
V15	UO ₂ pin cell, accident conditions, kinetics parameters	FU1	S7–S12	0	(a), (h)–(j)
V16	Spent UO ₂ pin cell, accident conditions, kinetics parameters	FU4	S7–S12	0	(a), (h)–(j)
V17	MOX pin cell, accident conditions, kinetics parameters	FU2	S7–S12	0	(a), (h)–(j)
V18	Spent MOX pin cell, accident conditions, kinetics parameters	FU11	S7–S12	0	(a), (h)–(j)

^aAll cases have G1 cell geometry given in Table 2.2.

^bRefer to Table 2.1 for material definitions.

^cRefer to Table 2.3 for state definitions.

^dParameter definitions given in Sect. 2.5.

Table 2.5. Specification of assembly variants

Variant	Description	Assembly cell ^a	Cell type ^b	Fuel material ^c	States ^d	Maximum burnup (MWd/kg)	Parameters to compute ^e
V11	UO ₂ assembly	1,4,5 2 3	G1 G2 G3/G4 ^f	FU1	S1–S6	60	(a)–(h)
V12	MOX assembly	1,4,5 2 3	G1 G2 G3/G4 ^f	FU1	S1–S6	60	(a)–(h)

^aRefer to Fig. 2.1 for assembly cell locations.

^bRefer to Table 2.2 for cell types.

^cRefer to Table 2.1 for material definitions.

^dRefer to Table 2.3 for state definitions.

^eParameter definitions given in Sect. 2.5.

^fCell type G3 is used only for State 2; G4 is used for all other states.

Table 2.6. Multiassembly variant specifications

Variant	Description	Assembly ^a	Assembly cell ^b	Fuel material ^c	State ^d	Maximum burnup (MWd/kg)	Parameters to compute ^e
V13	Multiassembly with uniform MOX assembly	K1	1-5	FU1	S1, S4	60	(a), (b), (e)
		K2	1-5	FU2			
V14	Multiassembly with graded MOX assembly	K1	1-3	FU12	S1, S6	60	(a), (b), (e)
			4	FU13			
			5	FU14			
V19	Multiassembly, accident conditions, kinetics parameters	K1	1-5	FU2	S7-S12	0	(a), (b), (i), (j)
		K2	1-5	FU1			
V20	Multiassembly with spent UO ₂ assemblies, accident conditions, kinetics parameters	K1	1-5	FU2	S7-S12	0	(a), (b), (i), (j)
		K2	1-5	FU4			

^aRefer to Fig. 2.2.

^bRefer to Fig. 2.1 for assembly cell locations.

^cRefer to Table 2.2 for material definitions.

^dRefer to Table 2.3 for state definitions.

^eParameter definitions given in Sect. 2.5.

Fig. 2.1. Diagram of K331 assembly design showing cell locations and types.

Fig. 2.2. Geometry of MK2 multiassembly structure.

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3. MODELING AND METHODS

3.1 HELIOS DESCRIPTION

The benchmark calculations were performed with the HELIOS code system. HELIOS is a two-dimensional (2-D) fuel assembly analysis code developed by Studsvik Scandpower, Inc. The neutron and gamma transport calculations are based on current coupling of space elements, which are internally treated by collision probabilities. The resonance treatment is based on the subgroup method. Further details can be found in Refs. 2 and 3. The HELIOS system consists of the AURORA input processor, HELIOS calculation module, ZENITH output processor, and ORION geometry viewer.

3.2 HELIOS MODELING OPTIONS

HELIOS has several options that can be used to control the resonance processing, cell coupling order, collision probability meshing, and iterative solution. HELIOS assumes default values for these parameters, which generally provide the best solution in a reasonable amount of computer time. The values used in these calculations are as follows:

Coupling parameter:	4 (4 azimuthal angular segments, 1 polar segment)
Resonance option:	4 (separate groups for ^{238}U and all other isotopes)
Critical spectrum:	Default option to use critical spectrum for depletion and output disabled
Relaxation factors:	ω_3 (thermal iteration relaxation factor) and ω_4 (deep thermal iteration relaxation factor) were set to 1.0. Several benchmark variants do not converge with the default value of 1.4 with the 89- and 190-group libraries.

3.3 GEOMETRIC MODELING

The benchmark problems consist of three different configurations: pin cells, assemblies, and multiple assemblies.

The pin cell geometric modeling is very simple. It consists of a single fuel pin, cladding, and moderator region with reflective boundary conditions. A diagram of the pin cell geometry, obtained from the ORION geometry viewer, is presented in Fig. 3.1. The fuel pin is modeled using two regions to capture the higher depletion at the periphery of the fuel material. The outer rim is 10% of the pin radius. The moderator is subdivided into six regions. This geometric model is used for benchmark Variants 1-4, 7-10, 15-18, as described in Chap. 2.

The VVER-1000 assembly is modeled using one-sixth assembly symmetry with rotational boundary conditions. A diagram of the assembly geometry is shown in Fig. 3.2. The assembly consists of 312 fuel pins, 18 control pins or water hole locations, and a central instrumentation tube. The fuel pin model is identical to that described previously. Additional regions are included in and around control pins to model the sharp flux gradients near these pins. The assembly model is used to model the benchmark Variants 11 and 12, which are UO_2 and MOX assemblies, respectively.

Several of the benchmark variants represent an infinite lattice of MOX assemblies surrounded by UO_2 assemblies at a ratio of 1 MOX assembly per 3 UO_2 assemblies. This system of assemblies is modeled with one-twelfth of a MOX assembly with one-fourth of a UO_2 assembly, as shown in Fig. 3.3. This model represents the repeating section shown in Fig. 2.1. The modeling details are the same as for the assembly model. Note, however, that in these benchmarks

there is no central tube or control rod locations. The boundary conditions are specular mirror reflection on all surfaces.

3.4 CROSS-SECTION DATA

HELIOS's cross-section libraries are based on ENDF/B-VI revision 2 with ^{235}U from revision 3. The ^{238}U resonance integral in the production libraries has been reduced by 3.4% to produce better agreement with critical experiments. Unadjusted libraries are also available but were not used for the benchmark calculations.

The HELIOS library contains data for 271 nuclides, of which 32 are actinides and 115 are FPs. No lumped FPs are used. The available actinides and FPs are given in Table 3.1.

The cross sections are available in 34-, 89-, and 190-group structures. Preliminary calculations of Variants 1, 2, and 10 (UO_2 , WG MOX, and RG MOX pin cells, respectively) were performed with each of the libraries to determine their accuracy. The comparison k_{inf} values at 0 MWd/kg and 60 MWd/kg are shown in Table 3.2. The results show that both the 34- and 89-group libraries agree well with the 190-group results for the UO_2 fuel. However, for the WG and RG MOX, the 34-group results show rather large differences at 0 MWd/kg. The 89-group results for these cases agree well with the reference 190-group results.

The 190-group library was used for all calculations of these benchmarks to provide the highest accuracy available. Based on the library comparisons, the 89-group library was shown to produce accurate results and is recommended for the analysis of MOX fuel. The 34-group library is sufficient for UO_2 analysis but should be avoided when considering MOX systems.

3.5 KINETICS PARAMETER CALCULATIONS

Several of the benchmark variants (V15–V20) were designed to provide benchmarking of accident conditions and kinetics parameters (delayed neutron fractions and prompt neutron lifetimes). HELIOS has the capability to compute effective delayed neutron fractions via the BONE operator in ZENITH. This option, however, uses the critical spectrum for the calculation and therefore is not consistent with the effective delayed neutron fraction that is required for this benchmark. Therefore, the VENTURE⁶ code system was used to compute the kinetics parameters.

VENTURE is a reactor analysis system developed at ORNL. The transport method is based on finite-difference diffusion theory, and several modules are available for fuel depletion, fuel management, and perturbation analyses.

The calculational procedure for the kinetics parameters consists of transferring the homogenized cross section from HELIOS to VENTURE with the recently developed PEGASUS module. VENTURE is then used to compute the effective delayed neutron fraction and prompt neutron lifetime using an infinite, homogenous model. The effective delayed neutron fraction is computed as the real delayed neutron fraction from HELIOS multiplied by the ratio of the multiplication factor with the total (prompt and delayed) fission spectrum to the multiplication factor computed with the delayed neutron spectrum. This method of computing the effective delayed neutron fraction as the ratio of two eigenvalues is a common approximation of the rigorous adjoint-weighting method. The ratio of multiplication factors is obtained from two VENTURE eigenvalue calculations. The prompt neutron lifetime is computed as part of the VENTURE adjoint calculation.

Table 3.1. Actinides and FPs in HELIOS library

²³³ Th	²⁴² Th	²³¹ Pa	²³² Pa	²³³ Pa	²³⁴ Pa	²³⁹ Np	^{242m} Am
²³⁵ U	²³⁶ U	²³⁷ U	²³⁸ U	²³⁷ Np	²³⁸ Np	²⁴² Am	²³⁴ U
²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	²⁴¹ Am	²³³ U	
²⁴² Cm	²⁴³ Cm	²⁴⁴ Cm	²⁴⁵ Cm	²⁴⁶ Cm	²³² U	²³⁶ U	²⁴³ Am
⁸¹ Br	⁸³ Kr	⁸⁵ Kr	⁸⁹ Sr	⁸⁹ Y	⁹⁰ Sr	⁹¹ Y	⁹³ Zr
⁹⁶ Zr	⁹⁵ Zr	⁹⁵ Nb	⁹⁵ Mo	⁹⁶ Mo	⁹⁷ Mo	⁹⁸ Mo	⁹⁹ Mo
⁹⁹ Tc	¹⁰⁰ Ru	¹⁰¹ Ru	¹⁰² Ru	¹⁰³ Ru	¹⁰⁴ Ru	¹⁰⁵ Ru	¹⁰⁶ Ru
¹⁰⁶ Pd	¹⁰⁵ Rh	¹⁰⁵ Pd	¹⁰³ Rh	¹⁰⁴ Pd	¹⁰⁷ Pd	¹⁰⁸ Pd	¹⁰⁹ Ag
¹¹⁰ Cd	¹¹¹ Cd	¹¹⁰ Ag	¹¹¹ Ag	¹²⁵ Sb	¹²⁷ Sb	¹²⁷ I	^{127m} Te
^{129m} Te	¹²⁹ I	¹³² Te	¹³² Xe	¹³¹ I	¹³¹ Xe	¹³⁵ I	¹³⁵ Xe
¹³⁶ Xe	¹³⁷ Cs	¹³⁷ Ba	¹³⁵ Cs	¹³⁶ Cs	¹³³ Xe	¹³⁴ Xe	¹³³ Cs
¹³⁴ Cs	¹³⁴ Ba	¹⁴⁰ Ba	¹⁴⁰ La	¹³⁹ La	¹⁴² Ce	¹⁴³ Ce	¹⁴³ Ce
¹⁴⁴ Ce	¹⁴⁷ Nd	¹⁴⁸ Nd	¹⁴⁹ Pm	¹⁵⁰ Sm	¹⁵¹ Sm	¹⁵² Sm	¹⁵³ Sm
¹⁵⁴ Sm	¹⁵³ Eu	¹⁵⁴ Eu	¹⁵⁵ Eu	¹⁵⁶ Eu	¹⁵⁷ Eu	¹⁵⁷ Gd	¹⁵⁶ Gd
¹⁵⁵ Gd	¹⁵⁴ Gd	¹⁵¹ Eu	¹⁴⁹ Sm	¹⁴⁷ Pm	¹⁴⁸ Pm	¹⁴⁸ Sm	^{148m} Pm
¹⁴⁷ Sm	¹⁵⁰ Nd	¹⁵¹ Pm	¹⁵⁸ Gd	¹⁵⁹ Tb	¹⁶⁰ Tb	¹⁶¹ Tb	¹⁶¹ Dy
¹⁶² Dy	¹⁶³ Dy	¹⁶⁴ Dy	¹⁶⁵ Ho	¹⁶⁰ Dy	¹⁶⁰ Gd	¹⁰⁰ Mo	¹¹³ Cd
¹¹⁵ In		⁹⁰ Y					

Table 3.2. Comparison of k_{inf} values from calculations using the 34-, 89-, and 190-group libraries

Variant	State	Burnup = 0 MWd/kg			Burnup = 60 MWd/kg		
		Ref.	Difference from ref.		Ref.	Difference from ref.	
		k_{inf}	(% dk/k ²)		k_{inf}	(% dk/k ²)	
		190	34	89	190	34	89
		groups	groups	groups	groups	groups	groups
V1	S1	1.2750	-0.15	-0.15	0.8577	-0.26	0.04
	S3	1.3315	-0.18	-0.15	0.8932	-0.21	0.03
	S4	1.3227	-0.15	-0.15	0.8894	-0.25	0.01
	S5	1.3393	-0.14	-0.13	0.9046	-0.40	0.00
	S6	1.3754	-0.05	-0.09	0.9321	-0.56	-0.20
V2	S1	1.2188	0.58	0.15	0.8465	-0.10	0.14
	S3	1.2481	0.55	0.15	0.8752	-0.05	0.14
	S4	1.2383	0.57	0.15	0.8762	-0.08	0.12
	S5	1.2583	0.46	0.13	0.8916	-0.20	0.10
	S6	1.3309	0.34	0.12	0.9262	-0.33	0.07
V10	S1	1.1135	-0.39	-0.19	0.9274	0.22	0.31
	S3	1.1270	-0.45	-0.21	0.9394	0.19	0.32
	S4	1.1195	-0.44	-0.20	0.9486	0.21	0.32
	S5	1.1381	-0.41	-0.19	0.9646	0.19	0.31
	S6	1.2091	-0.24	-0.15	1.0334	0.33	0.29

Fig. 3.1. Geometric model of pin cell variants.

Fig. 3.2. Geometric model of assembly variants (one-sixth assembly).

Fig. 3.3. Geometric model of multiassembly structure.

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4. CALCULATIONAL RESULTS

All of the calculational results that were requested in the benchmark specifications were computed with HELIOS and are presented in Table 4.1 through Table 4.34 and Fig. 4.1 through Fig. 4.58. The quantities presented are those discussed in the problem specifications in Sect. 2.5. In particular, note that the k_0 value is the ratio of the system's total production rate to total absorption rate computed with the problem's specified buckling value and is therefore not equivalent to k_{inf} . The cell relative reaction rates given in the tables (e.g., Table 4.16) are relative to the total corresponding reaction rate for the entire cell.

Table 4.1. Values of k_{eff} and k_0 at zero burnup point for Variants 1–4, 7–14, and States 1–6

Variant	State											
	S1 ^a		S2		S3 ^a		S4 ^b		S5 ^b		S6 ^b	
	k_{eff}	k_0		k_0	k_{eff}	k_0	k_{eff}	k_0	k_{eff}	k_0	k_{eff}	k_0
V1	1.0648	1.2703	-	-	1.1110	1.3259	1.1039	1.3172	1.1173	1.3339	1.2207	1.3727
V2	1.0227	1.2166	-	-	1.0469	1.2455	1.0389	1.2358	1.0551	1.2558	1.1832	1.3292
V3	0.9128	1.0915	-	-	0.9500	1.1364	0.9453	1.1305	0.9604	1.1492	1.0603	1.1946
V4	0.8602	1.0269	-	-	0.8936	1.0672	0.8890	1.0615	0.9029	1.0787	1.0005	1.1262
V7	1.1046	1.3156	-	-	1.1321	1.3487	1.1229	1.3376	1.1369	1.3550	1.2595	1.4160
V8	0.9240	1.1005	-	-	0.9690	1.1547	0.9646	1.1492	0.9800	1.1682	1.0831	1.2167
V9	1.3228	1.5676	-	-	1.3543	1.6052	1.3425	1.5911	1.3593	1.6117	1.4713	1.6484
V10	0.9593	1.1154	-	-	0.9707	1.1287	0.9643	1.1212	0.9799	1.1399	1.0910	1.2093
V11	1.0791	1.2854	0.8681	1.0312	1.1351	1.3528	1.1203	1.3347	1.1326	1.3500	1.2226	1.3713
V12	1.0483	1.2451	0.8696	1.0313	1.0788	1.2816	1.0663	1.2665	1.0812	1.2849	1.1995	1.3445
V13	1.0627	1.2652	-	-	-	-	1.1006	1.3106	-	-	1.2179	1.3672
V14	1.2726	1.2726	-	-	-	-	-	-	-	-	1.3681	1.3681

^a¹³⁵Xe and ¹⁴⁹Sm number densities are 9.4581×10^{-9} and 7.3667×10^{-8} atoms/(b · cm), respectively.

^b¹³⁵Xe and ¹⁴⁹Sm number densities are zero.

Table 4.2. Values of k_{eff} , k_0 , and migration area vs burnup for Variants 1, 2, and 10–12, State 1

Burnup (MWd/kg)	Variant 1			Variant 2			Variant 10			Variant 11			Variant 12		
	k_{eff}	k_0	M^2 (cm ²)	k_{eff}	k_0	M^2 (cm ²)	k_{eff}	k_0	M^2 (cm ²)	k_{eff}	k_0	M^2 (cm ²)	k_{eff}	k_0	M^2 (cm ²)
0	1.0648	1.2703	66.66	1.0227	1.2166	64.17	0.9593	1.1154	53.28	1.0791	1.2854	66.08	1.0483	1.2451	63.84
2	1.0477	1.2498	66.36	0.9854	1.1721	63.62	0.9416	1.0947	53.08	1.0638	1.2671	65.86	1.0103	1.1998	63.32
4	1.0300	1.2287	66.07	0.9657	1.1485	63.37	0.9339	1.0858	53.02	1.0467	1.2468	65.61	0.9898	1.1755	63.09
6	1.0118	1.2069	65.78	0.9486	1.1282	63.16	0.9275	1.0783	52.96	1.0291	1.2259	65.36	0.9719	1.1542	62.90
8	0.9942	1.1859	65.52	0.9331	1.1098	62.97	0.9215	1.0714	52.92	1.0118	1.2053	65.14	0.9555	1.1348	62.73
10	0.9775	1.1660	65.28	0.9189	1.0929	62.81	0.9157	1.0647	52.88	0.9952	1.1855	64.93	0.9402	1.1167	62.58
12	0.9617	1.1472	65.07	0.9057	1.0772	62.67	0.9102	1.0582	52.85	0.9792	1.1665	64.75	0.9258	1.0996	62.45
14	0.9468	1.1295	64.88	0.8933	1.0624	62.53	0.9046	1.0518	52.82	0.9639	1.1484	64.58	0.9122	1.0834	62.32
16	0.9328	1.1127	64.71	0.8815	1.0484	62.41	0.8992	1.0456	52.79	0.9492	1.1309	64.42	0.8991	1.0679	62.21
18	0.9193	1.0968	64.55	0.8703	1.0351	62.30	0.8939	1.0394	52.77	0.9350	1.1141	64.28	0.8866	1.0531	62.11
20	0.9064	1.0814	64.41	0.8596	1.0223	62.20	0.8887	1.0334	52.74	0.9213	1.0979	64.15	0.8744	1.0387	62.01
22	0.8940	1.0667	64.27	0.8493	1.0101	62.10	0.8836	1.0275	52.72	0.9080	1.0821	64.03	0.8627	1.0248	61.93
24	0.8821	1.0525	64.15	0.8395	0.9984	62.28	0.8785	1.0216	52.71	0.8950	1.0667	63.92	0.8513	1.0113	61.84
26	0.8705	1.0388	64.03	0.8299	0.9871	61.94	0.8735	1.0158	52.69	0.8823	1.0517	63.81	0.8402	0.9982	62.11
28	0.8593	1.0255	63.93	0.8207	0.9762	61.87	0.8685	1.0101	52.67	0.8698	1.0370	63.71	0.8294	0.9855	61.70
30	0.8483	1.0125	63.84	0.8118	0.9657	61.80	0.8636	1.0045	52.66	0.8576	1.0225	63.62	0.8189	0.9731	61.64
32	0.8375	0.9997	63.76	0.8032	0.9554	61.73	0.8588	0.9989	52.64	0.8456	1.0083	63.53	0.8088	0.9611	61.58
34	0.8271	0.9874	63.66	0.7949	0.9456	61.68	0.8540	0.9934	52.64	0.8338	0.9944	63.45	0.7989	0.9494	61.53
36	0.8171	0.9755	63.58	0.7868	0.9360	61.63	0.8494	0.9880	52.63	0.8222	0.9807	63.37	0.7892	0.9380	61.49
38	0.8072	0.9637	63.49	0.7791	0.9269	61.58	0.8448	0.9827	52.62	0.8109	0.9673	63.29	0.7799	0.9270	61.45
40	0.7976	0.9524	63.42	0.7716	0.9180	61.54	0.8403	0.9775	52.61	0.7998	0.9541	63.22	0.7709	0.9163	61.41
42	0.7883	0.9414	63.34	0.7644	0.9094	61.50	0.8357	0.9723	52.61	0.7888	0.9412	63.15	0.7621	0.9060	61.38
44	0.7793	0.9306	63.28	0.7574	0.9012	61.47	0.8314	0.9673	52.61	0.7781	0.9285	63.09	0.7536	0.8961	61.36
46	0.7704	0.9202	63.21	0.7506	0.8932	61.44	0.8270	0.9623	52.61	0.7677	0.9162	63.03	0.7455	0.8864	61.33
48	0.7619	0.9100	63.16	0.7441	0.8855	61.41	0.8226	0.9572	52.60	0.7575	0.9041	62.97	0.7376	0.8771	61.32
50	0.7536	0.9002	63.10	0.7379	0.8781	61.39	0.8183	0.9523	52.61	0.7476	0.8924	62.92	0.7300	0.8682	61.31
52	0.7455	0.8906	63.05	0.7318	0.8709	61.37	0.8142	0.9475	52.61	0.7380	0.8810	62.87	0.7227	0.8596	61.30
54	0.7378	0.8814	62.99	0.7259	0.8640	61.36	0.8101	0.9428	52.61	0.7287	0.8700	62.83	0.7156	0.8513	61.29
56	0.7303	0.8726	62.95	0.7203	0.8574	61.35	0.8060	0.9382	52.62	0.7197	0.8594	62.79	0.7089	0.8434	61.29
58	0.7230	0.8639	62.91	0.7149	0.8511	61.34	0.8021	0.9336	52.62	0.7110	0.8491	62.75	0.7024	0.8358	61.29
60	0.7161	0.8557	62.87	0.7098	0.8451	61.32	0.7982	0.9291	52.62	0.7027	0.8393	62.72	0.6962	0.8285	61.30

Table 4.3. Values of k_{eff} , k_0 , and migration area vs burnup for Variants 1, 2, and 10-12, States 1-6

State	Variant 1			Variant 2			Variant 10			Variant 11			Variant 12		
	k_{eff}	k_0	M^2 (cm^2)	k_{eff}	k_0	M^2 (cm^2)	k_{eff}	k_0	M^2 (cm^2)	k_{eff}	k_0	M^2 (cm^2)	k_{eff}	k_0	M^2 (cm^2)
<i>Burnup = 0 MWd/kg</i>															
S1	1.0648	1.2703	66.66	1.0227	1.2166	64.17	0.9593	1.1154	53.28	1.0791	1.2854	66.08	1.0483	1.2451	63.84
S2	-	-	-	-	-	-	-	-	-	0.8681	1.0312	62.60	0.8696	1.0313	61.45
S3	1.1110	1.3259	67.66	1.0469	1.2455	64.61	0.9707	1.1287	53.45	1.1351	1.3528	67.25	1.0788	1.2816	64.38
S4	1.1039	1.3172	67.48	1.0389	1.2358	64.45	0.9643	1.1212	53.34	1.1203	1.3347	66.91	1.0663	1.2665	64.14
S5	1.1173	1.3339	67.79	1.0551	1.2558	64.82	0.9799	1.1399	53.65	1.1326	1.3500	67.19	1.0812	1.2849	64.48
S6	1.2207	1.3727	43.80	1.1832	1.3292	42.77	1.0910	1.2093	36.46	1.2226	1.3713	42.66	1.1995	1.3445	41.90
<i>Burnup = 10 MWd/kg</i>															
S1	0.9775	1.1660	65.28	0.9189	1.0929	62.81	0.9157	1.0647	52.88	0.9952	1.1855	64.93	0.9402	1.1167	62.58
S2	-	-	-	-	-	-	-	-	-	0.7817	0.9288	61.55	0.7669	0.9095	60.36
S3	1.0161	1.2125	66.09	0.9410	1.1194	63.22	0.9263	1.0771	53.04	1.0439	1.2441	65.92	0.9689	1.1511	63.09
S4	1.0150	1.2110	66.04	0.9478	1.1274	63.31	0.9333	1.0852	53.11	1.0336	1.2316	65.69	0.9707	1.1530	63.09
S5	1.0282	1.2274	66.35	0.9632	1.1463	63.65	0.9483	1.1031	53.40	1.0457	1.2466	65.96	0.9849	1.1705	63.40
S6	1.1337	1.2753	43.22	1.0797	1.2129	42.06	1.0567	1.1713	36.30	1.1368	1.2756	42.18	1.0892	1.2210	41.23
<i>Burnup = 20 MWd/kg</i>															
S1	0.9064	1.0814	64.41	0.8596	1.0223	62.20	0.8887	1.0334	52.74	0.9213	1.0979	64.15	0.8744	1.0387	62.01
S2	-	-	-	-	-	-	-	-	-	0.7246	0.8613	61.18	0.7094	0.8414	59.98
S3	0.9413	1.1235	65.13	0.8819	1.0491	62.60	0.8991	1.0456	52.89	0.9665	1.1522	65.06	0.9039	1.0740	62.53
S4	0.9411	1.1231	65.11	0.8879	1.0561	62.69	0.9066	1.0542	52.97	0.9569	1.1406	64.85	0.9040	1.0740	62.51
S5	0.9549	1.1401	65.42	0.9024	1.0740	63.00	0.9211	1.0716	53.24	0.9694	1.1561	65.12	0.9174	1.0904	62.79
S6	1.0572	1.1895	42.77	1.0090	1.1335	41.64	1.0283	1.1398	36.20	1.0560	1.1854	41.80	1.0083	1.1304	40.83
<i>Burnup = 30 MWd/kg</i>															
S1	0.8483	1.0125	63.84	0.8118	0.9657	61.80	0.8636	1.0045	52.66	0.8576	1.0225	63.62	0.8189	0.9731	61.64
S2	-	-	-	-	-	-	-	-	-	0.6736	0.8012	60.98	0.6603	0.7832	59.78
S3	0.8811	1.0520	64.51	0.8345	0.9929	62.20	0.8740	1.0166	52.80	0.9007	1.0745	64.48	0.8495	1.0097	62.17
S4	0.8806	1.0513	64.48	0.8393	0.9985	62.32	0.8817	1.0254	52.88	0.8904	1.0619	64.26	0.8472	1.0069	62.12
S5	0.8943	1.0682	64.79	0.8532	1.0155	62.55	0.8958	1.0424	53.14	0.9028	1.0773	64.52	0.8599	1.0225	62.38
S6	0.9902	1.1145	42.43	0.9505	1.0678	41.34	1.0017	1.1105	36.14	0.9809	1.1016	41.49	0.9376	1.0513	40.53

Table 4.3. (continued)

State	Variant 1			Variant 2			Variant 10			Variant 11			Variant 12		
	k_{eff}	k_0	M^2 (cm ²)	k_{eff}	k_0	M^2 (cm ²)	k_{eff}	k_0	M^2 (cm ²)	k_{eff}	k_0	M^2 (cm ²)	k_{eff}	k_0	M^2 (cm ²)
<i>Burnup = 40 MWd/kg</i>															
S1	0.7976	0.9524	63.42	0.7716	0.9180	61.54	0.8403	0.9775	52.61	0.7998	0.9541	63.22	0.7709	0.9163	61.41
S2	-	-	-	-	-	-	-	-	-	0.6267	0.7459	60.88	0.6175	0.7327	59.71
S3	0.8288	0.9900	64.04	0.7947	0.9457	61.94	0.8505	0.9895	52.75	0.8414	1.0043	64.04	0.8025	0.9542	61.96
S4	0.8275	0.9883	64.00	0.7981	0.9497	61.98	0.8583	0.9985	52.84	0.8297	0.9901	63.79	0.7976	0.9483	61.86
S5	0.8409	1.0049	64.29	0.8115	0.9661	62.26	0.8721	1.0151	53.09	0.8417	1.0049	64.05	0.8097	0.9632	62.10
S6	0.9289	1.0459	42.16	0.9005	1.0118	41.14	0.9768	1.0830	36.09	0.9090	1.0212	41.22	0.8751	0.9815	40.32
<i>Burnup = 50 MWd/kg</i>															
S1	0.7536	0.9002	63.10	0.7379	0.8781	61.39	0.8183	0.9523	52.61	0.7476	0.8924	62.92	0.7300	0.8682	61.31
S2	-	-	-	-	-	-	-	-	-	0.5846	0.6961	60.90	0.5812	0.6900	59.77
S3	0.7835	0.9363	63.68	0.7613	0.9062	61.78	0.8285	0.9642	52.75	0.7881	0.9413	63.70	0.7625	0.9073	61.86
S4	0.7813	0.9335	63.63	0.7633	0.9085	61.81	0.8364	0.9733	52.83	0.7749	0.9252	63.43	0.7552	0.8984	61.72
S5	0.7942	0.9494	63.90	0.7763	0.9245	62.07	0.8500	0.9896	53.07	0.7863	0.9393	63.67	0.7668	0.9126	61.95
S6	0.8738	0.9841	41.94	0.8582	0.9645	41.01	0.9534	1.0573	36.08	0.8419	0.9463	41.02	0.8217	0.9218	40.21
<i>Burnup = 60 MWd/kg</i>															
S1	0.7161	0.8557	62.87	0.7098	0.8451	61.32	0.7982	0.9291	52.62	0.7027	0.8393	62.72	0.6962	0.8285	61.30
S2	-	-	-	-	-	-	-	-	-	0.5485	0.6534	61.01	0.5515	0.6550	59.92
S3	0.7450	0.8906	63.41	0.7334	0.8734	61.72	0.8083	0.9410	52.77	0.7421	0.8868	63.46	0.7295	0.8686	61.86
S4	0.7420	0.8868	63.34	0.7342	0.8743	61.73	0.8161	0.9501	52.85	0.7277	0.8693	63.17	0.7200	0.8571	61.69
S5	0.7544	0.9021	63.60	0.7469	0.8898	61.97	0.8295	0.9661	53.08	0.7383	0.8825	63.38	0.7311	0.8707	61.89
S6	0.8262	0.9307	41.79	0.8229	0.9249	40.94	0.9318	1.0335	36.08	0.7831	0.8805	40.89	0.7775	0.8726	40.18

Table 4.4. Cell macroscopic cross sections, flux, and flux ratios vs burnup for Variants 1–4 and 7–10, State 1

Burnup (MWd/kg)	Σ_a (cm ⁻¹)	Σ_f (cm ⁻¹)	$\nu\Sigma_f$ (cm ⁻¹)	ϕ_{cell} (cm ⁻² ·s ⁻¹)	ϕ_{fuel}/ϕ_{cell}	ϕ_{clad}/ϕ_{cell}	ϕ_{mod}/ϕ_{cell}
<i>Variant 1</i>							
0	2.066E-2	1.068E-2	2.624E-2	3.109E+14	0.9974	0.9990	1.0019
10	2.096E-2	9.581E-3	2.445E-2	3.434E+14	0.9973	0.9989	1.0020
20	2.107E-2	8.709E-3	2.279E-2	3.752E+14	0.9971	0.9988	1.0021
30	2.110E-2	8.001E-3	2.136E-2	4.061E+14	0.9968	0.9989	1.0023
40	2.110E-2	7.400E-3	2.010E-2	4.371E+14	0.9965	0.9990	1.0025
50	2.110E-2	6.891E-3	1.899E-2	4.677E+14	0.9966	0.9992	1.0023
60	2.110E-2	6.472E-3	1.806E-2	4.966E+14	0.9967	0.9993	1.0023
<i>Variant 2</i>							
0	2.199E-2	9.365E-3	2.675E-2	3.410E+14	0.9950	0.9998	1.0032
10	2.200E-2	8.396E-3	2.402E-2	3.797E+14	0.9951	0.9997	1.0032
20	2.194E-2	7.818E-3	2.241E-2	4.074E+14	0.9952	0.9997	1.0031
30	2.186E-2	7.346E-3	2.110E-2	4.332E+14	0.9953	0.9997	1.0030
40	2.179E-2	6.947E-3	1.999E-2	4.579E+14	0.9954	0.9998	1.0029
50	2.171E-2	6.613E-3	1.906E-2	4.810E+14	0.9958	0.9996	1.0027
60	2.164E-2	6.338E-3	1.829E-2	5.020E+14	0.9961	0.9997	1.0025
<i>Variant 3</i>							
0	2.083E-2	8.524E-3	2.273E-2	3.813E+14	0.9969	0.9990	1.0022
<i>Variant 4</i>							
0	2.108E-2	8.116E-3	2.165E-2	4.005E+14	0.9967	0.9991	1.0023
<i>Variant 7</i>							
0	2.171E-2	1.000E-2	2.856E-2	3.193E+14	0.9951	0.9996	1.0032
<i>Variant 8</i>							
0	2.054E-2	9.187E-3	2.261E-2	3.612E+14	0.9967	0.9995	1.0022
<i>Variant 9</i>							
0	2.213E-2	1.185E-2	3.469E-2	2.667E+14	0.9955	0.9994	1.0030
<i>Variant 10</i>							
0	2.458E-2	9.522E-3	2.742E-2	3.346E+14	0.9937	1.0002	1.0039
10	2.461E-2	9.086E-3	2.620E-2	3.505E+14	0.9938	1.0001	1.0039
20	2.460E-2	8.805E-3	2.542E-2	3.615E+14	0.9938	1.0001	1.0038
30	2.457E-2	8.542E-3	2.469E-2	3.725E+14	0.9939	1.0001	1.0038
40	2.455E-2	8.295E-3	2.399E-2	3.836E+14	0.9940	1.0001	1.0037
50	2.451E-2	8.061E-3	2.334E-2	3.948E+14	0.9939	1.0004	1.0037
60	2.447E-2	7.844E-3	2.274E-2	4.057E+14	0.9941	1.0004	1.0036

**Table 4.5. Cell macroscopic cross sections, flux, and flux ratios vs burnup for
Variant 11, States 1 and 2**

State	Burnup (MWd/kg)	Σ_a (cm ⁻¹)	Σ_f (cm ⁻¹)	$v\Sigma_f$ (cm ⁻¹)	ϕ_{cell} (cm ⁻² ·s ⁻¹)	ϕ_{fuel}/ϕ_{cell}	ϕ_{clad}/ϕ_{cell}	ϕ_{mod}/ϕ_{cell}
<i>Pin 1</i>								
S1	0	2.376E-2	1.265E-2	3.103E-2	2.795E+14	1.0040	1.0004	0.9974
	10	2.407E-2	1.134E-2	2.884E-2	3.075E+14	1.0037	1.0005	0.9975
	20	2.409E-2	1.019E-2	2.659E-2	3.372E+14	1.0035	1.0006	0.9977
	30	2.398E-2	9.203E-3	2.453E-2	3.679E+14	1.0033	1.0006	0.9978
	40	2.383E-2	8.344E-3	2.266E-2	4.008E+14	1.0032	1.0006	0.9978
	50	2.370E-2	7.617E-3	2.103E-2	4.351E+14	1.0031	1.0007	0.9979
	60	2.361E-2	7.036E-3	1.970E-2	4.689E+14	1.0031	1.0007	0.9979
S2	0	2.227E-2	1.171E-2	2.876E-2	3.772E+14	1.0081	1.0007	0.9948
	10	2.264E-2	1.054E-2	2.685E-2	4.123E+14	1.0077	1.0008	0.9950
	20	2.269E-2	9.488E-3	2.478E-2	4.514E+14	1.0074	1.0008	0.9952
	30	2.259E-2	8.570E-3	2.285E-2	4.930E+14	1.0072	1.0009	0.9953
	40	2.245E-2	7.764E-3	2.109E-2	5.379E+14	1.0070	1.0010	0.9954
	50	2.231E-2	7.081E-3	1.955E-2	5.848E+14	1.0069	1.0010	0.9954
	60	2.221E-2	6.534E-3	1.829E-2	6.309E+14	1.0069	1.0010	0.9954
<i>Pin 29</i>								
S1	0	2.181E-2	1.154E-2	2.833E-2	2.774E+14	1.0037	1.0003	0.9976
	10	2.207E-2	1.042E-2	2.648E-2	3.054E+14	1.0035	1.0004	0.9977
	20	2.215E-2	9.482E-3	2.468E-2	3.348E+14	1.0034	1.0004	0.9978
	30	2.215E-2	8.683E-3	2.306E-2	3.655E+14	1.0033	1.0005	0.9978
	40	2.211E-2	7.970E-3	2.154E-2	3.982E+14	1.0033	1.0005	0.9978
	50	2.205E-2	7.336E-3	2.014E-2	4.324E+14	1.0033	1.0005	0.9978
	60	2.199E-2	6.797E-3	1.892E-2	4.661E+14	1.0033	1.0005	0.9978
S2	0	1.904E-2	9.726E-3	2.394E-2	3.527E+14	1.0062	1.0003	0.9960
	10	1.934E-2	8.824E-3	2.246E-2	3.862E+14	1.0060	1.0004	0.9962
	20	1.945E-2	8.035E-3	2.094E-2	4.232E+14	1.0058	1.0004	0.9962
	30	1.945E-2	7.349E-3	1.953E-2	4.624E+14	1.0058	1.0005	0.9963
	40	1.941E-2	6.733E-3	1.820E-2	5.045E+14	1.0058	1.0005	0.9963
	50	1.935E-2	6.185E-3	1.699E-2	5.484E+14	1.0057	1.0006	0.9963
	60	1.929E-2	5.720E-3	1.593E-2	5.915E+14	1.0057	1.0006	0.9963
<i>Pin 72</i>								
S1	0	2.291E-2	1.217E-2	2.988E-2	2.790E+14	1.0038	1.0003	0.9976
	10	2.320E-2	1.095E-2	2.784E-2	3.071E+14	1.0035	1.0003	0.9977
	20	2.325E-2	9.893E-3	2.579E-2	3.367E+14	1.0033	1.0004	0.9978
	30	2.319E-2	8.986E-3	2.391E-2	3.674E+14	1.0032	1.0004	0.9979
	40	2.309E-2	8.186E-3	2.218E-2	4.002E+14	1.0031	1.0005	0.9979
	50	2.298E-2	7.493E-3	2.064E-2	4.345E+14	1.0030	1.0005	0.9980
	60	2.290E-2	6.924E-3	1.934E-2	4.682E+14	1.0030	1.0005	0.9980
S2	0	1.623E-2	7.815E-3	1.929E-2	3.182E+14	1.0037	1.0002	0.9977
	10	1.651E-2	7.057E-3	1.802E-2	3.496E+14	1.0034	1.0003	0.9978
	20	1.660E-2	6.376E-3	1.667E-2	3.834E+14	1.0032	1.0003	0.9979
	30	1.658E-2	5.781E-3	1.542E-2	4.188E+14	1.0030	1.0004	0.9980
	40	1.653E-2	5.255E-3	1.426E-2	4.565E+14	1.0029	1.0004	0.9981
	50	1.648E-2	4.802E-3	1.324E-2	4.957E+14	1.0028	1.0004	0.9981
	60	1.644E-2	4.433E-3	1.238E-2	5.343E+14	1.0028	1.0004	0.9981

Table 4.6. Cell macroscopic cross sections, flux, and flux ratios vs burnup for
Variant 12, States 1 and 2

State	Burnup (MWd/kg)	Σ_a (cm ⁻¹)	Σ_f (cm ⁻¹)	$v\Sigma_f$ (cm ⁻¹)	ϕ_{cell} (cm ⁻² ·s ⁻¹)	ϕ_{fuel}/ϕ_{cell}	ϕ_{clad}/ϕ_{cell}	ϕ_{mod}/ϕ_{cell}
<i>Pin 1</i>								
S1	0	2.638E-2	1.173E-2	3.351E-2	3.027E+14	1.0025	1.0011	0.9981
	10	2.603E-2	1.023E-2	2.926E-2	3.383E+14	1.0024	1.0011	0.9982
	20	2.554E-2	9.231E-3	2.647E-2	3.661E+14	1.0023	1.0010	0.9983
	30	2.509E-2	8.421E-3	2.420E-2	3.941E+14	1.0023	1.0010	0.9983
	40	2.471E-2	7.774E-3	2.239E-2	4.224E+14	1.0024	1.0009	0.9983
	50	2.441E-2	7.269E-3	2.097E-2	4.499E+14	1.0025	1.0009	0.9982
	60	2.418E-2	6.878E-3	1.986E-2	4.754E+14	1.0026	1.0009	0.9982
S2	0	2.511E-2	1.111E-2	3.174E-2	3.906E+14	1.0063	1.0013	0.9957
	10	2.479E-2	9.693E-3	2.773E-2	4.373E+14	1.0061	1.0013	0.9959
	20	2.431E-2	8.735E-3	2.505E-2	4.758E+14	1.0060	1.0013	0.9959
	30	2.385E-2	7.951E-3	2.285E-2	5.152E+14	1.0060	1.0013	0.9960
	40	2.345E-2	7.321E-3	2.108E-2	5.554E+14	1.0060	1.0012	0.9959
	50	2.314E-2	6.827E-3	1.969E-2	5.947E+14	1.0062	1.0012	0.9958
	60	2.288E-2	6.442E-3	1.859E-2	6.315E+14	1.0063	1.0012	0.9958
<i>Pin 29</i>								
S1	0	2.308E-2	1.006E-2	2.874E-2	2.999E+14	1.0019	1.0009	0.9986
	10	2.313E-2	9.094E-3	2.602E-2	3.354E+14	1.0021	1.0008	0.9985
	20	2.312E-2	8.490E-3	2.433E-2	3.632E+14	1.0023	1.0008	0.9984
	30	2.306E-2	7.955E-3	2.284E-2	3.912E+14	1.0025	1.0008	0.9983
	40	2.295E-2	7.465E-3	2.148E-2	4.194E+14	1.0026	1.0008	0.9982
	50	2.281E-2	7.030E-3	2.026E-2	4.468E+14	1.0027	1.0007	0.9981
	60	2.266E-2	6.660E-3	1.921E-2	4.722E+14	1.0028	1.0007	0.9981
S2	0	2.062E-2	8.785E-3	2.510E-2	3.685E+14	1.0044	1.0008	0.9971
	10	2.066E-2	7.927E-3	2.267E-2	4.129E+14	1.0045	1.0008	0.9970
	20	2.060E-2	7.363E-3	2.110E-2	4.490E+14	1.0047	1.0008	0.9969
	30	2.049E-2	6.862E-3	1.970E-2	4.858E+14	1.0049	1.0008	0.9968
	40	2.034E-2	6.406E-3	1.842E-2	5.232E+14	1.0050	1.0008	0.9967
	50	2.017E-2	6.002E-3	1.729E-2	5.596E+14	1.0052	1.0007	0.9966
	60	2.001E-2	5.664E-3	1.633E-2	5.936E+14	1.0053	1.0007	0.9965
<i>Pin 72</i>								
S1	0	2.488E-2	1.098E-2	3.137E-2	3.019E+14	1.0022	1.0009	0.9984
	10	2.475E-2	9.738E-3	2.786E-2	3.375E+14	1.0022	1.0009	0.9984
	20	2.450E-2	8.926E-3	2.559E-2	3.654E+14	1.0022	1.0008	0.9984
	30	2.423E-2	8.236E-3	2.366E-2	3.934E+14	1.0023	1.0008	0.9984
	40	2.397E-2	7.650E-3	2.202E-2	4.216E+14	1.0023	1.0008	0.9983
	50	2.373E-2	7.166E-3	2.066E-2	4.491E+14	1.0024	1.0007	0.9983
	60	2.353E-2	6.778E-3	1.956E-2	4.747E+14	1.0026	1.0007	0.9982
S2	0	1.787E-2	7.297E-3	2.084E-2	3.402E+14	1.0025	1.0006	0.9983
	10	1.782E-2	6.466E-3	1.849E-2	3.804E+14	1.0024	1.0006	0.9983
	20	1.766E-2	5.895E-3	1.689E-2	4.125E+14	1.0024	1.0006	0.9984
	30	1.747E-2	5.408E-3	1.553E-2	4.449E+14	1.0023	1.0006	0.9984
	40	1.729E-2	4.996E-3	1.437E-2	4.777E+14	1.0023	1.0006	0.9984
	50	1.712E-2	4.658E-3	1.341E-2	5.098E+14	1.0024	1.0006	0.9984
	60	1.698E-2	4.388E-3	1.265E-2	5.394E+14	1.0024	1.0005	0.9984

Table 4.7. Isotopic concentration vs burnup for Variant 1, State 1

Burnup (MWd/kg)	Concentration (atoms/b · cm, in fuel)																
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	²⁴¹ Am	^{242m} Am	²⁴³ Am	²⁴² Cm	²⁴³ Cm	²⁴⁴ Cm	¹³⁵ Xe	¹⁴⁹ Sm	Total FP
0	8.737E-4	0.0	1.874E-2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.458E-9	7.367E-8	8.313E-8
2	8.271E-4	8.912E-6	1.872E-2	1.509E-9	1.786E-5	5.448E-7	4.873E-8	4.852E-10	7.284E-11	2.278E-13	3.978E-12	1.264E-12	0.0	0.0	1.009E-8	8.031E-8	6.640E-5
4	7.832E-4	1.726E-5	1.870E-2	9.533E-9	3.424E-5	1.982E-6	3.591E-7	7.440E-9	1.115E-9	6.460E-12	1.299E-10	3.895E-11	6.427E-14	2.744E-12	1.022E-8	8.594E-8	1.326E-4
6	7.416E-4	2.513E-5	1.867E-2	2.744E-8	4.832E-5	3.942E-6	1.044E-6	3.347E-8	4.969E-9	3.988E-11	9.168E-10	2.599E-10	6.825E-13	3.094E-11	1.030E-8	9.107E-8	1.991E-4
8	7.021E-4	3.255E-5	1.865E-2	5.807E-8	6.051E-5	6.211E-6	2.103E-6	9.246E-8	1.355E-8	1.342E-10	3.496E-9	9.398E-10	3.385E-12	1.630E-10	1.034E-8	9.550E-8	2.658E-4
10	6.645E-4	3.956E-5	1.862E-2	1.041E-7	7.113E-5	8.666E-6	3.487E-6	1.967E-7	2.836E-8	3.262E-10	9.589E-9	2.445E-9	1.129E-11	5.755E-10	1.035E-8	9.931E-8	3.325E-4
12	6.286E-4	4.619E-5	1.860E-2	1.678E-7	8.042E-5	1.123E-5	5.134E-6	3.558E-7	5.039E-8	6.479E-10	2.139E-8	5.179E-9	2.935E-11	1.582E-9	1.034E-8	1.026E-7	3.993E-4
14	5.943E-4	5.245E-5	1.857E-2	2.514E-7	8.855E-5	1.386E-5	6.981E-6	5.770E-7	8.011E-8	1.123E-9	4.141E-8	9.536E-9	6.426E-11	3.664E-9	1.032E-8	1.053E-7	4.661E-4
16	5.616E-4	5.836E-5	1.854E-2	3.568E-7	9.569E-5	1.652E-5	8.972E-6	8.648E-7	1.175E-7	1.764E-9	7.236E-8	1.587E-8	1.243E-10	7.492E-9	1.028E-8	1.076E-7	5.329E-4
18	5.303E-4	6.393E-5	1.852E-2	4.858E-7	1.020E-4	1.918E-5	1.106E-5	1.222E-6	1.624E-7	2.575E-9	1.170E-7	2.448E-8	2.188E-10	1.394E-8	1.023E-8	1.095E-7	5.998E-4
20	5.004E-4	6.918E-5	1.849E-2	6.400E-7	1.075E-4	2.182E-5	1.319E-5	1.650E-6	2.141E-7	3.551E-9	1.780E-7	3.558E-8	3.578E-10	2.407E-8	1.017E-8	1.111E-7	6.666E-4
22	4.718E-4	7.412E-5	1.846E-2	8.207E-7	1.123E-4	2.443E-5	1.535E-5	2.147E-6	2.718E-7	4.681E-9	2.579E-7	4.932E-8	5.516E-10	3.915E-8	1.010E-8	1.124E-7	7.334E-4
24	4.445E-4	7.875E-5	1.843E-2	1.029E-6	1.165E-4	2.701E-5	1.750E-5	2.714E-6	3.348E-7	5.948E-9	3.591E-7	6.577E-8	8.102E-10	6.064E-8	1.002E-8	1.134E-7	8.003E-4
26	4.184E-4	8.310E-5	1.840E-2	1.266E-6	1.202E-4	2.952E-5	1.962E-5	3.347E-6	4.021E-7	7.333E-9	4.836E-7	8.492E-8	1.143E-9	9.014E-8	9.943E-9	1.142E-7	8.671E-4
28	3.935E-4	8.716E-5	1.837E-2	1.532E-6	1.235E-4	3.199E-5	2.170E-5	4.045E-6	4.727E-7	8.812E-9	6.330E-7	1.067E-7	1.558E-9	1.294E-7	9.857E-9	1.147E-7	9.340E-4
30	3.697E-4	9.094E-5	1.834E-2	1.828E-6	1.263E-4	3.438E-5	2.371E-5	4.803E-6	5.457E-7	1.036E-8	8.087E-7	1.310E-7	2.062E-9	1.803E-7	9.767E-9	1.150E-7	1.001E-3
32	3.471E-4	9.446E-5	1.831E-2	2.154E-6	1.287E-4	3.670E-5	2.565E-5	5.619E-6	6.201E-7	1.197E-8	1.012E-6	1.577E-7	2.660E-9	2.448E-7	9.673E-9	1.151E-7	1.068E-3
34	3.255E-4	9.773E-5	1.828E-2	2.510E-6	1.308E-4	3.895E-5	2.751E-5	6.488E-6	6.950E-7	1.359E-8	1.243E-6	1.866E-7	3.357E-9	3.249E-7	9.578E-9	1.151E-7	1.135E-3
36	3.050E-4	1.007E-4	1.825E-2	2.895E-6	1.327E-4	4.112E-5	2.929E-5	7.408E-6	7.698E-7	1.523E-8	1.503E-6	2.173E-7	4.153E-9	4.225E-7	9.482E-9	1.150E-7	1.201E-3
38	2.854E-4	1.035E-4	1.822E-2	3.310E-6	1.342E-4	4.321E-5	3.098E-5	8.373E-6	8.436E-7	1.685E-8	1.791E-6	2.497E-7	5.050E-9	5.399E-7	9.385E-9	1.148E-7	1.268E-3
40	2.669E-4	1.060E-4	1.819E-2	3.753E-6	1.356E-4	4.521E-5	3.258E-5	9.379E-6	9.158E-7	1.844E-8	2.107E-6	2.835E-7	6.044E-9	6.788E-7	9.289E-9	1.145E-7	1.335E-3
42	2.493E-4	1.084E-4	1.815E-2	4.223E-6	1.367E-4	4.712E-5	3.409E-5	1.042E-5	9.859E-7	1.999E-8	2.451E-6	3.184E-7	7.132E-9	8.412E-7	9.192E-9	1.141E-7	1.402E-3
44	2.326E-4	1.104E-4	1.812E-2	4.719E-6	1.377E-4	4.895E-5	3.551E-5	1.150E-5	1.053E-6	2.148E-8	2.821E-6	3.542E-7	8.308E-9	1.029E-6	9.096E-9	1.137E-7	1.469E-3
46	2.168E-4	1.123E-4	1.809E-2	5.240E-6	1.385E-4	5.070E-5	3.683E-5	1.261E-5	1.118E-6	2.291E-8	3.217E-6	3.904E-7	9.567E-9	1.244E-6	9.002E-9	1.131E-7	1.536E-3
48	2.019E-4	1.140E-4	1.805E-2	5.785E-6	1.392E-4	5.236E-5	3.807E-5	1.374E-5	1.179E-6	2.426E-8	3.637E-6	4.269E-7	1.090E-8	1.487E-6	8.909E-9	1.126E-7	1.602E-3
50	1.878E-4	1.154E-4	1.802E-2	6.350E-6	1.398E-4	5.394E-5	3.922E-5	1.489E-5	1.236E-6	2.553E-8	4.080E-6	4.635E-7	1.230E-8	1.760E-6	8.818E-9	1.120E-7	1.669E-3
52	1.745E-4	1.167E-4	1.799E-2	6.936E-6	1.403E-4	5.544E-5	4.028E-5	1.606E-5	1.290E-6	2.671E-8	4.545E-6	4.998E-7	1.376E-8	2.065E-6	8.730E-9	1.114E-7	1.736E-3
54	1.620E-4	1.178E-4	1.795E-2	7.539E-6	1.407E-4	5.686E-5	4.127E-5	1.725E-5	1.340E-6	2.781E-8	5.028E-6	5.356E-7	1.526E-8	2.402E-6	8.645E-9	1.108E-7	1.803E-3
56	1.502E-4	1.187E-4	1.792E-2	8.157E-6	1.410E-4	5.819E-5	4.219E-5	1.845E-5	1.386E-6	2.882E-8	5.530E-6	5.707E-7	1.679E-8	2.771E-6	8.563E-9	1.103E-7	1.870E-3
58	1.392E-4	1.195E-4	1.788E-2	8.789E-6	1.412E-4	5.945E-5	4.303E-5	1.965E-5	1.429E-6	2.975E-8	6.047E-6	6.049E-7	1.835E-8	3.174E-6	8.484E-9	1.097E-7	1.936E-3
60	1.288E-4	1.201E-4	1.784E-2	9.432E-6	1.414E-4	6.064E-5	4.381E-5	2.086E-5	1.467E-6	3.059E-8	6.578E-6	6.381E-7	1.992E-8	3.611E-6	8.409E-9	1.092E-7	2.003E-3

Table 4.8. Isotopic concentration vs burnup for Variant 2, State 1

Burnup (MWd/kg)	Concentration (atoms/b · cm, in fuel)																
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	²⁴¹ Am	^{242m} Am	²⁴³ Am	²⁴² Cm	²⁴³ Cm	²⁴⁴ Cm	¹³⁵ Xe	¹⁴⁹ Sm	Total FP
0	3.839E-5	0.0	1.892E-2	0.0	6.588E-4	4.232E-5	7.025E-6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.458E-9	7.367E-8	8.313E-8
2	3.703E-5	3.125E-7	1.889E-2	1.581E-9	6.255E-4	5.501E-5	1.266E-5	2.025E-7	5.941E-8	2.760E-10	4.472E-9	1.489E-9	2.446E-12	9.710E-11	1.699E-8	1.664E-7	6.787E-5
4	3.569E-5	6.180E-7	1.887E-2	8.735E-9	5.951E-4	6.649E-5	1.868E-5	5.278E-7	1.494E-7	1.196E-9	2.170E-8	6.815E-9	2.202E-11	9.192E-10	1.667E-8	1.759E-7	1.355E-4
6	3.435E-5	9.153E-7	1.884E-2	2.275E-8	5.660E-4	7.690E-5	2.483E-5	9.834E-7	2.687E-7	2.843E-9	5.743E-8	1.709E-8	8.082E-11	3.560E-9	1.634E-8	1.777E-7	2.034E-4
8	3.304E-5	1.204E-6	1.881E-2	4.475E-8	5.381E-4	8.634E-5	3.099E-5	1.573E-6	4.147E-7	5.246E-9	1.173E-7	3.319E-8	2.050E-10	9.513E-9	1.602E-8	1.787E-7	2.714E-4
10	3.174E-5	1.483E-6	1.878E-2	7.595E-8	5.115E-4	9.485E-5	3.704E-5	2.297E-6	5.843E-7	8.386E-9	2.067E-7	5.576E-8	4.232E-10	2.065E-8	1.570E-8	1.790E-7	3.393E-4
12	3.046E-5	1.753E-6	1.875E-2	1.176E-7	4.861E-4	1.025E-4	4.292E-5	3.153E-6	7.740E-7	1.221E-8	3.304E-7	8.525E-8	7.647E-10	3.920E-8	1.539E-8	1.789E-7	4.073E-4
14	2.921E-5	2.013E-6	1.872E-2	1.709E-7	4.620E-4	1.093E-4	4.855E-5	4.140E-6	9.800E-7	1.662E-8	4.924E-7	1.219E-7	1.259E-9	6.766E-8	1.509E-8	1.784E-7	4.752E-4
16	2.798E-5	2.263E-6	1.870E-2	2.371E-7	4.392E-4	1.153E-4	5.389E-5	5.252E-6	1.199E-6	2.154E-8	6.962E-7	1.656E-7	1.933E-9	1.088E-7	1.479E-8	1.776E-7	5.431E-4
18	2.677E-5	2.503E-6	1.867E-2	3.173E-7	4.176E-4	1.206E-4	5.890E-5	6.484E-6	1.426E-6	2.683E-8	9.444E-7	2.163E-7	2.810E-9	1.656E-7	1.450E-8	1.765E-7	6.110E-4
20	2.558E-5	2.732E-6	1.864E-2	4.125E-7	3.972E-4	1.252E-4	6.357E-5	7.829E-6	1.658E-6	3.239E-8	1.239E-6	2.736E-7	3.913E-9	2.410E-7	1.421E-8	1.751E-7	6.788E-4
22	2.443E-5	2.951E-6	1.861E-2	5.234E-7	3.781E-4	1.291E-4	6.786E-5	9.281E-6	1.891E-6	3.811E-8	1.580E-6	3.370E-7	5.257E-9	3.383E-7	1.393E-8	1.735E-7	7.467E-4
24	2.330E-5	3.160E-6	1.857E-2	6.508E-7	3.601E-4	1.323E-4	7.176E-5	1.083E-5	2.122E-6	4.386E-8	1.970E-6	4.060E-7	6.852E-9	4.604E-7	1.366E-8	1.718E-7	8.145E-4
26	2.219E-5	3.358E-6	1.854E-2	7.951E-7	3.433E-4	1.350E-4	7.527E-5	1.247E-5	2.349E-6	4.956E-8	2.406E-6	4.798E-7	8.706E-9	6.106E-7	1.339E-8	1.699E-7	8.822E-4
28	2.112E-5	3.546E-6	1.851E-2	9.564E-7	3.277E-4	1.371E-4	7.838E-5	1.419E-5	2.567E-6	5.512E-8	2.888E-6	5.577E-7	1.082E-8	7.916E-7	1.314E-8	1.679E-7	9.500E-4
30	2.008E-5	3.724E-6	1.848E-2	1.135E-6	3.131E-4	1.387E-4	8.111E-5	1.599E-5	2.775E-6	6.044E-8	3.415E-6	6.388E-7	1.318E-8	1.006E-6	1.289E-8	1.659E-7	1.018E-3
32	1.906E-5	3.890E-6	1.845E-2	1.330E-6	2.996E-4	1.398E-4	8.345E-5	1.785E-5	2.971E-6	6.548E-8	3.983E-6	7.223E-7	1.579E-8	1.257E-6	1.264E-8	1.638E-7	1.085E-3
34	1.808E-5	4.047E-6	1.842E-2	1.542E-6	2.871E-4	1.404E-4	8.543E-5	1.976E-5	3.153E-6	7.016E-8	4.591E-6	8.073E-7	1.863E-8	1.547E-6	1.241E-8	1.617E-7	1.153E-3
36	1.713E-5	4.193E-6	1.838E-2	1.770E-6	2.755E-4	1.407E-4	8.705E-5	2.171E-5	3.320E-6	7.444E-8	5.235E-6	8.929E-7	2.167E-8	1.878E-6	1.218E-8	1.596E-7	1.221E-3
38	1.621E-5	4.329E-6	1.835E-2	2.012E-6	2.649E-4	1.406E-4	8.833E-5	2.370E-5	3.470E-6	7.831E-8	5.912E-6	9.782E-7	2.490E-8	2.250E-6	1.197E-8	1.575E-7	1.288E-3
40	1.533E-5	4.454E-6	1.832E-2	2.269E-6	2.551E-4	1.401E-4	8.929E-5	2.571E-5	3.603E-6	8.173E-8	6.620E-6	1.062E-6	2.828E-8	2.667E-6	1.176E-8	1.555E-7	1.356E-3
42	1.447E-5	4.570E-6	1.828E-2	2.538E-6	2.461E-4	1.394E-4	8.996E-5	2.774E-5	3.719E-6	8.469E-8	7.354E-6	1.145E-6	3.179E-8	3.129E-6	1.155E-8	1.534E-7	1.424E-3
44	1.365E-5	4.675E-6	1.825E-2	2.818E-6	2.379E-4	1.384E-4	9.036E-5	2.977E-5	3.818E-6	8.720E-8	8.113E-6	1.224E-6	3.539E-8	3.636E-6	1.136E-8	1.514E-7	1.491E-3
46	1.286E-5	4.772E-6	1.821E-2	3.108E-6	2.304E-4	1.372E-4	9.050E-5	3.179E-5	3.899E-6	8.925E-8	8.891E-6	1.300E-6	3.904E-8	4.190E-6	1.118E-8	1.494E-7	1.559E-3
48	1.211E-5	4.858E-6	1.818E-2	3.407E-6	2.235E-4	1.358E-4	9.042E-5	3.380E-5	3.964E-6	9.086E-8	9.686E-6	1.373E-6	4.272E-8	4.790E-6	1.100E-8	1.475E-7	1.626E-3
50	1.139E-5	4.936E-6	1.814E-2	3.712E-6	2.172E-4	1.342E-4	9.014E-5	3.580E-5	4.012E-6	9.206E-8	1.049E-5	1.440E-6	4.639E-8	5.437E-6	1.083E-8	1.456E-7	1.694E-3
52	1.069E-5	5.004E-6	1.811E-2	4.022E-6	2.115E-4	1.325E-4	8.968E-5	3.776E-5	4.045E-6	9.285E-8	1.131E-5	1.503E-6	5.001E-8	6.130E-6	1.067E-8	1.438E-7	1.761E-3
54	1.003E-5	5.064E-6	1.807E-2	4.335E-6	2.063E-4	1.307E-4	8.907E-5	3.969E-5	4.064E-6	9.328E-8	1.213E-5	1.561E-6	5.355E-8	6.869E-6	1.051E-8	1.420E-7	1.829E-3
56	9.405E-6	5.115E-6	1.804E-2	4.649E-6	2.016E-4	1.288E-4	8.832E-5	4.159E-5	4.069E-6	9.335E-8	1.296E-5	1.613E-6	5.698E-8	7.652E-6	1.036E-8	1.404E-7	1.896E-3
58	8.807E-6	5.159E-6	1.800E-2	4.963E-6	1.973E-4	1.269E-4	8.746E-5	4.343E-5	4.062E-6	9.312E-8	1.378E-5	1.660E-6	6.028E-8	8.478E-6	1.022E-8	1.387E-7	1.963E-3
60	8.240E-6	5.194E-6	1.796E-2	5.276E-6	1.933E-4	1.249E-4	8.651E-5	4.523E-5	4.044E-6	9.260E-8	1.460E-5	1.701E-6	6.342E-8	9.345E-6	1.009E-8	1.372E-7	2.031E-3

Table 4.9. Isotopic concentration vs burnup for Variant 10, State 1

Burnup (MWd/kg)	Concentration (atoms/b · cm, in fuel)																
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	²⁴¹ Am	^{242m} Am	²⁴³ Am	²⁴² Cm	²⁴³ Cm	²⁴⁴ Cm	¹³⁵ Xe	¹⁴⁹ Sm	Total FP
0	5.000E-5	0.0	2.210E-2	3.000E-5	1.160E-3	4.900E-4	1.900E-4	1.050E-4	2.500E-5	0.0	0.0	0.0	0.0	0.0	9.458E-9	7.367E-8	8.313E-8
2	4.872E-5	3.507E-7	2.207E-2	2.963E-5	1.133E-3	4.899E-4	1.970E-4	1.050E-4	2.508E-5	1.745E-7	2.453E-6	8.667E-7	2.461E-9	7.296E-8	2.546E-8	3.799E-7	8.334E-5
4	4.747E-5	6.913E-7	2.204E-2	2.946E-5	1.108E-3	4.894E-4	2.035E-4	1.052E-4	2.521E-5	3.177E-7	4.790E-6	1.547E-6	8.898E-9	2.842E-7	2.541E-8	4.944E-7	1.666E-4
6	4.624E-5	1.021E-6	2.200E-2	2.944E-5	1.083E-3	4.887E-4	2.096E-4	1.054E-4	2.536E-5	4.351E-7	7.009E-6	2.081E-6	1.809E-8	6.210E-7	2.534E-8	5.370E-7	2.500E-4
8	4.503E-5	1.340E-6	2.197E-2	2.955E-5	1.060E-3	4.879E-4	2.153E-4	1.057E-4	2.555E-5	5.314E-7	9.117E-6	2.505E-6	2.913E-8	1.072E-6	2.526E-8	5.556E-7	3.335E-4
10	4.384E-5	1.648E-6	2.194E-2	2.975E-5	1.037E-3	4.868E-4	2.205E-4	1.061E-4	2.576E-5	6.105E-7	1.112E-5	2.844E-6	4.133E-8	1.625E-6	2.518E-8	5.655E-7	4.170E-4
12	4.268E-5	1.946E-6	2.190E-2	3.003E-5	1.015E-3	4.855E-4	2.253E-4	1.065E-4	2.598E-5	6.756E-7	1.303E-5	3.118E-6	5.418E-8	2.272E-6	2.510E-8	5.717E-7	5.005E-4
14	4.154E-5	2.233E-6	2.187E-2	3.037E-5	9.934E-4	4.841E-4	2.297E-4	1.070E-4	2.623E-5	7.295E-7	1.485E-5	3.343E-6	6.733E-8	3.004E-6	2.501E-8	5.759E-7	5.839E-4
16	4.042E-5	2.511E-6	2.183E-2	3.075E-5	9.725E-4	4.825E-4	2.337E-4	1.077E-4	2.648E-5	7.743E-7	1.659E-5	3.531E-6	8.051E-8	3.813E-6	2.492E-8	5.788E-7	6.673E-4
18	3.933E-5	2.778E-6	2.180E-2	3.117E-5	9.522E-4	4.807E-4	2.374E-4	1.083E-4	2.674E-5	8.116E-7	1.826E-5	3.691E-6	9.354E-8	4.693E-6	2.483E-8	5.807E-7	7.507E-4
20	3.825E-5	3.037E-6	2.177E-2	3.163E-5	9.324E-4	4.787E-4	2.407E-4	1.090E-4	2.700E-5	8.428E-7	1.985E-5	3.830E-6	1.063E-7	5.636E-6	2.473E-8	5.817E-7	8.341E-4
22	3.720E-5	3.285E-6	2.173E-2	3.211E-5	9.133E-4	4.766E-4	2.438E-4	1.098E-4	2.726E-5	8.690E-7	2.138E-5	3.954E-6	1.187E-7	6.637E-6	2.464E-8	5.819E-7	9.174E-4
24	3.617E-5	3.525E-6	2.170E-2	3.262E-5	8.946E-4	4.743E-4	2.465E-4	1.106E-4	2.751E-5	8.913E-7	2.285E-5	4.064E-6	1.307E-7	7.691E-6	2.454E-8	5.816E-7	1.001E-3
26	3.515E-5	3.756E-6	2.166E-2	3.314E-5	8.766E-4	4.719E-4	2.489E-4	1.115E-4	2.776E-5	9.101E-7	2.426E-5	4.166E-6	1.423E-7	8.793E-6	2.444E-8	5.808E-7	1.084E-3
28	3.416E-5	3.977E-6	2.163E-2	3.368E-5	8.590E-4	4.694E-4	2.510E-4	1.124E-4	2.800E-5	9.262E-7	2.562E-5	4.261E-6	1.534E-7	9.939E-6	2.435E-8	5.795E-7	1.167E-3
30	3.319E-5	4.190E-6	2.159E-2	3.424E-5	8.420E-4	4.667E-4	2.529E-4	1.134E-4	2.823E-5	9.400E-7	2.693E-5	4.350E-6	1.641E-7	1.112E-5	2.425E-8	5.779E-7	1.250E-3
32	3.224E-5	4.394E-6	2.156E-2	3.481E-5	8.254E-4	4.638E-4	2.545E-4	1.144E-4	2.845E-5	9.518E-7	2.819E-5	4.435E-6	1.744E-7	1.235E-5	2.415E-8	5.759E-7	1.334E-3
34	3.131E-5	4.590E-6	2.152E-2	3.539E-5	8.094E-4	4.609E-4	2.559E-4	1.154E-4	2.866E-5	9.619E-7	2.941E-5	4.516E-6	1.843E-7	1.360E-5	2.405E-8	5.736E-7	1.417E-3
36	3.039E-5	4.778E-6	2.149E-2	3.598E-5	7.938E-4	4.578E-4	2.571E-4	1.165E-4	2.884E-5	9.705E-7	3.058E-5	4.593E-6	1.937E-7	1.489E-5	2.395E-8	5.710E-7	1.500E-3
38	2.950E-5	4.958E-6	2.145E-2	3.658E-5	7.786E-4	4.546E-4	2.580E-4	1.175E-4	2.902E-5	9.778E-7	3.172E-5	4.668E-6	2.028E-7	1.620E-5	2.384E-8	5.683E-7	1.583E-3
40	2.862E-5	5.129E-6	2.141E-2	3.719E-5	7.640E-4	4.513E-4	2.588E-4	1.186E-4	2.917E-5	9.839E-7	3.283E-5	4.741E-6	2.115E-7	1.753E-5	2.374E-8	5.653E-7	1.666E-3
42	2.777E-5	5.293E-6	2.138E-2	3.780E-5	7.498E-4	4.479E-4	2.593E-4	1.197E-4	2.931E-5	9.889E-7	3.389E-5	4.810E-6	2.198E-7	1.889E-5	2.364E-8	5.622E-7	1.749E-3
44	2.693E-5	5.450E-6	2.134E-2	3.842E-5	7.360E-4	4.444E-4	2.597E-4	1.209E-4	2.943E-5	9.930E-7	3.493E-5	4.878E-6	2.278E-7	2.026E-5	2.354E-8	5.591E-7	1.832E-3
46	2.612E-5	5.598E-6	2.130E-2	3.904E-5	7.226E-4	4.408E-4	2.598E-4	1.220E-4	2.953E-5	9.961E-7	3.594E-5	4.942E-6	2.355E-7	2.165E-5	2.344E-8	5.558E-7	1.915E-3
48	2.532E-5	5.740E-6	2.127E-2	3.967E-5	7.096E-4	4.371E-4	2.598E-4	1.232E-4	2.961E-5	9.983E-7	3.691E-5	5.005E-6	2.428E-7	2.306E-5	2.333E-8	5.525E-7	1.998E-3
50	2.453E-5	5.874E-6	2.123E-2	4.030E-5	6.971E-4	4.333E-4	2.597E-4	1.243E-4	2.967E-5	9.997E-7	3.786E-5	5.065E-6	2.499E-7	2.448E-5	2.323E-8	5.490E-7	2.081E-3
52	2.377E-5	6.001E-6	2.119E-2	4.094E-5	6.849E-4	4.294E-4	2.594E-4	1.255E-4	2.971E-5	1.000E-6	3.878E-5	5.122E-6	2.567E-7	2.592E-5	2.313E-8	5.455E-7	2.164E-3
54	2.302E-5	6.121E-6	2.116E-2	4.157E-5	6.731E-4	4.255E-4	2.589E-4	1.267E-4	2.973E-5	1.000E-6	3.967E-5	5.176E-6	2.631E-7	2.736E-5	2.302E-8	5.419E-7	2.246E-3
56	2.230E-5	6.235E-6	2.112E-2	4.220E-5	6.617E-4	4.215E-4	2.584E-4	1.278E-4	2.973E-5	9.992E-7	4.054E-5	5.228E-6	2.693E-7	2.881E-5	2.292E-8	5.384E-7	2.329E-3
58	2.158E-5	6.342E-6	2.108E-2	4.283E-5	6.506E-4	4.174E-4	2.577E-4	1.290E-4	2.971E-5	9.976E-7	4.139E-5	5.276E-6	2.753E-7	3.027E-5	2.282E-8	5.348E-7	2.412E-3
60	2.089E-5	6.442E-6	2.105E-2	4.346E-5	6.399E-4	4.133E-4	2.568E-4	1.302E-4	2.967E-5	9.952E-7	4.221E-5	5.322E-6	2.809E-7	3.174E-5	2.272E-8	5.312E-7	2.495E-3

Table 4.10. Isotopic concentration in pin 1 vs burnup for Variant 11, State 1

Burnup (MWd/kg)	Concentration (atoms/b · cm, in fuel)										Total FP
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	¹³⁵ Xe	¹⁴⁹ Sm	
0	8.737E-4	0.0	1.874E-2	0.0	0.0	0.0	0.0	0.0	9.458E-9	7.367E-8	8.312E-8
2	8.241E-4	9.130E-6	1.872E-2	1.364E-9	1.699E-5	5.439E-7	4.536E-8	4.835E-10	9.716E-9	7.450E-8	7.048E-5
4	7.772E-4	1.770E-5	1.870E-2	8.656E-9	3.243E-5	2.000E-6	3.378E-7	7.546E-9	9.767E-9	7.895E-8	1.408E-4
6	7.327E-4	2.579E-5	1.868E-2	2.499E-8	4.552E-5	4.003E-6	9.889E-7	3.442E-8	9.771E-9	8.272E-8	2.115E-4
8	6.904E-4	3.341E-5	1.865E-2	5.303E-8	5.665E-5	6.334E-6	2.002E-6	9.622E-8	9.739E-9	8.584E-8	2.822E-4
10	6.500E-4	4.061E-5	1.863E-2	9.520E-8	6.615E-5	8.860E-6	3.332E-6	2.068E-7	9.681E-9	8.840E-8	3.529E-4
12	6.115E-4	4.741E-5	1.860E-2	1.538E-7	7.427E-5	1.150E-5	4.915E-6	3.776E-7	9.603E-9	9.047E-8	4.236E-4
14	5.748E-4	5.383E-5	1.858E-2	2.307E-7	8.121E-5	1.419E-5	6.687E-6	6.172E-7	9.509E-9	9.211E-8	4.942E-4
16	5.397E-4	5.988E-5	1.855E-2	3.281E-7	8.714E-5	1.690E-5	8.590E-6	9.317E-7	9.403E-9	9.338E-8	5.647E-4
18	5.062E-4	6.557E-5	1.853E-2	4.475E-7	9.220E-5	1.959E-5	1.057E-5	1.325E-6	9.286E-9	9.430E-8	6.350E-4
20	4.742E-4	7.093E-5	1.850E-2	5.906E-7	9.649E-5	2.225E-5	1.259E-5	1.799E-6	9.161E-9	9.492E-8	7.053E-4
22	4.437E-4	7.595E-5	1.847E-2	7.585E-7	1.001E-4	2.485E-5	1.461E-5	2.354E-6	9.029E-9	9.528E-8	7.755E-4
24	4.146E-4	8.065E-5	1.844E-2	9.526E-7	1.032E-4	2.740E-5	1.661E-5	2.989E-6	8.892E-9	9.540E-8	8.456E-4
26	3.869E-4	8.504E-5	1.842E-2	1.174E-6	1.057E-4	2.986E-5	1.855E-5	3.702E-6	8.750E-9	9.531E-8	9.155E-4
28	3.605E-4	8.912E-5	1.839E-2	1.422E-6	1.078E-4	3.225E-5	2.042E-5	4.491E-6	8.606E-9	9.505E-8	9.853E-4
30	3.354E-4	9.291E-5	1.836E-2	1.699E-6	1.096E-4	3.454E-5	2.221E-5	5.351E-6	8.459E-9	9.462E-8	1.055E-3
32	3.116E-4	9.641E-5	1.833E-2	2.003E-6	1.109E-4	3.674E-5	2.391E-5	6.279E-6	8.311E-9	9.406E-8	1.125E-3
34	2.890E-4	9.964E-5	1.830E-2	2.336E-6	1.121E-4	3.884E-5	2.550E-5	7.271E-6	8.164E-9	9.339E-8	1.194E-3
36	2.676E-4	1.026E-4	1.827E-2	2.696E-6	1.129E-4	4.084E-5	2.700E-5	8.322E-6	8.016E-9	9.262E-8	1.263E-3
38	2.474E-4	1.053E-4	1.824E-2	3.083E-6	1.136E-4	4.274E-5	2.839E-5	9.427E-6	7.870E-9	9.177E-8	1.333E-3
40	2.283E-4	1.077E-4	1.821E-2	3.496E-6	1.140E-4	4.453E-5	2.967E-5	1.058E-5	7.726E-9	9.086E-8	1.402E-3
42	2.103E-4	1.099E-4	1.818E-2	3.934E-6	1.144E-4	4.622E-5	3.084E-5	1.178E-5	7.585E-9	8.990E-8	1.471E-3
44	1.933E-4	1.118E-4	1.814E-2	4.394E-6	1.145E-4	4.781E-5	3.192E-5	1.302E-5	7.446E-9	8.891E-8	1.540E-3
46	1.774E-4	1.135E-4	1.811E-2	4.876E-6	1.146E-4	4.930E-5	3.289E-5	1.429E-5	7.312E-9	8.790E-8	1.609E-3
48	1.625E-4	1.150E-4	1.808E-2	5.377E-6	1.146E-4	5.069E-5	3.377E-5	1.559E-5	7.182E-9	8.689E-8	1.678E-3
50	1.486E-4	1.163E-4	1.804E-2	5.896E-6	1.145E-4	5.198E-5	3.456E-5	1.691E-5	7.057E-9	8.587E-8	1.746E-3
52	1.356E-4	1.173E-4	1.801E-2	6.429E-6	1.143E-4	5.317E-5	3.527E-5	1.825E-5	6.936E-9	8.486E-8	1.815E-3
54	1.236E-4	1.182E-4	1.797E-2	6.974E-6	1.141E-4	5.428E-5	3.590E-5	1.961E-5	6.821E-9	8.388E-8	1.884E-3
56	1.124E-4	1.188E-4	1.794E-2	7.530E-6	1.139E-4	5.530E-5	3.645E-5	2.098E-5	6.712E-9	8.292E-8	1.952E-3
58	1.020E-4	1.193E-4	1.790E-2	8.093E-6	1.136E-4	5.624E-5	3.694E-5	2.235E-5	6.609E-9	8.200E-8	2.021E-3
60	9.241E-5	1.196E-4	1.786E-2	8.660E-6	1.133E-4	5.710E-5	3.736E-5	2.372E-5	6.512E-9	8.111E-8	2.090E-3

Table 4.11. Isotopic concentration in pin 29 vs burnup for Variant 11, State 1

Burnup (MWd/kg)	Concentration (atoms/b · cm, in fuel)										
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	¹³⁵ Xe	¹⁴⁹ Sm	Total FP
0	8.737E-4	0.0	1.874E-2	0.0	0.0	0.0	0.0	0.0	9.458E-9	7.367E-8	8.312E-8
2	8.287E-4	8.398E-6	1.872E-2	1.261E-9	1.583E-5	4.663E-7	3.760E-8	3.625E-10	9.676E-9	7.658E-8	6.391E-5
4	7.861E-4	1.632E-5	1.870E-2	7.882E-9	3.045E-5	1.724E-6	2.821E-7	5.676E-9	9.745E-9	8.128E-8	1.277E-4
6	7.455E-4	2.383E-5	1.868E-2	2.252E-8	4.306E-5	3.470E-6	8.316E-7	2.599E-8	9.774E-9	8.517E-8	1.919E-4
8	7.067E-4	3.095E-5	1.866E-2	4.744E-8	5.397E-5	5.523E-6	1.695E-6	7.289E-8	9.771E-9	8.844E-8	2.562E-4
10	6.695E-4	3.772E-5	1.863E-2	8.473E-8	6.346E-5	7.773E-6	2.839E-6	1.572E-7	9.744E-9	9.116E-8	3.207E-4
12	6.339E-4	4.415E-5	1.861E-2	1.363E-7	7.172E-5	1.015E-5	4.216E-6	2.881E-7	9.698E-9	9.342E-8	3.852E-4
14	5.997E-4	5.026E-5	1.859E-2	2.041E-7	7.892E-5	1.260E-5	5.774E-6	4.728E-7	9.637E-9	9.525E-8	4.498E-4
16	5.668E-4	5.606E-5	1.857E-2	2.896E-7	8.520E-5	1.511E-5	7.467E-6	7.165E-7	9.563E-9	9.671E-8	5.145E-4
18	5.353E-4	6.157E-5	1.854E-2	3.946E-7	9.066E-5	1.763E-5	9.252E-6	1.023E-6	9.478E-9	9.783E-8	5.792E-4
20	5.050E-4	6.678E-5	1.852E-2	5.203E-7	9.540E-5	2.015E-5	1.109E-5	1.395E-6	9.384E-9	9.865E-8	6.440E-4
22	4.759E-4	7.172E-5	1.849E-2	6.682E-7	9.950E-5	2.266E-5	1.296E-5	1.833E-6	9.283E-9	9.919E-8	7.089E-4
24	4.480E-4	7.638E-5	1.846E-2	8.393E-7	1.030E-4	2.514E-5	1.482E-5	2.338E-6	9.174E-9	9.952E-8	7.738E-4
26	4.212E-4	8.077E-5	1.844E-2	1.035E-6	1.061E-4	2.758E-5	1.667E-5	2.909E-6	9.060E-9	9.962E-8	8.389E-4
28	3.955E-4	8.491E-5	1.841E-2	1.255E-6	1.086E-4	2.998E-5	1.847E-5	3.544E-6	8.940E-9	9.953E-8	9.039E-4
30	3.709E-4	8.879E-5	1.838E-2	1.501E-6	1.108E-4	3.232E-5	2.023E-5	4.243E-6	8.817E-9	9.927E-8	9.691E-4
32	3.474E-4	9.242E-5	1.836E-2	1.773E-6	1.126E-4	3.459E-5	2.191E-5	5.002E-6	8.691E-9	9.886E-8	1.034E-3
34	3.249E-4	9.581E-5	1.833E-2	2.071E-6	1.141E-4	3.680E-5	2.353E-5	5.820E-6	8.562E-9	9.833E-8	1.100E-3
36	3.034E-4	9.896E-5	1.830E-2	2.395E-6	1.154E-4	3.893E-5	2.506E-5	6.693E-6	8.432E-9	9.769E-8	1.165E-3
38	2.829E-4	1.019E-4	1.827E-2	2.745E-6	1.163E-4	4.099E-5	2.651E-5	7.618E-6	8.300E-9	9.695E-8	1.230E-3
40	2.633E-4	1.046E-4	1.824E-2	3.120E-6	1.171E-4	4.296E-5	2.788E-5	8.592E-6	8.168E-9	9.614E-8	1.296E-3
42	2.448E-4	1.070E-4	1.821E-2	3.519E-6	1.177E-4	4.486E-5	2.915E-5	9.612E-6	8.037E-9	9.526E-8	1.361E-3
44	2.271E-4	1.093E-4	1.818E-2	3.942E-6	1.181E-4	4.666E-5	3.034E-5	1.067E-5	7.906E-9	9.434E-8	1.427E-3
46	2.104E-4	1.113E-4	1.815E-2	4.388E-6	1.183E-4	4.838E-5	3.144E-5	1.177E-5	7.777E-9	9.337E-8	1.492E-3
48	1.946E-4	1.131E-4	1.812E-2	4.854E-6	1.185E-4	5.001E-5	3.245E-5	1.291E-5	7.650E-9	9.239E-8	1.558E-3
50	1.797E-4	1.147E-4	1.809E-2	5.340E-6	1.185E-4	5.155E-5	3.337E-5	1.407E-5	7.525E-9	9.138E-8	1.624E-3
52	1.656E-4	1.161E-4	1.806E-2	5.843E-6	1.185E-4	5.301E-5	3.422E-5	1.526E-5	7.404E-9	9.038E-8	1.689E-3
54	1.524E-4	1.173E-4	1.802E-2	6.362E-6	1.183E-4	5.438E-5	3.499E-5	1.647E-5	7.286E-9	8.938E-8	1.755E-3
56	1.400E-4	1.184E-4	1.799E-2	6.894E-6	1.181E-4	5.566E-5	3.568E-5	1.770E-5	7.172E-9	8.840E-8	1.821E-3
58	1.284E-4	1.192E-4	1.796E-2	7.437E-6	1.179E-4	5.685E-5	3.630E-5	1.895E-5	7.063E-9	8.744E-8	1.886E-3
60	1.176E-4	1.199E-4	1.792E-2	7.989E-6	1.176E-4	5.796E-5	3.686E-5	2.021E-5	6.958E-9	8.650E-8	1.952E-3

Table 4.12. Isotopic concentration in pin 72 vs burnup for Variant 11, State 1

Burnup (MWd/kg)	Concentration (atoms/b · cm, in fuel)										Total FP
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	¹³⁵ Xe	¹⁴⁹ Sm	
0	8.737E-4	0.0	1.874E-2	0.0	0.0	0.0	0.0	0.0	9.458E-9	7.367E-8	8.312E-8
2	8.259E-4	8.833E-6	1.872E-2	1.318E-9	1.646E-5	5.108E-7	4.201E-8	4.307E-10	9.697E-9	7.519E-8	6.784E-5
4	7.808E-4	1.714E-5	1.870E-2	8.317E-9	3.154E-5	1.881E-6	3.136E-7	6.726E-9	9.754E-9	7.969E-8	1.355E-4
6	7.378E-4	2.499E-5	1.868E-2	2.391E-8	4.439E-5	3.776E-6	9.201E-7	3.071E-8	9.766E-9	8.348E-8	2.036E-4
8	6.969E-4	3.242E-5	1.865E-2	5.059E-8	5.540E-5	5.989E-6	1.867E-6	8.594E-8	9.744E-9	8.663E-8	2.717E-4
10	6.578E-4	3.945E-5	1.863E-2	9.064E-8	6.486E-5	8.399E-6	3.114E-6	1.849E-7	9.697E-9	8.923E-8	3.399E-4
12	6.204E-4	4.610E-5	1.861E-2	1.462E-7	7.302E-5	1.093E-5	4.604E-6	3.381E-7	9.630E-9	9.134E-8	4.080E-4
14	5.847E-4	5.240E-5	1.858E-2	2.192E-7	8.004E-5	1.353E-5	6.281E-6	5.534E-7	9.547E-9	9.303E-8	4.762E-4
16	5.504E-4	5.835E-5	1.856E-2	3.114E-7	8.609E-5	1.615E-5	8.089E-6	8.367E-7	9.452E-9	9.434E-8	5.443E-4
18	5.177E-4	6.398E-5	1.853E-2	4.245E-7	9.129E-5	1.878E-5	9.982E-6	1.192E-6	9.347E-9	9.531E-8	6.124E-4
20	4.863E-4	6.928E-5	1.851E-2	5.601E-7	9.573E-5	2.139E-5	1.192E-5	1.621E-6	9.232E-9	9.599E-8	6.805E-4
22	4.563E-4	7.428E-5	1.848E-2	7.193E-7	9.953E-5	2.397E-5	1.387E-5	2.125E-6	9.110E-9	9.639E-8	7.485E-4
24	4.276E-4	7.897E-5	1.845E-2	9.035E-7	1.028E-4	2.650E-5	1.580E-5	2.703E-6	8.982E-9	9.656E-8	8.165E-4
26	4.002E-4	8.337E-5	1.843E-2	1.113E-6	1.055E-4	2.897E-5	1.770E-5	3.355E-6	8.850E-9	9.652E-8	8.845E-4
28	3.741E-4	8.749E-5	1.840E-2	1.350E-6	1.077E-4	3.137E-5	1.953E-5	4.078E-6	8.713E-9	9.629E-8	9.524E-4
30	3.491E-4	9.133E-5	1.837E-2	1.613E-6	1.096E-4	3.369E-5	2.130E-5	4.869E-6	8.573E-9	9.590E-8	1.020E-3
32	3.253E-4	9.489E-5	1.834E-2	1.903E-6	1.112E-4	3.593E-5	2.299E-5	5.725E-6	8.432E-9	9.538E-8	1.088E-3
34	3.027E-4	9.819E-5	1.831E-2	2.221E-6	1.124E-4	3.809E-5	2.459E-5	6.643E-6	8.289E-9	9.473E-8	1.156E-3
36	2.812E-4	1.012E-4	1.828E-2	2.565E-6	1.134E-4	4.015E-5	2.609E-5	7.619E-6	8.146E-9	9.398E-8	1.224E-3
38	2.608E-4	1.040E-4	1.825E-2	2.936E-6	1.141E-4	4.213E-5	2.750E-5	8.649E-6	8.003E-9	9.315E-8	1.291E-3
40	2.414E-4	1.066E-4	1.822E-2	3.332E-6	1.146E-4	4.400E-5	2.881E-5	9.728E-6	7.861E-9	9.226E-8	1.359E-3
42	2.231E-4	1.089E-4	1.819E-2	3.753E-6	1.150E-4	4.579E-5	3.001E-5	1.085E-5	7.721E-9	9.130E-8	1.427E-3
44	2.059E-4	1.109E-4	1.816E-2	4.197E-6	1.152E-4	4.747E-5	3.112E-5	1.202E-5	7.584E-9	9.031E-8	1.494E-3
46	1.896E-4	1.128E-4	1.813E-2	4.663E-6	1.154E-4	4.906E-5	3.214E-5	1.322E-5	7.449E-9	8.930E-8	1.562E-3
48	1.743E-4	1.144E-4	1.810E-2	5.148E-6	1.154E-4	5.055E-5	3.306E-5	1.445E-5	7.318E-9	8.827E-8	1.629E-3
50	1.599E-4	1.158E-4	1.806E-2	5.652E-6	1.153E-4	5.195E-5	3.390E-5	1.571E-5	7.190E-9	8.724E-8	1.697E-3
52	1.465E-4	1.170E-4	1.803E-2	6.171E-6	1.151E-4	5.325E-5	3.465E-5	1.700E-5	7.068E-9	8.621E-8	1.764E-3
54	1.339E-4	1.180E-4	1.800E-2	6.704E-6	1.149E-4	5.446E-5	3.533E-5	1.830E-5	6.949E-9	8.520E-8	1.832E-3
56	1.222E-4	1.188E-4	1.796E-2	7.248E-6	1.147E-4	5.559E-5	3.593E-5	1.961E-5	6.837E-9	8.422E-8	1.899E-3
58	1.114E-4	1.194E-4	1.793E-2	7.800E-6	1.144E-4	5.663E-5	3.646E-5	2.094E-5	6.729E-9	8.326E-8	1.967E-3
60	1.013E-4	1.199E-4	1.789E-2	8.359E-6	1.141E-4	5.758E-5	3.693E-5	2.227E-5	6.628E-9	8.235E-8	2.034E-3

Table 4.13. Isotopic concentration in pin 1 vs burnup for Variant 12, State 1

Burnup (MWd/kg)	Concentration (atoms/b · cm, in fuel)										
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	¹³⁵ Xe	¹⁴⁹ Sm	Total FP
0	3.839E-5	0.0	1.892E-2	0.0	6.588E-4	4.232E-5	7.025E-6	0.0	9.458E-9	7.367E-8	8.312E-8
2	3.693E-5	3.132E-7	1.889E-2	1.425E-9	6.180E-4	5.708E-5	1.262E-5	2.268E-7	1.660E-8	1.491E-7	7.495E-5
4	3.549E-5	6.204E-7	1.887E-2	7.903E-9	5.803E-4	7.035E-5	1.866E-5	5.964E-7	1.611E-8	1.541E-7	1.494E-4
6	3.405E-5	9.207E-7	1.884E-2	2.070E-8	5.443E-4	8.227E-5	2.487E-5	1.122E-6	1.562E-8	1.535E-7	2.237E-4
8	3.262E-5	1.213E-6	1.882E-2	4.097E-8	5.101E-4	9.294E-5	3.109E-5	1.812E-6	1.513E-8	1.525E-7	2.978E-4
10	3.121E-5	1.498E-6	1.879E-2	6.998E-8	4.776E-4	1.024E-4	3.718E-5	2.670E-6	1.467E-8	1.511E-7	3.716E-4
12	2.982E-5	1.774E-6	1.876E-2	1.091E-7	4.469E-4	1.108E-4	4.304E-5	3.700E-6	1.421E-8	1.494E-7	4.449E-4
14	2.845E-5	2.042E-6	1.874E-2	1.595E-7	4.179E-4	1.181E-4	4.859E-5	4.900E-6	1.376E-8	1.474E-7	5.180E-4
16	2.710E-5	2.301E-6	1.871E-2	2.227E-7	3.907E-4	1.243E-4	5.378E-5	6.270E-6	1.333E-8	1.452E-7	5.906E-4
18	2.577E-5	2.550E-6	1.868E-2	2.996E-7	3.654E-4	1.296E-4	5.856E-5	7.805E-6	1.291E-8	1.428E-7	6.630E-4
20	2.447E-5	2.790E-6	1.865E-2	3.915E-7	3.417E-4	1.339E-4	6.289E-5	9.499E-6	1.250E-8	1.403E-7	7.349E-4
22	2.320E-5	3.020E-6	1.862E-2	4.990E-7	3.198E-4	1.373E-4	6.675E-5	1.135E-5	1.211E-8	1.377E-7	8.066E-4
24	2.195E-5	3.240E-6	1.859E-2	6.228E-7	2.996E-4	1.399E-4	7.013E-5	1.334E-5	1.174E-8	1.351E-7	8.780E-4
26	2.074E-5	3.449E-6	1.856E-2	7.632E-7	2.810E-4	1.417E-4	7.302E-5	1.546E-5	1.137E-8	1.324E-7	9.491E-4
28	1.956E-5	3.648E-6	1.853E-2	9.203E-7	2.640E-4	1.428E-4	7.543E-5	1.770E-5	1.103E-8	1.297E-7	1.020E-3
30	1.841E-5	3.837E-6	1.850E-2	1.094E-6	2.485E-4	1.432E-4	7.737E-5	2.006E-5	1.070E-8	1.270E-7	1.091E-3
32	1.730E-5	4.014E-6	1.847E-2	1.283E-6	2.344E-4	1.430E-4	7.884E-5	2.250E-5	1.039E-8	1.244E-7	1.161E-3
34	1.623E-5	4.181E-6	1.844E-2	1.488E-6	2.217E-4	1.422E-4	7.989E-5	2.503E-5	1.009E-8	1.218E-7	1.231E-3
36	1.519E-5	4.337E-6	1.840E-2	1.706E-6	2.102E-4	1.410E-4	8.052E-5	2.762E-5	9.807E-9	1.193E-7	1.301E-3
38	1.420E-5	4.482E-6	1.837E-2	1.937E-6	1.999E-4	1.394E-4	8.079E-5	3.026E-5	9.540E-9	1.168E-7	1.371E-3
40	1.324E-5	4.616E-6	1.834E-2	2.179E-6	1.907E-4	1.374E-4	8.072E-5	3.293E-5	9.288E-9	1.144E-7	1.440E-3
42	1.232E-5	4.738E-6	1.830E-2	2.430E-6	1.825E-4	1.351E-4	8.033E-5	3.562E-5	9.050E-9	1.121E-7	1.510E-3
44	1.145E-5	4.851E-6	1.827E-2	2.688E-6	1.751E-4	1.326E-4	7.968E-5	3.832E-5	8.826E-9	1.098E-7	1.579E-3
46	1.062E-5	4.952E-6	1.824E-2	2.951E-6	1.686E-4	1.299E-4	7.880E-5	4.100E-5	8.614E-9	1.077E-7	1.649E-3
48	9.830E-6	5.043E-6	1.820E-2	3.217E-6	1.628E-4	1.270E-4	7.771E-5	4.365E-5	8.415E-9	1.056E-7	1.718E-3
50	9.082E-6	5.124E-6	1.817E-2	3.484E-6	1.577E-4	1.241E-4	7.647E-5	4.627E-5	8.228E-9	1.037E-7	1.787E-3
52	8.376E-6	5.194E-6	1.813E-2	3.749E-6	1.531E-4	1.210E-4	7.509E-5	4.884E-5	8.051E-9	1.018E-7	1.857E-3
54	7.710E-6	5.255E-6	1.809E-2	4.010E-6	1.491E-4	1.180E-4	7.362E-5	5.135E-5	7.885E-9	9.997E-8	1.926E-3
56	7.085E-6	5.307E-6	1.806E-2	4.266E-6	1.455E-4	1.150E-4	7.207E-5	5.379E-5	7.728E-9	9.825E-8	1.995E-3
58	6.499E-6	5.349E-6	1.802E-2	4.515E-6	1.422E-4	1.120E-4	7.047E-5	5.616E-5	7.581E-9	9.661E-8	2.064E-3
60	5.950E-6	5.383E-6	1.798E-2	4.754E-6	1.394E-4	1.091E-4	6.885E-5	5.845E-5	7.443E-9	9.507E-8	2.133E-3

Table 4.14. Isotopic concentration in pin 29 vs burnup for Variant 12, State 1

Burnup (MWd/kg)	Concentration (atoms/b · cm, in fuel)										Total FP
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	¹³⁵ Xe	¹⁴⁹ Sm	
0	3.839E-5	0.0	1.892E-2	0.0	6.588E-4	4.232E-5	7.025E-6	0.0	9.458E-9	7.367E-8	8.312E-8
2	3.712E-5	2.842E-7	1.889E-2	1.312E-9	6.259E-4	5.456E-5	1.196E-5	1.861E-7	1.593E-8	1.521E-7	6.395E-5
4	3.585E-5	5.640E-7	1.887E-2	7.258E-9	5.954E-4	6.581E-5	1.724E-5	4.772E-7	1.562E-8	1.630E-7	1.279E-4
6	3.458E-5	8.385E-7	1.885E-2	1.894E-8	5.659E-4	7.616E-5	2.266E-5	8.820E-7	1.531E-8	1.635E-7	1.923E-4
8	3.333E-5	1.107E-6	1.882E-2	3.734E-8	5.373E-4	8.567E-5	2.812E-5	1.406E-6	1.499E-8	1.631E-7	2.569E-4
10	3.208E-5	1.370E-6	1.880E-2	6.350E-8	5.098E-4	9.438E-5	3.353E-5	2.054E-6	1.468E-8	1.623E-7	3.216E-4
12	3.084E-5	1.626E-6	1.877E-2	9.854E-8	4.833E-4	1.023E-4	3.880E-5	2.829E-6	1.436E-8	1.611E-7	3.865E-4
14	2.961E-5	1.876E-6	1.875E-2	1.436E-7	4.579E-4	1.095E-4	4.390E-5	3.732E-6	1.404E-8	1.595E-7	4.516E-4
16	2.840E-5	2.118E-6	1.872E-2	1.997E-7	4.335E-4	1.160E-4	4.877E-5	4.764E-6	1.373E-8	1.577E-7	5.168E-4
18	2.720E-5	2.354E-6	1.869E-2	2.680E-7	4.103E-4	1.218E-4	5.336E-5	5.925E-6	1.341E-8	1.557E-7	5.821E-4
20	2.602E-5	2.582E-6	1.867E-2	3.494E-7	3.881E-4	1.268E-4	5.765E-5	7.213E-6	1.310E-8	1.534E-7	6.476E-4
22	2.485E-5	2.802E-6	1.864E-2	4.447E-7	3.671E-4	1.312E-4	6.161E-5	8.627E-6	1.279E-8	1.511E-7	7.131E-4
24	2.370E-5	3.015E-6	1.861E-2	5.547E-7	3.472E-4	1.350E-4	6.522E-5	1.016E-5	1.249E-8	1.485E-7	7.788E-4
26	2.257E-5	3.219E-6	1.859E-2	6.798E-7	3.284E-4	1.381E-4	6.846E-5	1.182E-5	1.219E-8	1.459E-7	8.446E-4
28	2.147E-5	3.416E-6	1.856E-2	8.204E-7	3.108E-4	1.407E-4	7.134E-5	1.358E-5	1.189E-8	1.433E-7	9.106E-4
30	2.038E-5	3.604E-6	1.853E-2	9.766E-7	2.942E-4	1.427E-4	7.383E-5	1.546E-5	1.160E-8	1.406E-7	9.766E-4
32	1.932E-5	3.783E-6	1.850E-2	1.148E-6	2.788E-4	1.441E-4	7.595E-5	1.743E-5	1.131E-8	1.379E-7	1.043E-3
34	1.829E-5	3.954E-6	1.847E-2	1.335E-6	2.644E-4	1.450E-4	7.771E-5	1.950E-5	1.103E-8	1.351E-7	1.109E-3
36	1.728E-5	4.116E-6	1.844E-2	1.537E-6	2.510E-4	1.454E-4	7.910E-5	2.165E-5	1.076E-8	1.324E-7	1.175E-3
38	1.630E-5	4.268E-6	1.841E-2	1.752E-6	2.387E-4	1.454E-4	8.014E-5	2.387E-5	1.049E-8	1.298E-7	1.241E-3
40	1.535E-5	4.412E-6	1.838E-2	1.980E-6	2.274E-4	1.449E-4	8.085E-5	2.616E-5	1.024E-8	1.271E-7	1.308E-3
42	1.443E-5	4.546E-6	1.835E-2	2.220E-6	2.170E-4	1.441E-4	8.124E-5	2.849E-5	9.991E-9	1.246E-7	1.374E-3
44	1.355E-5	4.672E-6	1.832E-2	2.470E-6	2.074E-4	1.429E-4	8.135E-5	3.087E-5	9.752E-9	1.221E-7	1.440E-3
46	1.269E-5	4.788E-6	1.828E-2	2.728E-6	1.987E-4	1.414E-4	8.120E-5	3.328E-5	9.523E-9	1.196E-7	1.507E-3
48	1.187E-5	4.894E-6	1.825E-2	2.994E-6	1.908E-4	1.397E-4	8.080E-5	3.570E-5	9.304E-9	1.173E-7	1.573E-3
50	1.109E-5	4.992E-6	1.822E-2	3.264E-6	1.837E-4	1.377E-4	8.019E-5	3.813E-5	9.094E-9	1.150E-7	1.640E-3
52	1.033E-5	5.080E-6	1.818E-2	3.538E-6	1.772E-4	1.356E-4	7.939E-5	4.055E-5	8.894E-9	1.128E-7	1.706E-3
54	9.616E-6	5.159E-6	1.815E-2	3.813E-6	1.713E-4	1.333E-4	7.843E-5	4.296E-5	8.703E-9	1.107E-7	1.773E-3
56	8.934E-6	5.230E-6	1.812E-2	4.087E-6	1.660E-4	1.308E-4	7.733E-5	4.535E-5	8.522E-9	1.087E-7	1.839E-3
58	8.286E-6	5.292E-6	1.808E-2	4.358E-6	1.612E-4	1.283E-4	7.612E-5	4.770E-5	8.350E-9	1.068E-7	1.906E-3
60	7.672E-6	5.345E-6	1.805E-2	4.625E-6	1.569E-4	1.257E-4	7.483E-5	5.000E-5	8.187E-9	1.049E-7	1.972E-3

Table 4.15. Isotopic concentrations in pin 72 vs burnup for Variant 12, State 1

Burnup (MWd/kg)	Concentration (atoms/b · cm, in fuel)										
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	¹³⁵ Xe	¹⁴⁹ Sm	Total FP
0	8.737E-4	0.0	1.874E-2	0.0	0.0	0.0	0.0	0.0	9.458E-9	7.367E-8	8.312E-8
2	8.259E-4	8.833E-6	1.872E-2	1.318E-9	1.646E-5	5.108E-7	4.201E-8	4.307E-10	9.697E-9	7.519E-8	6.784E-5
4	7.808E-4	1.714E-5	1.870E-2	8.317E-9	3.154E-5	1.881E-6	3.136E-7	6.726E-9	9.754E-9	7.969E-8	1.355E-4
6	7.378E-4	2.499E-5	1.868E-2	2.391E-8	4.439E-5	3.776E-6	9.201E-7	3.071E-8	9.766E-9	8.348E-8	2.036E-4
8	6.969E-4	3.242E-5	1.865E-2	5.059E-8	5.540E-5	5.989E-6	1.867E-6	8.594E-8	9.744E-9	8.663E-8	2.717E-4
10	6.578E-4	3.945E-5	1.863E-2	9.064E-8	6.486E-5	8.399E-6	3.114E-6	1.849E-7	9.697E-9	8.923E-8	3.399E-4
12	6.204E-4	4.610E-5	1.861E-2	1.462E-7	7.302E-5	1.093E-5	4.604E-6	3.381E-7	9.630E-9	9.134E-8	4.080E-4
14	5.847E-4	5.240E-5	1.858E-2	2.192E-7	8.004E-5	1.353E-5	6.281E-6	5.534E-7	9.547E-9	9.303E-8	4.762E-4
16	5.504E-4	5.835E-5	1.856E-2	3.114E-7	8.609E-5	1.615E-5	8.089E-6	8.367E-7	9.452E-9	9.434E-8	5.443E-4
18	5.177E-4	6.398E-5	1.853E-2	4.245E-7	9.129E-5	1.878E-5	9.982E-6	1.192E-6	9.347E-9	9.531E-8	6.124E-4
20	4.863E-4	6.928E-5	1.851E-2	5.601E-7	9.573E-5	2.139E-5	1.192E-5	1.621E-6	9.232E-9	9.599E-8	6.805E-4
22	4.563E-4	7.428E-5	1.848E-2	7.193E-7	9.953E-5	2.397E-5	1.387E-5	2.125E-6	9.110E-9	9.639E-8	7.485E-4
24	4.276E-4	7.897E-5	1.845E-2	9.035E-7	1.028E-4	2.650E-5	1.580E-5	2.703E-6	8.982E-9	9.656E-8	8.165E-4
26	4.002E-4	8.337E-5	1.843E-2	1.113E-6	1.055E-4	2.897E-5	1.770E-5	3.355E-6	8.850E-9	9.652E-8	8.845E-4
28	3.741E-4	8.749E-5	1.840E-2	1.350E-6	1.077E-4	3.137E-5	1.953E-5	4.078E-6	8.713E-9	9.629E-8	9.524E-4
30	3.491E-4	9.133E-5	1.837E-2	1.613E-6	1.096E-4	3.369E-5	2.130E-5	4.869E-6	8.573E-9	9.590E-8	1.020E-3
32	3.253E-4	9.489E-5	1.834E-2	1.903E-6	1.112E-4	3.593E-5	2.299E-5	5.725E-6	8.432E-9	9.538E-8	1.088E-3
34	3.027E-4	9.819E-5	1.831E-2	2.221E-6	1.124E-4	3.809E-5	2.459E-5	6.643E-6	8.289E-9	9.473E-8	1.156E-3
36	2.812E-4	1.012E-4	1.828E-2	2.565E-6	1.134E-4	4.015E-5	2.609E-5	7.619E-6	8.146E-9	9.398E-8	1.224E-3
38	2.608E-4	1.040E-4	1.825E-2	2.936E-6	1.141E-4	4.213E-5	2.750E-5	8.649E-6	8.003E-9	9.315E-8	1.291E-3
40	2.414E-4	1.066E-4	1.822E-2	3.332E-6	1.146E-4	4.400E-5	2.881E-5	9.728E-6	7.861E-9	9.226E-8	1.359E-3
42	2.231E-4	1.089E-4	1.819E-2	3.753E-6	1.150E-4	4.579E-5	3.001E-5	1.085E-5	7.721E-9	9.130E-8	1.427E-3
44	2.059E-4	1.109E-4	1.816E-2	4.197E-6	1.152E-4	4.747E-5	3.112E-5	1.202E-5	7.584E-9	9.031E-8	1.494E-3
46	1.896E-4	1.128E-4	1.813E-2	4.663E-6	1.154E-4	4.906E-5	3.214E-5	1.322E-5	7.449E-9	8.930E-8	1.562E-3
48	1.743E-4	1.144E-4	1.810E-2	5.148E-6	1.154E-4	5.055E-5	3.306E-5	1.445E-5	7.318E-9	8.827E-8	1.629E-3
50	1.599E-4	1.158E-4	1.806E-2	5.652E-6	1.153E-4	5.195E-5	3.390E-5	1.571E-5	7.190E-9	8.724E-8	1.697E-3
52	1.465E-4	1.170E-4	1.803E-2	6.171E-6	1.151E-4	5.325E-5	3.465E-5	1.700E-5	7.068E-9	8.621E-8	1.764E-3
54	1.339E-4	1.180E-4	1.800E-2	6.704E-6	1.149E-4	5.446E-5	3.533E-5	1.830E-5	6.949E-9	8.520E-8	1.832E-3
56	1.222E-4	1.188E-4	1.796E-2	7.248E-6	1.147E-4	5.559E-5	3.593E-5	1.961E-5	6.837E-9	8.422E-8	1.899E-3
58	1.114E-4	1.194E-4	1.793E-2	7.800E-6	1.144E-4	5.663E-5	3.646E-5	2.094E-5	6.729E-9	8.326E-8	1.967E-3
60	1.013E-4	1.199E-4	1.789E-2	8.359E-6	1.141E-4	5.758E-5	3.693E-5	2.227E-5	6.628E-9	8.235E-8	2.034E-3

**Table 4.16. Cell relative absorption reaction rates vs burnup
for Variants 1–4 and 7–10, State 1**

Burnup (MWd/kg)	Relative absorption rate										Total FP
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	¹³⁵ Xe	¹⁴⁹ Sm	
Variant 1											
0	6.019E-1	0.0	2.917E-1	0.0	0.0	0.0	0.0	0.0	2.169E-2	5.352E-3	2.704E-2
10	4.118E-1	4.703E-3	2.851E-1	4.112E-5	1.426E-1	2.356E-2	6.192E-3	1.043E-4	2.088E-2	6.323E-3	5.238E-2
20	2.982E-1	7.544E-3	2.823E-1	2.442E-4	1.986E-1	4.499E-2	2.205E-2	8.569E-4	1.962E-2	6.742E-3	7.268E-2
30	2.183E-1	9.382E-3	2.807E-1	6.937E-4	2.253E-1	5.902E-2	3.875E-2	2.402E-3	1.872E-2	6.898E-3	9.125E-2
40	1.580E-1	1.058E-2	2.794E-1	1.433E-3	2.386E-1	6.873E-2	5.297E-2	4.459E-3	1.796E-2	6.906E-3	1.084E-1
50	1.120E-1	1.126E-2	2.780E-1	2.448E-3	2.449E-1	7.541E-2	6.385E-2	6.690E-3	1.729E-2	6.830E-3	1.239E-1
60	7.725E-2	1.156E-2	2.763E-1	3.666E-3	2.474E-1	7.991E-2	7.150E-2	8.831E-3	1.668E-2	6.719E-3	1.378E-1
Variant 2											
0	1.462E-2	0.0	2.694E-1	0.0	5.852E-1	6.365E-2	6.401E-3	0.0	8.911E-3	2.220E-3	1.113E-2
10	1.238E-2	1.939E-4	2.687E-1	1.828E-5	4.864E-1	9.587E-2	3.547E-2	1.173E-3	1.563E-2	5.664E-3	4.823E-2
20	1.053E-2	3.488E-4	2.689E-1	1.057E-4	4.146E-1	1.103E-1	6.539E-2	3.735E-3	1.564E-2	6.088E-3	7.067E-2
30	8.722E-3	4.654E-4	2.691E-1	3.094E-4	3.569E-1	1.166E-1	8.949E-2	6.988E-3	1.561E-2	6.319E-3	9.088E-2
40	7.007E-3	5.503E-4	2.691E-1	6.549E-4	3.139E-1	1.174E-1	1.051E-1	1.025E-2	1.552E-2	6.431E-3	1.094E-1
50	5.445E-3	6.036E-4	2.689E-1	1.127E-3	2.849E-1	1.149E-1	1.121E-1	1.316E-2	1.539E-2	6.465E-3	1.261E-1
60	4.094E-3	6.300E-4	2.683E-1	1.671E-3	2.667E-1	1.105E-1	1.127E-1	1.553E-2	1.524E-2	6.459E-3	1.410E-1
Variant 3											
0	2.380E-1	9.611E-3	2.871E-1	2.728E-3	2.473E-1	6.410E-2	3.768E-2	2.470E-3	1.968E-2	4.793E-3	2.447E-2
Variant 4											
0	2.235E-1	9.107E-3	2.813E-1	2.551E-3	2.316E-1	6.040E-2	3.521E-2	2.376E-3	1.810E-2	4.417E-3	6.341E-2
Variant 7											
0	1.590E-2	0.0	2.735E-1	0.0	6.448E-1	0.0	0.0	0.0	1.004E-2	2.501E-3	1.254E-2
Variant 8											
0	5.140E-1	0.0	3.002E-1	0.0	0.0	7.246E-2	0.0	0.0	2.414E-2	5.901E-3	3.004E-2
Variant 9											
0	1.552E-2	0.0	2.652E-1	0.0	0.0	0.0	6.554E-1	0.0	9.255E-3	2.336E-3	1.159E-2
Variant 10											
0	1.025E-2	0.0	2.532E-1	3.575E-3	4.319E-1	1.537E-1	8.081E-2	2.065E-2	2.673E-3	7.009E-4	3.374E-3
10	8.907E-3	1.640E-4	2.512E-1	3.508E-3	3.900E-1	1.487E-1	9.350E-2	2.043E-2	6.958E-3	5.228E-3	3.412E-2
20	7.836E-3	2.910E-4	2.497E-1	3.768E-3	3.615E-1	1.449E-1	1.036E-1	2.059E-2	7.052E-3	5.538E-3	5.255E-2
30	6.877E-3	3.909E-4	2.484E-1	4.134E-3	3.376E-1	1.414E-1	1.107E-1	2.097E-2	7.180E-3	5.700E-3	6.902E-2
40	6.011E-3	4.690E-4	2.472E-1	4.560E-3	3.174E-1	1.378E-1	1.155E-1	2.150E-2	7.326E-3	5.799E-3	8.422E-2
50	5.228E-3	5.293E-4	2.460E-1	5.025E-3	3.001E-1	1.342E-1	1.183E-1	2.208E-2	7.481E-3	5.863E-3	9.848E-2
60	4.521E-3	5.739E-4	2.449E-1	5.515E-3	2.854E-1	1.306E-1	1.196E-1	2.268E-2	7.639E-3	5.911E-3	1.119E-1

Table 4.17. Cell relative absorption reaction rates for Variant 11, States 1 and 2

Burnup (MWd/kg)	Relative absorption rate										
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	¹³⁵ Xe	¹⁴⁹ Sm	Total FP
Pin 1, State 1											
0	6.196E-1	0.0	2.692E-1	0.0	0.0	0.0	0.0	0.0	2.405E-2	5.869E-3	2.992E-2
10	4.293E-1	4.335E-3	2.643E-1	4.110E-5	1.409E-1	2.261E-2	6.384E-3	9.806E-5	2.278E-2	6.489E-3	5.482E-2
20	3.101E-1	7.023E-3	2.635E-1	2.539E-4	1.968E-1	4.451E-2	2.351E-2	8.404E-4	2.145E-2	6.899E-3	7.576E-2
30	2.234E-1	8.809E-3	2.643E-1	7.482E-4	2.229E-1	5.927E-2	4.183E-2	2.424E-3	2.038E-2	7.042E-3	9.530E-2
40	1.566E-1	9.963E-3	2.654E-1	1.594E-3	2.358E-1	6.950E-2	5.722E-2	4.586E-3	1.941E-2	7.020E-3	1.135E-1
50	1.052E-1	1.061E-2	2.660E-1	2.785E-3	2.419E-1	7.647E-2	6.852E-2	6.959E-3	1.849E-2	6.899E-3	1.301E-1
60	6.710E-2	1.084E-2	2.659E-1	4.212E-3	2.442E-1	8.090E-2	7.583E-2	9.250E-3	1.767E-2	6.732E-3	1.447E-1
Pin 1, State 2											
0	6.095E-1	0.0	2.811E-1	0.0	0.0	0.0	0.0	0.0	2.317E-2	5.657E-3	2.882E-2
10	4.227E-1	4.479E-3	2.751E-1	4.034E-5	1.381E-1	2.279E-2	6.249E-3	1.000E-4	2.198E-2	6.263E-3	5.388E-2
20	3.051E-1	7.250E-3	2.740E-1	2.490E-4	1.928E-1	4.482E-2	2.300E-2	8.558E-4	2.068E-2	6.653E-3	7.493E-2
30	2.195E-1	9.097E-3	2.746E-1	7.326E-4	2.182E-1	5.966E-2	4.088E-2	2.469E-3	1.962E-2	6.782E-3	9.453E-2
40	1.536E-1	1.029E-2	2.757E-1	1.558E-3	2.306E-1	6.995E-2	5.584E-2	4.674E-3	1.864E-2	6.747E-3	1.128E-1
50	1.030E-1	1.097E-2	2.764E-1	2.716E-3	2.362E-1	7.697E-2	6.675E-2	7.100E-3	1.772E-2	6.617E-3	1.294E-1
60	6.559E-2	1.122E-2	2.763E-1	4.100E-3	2.381E-1	8.144E-2	7.375E-2	9.449E-3	1.690E-2	6.444E-3	1.440E-1
Pin 29, State 1											
0	6.144E-1	0.0	2.756E-1	0.0	0.0	0.0	0.0	0.0	2.305E-2	5.672E-3	2.872E-2
10	4.357E-1	4.233E-3	2.707E-1	3.567E-5	1.341E-1	2.077E-2	5.352E-3	7.997E-5	2.179E-2	6.414E-3	5.224E-2
20	3.227E-1	6.877E-3	2.688E-1	2.165E-4	1.904E-1	4.123E-2	2.016E-2	6.970E-4	2.072E-2	6.816E-3	7.208E-2
30	2.397E-1	8.657E-3	2.683E-1	6.354E-4	2.184E-1	5.541E-2	3.676E-2	2.048E-3	1.991E-2	6.980E-3	9.071E-2
40	1.745E-1	9.847E-3	2.682E-1	1.362E-3	2.329E-1	6.565E-2	5.161E-2	3.951E-3	1.917E-2	6.997E-3	1.083E-1
50	1.226E-1	1.057E-2	2.682E-1	2.413E-3	2.402E-1	7.308E-2	6.338E-2	6.114E-3	1.844E-2	6.918E-3	1.247E-1
60	8.241E-2	1.092E-2	2.679E-1	3.723E-3	2.432E-1	7.825E-2	7.174E-2	8.279E-3	1.772E-2	6.785E-3	1.394E-1
Pin 29, State 2											
0	5.897E-1	0.0	3.048E-1	0.0	0.0	0.0	0.0	0.0	2.084E-2	5.136E-3	2.597E-2
10	4.186E-1	4.581E-3	2.983E-1	3.392E-5	1.271E-1	2.115E-2	5.055E-3	8.372E-5	1.968E-2	5.802E-3	4.977E-2
20	3.095E-1	7.441E-3	2.958E-1	2.054E-4	1.802E-1	4.197E-2	1.901E-2	7.281E-4	1.865E-2	6.148E-3	6.995E-2
30	2.293E-1	9.379E-3	2.950E-1	6.009E-4	2.062E-1	5.638E-2	3.458E-2	2.140E-3	1.787E-2	6.277E-3	8.883E-2
40	1.663E-1	1.068E-2	2.948E-1	1.283E-3	2.193E-1	6.674E-2	4.839E-2	4.133E-3	1.715E-2	6.269E-3	1.066E-1
50	1.165E-1	1.149E-2	2.947E-1	2.263E-3	2.255E-1	7.422E-2	5.922E-2	6.406E-3	1.643E-2	6.176E-3	1.231E-1
60	7.800E-2	1.187E-2	2.943E-1	3.479E-3	2.276E-1	7.939E-2	6.681E-2	8.688E-3	1.574E-2	6.036E-3	1.380E-1
Pin 72, State 1											
0	6.182E-1	0.0	2.712E-1	0.0	0.0	0.0	0.0	0.0	2.369E-2	5.805E-3	2.950E-2
10	4.327E-1	4.291E-3	2.663E-1	3.882E-5	1.380E-1	2.178E-2	5.940E-3	9.023E-5	2.244E-2	6.466E-3	5.386E-2
20	3.160E-1	6.957E-3	2.651E-1	2.384E-4	1.941E-1	4.304E-2	2.208E-2	7.782E-4	2.122E-2	6.873E-3	7.438E-2
30	2.306E-1	8.736E-3	2.654E-1	7.023E-4	2.210E-1	5.758E-2	3.972E-2	2.262E-3	2.026E-2	7.026E-3	9.359E-2
40	1.642E-1	9.903E-3	2.660E-1	1.502E-3	2.346E-1	6.785E-2	5.496E-2	4.313E-3	1.938E-2	7.019E-3	1.116E-1
50	1.123E-1	1.058E-2	2.665E-1	2.642E-3	2.411E-1	7.506E-2	6.651E-2	6.598E-3	1.853E-2	6.914E-3	1.282E-1
60	7.306E-2	1.086E-2	2.663E-1	4.030E-3	2.437E-1	7.983E-2	7.430E-2	8.838E-3	1.773E-2	6.759E-3	1.429E-1
Pin 72, State 2											
0	5.526E-1	0.0	3.487E-1	0.0	0.0	0.0	0.0	0.0	1.767E-2	4.376E-3	2.204E-2
10	3.868E-1	5.281E-3	3.410E-1	3.356E-5	1.189E-1	2.267E-2	5.067E-3	1.032E-4	1.659E-2	4.835E-3	4.725E-2
20	2.811E-1	8.534E-3	3.382E-1	2.050E-4	1.660E-1	4.416E-2	1.872E-2	8.857E-4	1.558E-2	5.104E-3	6.890E-2
30	2.038E-1	1.071E-2	3.375E-1	5.992E-4	1.878E-1	5.858E-2	3.345E-2	2.569E-3	1.478E-2	5.184E-3	8.900E-2
40	1.439E-1	1.213E-2	3.375E-1	1.270E-3	1.980E-1	6.858E-2	4.593E-2	4.893E-3	1.405E-2	5.145E-3	1.077E-1
50	9.760E-2	1.297E-2	3.373E-1	2.213E-3	2.021E-1	7.545E-2	5.515E-2	7.478E-3	1.335E-2	5.034E-3	1.248E-1
60	6.301E-2	1.330E-2	3.363E-1	3.348E-3	2.029E-1	7.987E-2	6.117E-2	1.001E-2	1.270E-2	4.892E-3	1.399E-1

Table 4.18. Cell relative absorption reaction rates for Variant 12, States 1 and 2

Burnup (MWd/kg)	Relative absorption rate										Total FP
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	¹³⁵ Xe	¹⁴⁹ Sm	
Pin 1, State 1											
0	1.475E-2	0.0	2.385E-1	0.0	6.179E-1	5.908E-2	6.713E-3	0.0	1.056E-2	2.587E-3	1.315E-2
10	1.281E-2	1.513E-4	2.421E-1	1.836E-5	5.032E-1	9.663E-2	3.915E-2	1.099E-3	1.819E-2	5.855E-3	5.158E-2
20	1.109E-2	2.733E-4	2.471E-1	1.147E-4	4.152E-1	1.143E-1	7.462E-2	3.457E-3	1.795E-2	6.256E-3	7.469E-2
30	9.199E-3	3.692E-4	2.518E-1	3.562E-4	3.445E-1	1.218E-1	1.029E-1	6.398E-3	1.764E-2	6.472E-3	9.630E-2
40	7.221E-3	4.393E-4	2.555E-1	7.803E-4	2.956E-1	1.219E-1	1.187E-1	9.380E-3	1.729E-2	6.557E-3	1.164E-1
50	5.336E-3	4.840E-4	2.581E-1	1.352E-3	2.671E-1	1.171E-1	1.222E-1	1.204E-2	1.695E-2	6.557E-3	1.345E-1
60	3.715E-3	5.057E-4	2.595E-1	1.970E-3	2.528E-1	1.103E-1	1.177E-1	1.421E-2	1.664E-2	6.512E-3	1.502E-1
Pin 1, State 2											
0	1.469E-2	0.0	2.460E-1	0.0	6.108E-1	5.895E-2	6.646E-3	0.0	1.032E-2	2.529E-3	1.285E-2
10	1.274E-2	1.539E-4	2.495E-1	1.823E-5	4.971E-1	9.629E-2	3.871E-2	1.104E-3	1.775E-2	5.718E-3	5.106E-2
20	1.100E-2	2.785E-4	2.548E-1	1.135E-4	4.094E-1	1.140E-1	7.360E-2	3.479E-3	1.747E-2	6.093E-3	7.420E-2
30	9.099E-3	3.770E-4	2.598E-1	3.516E-4	3.391E-1	1.216E-1	1.012E-1	6.452E-3	1.712E-2	6.285E-3	9.583E-2
40	7.124E-3	4.495E-4	2.639E-1	7.678E-4	2.903E-1	1.218E-1	1.165E-1	9.483E-3	1.673E-2	6.348E-3	1.159E-1
50	5.252E-3	4.962E-4	2.668E-1	1.327E-3	2.618E-1	1.172E-1	1.197E-1	1.220E-2	1.635E-2	6.329E-3	1.340E-1
60	3.647E-3	5.195E-4	2.685E-1	1.928E-3	2.474E-1	1.105E-1	1.150E-1	1.443E-2	1.600E-2	6.267E-3	1.497E-1
Pin 29, State 1											
0	1.485E-2	0.0	2.561E-1	0.0	5.983E-1	6.104E-2	6.586E-3	0.0	9.772E-3	2.420E-3	1.219E-2
10	1.291E-2	1.519E-4	2.555E-1	1.609E-5	5.041E-1	9.203E-2	3.363E-2	9.459E-4	1.644E-2	5.740E-3	4.757E-2
20	1.127E-2	2.719E-4	2.557E-1	9.648E-5	4.314E-1	1.077E-1	6.361E-2	2.927E-3	1.672E-2	6.142E-3	6.930E-2
30	9.576E-3	3.658E-4	2.564E-1	2.955E-4	3.685E-1	1.160E-1	9.005E-2	5.448E-3	1.688E-2	6.385E-3	8.963E-2
40	7.823E-3	4.365E-4	2.575E-1	6.555E-4	3.185E-1	1.188E-1	1.087E-1	8.117E-3	1.688E-2	6.510E-3	1.089E-1
50	6.088E-3	4.855E-4	2.587E-1	1.173E-3	2.834E-1	1.173E-1	1.177E-1	1.065E-2	1.673E-2	6.550E-3	1.269E-1
60	4.495E-3	5.139E-4	2.596E-1	1.784E-3	2.619E-1	1.130E-1	1.183E-1	1.287E-2	1.652E-2	6.535E-3	1.430E-1
Pin 29, State 2											
0	1.467E-2	0.0	2.783E-1	0.0	5.772E-1	6.110E-2	6.380E-3	0.0	8.959E-3	2.225E-3	1.118E-2
10	1.270E-2	1.599E-4	2.777E-1	1.570E-5	4.848E-1	9.209E-2	3.244E-2	9.633E-4	1.502E-2	5.259E-3	4.592E-2
20	1.102E-2	2.876E-4	2.783E-1	9.344E-5	4.130E-1	1.079E-1	6.097E-2	2.995E-3	1.520E-2	5.596E-3	6.791E-2
30	9.303E-3	3.888E-4	2.796E-1	2.841E-4	3.512E-1	1.163E-1	8.579E-2	5.602E-3	1.527E-2	5.788E-3	8.847E-2
40	7.552E-3	4.661E-4	2.812E-1	6.257E-4	3.021E-1	1.192E-1	1.030E-1	8.389E-3	1.519E-2	5.871E-3	1.080E-1
50	5.843E-3	5.205E-4	2.828E-1	1.113E-3	2.676E-1	1.177E-1	1.109E-1	1.106E-2	1.499E-2	5.878E-3	1.260E-1
60	4.292E-3	5.526E-4	2.840E-1	1.682E-3	2.464E-1	1.134E-1	1.110E-1	1.340E-2	1.473E-2	5.842E-3	1.422E-1
Pin 72, State 1											
0	1.481E-2	0.0	2.455E-1	0.0	6.102E-1	5.988E-2	6.667E-3	0.0	1.026E-2	2.526E-3	1.279E-2
10	1.287E-2	1.514E-4	2.471E-1	1.734E-5	5.046E-1	9.450E-2	3.670E-2	1.030E-3	1.752E-2	5.813E-3	4.995E-2
20	1.119E-2	2.722E-4	2.499E-1	1.066E-4	4.231E-1	1.114E-1	6.989E-2	3.217E-3	1.753E-2	6.216E-3	7.251E-2
30	9.394E-3	3.671E-4	2.529E-1	3.303E-4	3.550E-1	1.195E-1	9.771E-2	5.973E-3	1.743E-2	6.446E-3	9.364E-2
40	7.507E-3	4.375E-4	2.556E-1	7.299E-4	3.047E-1	1.209E-1	1.151E-1	8.827E-3	1.721E-2	6.547E-3	1.135E-1
50	5.668E-3	4.842E-4	2.577E-1	1.285E-3	2.728E-1	1.175E-1	1.211E-1	1.145E-2	1.694E-2	6.562E-3	1.316E-1
60	4.037E-3	5.087E-4	2.590E-1	1.908E-3	2.555E-1	1.117E-1	1.186E-1	1.365E-2	1.664E-2	6.527E-3	1.476E-1
Pin 72, State 2											
0	1.438E-2	0.0	3.144E-1	0.0	5.437E-1	6.045E-2	6.056E-3	0.0	7.713E-3	1.930E-3	9.643E-3
10	1.230E-2	1.810E-4	3.151E-1	1.606E-5	4.450E-1	9.433E-2	3.282E-2	1.139E-3	1.306E-2	4.397E-3	4.552E-2
20	1.048E-2	3.262E-4	3.178E-1	9.659E-5	3.685E-1	1.105E-1	6.137E-2	3.567E-3	1.294E-2	4.653E-3	6.937E-2
30	8.632E-3	4.414E-4	3.207E-1	2.932E-4	3.057E-1	1.178E-1	8.440E-2	6.644E-3	1.277E-2	4.781E-3	9.143E-2
40	6.779E-3	5.278E-4	3.234E-1	6.359E-4	2.597E-1	1.188E-1	9.799E-2	9.851E-3	1.251E-2	4.814E-3	1.119E-1
50	5.042E-3	5.857E-4	3.254E-1	1.102E-3	2.305E-1	1.152E-1	1.019E-1	1.281E-2	1.222E-2	4.791E-3	1.304E-1
60	3.545E-3	6.168E-4	3.265E-1	1.614E-3	2.142E-1	1.094E-1	9.871E-2	1.530E-2	1.194E-2	4.733E-3	1.466E-1

**Table 4.19. Fuel-averaged microscopic absorption cross section
for Variant 11, States 1 and 2**

Burnup (MWd/kg)	Microscopic absorption cross section (b)										Total FP
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	¹³⁵ Xe	¹⁴⁹ Sm	
Pin 1, State 1											
0	5.068E+1	8.416E+0	1.026E+0	3.669E+1	1.863E+2	2.409E+2	1.642E+2	3.119E+1	1.817E+5	5.694E+3	2.572E+4
10	4.782E+1	7.728E+0	1.027E+0	3.126E+1	1.543E+2	1.848E+2	1.387E+2	3.433E+1	1.704E+5	5.314E+3	1.125E+1
20	4.738E+1	7.174E+0	1.032E+0	3.115E+1	1.478E+2	1.449E+2	1.352E+2	3.384E+1	1.697E+5	5.265E+3	7.782E+0
30	4.804E+1	6.838E+0	1.038E+0	3.176E+1	1.468E+2	1.238E+2	1.358E+2	3.267E+1	1.738E+5	5.368E+3	6.515E+0
40	4.918E+1	6.630E+0	1.045E+0	3.268E+1	1.482E+2	1.119E+2	1.383E+2	3.107E+1	1.800E+5	5.538E+3	5.805E+0
50	5.044E+1	6.504E+0	1.051E+0	3.367E+1	1.506E+2	1.049E+2	1.413E+2	2.933E+1	1.868E+5	5.726E+3	5.310E+0
60	5.155E+1	6.434E+0	1.057E+0	3.453E+1	1.530E+2	1.006E+2	1.441E+2	2.769E+1	1.926E+5	5.893E+3	4.916E+0
Pin 1, State 2											
0	4.672E+1	8.179E+0	1.004E+0	3.367E+1	1.710E+2	2.283E+2	1.505E+2	2.995E+1	1.640E+5	5.143E+3	2.322E+4
10	4.428E+1	7.510E+0	1.006E+0	2.885E+1	1.422E+2	1.752E+2	1.277E+2	3.293E+1	1.546E+5	4.824E+3	1.040E+1
20	4.390E+1	6.975E+0	1.011E+0	2.877E+1	1.364E+2	1.375E+2	1.246E+2	3.246E+1	1.540E+5	4.783E+3	7.249E+0
30	4.447E+1	6.653E+0	1.016E+0	2.930E+1	1.353E+2	1.174E+2	1.251E+2	3.135E+1	1.576E+5	4.870E+3	6.088E+0
40	4.544E+1	6.452E+0	1.022E+0	3.009E+1	1.365E+2	1.060E+2	1.271E+2	2.982E+1	1.629E+5	5.014E+3	5.432E+0
50	4.650E+1	6.331E+0	1.028E+0	3.092E+1	1.385E+2	9.936E+1	1.296E+2	2.817E+1	1.685E+5	5.171E+3	4.971E+0
60	4.741E+1	6.266E+0	1.033E+0	3.162E+1	1.403E+2	9.528E+1	1.319E+2	2.661E+1	1.734E+5	5.306E+3	4.602E+0
Pin 29, State 1											
0	4.612E+1	8.204E+0	9.641E-1	3.296E+1	1.721E+2	2.342E+2	1.498E+2	3.065E+1	1.598E+5	5.049E+3	2.266E+4
10	4.318E+1	7.447E+0	9.639E-1	2.794E+1	1.403E+2	1.774E+2	1.251E+2	3.375E+1	1.484E+5	4.669E+3	1.081E+1
20	4.257E+1	6.860E+0	9.673E-1	2.772E+1	1.330E+2	1.363E+2	1.211E+2	3.329E+1	1.471E+5	4.603E+3	7.457E+0
30	4.305E+1	6.496E+0	9.723E-1	2.821E+1	1.313E+2	1.142E+2	1.211E+2	3.216E+1	1.504E+5	4.685E+3	6.236E+0
40	4.405E+1	6.262E+0	9.777E-1	2.903E+1	1.323E+2	1.016E+2	1.231E+2	3.058E+1	1.561E+5	4.840E+3	5.559E+0
50	4.525E+1	6.112E+0	9.834E-1	2.996E+1	1.344E+2	9.401E+1	1.260E+2	2.882E+1	1.625E+5	5.021E+3	5.093E+0
60	4.636E+1	6.022E+0	9.886E-1	3.083E+1	1.368E+2	8.930E+1	1.287E+2	2.710E+1	1.685E+5	5.189E+3	4.725E+0
Pin 29, State 2											
0	3.865E+1	7.809E+0	9.311E-1	2.731E+1	1.427E+2	2.096E+2	1.237E+2	2.831E+1	1.262E+5	3.993E+3	1.789E+4
10	3.637E+1	7.064E+0	9.313E-1	2.329E+1	1.165E+2	1.583E+2	1.036E+2	3.097E+1	1.175E+5	3.702E+3	9.029E+0
20	3.585E+1	6.517E+0	9.345E-1	2.309E+1	1.105E+2	1.218E+2	1.002E+2	3.053E+1	1.163E+5	3.645E+3	6.353E+0
30	3.616E+1	6.181E+0	9.387E-1	2.343E+1	1.089E+2	1.021E+2	1.000E+2	2.951E+1	1.186E+5	3.700E+3	5.363E+0
40	3.687E+1	5.964E+0	9.436E-1	2.401E+1	1.093E+2	9.070E+1	1.014E+2	2.809E+1	1.226E+5	3.808E+3	4.805E+0
50	3.772E+1	5.827E+0	9.484E-1	2.467E+1	1.107E+2	8.380E+1	1.033E+2	2.650E+1	1.271E+5	3.934E+3	4.414E+0
60	3.849E+1	5.745E+0	9.527E-1	2.527E+1	1.123E+2	7.948E+1	1.052E+2	2.495E+1	1.312E+5	4.049E+3	4.102E+0
Pin 72, State 1											
0	4.874E+1	8.304E+0	9.966E-1	3.504E+1	1.801E+2	2.376E+2	1.579E+2	3.091E+1	1.726E+5	5.429E+3	2.445E+4
10	4.590E+1	7.589E+0	9.972E-1	2.988E+1	1.484E+2	1.810E+2	1.331E+2	3.404E+1	1.615E+5	5.056E+3	1.106E+1
20	4.543E+1	7.020E+0	1.002E+0	2.976E+1	1.417E+2	1.406E+2	1.295E+2	3.356E+1	1.607E+5	5.006E+3	7.641E+0
30	4.607E+1	6.670E+0	1.007E+0	3.036E+1	1.406E+2	1.192E+2	1.300E+2	3.240E+1	1.648E+5	5.109E+3	6.397E+0
40	4.723E+1	6.452E+0	1.014E+0	3.129E+1	1.421E+2	1.071E+2	1.325E+2	3.079E+1	1.711E+5	5.283E+3	5.703E+0
50	4.853E+1	6.318E+0	1.020E+0	3.231E+1	1.446E+2	9.988E+1	1.356E+2	2.902E+1	1.781E+5	5.478E+3	5.222E+0
60	4.969E+1	6.241E+0	1.025E+0	3.321E+1	1.471E+2	9.550E+1	1.386E+2	2.734E+1	1.843E+5	5.654E+3	4.838E+0
Pin 72, State 2											
0	3.087E+1	7.387E+0	9.079E-1	2.142E+1	1.115E+2	1.805E+2	9.636E+1	2.554E+1	9.115E+4	2.899E+3	1.294E+4
10	2.919E+1	6.648E+0	9.088E-1	1.839E+1	9.099E+1	1.340E+2	8.079E+1	2.771E+1	8.496E+4	2.690E+3	6.903E+0
20	2.885E+1	6.148E+0	9.121E-1	1.827E+1	8.656E+1	1.030E+2	7.839E+1	2.727E+1	8.424E+4	2.654E+3	5.054E+0
30	2.912E+1	5.847E+0	9.163E-1	1.853E+1	8.546E+1	8.672E+1	7.830E+1	2.632E+1	8.599E+4	2.696E+3	4.350E+0
40	2.964E+1	5.661E+0	9.209E-1	1.895E+1	8.585E+1	7.749E+1	7.927E+1	2.501E+1	8.885E+4	2.773E+3	3.940E+0
50	3.024E+1	5.549E+0	9.253E-1	1.940E+1	8.685E+1	7.197E+1	8.062E+1	2.358E+1	9.198E+4	2.860E+3	3.644E+0
60	3.076E+1	5.485E+0	9.291E-1	1.980E+1	8.789E+1	6.857E+1	8.188E+1	2.222E+1	9.473E+4	2.937E+3	3.400E+0

**Table 4.20. Fuel-averaged microscopic absorption cross section
for Variant 12, States 1 and 2**

Burnup (MWd/kg)	Microscopic absorption cross section (b)										
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	¹³⁵ Xe	¹⁴⁹ Sm	Total FP
Pin 1, State 1											
0	3.048E+1	8.817E+0	1.000E+0	2.221E+1	7.441E+1	1.108E+2	7.581E+1	3.276E+1	8.859E+4	2.787E+3	1.255E+4
10	3.214E+1	7.906E+0	1.009E+0	2.054E+1	8.250E+1	7.387E+1	8.244E+1	3.223E+1	9.709E+4	3.033E+3	1.087E+1
20	3.482E+1	7.526E+0	1.018E+0	2.250E+1	9.335E+1	6.560E+1	9.115E+1	2.796E+1	1.103E+5	3.425E+3	7.807E+0
30	3.770E+1	7.261E+0	1.027E+0	2.458E+1	1.046E+2	6.420E+1	1.003E+2	2.407E+1	1.244E+5	3.845E+3	6.664E+0
40	4.054E+1	7.074E+0	1.036E+0	2.662E+1	1.152E+2	6.591E+1	1.093E+2	2.117E+1	1.383E+5	4.260E+3	6.005E+0
50	4.314E+1	6.936E+0	1.043E+0	2.850E+1	1.244E+2	6.932E+1	1.174E+2	1.911E+1	1.512E+5	4.645E+3	5.523E+0
60	4.540E+1	6.832E+0	1.050E+0	3.014E+1	1.319E+2	7.355E+1	1.244E+2	1.768E+1	1.626E+5	4.982E+3	5.121E+0
Pin 1, State 2											
0	2.889E+1	8.534E+0	9.822E-1	2.099E+1	7.003E+1	1.052E+2	7.146E+1	3.133E+1	8.239E+4	2.593E+3	1.167E+4
10	3.043E+1	7.661E+0	9.900E-1	1.943E+1	7.762E+1	7.010E+1	7.764E+1	3.083E+1	9.026E+4	2.822E+3	1.025E+1
20	3.286E+1	7.299E+0	9.989E-1	2.120E+1	8.761E+1	6.229E+1	8.558E+1	2.678E+1	1.022E+5	3.175E+3	7.382E+0
30	3.545E+1	7.047E+0	1.007E+0	2.305E+1	9.788E+1	6.094E+1	9.383E+1	2.307E+1	1.148E+5	3.549E+3	6.303E+0
40	3.796E+1	6.869E+0	1.015E+0	2.486E+1	1.074E+2	6.253E+1	1.018E+2	2.031E+1	1.270E+5	3.915E+3	5.676E+0
50	4.023E+1	6.739E+0	1.022E+0	2.650E+1	1.155E+2	6.573E+1	1.089E+2	1.835E+1	1.383E+5	4.248E+3	5.215E+0
60	4.217E+1	6.640E+0	1.028E+0	2.790E+1	1.221E+2	6.969E+1	1.149E+2	1.699E+1	1.479E+5	4.536E+3	4.829E+0
Pin 29, State 1											
0	2.686E+1	8.619E+0	9.400E-1	1.916E+1	6.305E+1	1.001E+2	6.509E+1	3.231E+1	7.173E+4	2.281E+3	1.018E+4
10	2.800E+1	7.717E+0	9.457E-1	1.763E+1	6.880E+1	6.784E+1	6.980E+1	3.203E+1	7.796E+4	2.461E+3	1.029E+1
20	3.012E+1	7.324E+0	9.525E-1	1.920E+1	7.730E+1	5.906E+1	7.673E+1	2.822E+1	8.872E+4	2.783E+3	7.442E+0
30	3.258E+1	7.039E+0	9.598E-1	2.098E+1	8.687E+1	5.641E+1	8.458E+1	2.444E+1	1.010E+5	3.150E+3	6.364E+0
40	3.516E+1	6.828E+0	9.671E-1	2.284E+1	9.666E+1	5.660E+1	9.279E+1	2.142E+1	1.138E+5	3.534E+3	5.749E+0
50	3.767E+1	6.671E+0	9.741E-1	2.465E+1	1.058E+2	5.844E+1	1.007E+2	1.916E+1	1.262E+5	3.907E+3	5.306E+0
60	3.993E+1	6.552E+0	9.803E-1	2.628E+1	1.137E+2	6.124E+1	1.078E+2	1.754E+1	1.375E+5	4.244E+3	4.940E+0
Pin 29, State 2											
0	2.370E+1	8.111E+0	9.126E-1	1.671E+1	5.435E+1	8.954E+1	5.634E+1	2.949E+1	5.875E+4	1.874E+3	8.345E+3
10	2.459E+1	7.252E+0	9.176E-1	1.536E+1	5.907E+1	6.062E+1	6.010E+1	2.913E+1	6.359E+4	2.013E+3	8.869E+0
20	2.623E+1	6.901E+0	9.236E-1	1.657E+1	6.592E+1	5.270E+1	6.552E+1	2.572E+1	7.184E+4	2.259E+3	6.496E+0
30	2.812E+1	6.648E+0	9.297E-1	1.792E+1	7.354E+1	5.023E+1	7.160E+1	2.233E+1	8.112E+4	2.537E+3	5.582E+0
40	3.009E+1	6.462E+0	9.359E-1	1.933E+1	8.127E+1	5.029E+1	7.790E+1	1.962E+1	9.074E+4	2.825E+3	5.050E+0
50	3.197E+1	6.325E+0	9.417E-1	2.067E+1	8.838E+1	5.184E+1	8.389E+1	1.759E+1	9.996E+4	3.101E+3	4.661E+0
60	3.366E+1	6.221E+0	9.469E-1	2.189E+1	9.447E+1	5.427E+1	8.922E+1	1.612E+1	1.083E+5	3.350E+3	4.339E+0
Pin 72, State 1											
0	2.886E+1	8.712E+0	9.712E-1	2.079E+1	6.930E+1	1.059E+2	7.102E+1	3.252E+1	8.117E+4	2.565E+3	1.151E+4
10	3.032E+1	7.809E+0	9.784E-1	1.927E+1	7.646E+1	7.099E+1	7.687E+1	3.209E+1	8.884E+4	2.789E+3	1.062E+1
20	3.282E+1	7.421E+0	9.869E-1	2.110E+1	8.647E+1	6.251E+1	8.500E+1	2.799E+1	1.013E+5	3.160E+3	7.654E+0
30	3.562E+1	7.147E+0	9.954E-1	2.312E+1	9.731E+1	6.057E+1	9.390E+1	2.412E+1	1.151E+5	3.571E+3	6.541E+0
40	3.845E+1	6.950E+0	1.004E+0	2.516E+1	1.079E+2	6.165E+1	1.029E+2	2.116E+1	1.291E+5	3.989E+3	5.903E+0
50	4.112E+1	6.804E+0	1.011E+0	2.708E+1	1.174E+2	6.440E+1	1.112E+2	1.902E+1	1.423E+5	4.383E+3	5.439E+0
60	4.345E+1	6.693E+0	1.018E+0	2.878E+1	1.253E+2	6.811E+1	1.185E+2	1.751E+1	1.539E+5	4.732E+3	5.053E+0
Pin 72, State 2											
0	2.012E+1	7.550E+0	8.931E-1	1.391E+1	4.435E+1	7.675E+1	4.632E+1	2.615E+1	4.382E+4	1.408E+3	6.233E+3
10	2.086E+1	6.721E+0	8.984E-1	1.285E+1	4.854E+1	5.101E+1	4.949E+1	2.556E+1	4.768E+4	1.519E+3	6.969E+0
20	2.216E+1	6.411E+0	9.044E-1	1.378E+1	5.428E+1	4.466E+1	5.380E+1	2.237E+1	5.392E+4	1.705E+3	5.278E+0
30	2.360E+1	6.197E+0	9.103E-1	1.480E+1	6.042E+1	4.305E+1	5.848E+1	1.935E+1	6.077E+4	1.910E+3	4.605E+0
40	2.504E+1	6.047E+0	9.161E-1	1.581E+1	6.635E+1	4.367E+1	6.316E+1	1.703E+1	6.765E+4	2.116E+3	4.197E+0
50	2.638E+1	5.938E+0	9.212E-1	1.675E+1	7.155E+1	4.553E+1	6.746E+1	1.535E+1	7.409E+4	2.309E+3	3.887E+0
60	2.754E+1	5.856E+0	9.256E-1	1.757E+1	7.581E+1	4.814E+1	7.114E+1	1.416E+1	7.968E+4	2.476E+3	3.622E+0

Table 4.21. Cell relative production reaction rate for uranium and plutonium isotopes vs burnup for Variants 1–4 and 7–10

Burnup (MWd/kg)	Relative production rate							
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu
<i>Variant 1</i>								
0	9.334E-1	0.0	6.664E-2	0.0	0.0	0.0	0.0	0.0
10	6.912E-1	4.191E-4	7.311E-2	9.024E-6	2.232E-1	2.226E-4	1.170E-2	3.775E-6
20	5.381E-1	7.771E-4	7.900E-2	5.932E-5	3.361E-1	6.003E-4	4.499E-2	3.434E-5
30	4.202E-1	1.080E-3	8.419E-2	1.810E-4	4.081E-1	1.007E-3	8.451E-2	1.072E-4
40	3.232E-1	1.332E-3	8.917E-2	3.963E-4	4.601E-1	1.406E-3	1.229E-1	2.231E-4
50	2.423E-1	1.531E-3	9.397E-2	7.128E-4	5.002E-1	1.776E-3	1.567E-1	3.759E-4
60	1.758E-1	1.674E-3	9.828E-2	1.117E-3	5.317E-1	2.102E-3	1.846E-1	5.552E-4
<i>Variant 2</i>								
0	2.254E-2	0.0	7.331E-2	0.0	8.914E-1	1.033E-3	1.172E-2	0.0
10	2.132E-2	1.751E-5	8.095E-2	6.143E-6	8.227E-1	2.552E-3	7.225E-2	4.775E-5
20	1.947E-2	3.421E-5	8.567E-2	3.621E-5	7.481E-1	3.586E-3	1.422E-1	1.738E-4
30	1.717E-2	4.903E-5	8.976E-2	1.071E-4	6.809E-1	4.197E-3	2.058E-1	3.751E-4
40	1.458E-2	6.146E-5	9.346E-2	2.286E-4	6.296E-1	4.459E-3	2.539E-1	6.340E-4
50	1.189E-2	7.104E-5	9.687E-2	3.965E-4	5.971E-1	4.469E-3	2.830E-1	9.237E-4
60	9.313E-3	7.761E-5	9.990E-2	5.930E-4	5.808E-1	4.330E-3	2.954E-1	1.214E-3
<i>Variant 3</i>								
0	4.261E-1	9.712E-4	7.827E-2	6.333E-4	4.160E-1	9.890E-4	7.623E-2	9.886E-5
<i>Variant 4</i>								
0	4.240E-1	1.018E-3	8.306E-2	6.570E-4	4.136E-1	1.047E-3	7.574E-2	1.049E-4
<i>Variant 7</i>								
0	2.285E-2	0.0	6.792E-2	0.0	9.092E-1	0.0	0.0	0.0
<i>Variant 8</i>								
0	9.219E-1	0.0	7.694E-2	0.0	0.0	1.118E-3	0.0	0.0
<i>Variant 9</i>								
0	1.874E-2	0.0	5.388E-2	0.0	0.0	0.0	9.274E-1	0.0
<i>Variant 10</i>								
0	1.626E-2	0.0	8.643E-2	1.971E-3	7.171E-1	1.188E-2	1.636E-1	1.995E-3
10	1.479E-2	1.758E-5	8.986E-2	2.045E-3	6.765E-1	1.237E-2	1.982E-1	2.111E-3
20	1.343E-2	3.311E-5	9.193E-2	2.245E-3	6.451E-1	1.255E-2	2.261E-1	2.238E-3
30	1.215E-2	4.675E-5	9.393E-2	2.508E-3	6.191E-1	1.260E-2	2.485E-1	2.397E-3
40	1.094E-2	5.861E-5	9.588E-2	2.808E-3	5.973E-1	1.254E-2	2.662E-1	2.580E-3
50	9.787E-3	6.872E-5	9.768E-2	3.135E-3	5.792E-1	1.237E-2	2.798E-1	2.778E-3
60	8.695E-3	7.718E-5	9.946E-2	3.478E-3	5.642E-1	1.212E-2	2.898E-1	2.987E-3

Table 4.22. Cell relative production reaction rates for Variant 11, States 1 and 2

Burnup (MWd/kg)	Relative production rate							
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu
<i>Pin 1, State 1</i>								
0	9.425E-1	0.0	5.748E-2	0.0	0.0	0.0	0.0	0.0
10	7.091E-1	3.700E-4	6.292E-2	7.523E-6	2.156E-1	1.934E-4	1.174E-2	3.368E-6
20	5.554E-1	6.917E-4	6.848E-2	5.075E-5	3.276E-1	5.243E-4	4.697E-2	3.201E-5
30	4.318E-1	9.722E-4	7.397E-2	1.596E-4	4.013E-1	8.784E-4	9.021E-2	1.034E-4
40	3.260E-1	1.211E-3	7.952E-2	3.593E-4	4.574E-1	1.221E-3	1.328E-1	2.212E-4
50	2.348E-1	1.402E-3	8.495E-2	6.601E-4	5.034E-1	1.531E-3	1.705E-1	3.805E-4
60	1.594E-1	1.536E-3	8.986E-2	1.045E-3	5.408E-1	1.792E-3	2.006E-1	5.694E-4
<i>Pin 1, State 2</i>								
0	9.350E-1	0.0	6.500E-2	0.0	0.0	0.0	0.0	0.0
10	7.036E-1	4.068E-4	7.064E-2	7.952E-6	2.134E-1	2.150E-4	1.162E-2	3.770E-6
20	5.508E-1	7.601E-4	7.674E-2	5.358E-5	3.243E-1	5.824E-4	4.646E-2	3.577E-5
30	4.279E-1	1.070E-3	8.290E-2	1.683E-4	3.970E-1	9.765E-4	8.918E-2	1.156E-4
40	3.227E-1	1.334E-3	8.923E-2	3.789E-4	4.523E-1	1.360E-3	1.312E-1	2.475E-4
50	2.322E-1	1.547E-3	9.549E-2	6.959E-4	4.973E-1	1.708E-3	1.682E-1	4.265E-4
60	1.574E-1	1.698E-3	1.012E-1	1.101E-3	5.339E-1	2.003E-3	1.977E-1	6.394E-4
<i>Pin 29, State 1</i>								
0	9.363E-1	0.0	6.374E-2	0.0	0.0	0.0	0.0	0.0
10	7.156E-1	3.748E-4	6.948E-2	7.051E-6	2.044E-1	1.877E-4	9.827E-3	2.842E-6
20	5.700E-1	7.026E-4	7.497E-2	4.654E-5	3.136E-1	5.201E-4	3.991E-2	2.729E-5
30	4.533E-1	9.905E-4	8.019E-2	1.448E-4	3.858E-1	8.903E-4	7.797E-2	8.919E-5
40	3.529E-1	1.240E-3	8.545E-2	3.256E-4	4.405E-1	1.264E-3	1.170E-1	1.936E-4
50	2.648E-1	1.447E-3	9.077E-2	6.026E-4	4.851E-1	1.618E-3	1.533E-1	3.389E-4
60	1.892E-1	1.606E-3	9.586E-2	9.693E-4	5.221E-1	1.933E-3	1.842E-1	5.180E-4
<i>Pin 29, State 2</i>								
0	9.216E-1	0.0	7.840E-2	0.0	0.0	0.0	0.0	0.0
10	7.049E-1	4.479E-4	8.484E-2	7.977E-6	1.999E-1	2.282E-4	9.599E-3	3.483E-6
20	5.612E-1	8.403E-4	9.143E-2	5.263E-5	3.066E-1	6.327E-4	3.897E-2	3.340E-5
30	4.458E-1	1.188E-3	9.793E-2	1.637E-4	3.770E-1	1.085E-3	7.608E-2	1.093E-4
40	3.465E-1	1.492E-3	1.046E-1	3.681E-4	4.300E-1	1.546E-3	1.140E-1	2.378E-4
50	2.595E-1	1.747E-3	1.115E-1	6.810E-4	4.729E-1	1.985E-3	1.491E-1	4.177E-4
60	1.850E-1	1.944E-3	1.181E-1	1.095E-3	5.082E-1	2.379E-3	1.789E-1	6.401E-4
<i>Pin 72, State 1</i>								
0	9.401E-1	0.0	5.989E-2	0.0	0.0	0.0	0.0	0.0
10	7.125E-1	3.718E-4	6.542E-2	7.316E-6	2.106E-1	1.911E-4	1.090E-2	3.144E-6
20	5.623E-1	6.958E-4	7.094E-2	4.893E-5	3.213E-1	5.232E-4	4.390E-2	2.999E-5
30	4.415E-1	9.791E-4	7.631E-2	1.533E-4	3.944E-1	8.849E-4	8.500E-2	9.736E-5
40	3.377E-1	1.222E-3	8.174E-2	3.451E-4	4.500E-1	1.241E-3	1.263E-1	2.097E-4
50	2.474E-1	1.420E-3	8.715E-2	6.364E-4	4.956E-1	1.570E-3	1.635E-1	3.637E-4
60	1.714E-1	1.565E-3	9.219E-2	1.014E-3	5.332E-1	1.854E-3	1.943E-1	5.496E-4
<i>Pin 72, State 2</i>								
0	9.019E-1	0.0	9.811E-2	0.0	0.0	0.0	0.0	0.0
10	6.839E-1	5.788E-4	1.063E-1	1.010E-5	1.985E-1	3.091E-4	1.025E-2	5.162E-6
20	5.391E-1	1.086E-3	1.152E-1	6.757E-5	3.021E-1	8.486E-4	4.120E-2	4.921E-5
30	4.222E-1	1.536E-3	1.243E-1	2.114E-4	3.699E-1	1.442E-3	7.957E-2	1.602E-4
40	3.215E-1	1.927E-3	1.337E-1	4.751E-4	4.208E-1	2.033E-3	1.178E-1	3.465E-4
50	2.344E-1	2.249E-3	1.432E-1	8.737E-4	4.617E-1	2.584E-3	1.519E-1	6.034E-4
60	1.615E-1	2.487E-3	1.519E-1	1.389E-3	4.947E-1	3.060E-3	1.796E-1	9.146E-4

Table 4.23. Cell relative production reaction rates for Variant 12, States 1 and 2

Burnup (MWd/kg)	Relative production rate							
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu
<i>Pin 1, State 1</i>								
0	2.221E-2	0.0	6.066E-2	0.0	9.046E-1	8.400E-4	1.174E-2	0.0
10	2.189E-2	1.439E-5	6.849E-2	4.942E-6	8.298E-1	2.290E-3	7.728E-2	4.621E-5
20	2.069E-2	2.903E-5	7.424E-2	3.122E-5	7.413E-1	3.267E-3	1.596E-1	1.798E-4
30	1.854E-2	4.289E-5	7.952E-2	9.748E-5	6.599E-1	3.779E-3	2.361E-1	4.105E-4
40	1.558E-2	5.497E-5	8.426E-2	2.144E-4	6.025E-1	3.884E-3	2.897E-1	7.213E-4
50	1.219E-2	6.443E-5	8.836E-2	3.730E-4	5.744E-1	3.718E-3	3.146E-1	1.073E-3
60	8.905E-3	7.086E-5	9.178E-2	5.464E-4	5.688E-1	3.434E-3	3.168E-1	1.423E-3
<i>Pin 1, State 2</i>								
0	2.218E-2	0.0	6.631E-2	0.0	8.989E-1	9.120E-4	1.169E-2	0.0
10	2.183E-2	1.543E-5	7.480E-2	5.190E-6	8.238E-1	2.486E-3	7.683E-2	5.035E-5
20	2.059E-2	3.121E-5	8.128E-2	3.277E-5	7.352E-1	3.557E-3	1.584E-1	1.963E-4
30	1.843E-2	4.628E-5	8.736E-2	1.023E-4	6.539E-1	4.127E-3	2.340E-1	4.498E-4
40	1.546E-2	5.956E-5	9.294E-2	2.251E-4	5.965E-1	4.259E-3	2.867E-1	7.936E-4
50	1.208E-2	7.009E-5	9.786E-2	3.919E-4	5.681E-1	4.093E-3	3.110E-1	1.186E-3
60	8.811E-3	7.740E-5	1.021E-1	5.744E-4	5.621E-1	3.795E-3	3.128E-1	1.578E-3
<i>Pin 29, State 1</i>								
0	2.259E-2	0.0	7.092E-2	0.0	8.937E-1	9.854E-4	1.177E-2	0.0
10	2.182E-2	1.483E-5	7.773E-2	4.884E-6	8.313E-1	2.403E-3	6.649E-2	4.059E-5
20	2.050E-2	2.938E-5	8.202E-2	2.927E-5	7.590E-1	3.424E-3	1.342E-1	1.515E-4
30	1.863E-2	4.301E-5	8.600E-2	8.889E-5	6.878E-1	4.070E-3	2.016E-1	3.432E-4
40	1.621E-2	5.527E-5	8.996E-2	1.956E-4	6.287E-1	4.364E-3	2.573E-1	6.127E-4
50	1.336E-2	6.555E-5	9.383E-2	3.485E-4	5.892E-1	4.368E-3	2.935E-1	9.402E-4
60	1.037E-2	7.334E-5	9.740E-2	5.294E-4	5.705E-1	4.181E-3	3.088E-1	1.292E-3
<i>Pin 29, State 2</i>								
0	2.264E-2	0.0	8.300E-2	0.0	8.815E-1	1.153E-3	1.169E-2	0.0
10	2.181E-2	1.704E-5	9.117E-2	5.495E-6	8.182E-1	2.820E-3	6.578E-2	4.776E-5
20	2.042E-2	3.401E-5	9.681E-2	3.297E-5	7.455E-1	4.045E-3	1.324E-1	1.794E-4
30	1.848E-2	5.019E-5	1.022E-1	1.003E-4	6.743E-1	4.843E-3	1.981E-1	4.093E-4
40	1.602E-2	6.497E-5	1.077E-1	2.208E-4	6.152E-1	5.229E-3	2.521E-1	7.361E-4
50	1.317E-2	7.762E-5	1.131E-1	3.936E-4	5.757E-1	5.270E-3	2.867E-1	1.137E-3
60	1.020E-2	8.735E-5	1.181E-1	5.980E-4	5.565E-1	5.073E-3	3.009E-1	1.572E-3
<i>Pin 72, State 1</i>								
0	2.237E-2	0.0	6.477E-2	0.0	9.002E-1	8.996E-4	1.176E-2	0.0
10	2.187E-2	1.455E-5	7.207E-2	4.896E-6	8.311E-1	2.338E-3	7.240E-2	4.369E-5
20	2.064E-2	2.910E-5	7.715E-2	3.025E-5	7.496E-1	3.338E-3	1.484E-1	1.672E-4
30	1.864E-2	4.285E-5	8.187E-2	9.349E-5	6.719E-1	3.911E-3	2.217E-1	3.813E-4
40	1.593E-2	5.504E-5	8.632E-2	2.061E-4	6.125E-1	4.096E-3	2.773E-1	6.763E-4
50	1.275E-2	6.490E-5	9.038E-2	3.629E-4	5.788E-1	3.993E-3	3.077E-1	1.022E-3
60	9.541E-3	7.193E-5	9.391E-2	5.401E-4	5.678E-1	3.736E-3	3.154E-1	1.376E-3
<i>Pin 72, State 2</i>								
0	2.284E-2	0.0	9.980E-2	0.0	8.644E-1	1.390E-3	1.160E-2	0.0
10	2.205E-2	2.160E-5	1.114E-1	6.902E-6	7.921E-1	3.632E-3	7.053E-2	6.819E-5
20	2.053E-2	4.364E-5	1.203E-1	4.248E-5	7.100E-1	5.234E-3	1.429E-1	2.632E-4
30	1.831E-2	6.494E-5	1.289E-1	1.308E-4	6.330E-1	6.191E-3	2.112E-1	6.061E-4
40	1.547E-2	8.427E-5	1.372E-1	2.871E-4	5.745E-1	6.545E-3	2.619E-1	1.086E-3
50	1.227E-2	1.003E-4	1.449E-1	5.033E-4	5.407E-1	6.434E-3	2.885E-1	1.654E-3
60	9.108E-3	1.120E-4	1.518E-1	7.462E-4	5.284E-1	6.064E-3	2.938E-1	2.245E-3

**Table 4.24. Fuel-averaged microscopic production cross section
for Variant 11, States 1 and 2**

Burnup (MWd/kg)	Microscopic production cross section (b)							
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu
<i>Pin 1, State 1</i>								
0	1.007E+2	7.712E-1	2.862E-1	7.158E+0	3.409E+2	1.823E+0	3.610E+2	1.328E+0
10	9.464E+1	7.903E-1	2.930E-1	6.856E+0	2.827E+2	1.894E+0	3.057E+2	1.413E+0
20	9.365E+1	7.798E-1	2.960E-1	6.872E+0	2.715E+2	1.884E+0	2.982E+2	1.423E+0
30	9.497E+1	7.720E-1	2.972E-1	6.929E+0	2.702E+2	1.876E+0	2.997E+2	1.425E+0
40	9.732E+1	7.663E-1	2.976E-1	7.004E+0	2.733E+2	1.869E+0	3.051E+2	1.425E+0
50	9.992E+1	7.625E-1	2.978E-1	7.081E+0	2.781E+2	1.863E+0	3.119E+2	1.423E+0
60	1.022E+2	7.605E-1	2.980E-1	7.148E+0	2.827E+2	1.860E+0	3.181E+2	1.422E+0
<i>Pin 1, State 2</i>								
0	9.256E+1	7.854E-1	2.999E-1	6.983E+0	3.128E+2	1.877E+0	3.309E+2	1.379E+0
10	8.741E+1	8.088E-1	3.062E-1	6.745E+0	2.605E+2	1.959E+0	2.815E+2	1.472E+0
20	8.655E+1	7.986E-1	3.091E-1	6.761E+0	2.505E+2	1.951E+0	2.749E+2	1.481E+0
30	8.768E+1	7.912E-1	3.104E-1	6.811E+0	2.491E+2	1.943E+0	2.760E+2	1.484E+0
40	8.967E+1	7.860E-1	3.109E-1	6.876E+0	2.516E+2	1.937E+0	2.805E+2	1.484E+0
50	9.186E+1	7.826E-1	3.112E-1	6.941E+0	2.555E+2	1.932E+0	2.861E+2	1.483E+0
60	9.374E+1	7.811E-1	3.116E-1	6.997E+0	2.592E+2	1.930E+0	2.911E+2	1.483E+0
<i>Pin 29, State 1</i>								
0	9.131E+1	7.757E-1	2.898E-1	6.902E+0	3.141E+2	1.856E+0	3.292E+2	1.358E+0
10	8.513E+1	7.913E-1	2.969E-1	6.628E+0	2.566E+2	1.923E+0	2.757E+2	1.440E+0
20	8.379E+1	7.810E-1	3.006E-1	6.640E+0	2.440E+2	1.916E+0	2.671E+2	1.452E+0
30	8.474E+1	7.735E-1	3.024E-1	6.691E+0	2.414E+2	1.910E+0	2.673E+2	1.458E+0
40	8.679E+1	7.681E-1	3.034E-1	6.761E+0	2.436E+2	1.905E+0	2.719E+2	1.459E+0
50	8.925E+1	7.642E-1	3.039E-1	6.836E+0	2.479E+2	1.901E+0	2.782E+2	1.459E+0
60	9.156E+1	7.619E-1	3.043E-1	6.904E+0	2.525E+2	1.897E+0	2.844E+2	1.459E+0
<i>Pin 29, State 2</i>								
0	7.594E+1	7.855E-1	3.011E-1	6.554E+0	2.601E+2	1.911E+0	2.721E+2	1.413E+0
10	7.112E+1	8.020E-1	3.075E-1	6.360E+0	2.128E+2	1.983E+0	2.284E+2	1.496E+0
20	6.998E+1	7.923E-1	3.110E-1	6.370E+0	2.024E+2	1.977E+0	2.213E+2	1.508E+0
30	7.059E+1	7.858E-1	3.129E-1	6.408E+0	1.998E+2	1.973E+0	2.210E+2	1.513E+0
40	7.203E+1	7.812E-1	3.141E-1	6.460E+0	2.010E+2	1.970E+0	2.239E+2	1.516E+0
50	7.376E+1	7.783E-1	3.149E-1	6.515E+0	2.039E+2	1.967E+0	2.283E+2	1.517E+0
60	7.535E+1	7.766E-1	3.155E-1	6.564E+0	2.069E+2	1.966E+0	2.324E+2	1.517E+0
<i>Pin 72, State 1</i>								
0	9.670E+1	7.722E-1	2.871E-1	7.043E+0	3.293E+2	1.837E+0	3.472E+2	1.341E+0
10	9.071E+1	7.893E-1	2.941E-1	6.759E+0	2.718E+2	1.905E+0	2.932E+2	1.424E+0
20	8.966E+1	7.788E-1	2.973E-1	6.776E+0	2.603E+2	1.897E+0	2.856E+2	1.435E+0
30	9.095E+1	7.709E-1	2.987E-1	6.833E+0	2.588E+2	1.889E+0	2.869E+2	1.438E+0
40	9.332E+1	7.652E-1	2.993E-1	6.909E+0	2.619E+2	1.882E+0	2.924E+2	1.438E+0
50	9.601E+1	7.613E-1	2.995E-1	6.989E+0	2.669E+2	1.876E+0	2.995E+2	1.437E+0
60	9.842E+1	7.590E-1	2.997E-1	7.059E+0	2.718E+2	1.873E+0	3.060E+2	1.436E+0
<i>Pin 72, State 2</i>								
0	5.988E+1	7.855E-1	3.036E-1	6.183E+0	2.029E+2	1.939E+0	2.122E+2	1.445E+0
10	5.634E+1	7.952E-1	3.093E-1	6.037E+0	1.659E+2	1.994E+0	1.784E+2	1.513E+0
20	5.557E+1	7.857E-1	3.122E-1	6.048E+0	1.582E+2	1.989E+0	1.733E+2	1.522E+0
30	5.607E+1	7.795E-1	3.137E-1	6.078E+0	1.565E+2	1.985E+0	1.732E+2	1.526E+0
40	5.712E+1	7.756E-1	3.148E-1	6.116E+0	1.574E+2	1.982E+0	1.754E+2	1.528E+0
50	5.834E+1	7.733E-1	3.155E-1	6.155E+0	1.594E+2	1.980E+0	1.784E+2	1.529E+0
60	5.940E+1	7.725E-1	3.163E-1	6.188E+0	1.615E+2	1.980E+0	1.812E+2	1.530E+0

**Table 4.25. Fuel-averaged microscopic production cross section
for Variant 12, States 1 and 2**

Burnup (MWd/kg)	Microscopic production cross section (b)							
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu
<i>Pin 1, State 1</i>								
0	5.831E+1	8.456E-1	3.232E-1	6.266E+0	1.384E+2	2.001E+0	1.685E+2	1.465E+0
10	6.173E+1	8.457E-1	3.208E-1	6.216E+0	1.529E+2	1.968E+0	1.830E+2	1.523E+0
20	6.731E+1	8.284E-1	3.169E-1	6.349E+0	1.727E+2	1.943E+0	2.020E+2	1.507E+0
30	7.331E+1	8.137E-1	3.129E-1	6.487E+0	1.933E+2	1.921E+0	2.221E+2	1.490E+0
40	7.922E+1	8.020E-1	3.094E-1	6.624E+0	2.128E+2	1.903E+0	2.417E+2	1.475E+0
50	8.465E+1	7.929E-1	3.067E-1	6.752E+0	2.297E+2	1.890E+0	2.595E+2	1.463E+0
60	8.937E+1	7.862E-1	3.048E-1	6.864E+0	2.437E+2	1.881E+0	2.748E+2	1.454E+0
<i>Pin 1, State 2</i>								
0	5.514E+1	8.539E-1	3.346E-1	6.209E+0	1.303E+2	2.057E+0	1.589E+2	1.504E+0
10	5.833E+1	8.593E-1	3.321E-1	6.186E+0	1.439E+2	2.025E+0	1.724E+2	1.573E+0
20	6.339E+1	8.428E-1	3.283E-1	6.306E+0	1.621E+2	2.002E+0	1.898E+2	1.557E+0
30	6.877E+1	8.290E-1	3.245E-1	6.429E+0	1.808E+2	1.981E+0	2.078E+2	1.541E+0
40	7.400E+1	8.181E-1	3.213E-1	6.549E+0	1.983E+2	1.965E+0	2.252E+2	1.528E+0
50	7.875E+1	8.100E-1	3.190E-1	6.660E+0	2.133E+2	1.953E+0	2.408E+2	1.517E+0
60	8.281E+1	8.041E-1	3.174E-1	6.757E+0	2.255E+2	1.946E+0	2.540E+2	1.510E+0
<i>Pin 29, State 1</i>								
0	5.086E+1	8.478E-1	3.241E-1	6.061E+0	1.173E+2	2.013E+0	1.449E+2	1.488E+0
10	5.322E+1	8.471E-1	3.236E-1	6.018E+0	1.276E+2	1.992E+0	1.552E+2	1.546E+0
20	5.766E+1	8.327E-1	3.215E-1	6.131E+0	1.431E+2	1.976E+0	1.704E+2	1.536E+0
30	6.278E+1	8.200E-1	3.189E-1	6.254E+0	1.606E+2	1.960E+0	1.876E+2	1.525E+0
40	6.818E+1	8.091E-1	3.162E-1	6.380E+0	1.786E+2	1.945E+0	2.056E+2	1.513E+0
50	7.341E+1	8.001E-1	3.138E-1	6.503E+0	1.954E+2	1.932E+0	2.229E+2	1.502E+0
60	7.814E+1	7.929E-1	3.119E-1	6.615E+0	2.101E+2	1.922E+0	2.385E+2	1.493E+0
<i>Pin 29, State 2</i>								
0	4.452E+1	8.459E-1	3.312E-1	5.922E+0	1.010E+2	2.056E+0	1.256E+2	1.523E+0
10	4.636E+1	8.485E-1	3.308E-1	5.901E+0	1.094E+2	2.037E+0	1.338E+2	1.585E+0
20	4.979E+1	8.360E-1	3.290E-1	5.988E+0	1.219E+2	2.024E+0	1.457E+2	1.578E+0
30	5.372E+1	8.251E-1	3.269E-1	6.082E+0	1.358E+2	2.011E+0	1.590E+2	1.569E+0
40	5.782E+1	8.159E-1	3.247E-1	6.178E+0	1.499E+2	1.999E+0	1.728E+2	1.559E+0
50	6.175E+1	8.086E-1	3.229E-1	6.269E+0	1.630E+2	1.990E+0	1.859E+2	1.551E+0
60	6.528E+1	8.028E-1	3.215E-1	6.352E+0	1.742E+2	1.982E+0	1.976E+2	1.544E+0
<i>Pin 72, State 1</i>								
0	5.497E+1	8.458E-1	3.230E-1	6.170E+0	1.289E+2	2.005E+0	1.579E+2	1.476E+0
10	5.801E+1	8.451E-1	3.214E-1	6.127E+0	1.418E+2	1.977E+0	1.707E+2	1.533E+0
20	6.322E+1	8.289E-1	3.182E-1	6.254E+0	1.600E+2	1.956E+0	1.886E+2	1.519E+0
30	6.904E+1	8.149E-1	3.147E-1	6.391E+0	1.799E+2	1.936E+0	2.081E+2	1.504E+0
40	7.496E+1	8.033E-1	3.115E-1	6.528E+0	1.994E+2	1.919E+0	2.277E+2	1.490E+0
50	8.051E+1	7.940E-1	3.088E-1	6.658E+0	2.169E+2	1.905E+0	2.460E+2	1.477E+0
60	8.540E+1	7.869E-1	3.068E-1	6.774E+0	2.316E+2	1.895E+0	2.619E+2	1.468E+0
<i>Pin 72, State 2</i>								
0	3.730E+1	8.352E-1	3.307E-1	5.754E+0	8.226E+1	2.058E+0	1.035E+2	1.539E+0
10	3.883E+1	8.325E-1	3.296E-1	5.733E+0	8.968E+1	2.039E+0	1.104E+2	1.588E+0
20	4.151E+1	8.203E-1	3.274E-1	5.797E+0	1.001E+2	2.024E+0	1.198E+2	1.578E+0
30	4.450E+1	8.103E-1	3.251E-1	5.865E+0	1.112E+2	2.011E+0	1.301E+2	1.569E+0
40	4.750E+1	8.023E-1	3.230E-1	5.932E+0	1.220E+2	2.000E+0	1.403E+2	1.560E+0
50	5.029E+1	7.963E-1	3.214E-1	5.995E+0	1.315E+2	1.993E+0	1.497E+2	1.553E+0
60	5.270E+1	7.921E-1	3.205E-1	6.050E+0	1.393E+2	1.988E+0	1.577E+2	1.548E+0

Table 4.26. Fuel-averaged microscopic absorption cross sections for uranium and plutonium isotopes vs burnup for Variants 1-4 and 1-10, State 1

Burnup (MWd/kg)	Microscopic absorption cross section (b)										
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	¹³⁵ Xe	¹⁴⁹ Sm	Total FP
Variant 1											
0	4.292E+1	8.621E+0	9.693E-1	2.729E+1	1.491E+2	2.242E+2	1.272E+2	3.352E+1	1.429E+5	4.526E+3	2.027E+4
10	3.919E+1	7.517E+0	9.681E-1	2.499E+1	1.267E+2	1.719E+2	1.123E+2	3.354E+1	1.275E+5	4.026E+3	9.960E+0
20	3.789E+1	6.931E+0	9.705E-1	2.426E+1	1.175E+2	1.311E+2	1.062E+2	3.302E+1	1.227E+5	3.856E+3	6.930E+0
30	3.759E+1	6.569E+0	9.743E-1	2.416E+1	1.136E+2	1.093E+2	1.041E+2	3.185E+1	1.220E+5	3.821E+3	5.805E+0
40	3.771E+1	6.355E+0	9.785E-1	2.432E+1	1.121E+2	9.684E+1	1.035E+2	3.028E+1	1.232E+5	3.842E+3	5.171E+0
50	3.796E+1	6.212E+0	9.823E-1	2.455E+1	1.116E+2	8.901E+1	1.037E+2	2.860E+1	1.248E+5	3.882E+3	4.727E+0
60	3.819E+1	6.131E+0	9.857E-1	2.475E+1	1.114E+2	8.390E+1	1.039E+2	2.696E+1	1.263E+5	3.919E+3	4.380E+0
Variant 2											
0	2.531E+1	9.045E+0	9.465E-1	1.547E+1	5.906E+1	9.997E+1	6.057E+1	3.529E+1	6.262E+4	2.003E+3	8.900E+3
10	2.593E+1	8.691E+0	9.512E-1	1.600E+1	6.323E+1	6.720E+1	6.367E+1	3.396E+1	6.619E+4	2.103E+3	9.451E+0
20	2.727E+1	8.462E+0	9.566E-1	1.699E+1	6.918E+1	5.844E+1	6.820E+1	3.162E+1	7.297E+4	2.305E+3	6.901E+0
30	2.870E+1	8.258E+0	9.620E-1	1.801E+1	7.530E+1	5.554E+1	7.290E+1	2.888E+1	8.004E+4	2.516E+3	5.900E+0
40	3.009E+1	8.132E+0	9.672E-1	1.900E+1	8.101E+1	5.517E+1	7.744E+1	2.624E+1	8.692E+4	2.723E+3	5.312E+0
50	3.136E+1	8.020E+0	9.718E-1	1.991E+1	8.600E+1	5.613E+1	8.155E+1	2.410E+1	9.322E+4	2.912E+3	4.884E+0
60	3.247E+1	7.926E+0	9.760E-1	2.070E+1	9.016E+1	5.783E+1	8.511E+1	2.244E+1	9.875E+4	3.078E+3	4.537E+0
Variant 3											
0	3.952E+1	6.993E+0	9.843E-1	2.549E+1	1.185E+2	1.112E+2	1.091E+2	3.262E+1	1.307E+5	4.088E+3	1.850E+4
Variant 4											
0	3.757E+1	6.709E+0	9.765E-1	2.413E+1	1.124E+2	1.061E+2	1.032E+2	3.177E+1	1.218E+5	3.815E+3	1.925E+1
Variant 7											
0	2.717E+1	9.006E+0	9.485E-1	1.653E+1	6.422E+1	2.405E+2	6.503E+1	3.518E+1	6.964E+4	2.228E+3	9.897E+3
Variant 8											
0	4.570E+1	8.754E+0	9.836E-1	2.956E+1	1.561E+2	1.061E+2	1.355E+2	3.420E+1	1.582E+5	4.965E+3	2.240E+4
Variant 9											
0	2.702E+1	8.206E+0	9.373E-1	1.600E+1	7.955E+1	2.291E+2	6.581E+1	3.294E+1	6.542E+4	2.120E+3	9.322E+3
Variant 10											
0	1.525E+1	8.119E+0	8.524E-1	8.865E+0	2.770E+1	2.333E+1	3.164E+1	1.463E+1	2.102E+4	7.078E+2	3.019E+3
10	1.513E+1	7.412E+0	8.528E-1	8.780E+0	2.800E+1	2.275E+1	3.158E+1	1.434E+1	2.058E+4	6.884E+2	6.093E+0
20	1.525E+1	7.132E+0	8.541E-1	8.867E+0	2.886E+1	2.253E+1	3.202E+1	1.406E+1	2.122E+4	7.086E+2	4.690E+0
30	1.541E+1	6.937E+0	8.557E-1	8.979E+0	2.982E+1	2.253E+1	3.255E+1	1.375E+1	2.202E+4	7.336E+2	4.105E+0
40	1.560E+1	6.791E+0	8.574E-1	9.108E+0	3.085E+1	2.268E+1	3.314E+1	1.346E+1	2.292E+4	7.617E+2	3.755E+0
50	1.581E+1	6.683E+0	8.595E-1	9.249E+0	3.193E+1	2.298E+1	3.380E+1	1.318E+1	2.389E+4	7.921E+2	3.511E+0
60	1.602E+1	6.596E+0	8.615E-1	9.395E+0	3.302E+1	2.339E+1	3.449E+1	1.290E+1	2.490E+4	8.238E+2	3.321E+0

Table 4.27. Fuel-averaged microscopic production cross section for uranium and plutonium isotopes vs burnup, Variant 1–4 and 7–10, State 1

Burnup (MWd/kg)	Microscopic production cross section (b)							
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu
<i>Variant 1</i>								
0	8.454E+1	7.972E-1	2.813E-1	6.507E+0	2.710E+2	1.884E+0	2.796E+2	1.385E+0
10	7.669E+1	7.810E-1	2.894E-1	6.394E+0	2.313E+2	1.894E+0	2.474E+2	1.415E+0
20	7.392E+1	7.720E-1	2.937E-1	6.371E+0	2.150E+2	1.891E+0	2.344E+2	1.431E+0
30	7.325E+1	7.655E-1	2.959E-1	6.382E+0	2.083E+2	1.888E+0	2.298E+2	1.439E+0
40	7.346E+1	7.618E-1	2.974E-1	6.406E+0	2.058E+2	1.887E+0	2.287E+2	1.443E+0
50	7.395E+1	7.600E-1	2.989E-1	6.434E+0	2.051E+2	1.887E+0	2.291E+2	1.447E+0
60	7.440E+1	7.597E-1	3.002E-1	6.457E+0	2.049E+2	1.889E+0	2.297E+2	1.451E+0
<i>Variant 2</i>								
0	4.748E+01	8.673E-01	3.134E-01	5.824E+00	1.094E+02	1.973E+00	1.349E+02	1.512E+00
10	4.877E+01	8.571E-01	3.129E-01	5.873E+00	1.168E+02	1.953E+00	1.416E+02	1.510E+00
20	5.156E+01	8.482E-01	3.114E-01	5.946E+00	1.276E+02	1.941E+00	1.515E+02	1.503E+00
30	5.454E+01	8.397E-01	3.098E-01	6.018E+00	1.387E+02	1.930E+00	1.618E+02	1.496E+00
40	5.745E+01	8.334E-01	3.082E-01	6.087E+00	1.491E+02	1.922E+00	1.718E+02	1.490E+00
50	6.010E+01	8.285E-01	3.074E-01	6.150E+00	1.582E+02	1.917E+00	1.807E+02	1.485E+00
60	6.241E+01	8.250E-01	3.071E-01	6.206E+00	1.659E+02	1.914E+00	1.885E+02	1.483E+00
<i>Variant 3</i>								
0	7.723E+1	7.713E-1	2.929E-1	6.458E+0	2.176E+2	1.872E+0	2.409E+2	1.425E+0
<i>Variant 4</i>								
0	7.320E+1	7.699E-1	2.961E-1	6.382E+0	2.061E+2	1.889E+0	2.280E+2	1.441E+0
<i>Variant 7</i>								
0	5.137E+1	8.593E-1	3.099E-1	5.867E+0	1.191E+2	2.029E+0	1.447E+2	1.495E+0
<i>Variant 8</i>								
0	9.021E+1	7.944E-1	2.775E-1	6.679E+0	2.842E+2	1.802E+0	2.980E+2	1.370E+0
<i>Variant 9</i>								
0	5.114E+1	8.199E-1	2.985E-1	5.790E+0	1.448E+2	1.981E+0	1.460E+2	1.458E+0
<i>Variant 10</i>								
0	2.698E+1	8.647E-1	3.245E-1	5.450E+0	5.130E+1	2.013E+0	7.145E+1	1.577E+0
10	2.675E+1	8.460E-1	3.248E-1	5.451E+0	5.173E+1	2.015E+0	7.128E+1	1.579E+0
20	2.701E+1	8.387E-1	3.249E-1	5.461E+0	5.322E+1	2.016E+0	7.225E+1	1.579E+0
30	2.735E+1	8.335E-1	3.250E-1	5.472E+0	5.493E+1	2.016E+0	7.339E+1	1.579E+0
40	2.774E+1	8.296E-1	3.251E-1	5.483E+0	5.676E+1	2.017E+0	7.468E+1	1.579E+0
50	2.818E+1	8.264E-1	3.250E-1	5.494E+0	5.869E+1	2.016E+0	7.611E+1	1.579E+0
60	2.864E+1	8.242E-1	3.251E-1	5.505E+0	6.066E+1	2.017E+0	7.761E+1	1.579E+0

Table 4.28. k_{eff} and k_0 values for Variants 15–18, States 7–12

Variant	State											
	S7		S8		S9		S10		S11		S12	
	k_{eff}	k_0	k_{eff}	k_0	k_{eff}	k_0	k_{eff}	k_0	k_{eff}	k_0	k_{eff}	k_0
V15	1.3846	1.3727	1.3561	1.3445	1.0748	1.0737	1.2669	1.2607	1.0000	1.3727	1.0000	1.4578
V16	1.1107	1.1084	1.0818	1.0800	0.8081	0.8048	1.0250	1.0246	1.0000	1.1084	1.0000	1.2026
V17	1.2682	1.2644	1.2341	1.2306	0.9732	0.9727	1.2085	1.2061	1.0000	1.2644	1.0000	1.3818
V18	1.0809	1.0798	1.0498	1.0491	0.7911	0.7853	1.0164	1.0162	1.0000	1.0798	1.0000	1.1771
V19	1.3743	1.3743	1.3457	1.3457	1.0684	1.0684	1.2619	1.2619	1.0000	1.3646	1.0000	1.4521
V20	1.1759	1.1759	1.1471	1.1471	0.8706	0.8706	1.0888	1.0888	1.0000	1.1726	1.0000	1.2677

Table 4.29. Values of critical buckling for Variants 15–18, States 11 and 12

State	Critical buckling (cm^{-2})					
	Variant 15	Variant 16	Variant 17	Variant 18	Variant 19	Variant 20
S11	5.607E-3	1.694E-3	4.131E-3	1.270E-3	5.568E-3	2.706E-3
S12	1.049E-2	4.772E-3	8.949E-3	4.234E-3	1.054E-2	6.362E-3

Table 4.30. Fuel-averaged microscopic production cross sections ($\nu\sigma_f$) for uranium and plutonium isotopes for Variants 15–18

State	Fuel-averaged microscopic production cross section (b)							
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu
<i>Variant 15</i>								
S7	8.749E+1	7.964E-1	2.849E-1	6.605E+0	2.761E+2	1.901E+0	2.877E+2	1.403E+0
S8	8.660E+1	7.938E-1	2.854E-1	6.570E+0	2.797E+2	1.903E+0	2.877E+2	1.406E+0
S9	3.028E+1	6.377E-1	2.204E-1	5.124E+0	9.225E+1	1.687E+0	9.275E+1	1.231E+0
S10	8.279E+1	7.997E-1	2.841E-1	6.481E+0	2.640E+2	1.899E+0	2.730E+2	1.399E+0
S11	8.751E+1	7.962E-1	2.848E-1	6.605E+0	2.761E+2	1.901E+0	2.878E+2	1.403E+0
S12	1.188E+2	8.270E-1	2.976E-1	7.724E+0	2.915E+2	1.940E+0	3.300E+2	1.435E+0
<i>Variant 16</i>								
S7	8.068E+1	7.218E-1	2.904E-1	6.557E+0	2.250E+2	1.852E+0	2.508E+2	1.412E+0
S8	7.855E+1	7.360E-1	2.917E-1	6.498E+0	2.249E+2	1.863E+0	2.469E+2	1.418E+0
S9	2.739E+1	5.592E-1	2.140E-1	5.133E+0	6.390E+1	1.590E+0	7.510E+1	1.187E+0
S10	7.592E+1	7.244E-1	2.907E-1	6.433E+0	2.136E+2	1.853E+0	2.367E+2	1.411E+0
S11	8.066E+1	7.221E-1	2.906E-1	6.557E+0	2.249E+2	1.853E+0	2.508E+2	1.412E+0
S12	1.231E+2	7.226E-1	3.010E-1	7.955E+0	2.733E+2	1.870E+0	3.273E+2	1.430E+0
<i>Variant 17</i>								
S7	4.874E+1	8.672E-1	3.148E-1	5.864E+0	1.118E+2	1.977E+0	1.382E+2	1.519E+0
S8	4.716E+1	8.658E-1	3.159E-1	5.829E+0	1.103E+2	1.988E+0	1.345E+2	1.524E+0
S9	2.165E+1	6.627E-1	2.288E-1	5.025E+0	3.530E+1	1.661E+0	5.247E+1	1.249E+0
S10	4.713E+1	8.679E-1	3.141E-1	5.821E+0	1.080E+2	1.973E+0	1.336E+2	1.515E+0
S11	4.874E+1	8.673E-1	3.149E-1	5.864E+0	1.118E+2	1.978E+0	1.382E+2	1.519E+0
S12	7.534E+1	8.929E-1	3.266E-1	6.691E+0	1.540E+2	2.003E+0	1.962E+2	1.544E+0
<i>Variant 18</i>								
S7	6.253E+1	8.095E-1	3.027E-1	6.188E+0	1.569E+2	1.883E+0	1.844E+2	1.460E+0
S8	6.027E+1	8.138E-1	3.043E-1	6.135E+0	1.550E+2	1.893E+0	1.796E+2	1.466E+0
S9	2.444E+1	6.195E-1	2.159E-1	5.092E+0	4.566E+1	1.577E+0	6.151E+1	1.187E+0
S10	5.956E+1	8.114E-1	3.026E-1	6.110E+0	1.501E+2	1.881E+0	1.759E+2	1.458E+0
S11	6.252E+1	8.095E-1	3.027E-1	6.188E+0	1.569E+2	1.883E+0	1.844E+2	1.460E+0
S12	1.010E+2	8.202E-1	3.118E-1	7.397E+0	2.129E+2	1.894E+0	2.633E+2	1.472E+0

Table 4.31. Cell relative production rates for uranium and plutonium isotopes for Variants 15–18

State	Cell relative production rate							
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu
<i>Variant 15</i>								
S7	9.347E-1	0.0	6.530E-2	0.0	0.0	0.0	0.0	0.0
S8	9.340E-1	0.0	6.604E-2	0.0	0.0	0.0	0.0	0.0
S9	8.649E-1	0.0	1.351E-1	0.0	0.0	0.0	0.0	0.0
S10	9.314E-1	0.0	6.857E-2	0.0	0.0	0.0	0.0	0.0
S11	9.347E-1	0.0	6.527E-2	0.0	0.0	0.0	0.0	0.0
S12	9.490E-1	0.0	5.099E-2	0.0	0.0	0.0	0.0	0.0
<i>Variant 16</i>								
S7	4.299E-1	8.778E-4	7.493E-2	6.209E-4	4.153E-1	9.449E-4	7.665E-2	9.458E-5
S8	4.238E-1	9.063E-4	7.620E-2	6.230E-4	4.203E-1	9.622E-4	7.639E-2	9.614E-5
S9	4.234E-1	1.973E-3	1.602E-1	1.410E-3	3.422E-1	2.353E-3	6.657E-2	2.308E-4
S10	4.261E-1	9.279E-4	7.901E-2	6.417E-4	4.153E-1	9.955E-4	7.617E-2	9.958E-5
S11	4.299E-1	8.782E-4	7.499E-2	6.210E-4	4.153E-1	9.453E-4	7.665E-2	9.462E-5
S12	4.889E-1	6.551E-4	5.791E-2	5.615E-4	3.761E-1	7.113E-4	7.455E-2	7.142E-5
<i>Variant 17</i>								
S7	2.268E-2	0.0	7.217E-2	0.0	8.924E-1	1.014E-3	1.177E-2	0.0
S8	2.222E-2	0.0	7.334E-2	0.0	8.918E-1	1.032E-3	1.159E-2	0.0
S9	2.881E-2	0.0	1.500E-1	0.0	8.060E-1	2.436E-3	1.278E-2	0.0
S10	2.264E-2	0.0	7.431E-2	0.0	8.903E-1	1.045E-3	1.174E-2	0.0
S11	2.268E-2	0.0	7.219E-2	0.0	8.924E-1	1.014E-3	1.177E-2	0.0
S12	2.583E-2	0.0	5.517E-2	0.0	9.059E-1	7.568E-4	1.231E-2	0.0
<i>Variant 18</i>								
S7	1.742E-2	4.007E-5	7.797E-2	9.643E-5	7.041E-1	3.842E-3	1.956E-1	3.520E-4
S8	1.703E-2	4.086E-5	7.949E-2	9.697E-5	7.054E-1	3.919E-3	1.931E-1	3.586E-4
S9	2.024E-2	9.116E-5	1.653E-1	2.358E-4	6.089E-1	9.562E-3	1.939E-1	8.509E-4
S10	1.730E-2	4.188E-5	8.124E-2	9.925E-5	7.020E-1	4.001E-3	1.944E-1	3.664E-4
S11	1.742E-2	4.008E-5	7.797E-2	9.643E-5	7.041E-1	3.842E-3	1.956E-1	3.520E-4
S12	2.088E-2	3.013E-5	5.958E-2	8.551E-5	7.086E-1	2.867E-3	2.071E-1	2.633E-4

Table 4.32. Fuel-averaged microscopic absorption cross sections (σ_a) for uranium and plutonium isotopes for Variants 15–18

State	Fuel-averaged microscopic absorption cross section (b)										
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	¹³⁵ Xe	¹⁴⁹ Sm	All FP
Variant 15											
S7	4.426E+1	8.359E+0	9.585E-1	2.847E+1	1.516E+2	2.172E+2	1.308E+2	3.238E+1	1.523E+5	4.808E+3	1.550E+3
S8	4.384E+1	8.231E+0	1.015E+0	2.805E+1	1.539E+2	2.161E+2	1.309E+2	3.228E+1	1.495E+5	4.714E+3	1.522E+3
S9	1.642E+1	6.253E+0	6.987E-1	9.463E+0	5.156E+1	1.339E+2	4.196E+1	2.395E+1	2.581E+4	8.872E+2	2.815E+2
S10	4.205E+1	8.520E+0	9.619E-1	2.675E+1	1.452E+2	2.196E+2	1.242E+2	3.299E+1	1.399E+5	4.435E+3	1.427E+3
S11	4.427E+1	8.359E+0	9.585E-1	2.847E+1	1.516E+2	2.172E+2	1.309E+2	3.238E+1	1.524E+5	4.809E+3	1.550E+3
S12	5.929E+1	8.804E+0	9.797E-1	4.191E+1	1.547E+2	2.312E+2	1.501E+2	3.380E+1	2.250E+5	6.030E+3	2.276E+3
Variant 16											
S7	4.113E+1	5.437E+0	9.960E-1	2.682E+1	1.223E+2	1.091E+2	1.135E+2	2.846E+1	1.402E+5	4.373E+3	1.321E+1
S8	4.010E+1	5.797E+0	1.057E+0	2.600E+1	1.226E+2	1.147E+2	1.119E+2	2.971E+1	1.347E+5	4.201E+3	1.308E+1
S9	1.530E+1	4.005E+0	7.408E-1	8.872E+0	3.535E+1	4.716E+1	3.359E+1	2.079E+1	2.025E+4	6.929E+2	7.689E+0
S10	3.889E+1	5.510E+0	9.983E-1	2.507E+1	1.164E+2	1.091E+2	1.071E+2	2.884E+1	1.277E+5	4.003E+3	1.300E+1
S11	4.112E+1	5.437E+0	9.959E-1	2.682E+1	1.223E+2	1.091E+2	1.135E+2	2.845E+1	1.401E+5	4.372E+3	1.321E+1
S12	6.145E+1	5.088E+0	1.022E+0	4.424E+1	1.429E+2	1.189E+2	1.486E+2	2.713E+1	2.356E+5	6.151E+3	1.625E+1
Variant 17											
S7	2.586E+1	8.951E+0	9.450E-1	1.599E+1	6.015E+1	9.892E+1	6.207E+1	3.493E+1	6.657E+4	2.119E+3	6.929E+2
S8	2.506E+1	8.821E+0	1.007E+0	1.545E+1	5.959E+1	1.044E+2	6.043E+1	3.488E+1	6.319E+4	2.011E+3	6.584E+2
S9	1.255E+1	6.689E+0	7.143E-1	7.033E+0	1.913E+1	4.493E+1	2.317E+1	2.638E+1	8.876E+3	3.300E+2	1.089E+2
S10	2.511E+1	9.021E+0	9.477E-1	1.539E+1	5.822E+1	9.874E+1	6.000E+1	3.513E+1	6.223E+4	1.992E+3	6.499E+2
S11	2.586E+1	8.950E+0	9.450E-1	1.599E+1	6.015E+1	9.891E+1	6.207E+1	3.492E+1	6.656E+4	2.119E+3	6.928E+2
S12	3.865E+1	9.300E+0	9.482E-1	2.641E+1	8.029E+1	1.061E+2	8.858E+1	3.584E+1	1.265E+5	3.409E+3	1.293E+3
Variant 18											
S7	3.258E+1	7.679E+0	9.910E-1	2.078E+1	8.486E+1	5.826E+1	8.310E+1	2.371E+1	9.836E+4	3.071E+3	1.519E+1
S8	3.146E+1	7.710E+0	1.055E+0	1.999E+1	8.410E+1	6.019E+1	8.098E+1	2.576E+1	9.321E+4	2.910E+3	1.497E+1
S9	1.410E+1	5.929E+0	7.548E-1	7.925E+0	2.509E+1	2.413E+1	2.724E+1	1.700E+1	1.312E+4	4.577E+2	9.540E+0
S10	3.119E+1	7.758E+0	9.934E-1	1.969E+1	8.131E+1	5.781E+1	7.923E+1	2.389E+1	9.051E+4	2.841E+3	1.502E+1
S11	3.258E+1	7.681E+0	9.910E-1	2.078E+1	8.486E+1	5.826E+1	8.310E+1	2.370E+1	9.835E+4	3.071E+3	1.519E+1
S12	5.105E+1	7.717E+0	1.006E+0	3.613E+1	1.109E+2	6.841E+1	1.192E+2	2.168E+1	1.846E+5	4.824E+3	1.883E+1

Table 4.33. Cell relative absorption rates in uranium and plutonium isotopes for Variants 15–18

State	Cell relative absorption rate								
	²³⁵ U	²³⁶ U	²³⁸ U	²³⁸ Pu	²³⁹ Pu	²⁴⁰ Pu	²⁴¹ Pu	²⁴² Pu	All FP
<i>Variant 15</i>									
S7	6.491E-1	0.0	3.015E-1	0.0	0.0	0.0	0.0	0.0	0.0
S8	6.357E-1	0.0	3.158E-1	0.0	0.0	0.0	0.0	0.0	0.0
S9	5.038E-1	0.0	4.598E-1	0.0	0.0	0.0	0.0	0.0	0.0
S10	5.964E-1	0.0	2.927E-1	0.0	0.0	0.0	0.0	0.0	0.0
S11	6.491E-1	0.0	3.015E-1	0.0	0.0	0.0	0.0	0.0	0.0
S12	6.902E-1	0.0	2.447E-1	0.0	0.0	0.0	0.0	0.0	0.0
<i>Variant 16</i>									
S7	2.429E-1	7.329E-3	2.849E-1	2.815E-3	2.502E-1	6.169E-2	3.845E-2	2.113E-3	4.321E-2
S8	2.337E-1	7.709E-3	2.983E-1	2.692E-3	2.476E-1	6.400E-2	3.737E-2	2.176E-3	4.220E-2
S9	1.904E-1	1.137E-2	4.463E-1	1.962E-3	1.524E-1	5.617E-2	2.396E-2	3.251E-3	5.296E-2
S10	2.237E-1	7.231E-3	2.781E-1	2.563E-3	2.318E-1	6.008E-2	3.533E-2	2.085E-3	4.138E-2
S11	2.429E-1	7.330E-3	2.849E-1	2.815E-3	2.502E-1	6.169E-2	3.845E-2	2.113E-3	4.321E-2
S12	2.936E-1	5.547E-3	2.365E-1	3.756E-3	2.366E-1	5.437E-2	4.071E-2	1.630E-3	4.297E-2
<i>Variant 17</i>									
S7	1.521E-2	0.0	2.739E-1	0.0	6.072E-1	6.415E-2	6.682E-3	0.0	0.0
S8	1.453E-2	0.0	2.876E-1	0.0	5.928E-1	6.675E-2	6.411E-3	0.0	0.0
S9	1.624E-2	0.0	4.556E-1	0.0	4.248E-1	6.411E-2	5.488E-3	0.0	0.0
S10	1.454E-2	0.0	2.705E-1	0.0	5.787E-1	6.305E-2	6.359E-3	0.0	0.0
S11	1.521E-2	0.0	2.739E-1	0.0	6.072E-1	6.415E-2	6.682E-3	0.0	0.0
S12	1.831E-2	0.0	2.213E-1	0.0	6.525E-1	5.541E-2	7.677E-3	0.0	0.0
<i>Variant 18</i>									
S7	9.801E-3	4.105E-4	2.756E-1	3.497E-4	4.111E-1	1.284E-1	9.515E-2	6.172E-3	2.396E-2
S8	9.327E-3	4.062E-4	2.892E-1	3.314E-4	4.015E-1	1.307E-1	9.138E-2	6.610E-3	2.327E-2
S9	9.172E-3	6.851E-4	4.538E-1	2.883E-4	2.628E-1	1.150E-1	6.741E-2	9.567E-3	3.253E-2
S10	9.206E-3	4.069E-4	2.711E-1	3.250E-4	3.865E-1	1.250E-1	8.901E-2	6.102E-3	2.325E-2
S11	9.801E-3	4.106E-4	2.756E-1	3.497E-4	4.111E-1	1.284E-1	9.515E-2	6.171E-3	2.396E-2
S12	1.242E-2	3.336E-4	2.264E-1	4.916E-4	4.345E-1	1.219E-1	1.104E-1	4.564E-3	2.402E-2

Table 4.34. Delayed neutron fraction (β), effective delayed neutron fraction (β_{eff}), and prompt neutron lifetime for Variants 15–18

Variant	State	Delayed neutron fraction	Effective delayed neutron fraction	Prompt neutron lifetime (s)
V15	S7	7.374E-3	7.192E-3	2.111E-5
	S8	7.386E-3	7.194E-3	2.106E-5
	S9	8.153E-3	7.500E-3	1.591E-5
	S10	7.430E-3	7.202E-3	1.881E-5
	S11	7.457E-3	8.225E-3	2.035E-5
	S12	7.304E-3	8.354E-3	2.089E-5
V16	S7	5.515E-3	5.289E-3	1.909E-5
	S8	5.515E-3	5.276E-3	1.876E-5
	S9	6.991E-3	6.061E-3	1.253E-5
	S10	5.585E-3	5.317E-3	1.692E-5
	S11	5.551E-3	5.558E-3	1.888E-5
	S12	5.554E-3	5.846E-3	2.159E-5
V17	S7	3.353E-3	3.231E-3	1.088E-5
	S8	3.378E-3	3.248E-3	1.057E-5
	S9	4.691E-3	4.160E-3	8.483E-6
	S10	3.402E-3	3.266E-3	1.011E-5
	S11	3.442E-3	3.657E-3	1.065E-5
	S12	3.198E-3	3.583E-3	1.303E-5
V18	S7	4.085E-3	3.896E-3	1.427E-5
	S8	4.109E-3	3.908E-3	1.388E-5
	S9	5.711E-3	4.880E-3	9.493E-6
	S10	4.153E-3	3.938E-3	1.292E-5
	S11	4.113E-3	4.055E-3	1.417E-5
	S12	3.886E-3	4.046E-3	1.739E-5
V19	S7	6.338E-3	6.172E-3	1.943E-5
	S8	6.354E-3	6.179E-3	1.933E-5
	S9	7.201E-3	6.596E-3	1.486E-5
	S10	6.366E-3	6.161E-3	1.726E-5
	S11	6.425E-3	7.083E-3	1.878E-5
	S12	6.279E-3	7.191E-3	1.987E-5
V20	S7	4.833E-3	4.650E-3	1.772E-5
	S8	4.838E-3	4.645E-3	1.742E-5
	S9	6.206E-3	5.453E-3	1.239E-5
	S10	4.884E-3	4.667E-3	1.570E-5
	S11	4.887E-3	5.027E-3	1.744E-5
	S12	4.815E-3	5.198E-3	2.010E-5

Fig. 4.1. Pin numbering for Variants 11 and 12.

Fig. 4.2. Relative fission rate distribution for Variant 11, State 1, at 0 MWd/kg.

				0							
				1.050	1.049						
				1.037	1.040	1.053					
				1.031	1.030	0	1.048				
				1.024	1.004	1.027	1.030	1.025			
				0	1.017	1.023	1.024	1.021	0		
				0.997	1.004	1.009	0	1.010	1.005	0.997	
				0.964	0.962	0.970	0.997	0.997	0.971	0.962	0.964
				0.968	0.958	0.960	0.966	0.967	0.966	0.960	0.958
				0.996	0.978	0.975	0.975	0.976	0.976	0.975	0.975
				0.978	0.975	0.975	0.976	0.976	0.975	0.975	0.978
				0.997	0.996	0.996	0.996	0.996	0.996	0.996	0.997
				1.058	1.031	1.023	1.020	1.020	1.020	1.020	1.021
				1.024	1.033	1.059					

Fig. 4.3. Relative fission rate distribution for Variant 11, State 1, at 10 MWd/kg.

				0							
				1.044	1.043						
				1.031	1.035	1.049					
				1.026	1.027	0	1.044				
				1.022	1.003	1.023	1.026	1.023			
				0	1.015	1.020	1.021	1.018	0		
				0.999	1.004	1.008	0	1.009	1.005	0.999	
				0.969	0.967	0.974	0.998	0.998	0.974	0.967	0.969
				0.974	0.963	0.965	0.970	0.971	0.970	0.965	0.963
				0.974	0.963	0.965	0.970	0.971	0.970	0.965	0.963
				0.996	0.980	0.977	0.977	0.978	0.978	0.978	0.977
				0.980	0.997	0.996	0.996	0.996	0.996	0.996	0.997
				1.050	1.026	1.020	1.018	1.017	1.017	1.018	1.018
				1.021	1.028	1.051					

Fig. 4.4. Relative fission rate distribution for Variant 11, State 1, at 20 MWd/kg.

0
1.036 1.035
1.024 1.029 1.044
1.020 1.022 0 1.040
1.019 1.001 1.020 1.021 1.020
0 1.013 1.017 1.017 1.015 0
1.000 1.004 1.007 0 1.008 1.005 1.000
0.976 0.972 0.978 1.000 1.000 0.978 0.973 0.976
0.979 0.970 0.971 0.975 0.976 0.975 0.971 0.970 0.979
0.996 0.982 0.980 0.980 0.981 0.981 0.980 0.980 0.982 0.997
1.041 1.022 1.017 1.015 1.015 1.015 1.015 1.016 1.018 1.022 1.042

Fig. 4.5. Relative fission rate distribution for Variant 11, State 1, at 30 MWd/kg.

0
1.028 1.028
1.017 1.022 1.039
1.014 1.018 0 1.036
1.016 0.999 1.016 1.016 1.016
0 1.010 1.013 1.014 1.012 0
1.002 1.004 1.007 0 1.007 1.005 1.002
0.982 0.978 0.982 1.001 1.001 0.982 0.978 0.982
0.985 0.976 0.977 0.980 0.980 0.980 0.977 0.976 0.985
0.996 0.984 0.983 0.983 0.983 0.983 0.983 0.983 0.984 0.996
1.034 1.017 1.014 1.013 1.013 1.013 1.013 1.013 1.015 1.018 1.034

Fig. 4.6. Relative fission rate distribution for Variant 11, State 1, at 40 MWd/kg.

				0										
				1.022	1.021									
				1.011	1.017	1.034								
				1.009	1.014	0	1.033							
				1.014	0.996	1.012	1.013	1.014						
				0	1.009	1.011	1.011	1.010	0					
				1.004	1.005	1.006	0	1.006	1.005	1.004				
				0.987	0.982	0.984	1.003	1.003	0.985	0.982	0.987			
				0.989	0.980	0.981	0.983	0.984	0.983	0.981	0.980	0.989		
				0.996	0.985	0.985	0.985	0.985	0.985	0.985	0.985	0.996		
				1.029	1.014	1.013	1.012	1.012	1.012	1.012	1.012	1.013	1.014	1.029

Fig. 4.7. Relative fission rate distribution for Variant 11, State 1, at 50 MWd/kg.

				0										
				1.018	1.018									
				1.008	1.013	1.032								
				1.006	1.011	0	1.032							
				1.012	0.994	1.010	1.011	1.012						
				0	1.008	1.009	1.010	1.009	0					
				1.006	1.005	1.006	0	1.006	1.005	1.006				
				0.990	0.984	0.986	1.004	1.004	0.986	0.984	0.990			
				0.991	0.982	0.983	0.985	0.985	0.985	0.983	0.982	0.991		
				0.995	0.986	0.985	0.985	0.985	0.986	0.985	0.985	0.986	0.995	
				1.027	1.013	1.012	1.012	1.012	1.012	1.012	1.012	1.012	1.013	1.027

Fig. 4.8. Relative fission rate distribution for Variant 11, State 1, at 60 MWd/kg.

0
0.806 0.808
0.729 0.726 0.712
0.714 0.715 0 0.697
0.741 0.752 0.719 0.710 0.739
0 0.761 0.732 0.732 0.750 0
0.898 0.840 0.813 0 0.813 0.836 0.898
1.045 0.992 0.953 0.897 0.897 0.953 0.991 1.044
1.141 1.096 1.065 1.034 1.029 1.034 1.064 1.095 1.141
1.226 1.184 1.157 1.134 1.124 1.124 1.134 1.157 1.184 1.227
1.327 1.280 1.253 1.232 1.219 1.215 1.219 1.233 1.255 1.285 1.330

Fig. 4.9. Relative fission rate distribution for Variant 11, State 2, at 0 MWd/kg.

0
0.806 0.809
0.729 0.726 0.714
0.715 0.716 0 0.700
0.743 0.753 0.720 0.711 0.740
0 0.762 0.733 0.733 0.751 0
0.900 0.841 0.814 0 0.813 0.837 0.900
1.048 0.995 0.955 0.898 0.898 0.954 0.993 1.048
1.144 1.099 1.067 1.036 1.031 1.036 1.067 1.098 1.144
1.223 1.182 1.157 1.134 1.123 1.123 1.134 1.156 1.182 1.224
1.319 1.275 1.250 1.229 1.216 1.212 1.216 1.230 1.251 1.278 1.321

Fig. 4.10. Relative fission rate distribution for Variant 11, State 2, at 10 MWd/kg.

0
0.802 0.804
0.725 0.723 0.712
0.711 0.714 0 0.698
0.741 0.752 0.718 0.708 0.738
0 0.761 0.731 0.731 0.748 0
0.901 0.840 0.813 0 0.812 0.836 0.900
1.054 0.999 0.958 0.899 0.899 0.957 0.997 1.054
1.150 1.104 1.073 1.040 1.035 1.040 1.073 1.104 1.150
1.223 1.184 1.159 1.136 1.126 1.126 1.136 1.159 1.184 1.223
1.309 1.269 1.246 1.226 1.213 1.209 1.213 1.226 1.247 1.271 1.310

Fig. 4.11. Relative fission rate distribution for Variant 11, State 2, at 20 MWd/kg.

0
0.795 0.797
0.719 0.718 0.708
0.706 0.710 0 0.694
0.738 0.749 0.714 0.704 0.735
0 0.758 0.728 0.728 0.745 0
0.902 0.840 0.812 0 0.811 0.835 0.902
1.061 1.004 0.961 0.900 0.900 0.960 1.002 1.061
1.157 1.112 1.079 1.045 1.039 1.045 1.079 1.111 1.157
1.224 1.187 1.163 1.139 1.129 1.129 1.139 1.162 1.187 1.224
1.299 1.264 1.242 1.223 1.210 1.206 1.211 1.224 1.243 1.265 1.300

Fig. 4.12. Relative fission rate distribution for Variant 11, State 2, at 30 MWd/kg.

0
0.786 0.788
0.712 0.712 0.702
0.700 0.705 0 0.690
0.734 0.745 0.710 0.700 0.731
0 0.755 0.724 0.724 0.742 0
0.903 0.839 0.810 0 0.809 0.835 0.903
1.067 1.009 0.964 0.901 0.901 0.963 1.007 1.067
1.163 1.119 1.085 1.049 1.044 1.049 1.085 1.118 1.163
1.224 1.190 1.166 1.143 1.132 1.132 1.143 1.166 1.190 1.224
1.291 1.259 1.240 1.221 1.208 1.205 1.209 1.222 1.241 1.260 1.292

Fig. 4.13. Relative fission rate distribution for Variant 11, State 2, at 40 MWd/kg.

0
0.778 0.780
0.706 0.706 0.698
0.695 0.700 0 0.686
0.731 0.741 0.706 0.696 0.728
0 0.753 0.721 0.721 0.740 0
0.905 0.839 0.810 0 0.809 0.835 0.904
1.072 1.012 0.966 0.902 0.902 0.965 1.010 1.072
1.168 1.124 1.090 1.053 1.047 1.052 1.089 1.123 1.168
1.224 1.192 1.169 1.145 1.134 1.134 1.145 1.168 1.192 1.224
1.286 1.257 1.239 1.220 1.207 1.204 1.208 1.221 1.240 1.257 1.286

Fig. 4.14. Relative fission rate distribution for Variant 11, State 2, at 50 MWd/kg.

0
0.773 0.776
0.703 0.703 0.696
0.692 0.698 0 0.685
0.729 0.738 0.704 0.694 0.726
0 0.752 0.720 0.720 0.739 0
0.906 0.840 0.810 0 0.809 0.835 0.906
1.074 1.014 0.966 0.904 0.903 0.965 1.012 1.074
1.171 1.126 1.092 1.054 1.048 1.054 1.091 1.125 1.171
1.224 1.193 1.169 1.146 1.134 1.134 1.145 1.169 1.192 1.224
1.286 1.256 1.239 1.220 1.208 1.204 1.208 1.221 1.239 1.256 1.286

Fig. 4.15. Relative fission rate distribution for Variant 11, State 2, at 60 MWd/kg.

0
1.070 1.069
1.047 1.055 1.082
1.038 1.041 0 1.075
1.036 0.993 1.039 1.044 1.039
0 1.028 1.036 1.038 1.035 0
1.000 1.011 1.018 0 1.019 1.013 1.000
0.940 0.937 0.949 1.001 1.001 0.949 0.937 0.940
0.946 0.929 0.932 0.942 0.945 0.942 0.932 0.929 0.946
0.989 0.960 0.956 0.957 0.959 0.959 0.958 0.956 0.961 0.991
1.105 1.057 1.046 1.043 1.043 1.043 1.043 1.044 1.048 1.061 1.108

Fig. 4.16. Relative fission rate distribution for Variant 12, State 1, at 0 MWd/kg.

0
1.059 1.058
1.042 1.047 1.067
1.035 1.036 0 1.062
1.031 0.999 1.033 1.037 1.032
0 1.022 1.029 1.031 1.028 0
0.999 1.008 1.014 0 1.015 1.009 0.999
0.952 0.949 0.960 0.999 1.000 0.960 0.950 0.952
0.958 0.943 0.946 0.954 0.956 0.954 0.946 0.943 0.958
0.994 0.969 0.965 0.966 0.967 0.967 0.966 0.965 0.970 0.995
1.080 1.044 1.035 1.032 1.032 1.032 1.032 1.032 1.036 1.047 1.082

Fig. 4.17. Relative fission rate distribution for Variant 12, State 1, at 10 MWd/kg.

0
1.048 1.047
1.034 1.039 1.056
1.028 1.030 0 1.050
1.025 1.003 1.027 1.029 1.026
0 1.017 1.023 1.024 1.021 0
0.999 1.005 1.010 0 1.010 1.006 0.999
0.964 0.961 0.969 0.999 0.999 0.970 0.962 0.964
0.970 0.957 0.959 0.965 0.967 0.965 0.959 0.957 0.970
0.997 0.977 0.974 0.974 0.975 0.975 0.974 0.974 0.977 0.997
1.058 1.031 1.024 1.022 1.021 1.021 1.021 1.022 1.025 1.033 1.058

Fig. 4.18. Relative fission rate distribution for Variant 12, State 1, at 20 MWd/kg.

```

      0
    1.037 1.037
  1.025 1.030 1.046
    1.021 1.024 0 1.042
  1.020 1.003 1.020 1.022 1.020
    0 1.013 1.017 1.017 1.015 0
  1.000 1.004 1.007 0 1.008 1.004 1.000
    0.976 0.972 0.978 0.999 0.999 0.978 0.972 0.976
  0.980 0.969 0.971 0.975 0.976 0.975 0.971 0.969 0.980
    0.997 0.983 0.980 0.980 0.980 0.980 0.980 0.980 0.983 0.997
  1.040 1.021 1.017 1.015 1.014 1.014 1.014 1.015 1.017 1.022 1.040

```

Fig. 4.19. Relative fission rate distribution for Variant 12, State 1, at 30 MWd/kg.

```

      0
    1.028 1.028
  1.017 1.023 1.039
    1.014 1.018 0 1.037
  1.016 1.000 1.016 1.016 1.016
    0 1.010 1.013 1.013 1.011 0
  1.002 1.004 1.006 0 1.006 1.004 1.002
    0.984 0.979 0.983 1.001 1.001 0.983 0.979 0.984
  0.987 0.978 0.979 0.981 0.982 0.981 0.979 0.978 0.987
    0.997 0.985 0.983 0.983 0.984 0.984 0.984 0.984 0.985 0.996
  1.030 1.015 1.012 1.011 1.010 1.010 1.010 1.011 1.012 1.015 1.030

```

Fig. 4.20. Relative fission rate distribution for Variant 12, State 1, at 40 MWd/kg.

0
1.022 1.022
1.012 1.017 1.035
1.010 1.014 0 1.033
1.014 0.997 1.012 1.013 1.014
0 1.008 1.011 1.010 1.009 0
1.004 1.004 1.006 0 1.006 1.004 1.004
0.989 0.983 0.986 1.002 1.002 0.986 0.983 0.989
0.991 0.982 0.983 0.985 0.985 0.985 0.983 0.982 0.991
0.996 0.986 0.985 0.985 0.985 0.985 0.985 0.985 0.986 0.995
1.026 1.012 1.011 1.010 1.010 1.010 1.010 1.010 1.011 1.012 1.026

Fig. 4.21. Relative fission rate distribution for Variant 12, State 1 at 50 MWd/kg.

0
1.019 1.019
1.009 1.015 1.033
1.007 1.012 0 1.032
1.012 0.995 1.010 1.011 1.012
0 1.008 1.010 1.009 1.009 0
1.005 1.005 1.006 0 1.006 1.005 1.005
0.991 0.985 0.986 1.003 1.003 0.986 0.985 0.991
0.992 0.984 0.984 0.986 0.986 0.986 0.984 0.984 0.992
0.995 0.986 0.985 0.986 0.986 0.986 0.986 0.985 0.986 0.995
1.025 1.011 1.011 1.010 1.010 1.010 1.010 1.010 1.011 1.011 1.025

Fig. 4.22. Relative fission rate distribution for Variant 12, State 1, at 60 MWd/kg.

0
0.880 0.882
0.780 0.774 0.760
0.762 0.754 0 0.740
0.776 0.784 0.754 0.745 0.772
0 0.785 0.764 0.763 0.775 0
0.897 0.846 0.826 0 0.825 0.842 0.897
1.021 0.971 0.941 0.893 0.893 0.941 0.970 1.020
1.105 1.059 1.035 1.011 1.006 1.011 1.034 1.058 1.105
1.194 1.144 1.123 1.105 1.097 1.097 1.105 1.122 1.145 1.196
1.351 1.283 1.258 1.240 1.230 1.227 1.230 1.241 1.260 1.289 1.355

Fig. 4.23. Relative fission rate distribution for Variant 12, State 2, at 0 MWd/kg.

0
0.864 0.866
0.771 0.765 0.749
0.753 0.747 0 0.730
0.769 0.783 0.747 0.738 0.766
0 0.780 0.758 0.756 0.769 0
0.896 0.843 0.822 0 0.821 0.839 0.896
1.033 0.982 0.949 0.893 0.893 0.949 0.981 1.033
1.120 1.075 1.049 1.023 1.018 1.023 1.049 1.075 1.120
1.201 1.157 1.134 1.115 1.107 1.107 1.115 1.134 1.157 1.202
1.322 1.269 1.246 1.228 1.217 1.215 1.218 1.229 1.247 1.273 1.325

Fig. 4.24. Relative fission rate distribution for Variant 12, State 2, at 10 MWd/kg.

0
0.845 0.847
0.757 0.753 0.737
0.741 0.738 0 0.719
0.761 0.778 0.738 0.728 0.757
0 0.773 0.749 0.747 0.761 0
0.897 0.840 0.817 0 0.816 0.836 0.896
1.046 0.993 0.957 0.893 0.893 0.956 0.992 1.046
1.136 1.092 1.064 1.034 1.029 1.034 1.064 1.092 1.136
1.208 1.169 1.146 1.126 1.117 1.117 1.126 1.146 1.169 1.209
1.299 1.258 1.236 1.219 1.208 1.205 1.208 1.220 1.238 1.260 1.300

Fig. 4.25. Relative fission rate distribution for Variant 12, State 2, at 20 MWd/kg.

0
0.826 0.828
0.743 0.740 0.727
0.728 0.728 0 0.710
0.752 0.770 0.729 0.718 0.749
0 0.767 0.741 0.739 0.754 0
0.898 0.838 0.814 0 0.813 0.834 0.897
1.058 1.003 0.963 0.894 0.894 0.962 1.001 1.058
1.150 1.107 1.077 1.044 1.038 1.044 1.076 1.106 1.150
1.213 1.178 1.155 1.134 1.124 1.124 1.134 1.155 1.178 1.213
1.282 1.250 1.230 1.213 1.202 1.199 1.202 1.214 1.231 1.251 1.283

Fig. 4.26. Relative fission rate distribution for Variant 12, State 2, at 30 MWd/kg.

0
0.809 0.812
0.731 0.729 0.717
0.716 0.719 0 0.702
0.745 0.761 0.721 0.710 0.742
0 0.762 0.734 0.733 0.748 0
0.900 0.838 0.812 0 0.810 0.833 0.900
1.067 1.010 0.966 0.897 0.897 0.965 1.008 1.067
1.160 1.117 1.086 1.050 1.044 1.050 1.085 1.117 1.160
1.215 1.184 1.162 1.140 1.129 1.129 1.139 1.161 1.184 1.215
1.274 1.246 1.228 1.211 1.200 1.196 1.200 1.212 1.229 1.246 1.274

Fig. 4.27. Relative fission rate distribution for Variant 12, State 2, at 40 MWd/kg.

0
0.798 0.800
0.722 0.720 0.711
0.708 0.712 0 0.697
0.740 0.754 0.715 0.705 0.737
0 0.759 0.729 0.728 0.745 0
0.902 0.838 0.811 0 0.809 0.833 0.902
1.072 1.013 0.967 0.899 0.899 0.966 1.011 1.072
1.166 1.123 1.090 1.053 1.047 1.053 1.090 1.122 1.166
1.217 1.187 1.165 1.142 1.131 1.131 1.142 1.164 1.187 1.217
1.273 1.246 1.229 1.212 1.200 1.197 1.201 1.213 1.230 1.246 1.273

Fig. 4.28. Relative fission rate distribution for Variant 12, State 2, at 50 MWd/kg.

0
0.788 0.790
0.714 0.714 0.705
0.702 0.706 0 0.692
0.736 0.748 0.711 0.700 0.733
0 0.756 0.726 0.725 0.742 0
0.904 0.839 0.810 0 0.809 0.834 0.903
1.075 1.014 0.967 0.901 0.900 0.966 1.012 1.074
1.169 1.125 1.092 1.054 1.048 1.054 1.091 1.125 1.169
1.219 1.189 1.167 1.144 1.133 1.133 1.144 1.166 1.189 1.219
1.276 1.248 1.232 1.215 1.202 1.199 1.203 1.215 1.232 1.248 1.276

Fig. 4.29. Relative fission rate distribution for Variant 12, State 2, at 60 MWd/kg.

Fig. 4.30. Pin numbering for Variants 13 and 14.

Fig. 4.31. Relative fission rate distribution for Variant 13, State 1, at 0 MWd/kg.

0.859

0.843

0.834 0.845

0.839 0.849

0.841 0.842 0.853

0.849 0.849 0.862

0.856 0.858 0.860 0.876

0.875 0.876 0.881 0.903

0.904 0.907 0.911 0.921 0.953

0.965 0.971 0.978 0.995 1.043

1.085 1.090 1.097 1.108 1.133 1.192

0.998 0.998 1.004 1.015 1.037 1.081

0.987 0.989 0.996 1.010 1.034 1.095

0.986 0.988 0.992 1.000 1.015 1.043 1.102

0.989 0.990 0.994 1.003 1.019 1.048 1.106

0.988 0.989 0.991 0.997 1.006 1.023 1.052 1.109

0.990 0.990 0.993 0.999 1.008 1.025 1.054 1.112

0.989 0.989 0.991 0.994 1.000 1.010 1.027 1.057 1.115

0.990 0.990 0.992 0.996 1.002 1.012 1.030 1.060 1.118

0.989 0.989 0.991 0.993 0.997 1.003 1.014 1.033 1.064 1.124

0.989 0.989 0.991 0.994 0.998 1.006 1.018 1.038 1.072 1.135

0.998 0.996 0.997 0.999 1.002 1.008 1.017 1.032 1.056 1.093 1.162

Fig. 4.32. Relative fission rate distribution for Variant 13,
State 1, at 10 MWd/kg.

0.888

0.874

0.866 0.875

0.870 0.879

0.872 0.873 0.884

0.880 0.880 0.892

0.887 0.889 0.892 0.907

0.905 0.906 0.911 0.931

0.928 0.931 0.935 0.943 0.969

0.970 0.974 0.980 0.992 1.022

1.037 1.039 1.043 1.051 1.064 1.091

1.032 1.032 1.037 1.046 1.062 1.094

1.003 1.005 1.010 1.021 1.040 1.090

0.994 0.995 0.998 1.005 1.017 1.040 1.090

0.991 0.992 0.996 1.004 1.017 1.040 1.091

0.987 0.988 0.991 0.996 1.004 1.018 1.041 1.092

0.988 0.988 0.991 0.996 1.004 1.019 1.042 1.093

0.986 0.986 0.988 0.991 0.996 1.005 1.020 1.044 1.095

0.986 0.987 0.988 0.992 0.997 1.007 1.022 1.046 1.098

0.985 0.985 0.987 0.989 0.992 0.998 1.008 1.024 1.050 1.103

0.985 0.985 0.987 0.989 0.993 1.000 1.011 1.029 1.056 1.111

0.994 0.992 0.993 0.995 0.998 1.003 1.012 1.025 1.045 1.075 1.134

Fig. 4.33. Relative fission rate distribution for Variant 13,
State 1, at 20 MWd/kg.

0.915
 0.902
 0.894 0.903
 0.898 0.907
 0.901 0.902 0.912
 0.908 0.909 0.920
 0.915 0.916 0.919 0.933
 0.930 0.931 0.936 0.952
 0.947 0.949 0.953 0.959 0.978
 0.972 0.974 0.978 0.986 1.002
 1.009 1.009 1.011 1.016 1.021 1.035

 1.051 1.052 1.055 1.062 1.073 1.095
 1.013 1.014 1.018 1.027 1.039 1.080
 0.999 1.000 1.003 1.009 1.018 1.034 1.076
 0.993 0.994 0.998 1.004 1.015 1.032 1.075
 0.988 0.989 0.991 0.995 1.002 1.013 1.031 1.074
 0.987 0.988 0.990 0.994 1.002 1.013 1.031 1.075
 0.985 0.986 0.987 0.990 0.994 1.002 1.014 1.032 1.076
 0.985 0.985 0.987 0.990 0.995 1.003 1.015 1.034 1.079
 0.983 0.984 0.985 0.987 0.990 0.996 1.004 1.017 1.037 1.082
 0.984 0.984 0.985 0.987 0.991 0.997 1.007 1.021 1.042 1.088
 0.992 0.991 0.991 0.993 0.996 1.001 1.008 1.019 1.036 1.058 1.108

Fig. 4.34. Relative fission rate distribution for Variant 13, State 1, at 30 MWd/kg.

0.941
 0.929
 0.922 0.930
 0.925 0.934
 0.928 0.929 0.938
 0.934 0.935 0.946
 0.940 0.942 0.944 0.956
 0.952 0.953 0.957 0.970
 0.963 0.964 0.967 0.971 0.985
 0.975 0.976 0.978 0.982 0.992
 0.998 0.998 1.000 1.002 1.004 1.014

 1.059 1.060 1.063 1.067 1.072 1.087
 1.017 1.018 1.021 1.026 1.033 1.068
 1.002 1.003 1.005 1.009 1.016 1.026 1.062
 0.995 0.996 0.998 1.003 1.011 1.022 1.059
 0.989 0.990 0.992 0.995 1.000 1.009 1.021 1.058
 0.987 0.988 0.990 0.993 0.999 1.008 1.020 1.058
 0.984 0.985 0.986 0.989 0.993 0.999 1.008 1.021 1.059
 0.984 0.985 0.986 0.988 0.993 0.999 1.009 1.022 1.061
 0.982 0.983 0.984 0.986 0.989 0.993 1.000 1.010 1.024 1.063
 0.983 0.983 0.984 0.986 0.989 0.994 1.002 1.013 1.028 1.067
 0.991 0.990 0.991 0.992 0.994 0.998 1.005 1.013 1.026 1.041 1.083

Fig. 4.35. Relative fission rate distribution for Variant 13, State 1, at 40 MWd/kg.

0.967
 0.955
 0.948 0.957
 0.951 0.960
 0.953 0.954 0.963
 0.958 0.959 0.969
 0.963 0.964 0.966 0.977
 0.971 0.972 0.974 0.985
 0.977 0.978 0.979 0.982 0.992
 0.982 0.982 0.983 0.985 0.992
 1.002 1.002 1.002 1.004 1.005 1.014

 1.060 1.061 1.062 1.064 1.066 1.077
 1.017 1.017 1.019 1.022 1.026 1.056
 1.002 1.003 1.005 1.008 1.012 1.018 1.050
 0.995 0.996 0.998 1.001 1.006 1.013 1.047
 0.988 0.990 0.991 0.994 0.997 1.003 1.011 1.045
 0.987 0.987 0.989 0.991 0.996 1.002 1.010 1.044
 0.983 0.984 0.985 0.987 0.990 0.995 1.001 1.010 1.045
 0.983 0.984 0.985 0.987 0.990 0.995 1.002 1.011 1.045
 0.981 0.982 0.983 0.984 0.987 0.990 0.995 1.003 1.012 1.047
 0.982 0.982 0.983 0.984 0.987 0.991 0.996 1.004 1.014 1.049
 0.989 0.989 0.989 0.991 0.993 0.996 1.000 1.007 1.016 1.025 1.064

Fig. 4.36. Relative fission rate distribution for Variant 13, State 1, at 50 MWd/kg.

0.990
 0.978
 0.970 0.980
 0.973 0.982
 0.975 0.976 0.985
 0.979 0.979 0.989
 0.981 0.983 0.984 0.994
 0.987 0.987 0.988 0.998
 0.989 0.990 0.991 0.992 1.000
 0.991 0.991 0.991 0.992 0.999
 1.012 1.012 1.012 1.013 1.013 1.024

 1.057 1.058 1.058 1.059 1.059 1.068
 1.014 1.014 1.015 1.017 1.018 1.047
 1.000 1.002 1.002 1.004 1.007 1.010 1.041
 0.994 0.994 0.995 0.997 1.001 1.005 1.038
 0.987 0.988 0.989 0.991 0.994 0.998 1.003 1.036
 0.985 0.985 0.987 0.989 0.991 0.996 1.002 1.035
 0.982 0.983 0.984 0.985 0.987 0.990 0.995 1.001 1.035
 0.982 0.982 0.983 0.984 0.986 0.990 0.995 1.001 1.035
 0.980 0.981 0.981 0.982 0.984 0.986 0.990 0.995 1.002 1.036
 0.980 0.980 0.981 0.982 0.984 0.987 0.991 0.996 1.003 1.037
 0.988 0.988 0.988 0.989 0.990 0.993 0.996 1.001 1.007 1.014 1.052

Fig. 4.37. Relative fission rate distribution for Variant 13, State 1, at 60 MWd/kg.

0.830
 0.811
 0.801 0.813
 0.807 0.818
 0.809 0.810 0.823
 0.818 0.818 0.831
 0.826 0.827 0.830 0.847
 0.847 0.848 0.853 0.879
 0.882 0.885 0.891 0.902 0.943
 0.966 0.975 0.985 1.006 1.078
 1.167 1.178 1.189 1.207 1.248 1.367

 0.941 0.941 0.947 0.961 0.989 1.044
 0.959 0.961 0.969 0.986 1.018 1.085
 0.973 0.974 0.979 0.988 1.006 1.041 1.104
 0.983 0.984 0.990 1.000 1.019 1.054 1.114
 0.987 0.988 0.991 0.997 1.008 1.027 1.061 1.121
 0.991 0.992 0.995 1.002 1.013 1.032 1.066 1.125
 0.992 0.992 0.994 0.998 1.005 1.016 1.036 1.069 1.129
 0.994 0.994 0.996 1.001 1.008 1.019 1.039 1.073 1.134
 0.993 0.994 0.995 0.998 1.002 1.010 1.022 1.043 1.079 1.141
 0.994 0.994 0.996 0.999 1.004 1.013 1.027 1.049 1.088 1.153
 1.002 0.999 1.001 1.003 1.007 1.013 1.024 1.040 1.067 1.110 1.183

Fig. 4.38. Relative fission rate distribution for Variant 13, State 4, at 0 MWd/kg.

0.850
 0.834
 0.825 0.836
 0.831 0.840
 0.833 0.834 0.845
 0.841 0.841 0.854
 0.849 0.851 0.854 0.870
 0.870 0.871 0.876 0.899
 0.900 0.902 0.908 0.918 0.951
 0.962 0.968 0.976 0.993 1.042
 1.080 1.086 1.093 1.105 1.130 1.189

 0.995 0.995 1.001 1.012 1.035 1.079
 0.986 0.988 0.995 1.009 1.034 1.094
 0.987 0.988 0.992 1.000 1.016 1.044 1.102
 0.989 0.991 0.995 1.005 1.021 1.050 1.107
 0.989 0.990 0.993 0.998 1.008 1.025 1.054 1.110
 0.991 0.992 0.995 1.001 1.011 1.028 1.057 1.113
 0.990 0.991 0.993 0.997 1.003 1.013 1.030 1.060 1.117
 0.992 0.992 0.994 0.998 1.005 1.015 1.033 1.063 1.121
 0.991 0.992 0.993 0.995 1.000 1.006 1.018 1.037 1.068 1.127
 0.992 0.992 0.993 0.996 1.001 1.009 1.022 1.042 1.076 1.137
 1.000 0.998 0.999 1.001 1.005 1.011 1.020 1.036 1.060 1.097 1.164

Fig. 4.39. Relative fission rate distribution for Variant 13, State 4, at 10 MWd/kg.

0.880
 0.866
 0.858 0.868
 0.863 0.872
 0.866 0.867 0.877
 0.874 0.874 0.886
 0.882 0.883 0.887 0.902
 0.900 0.902 0.907 0.927
 0.925 0.927 0.932 0.941 0.967
 0.967 0.971 0.978 0.990 1.020
 1.033 1.034 1.039 1.047 1.060 1.086

 1.029 1.029 1.034 1.044 1.060 1.092
 1.002 1.004 1.010 1.021 1.039 1.089
 0.994 0.995 0.999 1.006 1.018 1.040 1.089
 0.992 0.993 0.997 1.005 1.019 1.042 1.091
 0.989 0.990 0.992 0.997 1.006 1.020 1.043 1.092
 0.989 0.990 0.993 0.998 1.007 1.021 1.045 1.094
 0.987 0.988 0.990 0.993 0.999 1.008 1.023 1.047 1.096
 0.988 0.989 0.990 0.994 1.000 1.009 1.025 1.049 1.100
 0.987 0.987 0.989 0.991 0.995 1.001 1.012 1.028 1.053 1.105
 0.987 0.987 0.989 0.992 0.996 1.003 1.015 1.033 1.060 1.113
 0.996 0.994 0.995 0.997 1.000 1.006 1.015 1.028 1.049 1.078 1.136

Fig. 4.40. Relative fission rate distribution for Variant 13, State 4, at 20 MWd/kg.

0.908
 0.895
 0.888 0.897
 0.893 0.901
 0.896 0.897 0.907
 0.903 0.904 0.916
 0.911 0.913 0.916 0.930
 0.927 0.928 0.933 0.950
 0.945 0.947 0.951 0.958 0.976
 0.970 0.972 0.976 0.984 1.000
 1.004 1.005 1.007 1.012 1.018 1.030

 1.048 1.049 1.053 1.060 1.070 1.092
 1.012 1.014 1.018 1.026 1.039 1.078
 0.999 1.001 1.004 1.009 1.019 1.034 1.075
 0.994 0.995 0.999 1.005 1.016 1.033 1.074
 0.989 0.990 0.993 0.997 1.004 1.015 1.032 1.074
 0.989 0.989 0.992 0.996 1.004 1.016 1.033 1.075
 0.986 0.987 0.989 0.992 0.996 1.004 1.016 1.034 1.077
 0.987 0.987 0.989 0.992 0.997 1.005 1.018 1.036 1.079
 0.985 0.986 0.987 0.989 0.992 0.998 1.007 1.020 1.039 1.083
 0.985 0.985 0.987 0.989 0.993 1.000 1.010 1.024 1.044 1.089
 0.993 0.992 0.993 0.995 0.998 1.003 1.011 1.022 1.039 1.060 1.107

Fig. 4.41. Relative fission rate distribution for Variant 13, State 4, at 30 MWd/kg.

0.936
 0.924
 0.918 0.926
 0.922 0.930
 0.924 0.925 0.935
 0.931 0.932 0.943
 0.938 0.939 0.942 0.954
 0.950 0.951 0.955 0.969
 0.962 0.963 0.966 0.970 0.983
 0.973 0.974 0.977 0.980 0.989
 0.995 0.994 0.996 0.998 1.000 1.009

 1.057 1.058 1.060 1.065 1.070 1.084
 1.017 1.018 1.021 1.026 1.033 1.066
 1.002 1.004 1.006 1.010 1.017 1.026 1.060
 0.996 0.997 1.000 1.004 1.012 1.023 1.058
 0.990 0.991 0.993 0.996 1.002 1.010 1.022 1.057
 0.988 0.989 0.991 0.995 1.001 1.010 1.021 1.058
 0.986 0.987 0.988 0.990 0.994 1.001 1.010 1.022 1.058
 0.986 0.986 0.988 0.990 0.995 1.001 1.011 1.023 1.060
 0.984 0.985 0.986 0.988 0.991 0.995 1.002 1.012 1.025 1.063
 0.984 0.984 0.986 0.988 0.991 0.997 1.004 1.015 1.029 1.066
 0.992 0.991 0.992 0.994 0.996 1.001 1.007 1.016 1.028 1.042 1.082

Fig. 4.42. Relative fission rate distribution for Variant 13, State 4, at 40 MWd/kg.

0.964
 0.952
 0.946 0.954
 0.949 0.957
 0.951 0.952 0.962
 0.957 0.958 0.968
 0.962 0.963 0.965 0.976
 0.970 0.971 0.974 0.985
 0.976 0.977 0.979 0.981 0.991
 0.980 0.980 0.982 0.983 0.990
 0.999 0.998 0.999 1.000 1.001 1.009

 1.058 1.059 1.060 1.062 1.064 1.073
 1.016 1.017 1.019 1.022 1.025 1.053
 1.003 1.004 1.005 1.008 1.012 1.017 1.048
 0.996 0.997 0.999 1.002 1.007 1.013 1.045
 0.990 0.991 0.992 0.995 0.999 1.004 1.011 1.043
 0.988 0.988 0.990 0.993 0.997 1.003 1.011 1.043
 0.985 0.986 0.987 0.989 0.992 0.996 1.003 1.011 1.043
 0.985 0.985 0.986 0.988 0.992 0.996 1.003 1.011 1.044
 0.983 0.984 0.984 0.986 0.988 0.992 0.997 1.004 1.013 1.046
 0.983 0.983 0.984 0.986 0.989 0.993 0.998 1.006 1.015 1.048
 0.991 0.990 0.991 0.992 0.994 0.998 1.002 1.009 1.017 1.026 1.062

Fig. 4.43. Relative fission rate distribution for Variant 13, State 4, at 50 MWd/kg.

0.989
 0.977
 0.970 0.979
 0.973 0.982
 0.975 0.976 0.985
 0.979 0.980 0.989
 0.982 0.983 0.984 0.994
 0.987 0.988 0.989 0.998
 0.989 0.990 0.991 0.992 1.000
 0.990 0.990 0.990 0.991 0.997
 1.009 1.009 1.009 1.010 1.010 1.019

 1.055 1.056 1.056 1.057 1.056 1.065
 1.014 1.014 1.015 1.016 1.016 1.044
 1.001 1.002 1.003 1.004 1.007 1.009 1.039
 0.994 0.995 0.996 0.998 1.001 1.005 1.036
 0.988 0.989 0.990 0.992 0.995 0.998 1.003 1.034
 0.986 0.987 0.988 0.990 0.993 0.997 1.001 1.033
 0.983 0.984 0.985 0.986 0.988 0.992 0.996 1.001 1.033
 0.983 0.983 0.984 0.986 0.988 0.991 0.996 1.001 1.033
 0.981 0.982 0.983 0.984 0.985 0.988 0.992 0.996 1.002 1.034
 0.981 0.981 0.982 0.983 0.985 0.988 0.992 0.997 1.003 1.035
 0.989 0.989 0.989 0.990 0.992 0.994 0.997 1.002 1.007 1.013 1.049

Fig. 4.44. Relative fission rate distribution for Variant 13, State 4, at 60 MWd/kg.

0.887
 0.872
 0.860 0.870
 0.868 0.876
 0.870 0.871 0.883
 0.884 0.883 0.899
 0.901 0.902 0.907 0.932
 0.951 0.952 0.962 1.006
 1.063 1.067 1.077 1.100 1.184
 0.861 0.868 0.879 0.905 0.985
 0.933 0.939 0.948 0.963 0.998 1.079

 0.990 0.991 0.997 1.010 1.037 1.085
 0.985 0.987 0.995 1.010 1.039 1.101
 0.983 0.985 0.989 0.998 1.014 1.047 1.108
 0.986 0.987 0.992 1.001 1.018 1.051 1.111
 0.984 0.985 0.988 0.993 1.003 1.021 1.054 1.113
 0.985 0.986 0.989 0.994 1.005 1.023 1.056 1.115
 0.983 0.984 0.986 0.989 0.995 1.006 1.024 1.057 1.118
 0.984 0.984 0.986 0.990 0.996 1.007 1.026 1.060 1.121
 0.982 0.983 0.984 0.987 0.991 0.998 1.009 1.029 1.064 1.127
 0.983 0.983 0.985 0.987 0.992 1.000 1.013 1.035 1.073 1.139
 0.986 0.987 0.988 0.990 0.993 0.999 1.008 1.024 1.050 1.092 1.168

Fig. 4.45. Relative fission rate distribution for Variant 14, State 1, at 0 MWd/kg.

0.901
 0.887
 0.876 0.885
 0.884 0.892
 0.887 0.887 0.899
 0.901 0.900 0.915
 0.918 0.919 0.925 0.949
 0.966 0.967 0.978 1.018
 1.060 1.063 1.073 1.094 1.160
 0.835 0.839 0.848 0.867 0.915
 0.849 0.852 0.858 0.867 0.886 0.924

 1.033 1.034 1.040 1.052 1.073 1.111
 1.007 1.009 1.016 1.029 1.051 1.107
 0.996 0.998 1.002 1.009 1.023 1.051 1.106
 0.993 0.994 0.999 1.007 1.022 1.051 1.107
 0.989 0.990 0.993 0.998 1.007 1.023 1.051 1.108
 0.989 0.989 0.992 0.998 1.007 1.024 1.053 1.109
 0.986 0.987 0.989 0.992 0.998 1.008 1.025 1.054 1.112
 0.988 0.988 0.990 0.993 0.999 1.009 1.027 1.057 1.115
 0.986 0.986 0.988 0.990 0.994 1.000 1.011 1.030 1.061 1.121
 0.987 0.987 0.988 0.991 0.995 1.002 1.015 1.035 1.069 1.130
 0.991 0.991 0.992 0.994 0.997 1.003 1.012 1.027 1.051 1.088 1.158

Fig. 4.46. Relative fission rate distribution for Variant 14, State 1, at 10 MWd/kg.

0.939
 0.926
 0.916 0.924
 0.923 0.931
 0.926 0.927 0.939
 0.941 0.941 0.956
 0.959 0.960 0.966 0.989
 1.002 1.004 1.015 1.050
 1.073 1.076 1.085 1.102 1.147
 0.837 0.840 0.846 0.859 0.885
 0.830 0.832 0.835 0.842 0.852 0.873

 1.054 1.055 1.060 1.069 1.084 1.111
 1.017 1.018 1.024 1.034 1.050 1.096
 1.000 1.001 1.005 1.011 1.023 1.044 1.091
 0.994 0.994 0.998 1.006 1.018 1.041 1.089
 0.987 0.988 0.991 0.995 1.003 1.017 1.040 1.088
 0.986 0.986 0.989 0.994 1.002 1.016 1.040 1.089
 0.983 0.983 0.985 0.988 0.993 1.002 1.017 1.041 1.090
 0.984 0.983 0.985 0.988 0.994 1.003 1.018 1.043 1.093
 0.981 0.981 0.983 0.985 0.989 0.995 1.004 1.020 1.046 1.097
 0.982 0.982 0.983 0.985 0.989 0.996 1.007 1.025 1.052 1.104
 0.986 0.986 0.987 0.989 0.992 0.997 1.005 1.019 1.039 1.069 1.129

Fig. 4.47. Relative fission rate distribution for Variant 14, State 1, at 20 MWd/kg.

0.974
 0.961
 0.953 0.959
 0.959 0.966
 0.963 0.964 0.975
 0.977 0.978 0.992
 0.994 0.995 1.002 1.022
 1.030 1.032 1.042 1.068
 1.073 1.075 1.081 1.093 1.117
 0.849 0.850 0.855 0.862 0.877
 0.840 0.841 0.844 0.848 0.854 0.872

 1.059 1.061 1.064 1.070 1.080 1.098
 1.019 1.020 1.024 1.031 1.042 1.079
 1.002 1.002 1.005 1.011 1.019 1.034 1.073
 0.994 0.994 0.997 1.003 1.014 1.030 1.069
 0.986 0.987 0.989 0.993 1.000 1.011 1.028 1.068
 0.985 0.985 0.987 0.991 0.998 1.010 1.027 1.068
 0.981 0.981 0.983 0.986 0.990 0.998 1.010 1.027 1.069
 0.981 0.981 0.982 0.985 0.990 0.998 1.010 1.029 1.070
 0.978 0.979 0.980 0.982 0.985 0.991 0.999 1.012 1.031 1.074
 0.980 0.979 0.980 0.982 0.986 0.992 1.001 1.016 1.036 1.079
 0.983 0.983 0.984 0.986 0.989 0.993 1.001 1.012 1.028 1.050 1.099

Fig. 4.48. Relative fission rate distribution for Variant 14, State 1, at 30 MWd/kg.

1.007
 0.995
 0.987 0.993
 0.993 1.000
 0.997 0.998 1.009
 1.010 1.011 1.024
 1.024 1.026 1.031 1.048
 1.049 1.051 1.058 1.075
 1.066 1.066 1.071 1.076 1.085
 0.871 0.871 0.874 0.879 0.888
 0.868 0.869 0.871 0.874 0.878 0.895

 1.057 1.057 1.059 1.063 1.068 1.080
 1.017 1.017 1.019 1.024 1.030 1.060
 1.001 1.001 1.004 1.007 1.013 1.023 1.055
 0.994 0.993 0.996 1.000 1.007 1.018 1.051
 0.986 0.986 0.988 0.991 0.996 1.004 1.016 1.049
 0.984 0.983 0.985 0.989 0.994 1.003 1.015 1.049
 0.979 0.979 0.981 0.984 0.987 0.993 1.002 1.014 1.049
 0.980 0.979 0.980 0.983 0.987 0.993 1.002 1.015 1.050
 0.977 0.977 0.978 0.980 0.983 0.987 0.994 1.004 1.017 1.052
 0.978 0.977 0.978 0.980 0.983 0.988 0.995 1.006 1.020 1.055
 0.982 0.981 0.982 0.984 0.986 0.990 0.996 1.005 1.017 1.031 1.072

Fig. 4.49. Relative fission rate distribution for Variant 14, State 1, at 40 MWd/kg.

1.037
 1.025
 1.018 1.024
 1.024 1.030
 1.027 1.028 1.038
 1.038 1.039 1.050
 1.047 1.048 1.053 1.064
 1.061 1.061 1.065 1.073
 1.058 1.058 1.060 1.061 1.062
 0.900 0.899 0.901 0.904 0.911
 0.905 0.905 0.907 0.909 0.912 0.928

 1.050 1.051 1.052 1.053 1.055 1.064
 1.012 1.011 1.013 1.015 1.018 1.044
 0.998 0.998 1.000 1.002 1.006 1.011 1.039
 0.992 0.991 0.993 0.996 1.000 1.007 1.036
 0.984 0.984 0.986 0.988 0.992 0.997 1.004 1.034
 0.983 0.982 0.983 0.986 0.990 0.996 1.003 1.033
 0.978 0.978 0.979 0.981 0.984 0.988 0.995 1.002 1.033
 0.978 0.977 0.978 0.980 0.983 0.988 0.994 1.002 1.033
 0.975 0.975 0.976 0.978 0.980 0.983 0.988 0.995 1.003 1.034
 0.976 0.975 0.976 0.977 0.980 0.984 0.989 0.996 1.005 1.035
 0.980 0.979 0.981 0.982 0.984 0.987 0.991 0.997 1.006 1.014 1.051

Fig. 4.50. Relative fission rate distribution for Variant 14, State 1, at 50 MWd/kg.

1.061
 1.049
 1.042 1.048
 1.047 1.053
 1.050 1.050 1.059
 1.058 1.058 1.066
 1.061 1.062 1.064 1.072
 1.065 1.064 1.065 1.068
 1.051 1.051 1.051 1.050 1.048
 0.930 0.929 0.930 0.932 0.938
 0.942 0.942 0.943 0.945 0.948 0.965

 1.045 1.045 1.045 1.045 1.045 1.053
 1.007 1.005 1.006 1.007 1.008 1.034
 0.994 0.994 0.996 0.997 0.999 1.002 1.029
 0.989 0.988 0.989 0.991 0.994 0.998 1.026
 0.982 0.982 0.983 0.985 0.987 0.991 0.995 1.024
 0.981 0.979 0.980 0.982 0.985 0.989 0.994 1.023
 0.976 0.976 0.977 0.979 0.980 0.983 0.988 0.993 1.022
 0.977 0.975 0.976 0.977 0.979 0.983 0.987 0.992 1.022
 0.973 0.973 0.974 0.975 0.977 0.979 0.982 0.987 0.993 1.022
 0.974 0.973 0.974 0.975 0.976 0.979 0.983 0.988 0.994 1.023
 0.978 0.978 0.979 0.980 0.981 0.983 0.986 0.990 0.996 1.002 1.039

Fig. 4.51. Relative fission rate distribution for Variant 14, State 1, at 60 MWd/kg.

0.891
 0.881
 0.872 0.879
 0.877 0.883
 0.878 0.878 0.886
 0.886 0.885 0.895
 0.896 0.898 0.900 0.917
 0.935 0.935 0.942 0.973
 1.035 1.038 1.043 1.059 1.127
 0.832 0.835 0.841 0.861 0.926
 0.882 0.880 0.882 0.892 0.922 0.994

 1.047 1.039 1.038 1.049 1.078 1.142
 1.008 1.007 1.012 1.025 1.054 1.125
 0.997 0.999 1.001 1.006 1.019 1.049 1.114
 0.996 0.997 0.999 1.005 1.018 1.047 1.112
 0.994 0.996 0.997 1.000 1.006 1.019 1.047 1.113
 0.996 0.996 0.998 1.000 1.007 1.020 1.048 1.114
 0.996 0.997 0.997 0.999 1.002 1.008 1.021 1.050 1.116
 0.998 0.998 0.998 1.000 1.003 1.009 1.022 1.052 1.119
 0.997 0.998 0.998 0.999 1.001 1.004 1.010 1.024 1.055 1.125
 0.998 0.999 0.999 1.000 1.001 1.005 1.012 1.028 1.063 1.139
 1.001 1.001 1.001 1.001 1.003 1.005 1.010 1.020 1.041 1.085 1.182

Fig. 4.52. Relative fission rate distribution for Variant 14, State 6, at 0 MWd/kg.

0.913
 0.904
 0.897 0.903
 0.901 0.906
 0.902 0.902 0.909
 0.909 0.909 0.918
 0.920 0.922 0.925 0.940
 0.957 0.957 0.964 0.993
 1.040 1.042 1.047 1.062 1.115
 0.810 0.810 0.815 0.829 0.867
 0.812 0.807 0.807 0.812 0.829 0.865

 1.077 1.069 1.068 1.077 1.101 1.153
 1.021 1.021 1.025 1.036 1.059 1.119
 1.004 1.005 1.007 1.012 1.023 1.048 1.105
 1.000 1.001 1.003 1.008 1.019 1.043 1.101
 0.998 0.999 1.000 1.002 1.008 1.019 1.043 1.101
 0.999 1.000 1.001 1.003 1.008 1.020 1.044 1.103
 0.999 1.000 1.001 1.002 1.004 1.010 1.021 1.046 1.104
 1.002 1.001 1.002 1.003 1.006 1.011 1.023 1.048 1.107
 1.001 1.002 1.002 1.003 1.004 1.007 1.012 1.025 1.051 1.112
 1.003 1.002 1.003 1.003 1.004 1.008 1.014 1.028 1.058 1.124
 1.005 1.005 1.005 1.006 1.006 1.008 1.012 1.021 1.040 1.078 1.164

Fig. 4.53. Relative fission rate distribution for Variant 14, State 6, at 10 MWd/kg.

0.954
 0.945
 0.939 0.944
 0.942 0.946
 0.942 0.943 0.949
 0.949 0.949 0.957
 0.959 0.961 0.964 0.977
 0.991 0.992 0.998 1.021
 1.051 1.052 1.056 1.067 1.100
 0.811 0.810 0.812 0.820 0.839
 0.797 0.792 0.789 0.792 0.801 0.824

 1.088 1.081 1.079 1.086 1.104 1.143
 1.027 1.026 1.029 1.038 1.055 1.103
 1.007 1.008 1.009 1.013 1.022 1.040 1.086
 1.001 1.001 1.003 1.007 1.016 1.034 1.081
 0.997 0.998 0.999 1.001 1.005 1.014 1.032 1.080
 0.998 0.998 0.999 1.001 1.005 1.014 1.032 1.080
 0.998 0.998 0.999 1.000 1.001 1.006 1.015 1.033 1.081
 1.000 0.999 1.000 1.000 1.002 1.006 1.016 1.035 1.083
 0.999 1.000 1.000 1.000 1.001 1.003 1.007 1.017 1.037 1.088
 1.001 1.000 1.000 1.000 1.001 1.003 1.008 1.020 1.043 1.097
 1.003 1.003 1.003 1.003 1.003 1.005 1.008 1.015 1.030 1.060 1.131

Fig. 4.54. Relative fission rate distribution for Variant 14, State 6, at 20 MWd/kg.

0.997
 0.989
 0.983 0.987
 0.985 0.988
 0.985 0.985 0.990
 0.990 0.990 0.997
 0.998 0.999 1.002 1.012
 1.021 1.021 1.026 1.041
 1.053 1.053 1.055 1.060 1.073
 0.825 0.822 0.822 0.826 0.834
 0.811 0.806 0.803 0.803 0.809 0.829

 1.087 1.080 1.077 1.080 1.092 1.120
 1.027 1.026 1.027 1.033 1.044 1.080
 1.007 1.008 1.009 1.011 1.017 1.028 1.064
 1.001 1.000 1.001 1.004 1.010 1.022 1.058
 0.997 0.997 0.998 0.999 1.001 1.007 1.019 1.056
 0.997 0.997 0.997 0.998 1.001 1.007 1.019 1.056
 0.997 0.997 0.997 0.997 0.998 1.001 1.007 1.019 1.056
 0.999 0.998 0.998 0.998 0.998 1.001 1.007 1.019 1.058
 0.998 0.998 0.998 0.998 0.998 0.999 1.001 1.008 1.021 1.060
 0.999 0.998 0.998 0.998 0.998 0.999 1.002 1.009 1.025 1.067
 1.002 1.001 1.001 1.001 1.000 1.001 1.002 1.007 1.017 1.038 1.095

Fig. 4.55. Relative fission rate distribution for Variant 14, State 6, at 30 MWd/kg.

1.043	1.089
1.036	1.082
1.030 1.033	1.076 1.078
1.031 1.033	1.075 1.077
1.030 1.030 1.034	1.073 1.072 1.075
1.032 1.032 1.037	1.072 1.071 1.073
1.036 1.037 1.038 1.044	1.070 1.069 1.069 1.070
1.046 1.046 1.048 1.053	1.067 1.065 1.063 1.060
1.052 1.051 1.050 1.049	1.053 1.051 1.048 1.043 1.035
0.851 0.848 0.846 0.846 0.850	0.887 0.882 0.879 0.877 0.879
0.844 0.838 0.835 0.834 0.837 0.857	0.887 0.880 0.876 0.874 0.876 0.896
1.078 1.071 1.067 1.067 1.073 1.094	1.067 1.059 1.054 1.052 1.054 1.070
1.023 1.020 1.020 1.023 1.028 1.056	1.016 1.012 1.011 1.010 1.012 1.034
1.006 1.006 1.006 1.006 1.009 1.014 1.041	1.002 1.001 1.000 0.999 0.999 0.999 1.021
1.000 0.999 0.999 1.000 1.002 1.007 1.035	0.997 0.995 0.994 0.993 0.993 0.992 1.015
0.996 0.996 0.996 0.996 0.996 0.999 1.004 1.033	0.994 0.993 0.993 0.991 0.990 0.989 0.989 1.012
0.996 0.995 0.995 0.995 0.995 0.998 1.003 1.032	0.994 0.993 0.991 0.990 0.988 0.987 0.987 1.010
0.995 0.995 0.995 0.994 0.995 0.997 1.002 1.031	0.993 0.993 0.992 0.991 0.989 0.987 0.986 1.009
0.997 0.996 0.995 0.994 0.994 0.997 1.002 1.031	0.995 0.993 0.992 0.990 0.988 0.986 0.985 1.008
0.996 0.996 0.996 0.995 0.994 0.993 0.994 0.996 1.002 1.032	0.994 0.994 0.993 0.991 0.989 0.987 0.985 0.984 1.008
0.998 0.996 0.996 0.994 0.993 0.993 0.997 1.005 1.036	0.995 0.994 0.992 0.990 0.988 0.985 0.983 0.984 1.009
1.000 0.999 0.999 0.998 0.997 0.996 0.995 0.997 1.002 1.014 1.059	0.998 0.997 0.996 0.994 0.992 0.990 0.987 0.985 0.986 0.991 1.029

Fig. 4.56. Relative fission rate distribution for Variant 14,
State 6, at 40 MWd/kg.

Fig. 4.57. Relative fission rate distribution for Variant 14,
State 6, at 50 MWd/kg.

1.129
 1.120
 1.114 1.116
 1.112 1.113
 1.107 1.107 1.107
 1.103 1.100 1.099
 1.094 1.093 1.090 1.087
 1.081 1.078 1.073 1.065
 1.056 1.054 1.049 1.042 1.031
 0.924 0.918 0.914 0.911 0.912
 0.931 0.924 0.919 0.917 0.918 0.939

 1.057 1.049 1.043 1.039 1.038 1.053
 1.008 1.004 1.001 0.999 0.998 1.019
 0.997 0.996 0.994 0.991 0.989 0.986 1.006
 0.993 0.991 0.989 0.986 0.983 0.980 1.000
 0.990 0.989 0.988 0.986 0.983 0.980 0.976 0.997
 0.991 0.989 0.987 0.984 0.981 0.977 0.974 0.995
 0.990 0.989 0.989 0.986 0.983 0.979 0.975 0.972 0.993
 0.992 0.990 0.988 0.985 0.982 0.978 0.974 0.970 0.991
 0.991 0.990 0.989 0.987 0.984 0.980 0.976 0.971 0.968 0.990
 0.992 0.990 0.988 0.986 0.982 0.978 0.973 0.969 0.967 0.990
 0.995 0.994 0.993 0.990 0.987 0.983 0.979 0.974 0.972 0.973 1.010

**Fig. 4.58. Relative fission rate distribution for Variant 14,
State 6, at 60 MWd/kg.**

5. KENO CALCULATIONS

An additional, preliminary analysis of Variant 14 was performed with the KENO-VI⁶ Monte Carlo code using cross sections from HELIOS calculations. HELIOS cross sections were used so that calculations could be performed at all desired burnups.

A computer code was written to transfer the cross-section data from a ZENITH output file into AMPX working libraries for State 1 at 0-, 10-, 20-, 30-, 40-, 50-, and 60-MWd/kg burnup. The preliminary analysis was based on the HELIOS 34-group cross-section libraries because of limits in editing cross sections using ZENITH. The memory requirements were too large for the 89- or 190-group libraries. Note that at the time these calculations were being performed, Scandpower was in the process of developing an official code for the transfer of cross-section data into AMPX working library format. This code, however, was not available for this analysis.

The KENO model includes an exact representation of the problem (pins in an array of hexagonal cells). The results of the calculations along with the HELIOS results are presented in Table 5.1. The differences between the HELIOS and KENO-VI results have not been completely investigated. The differences may be attributed to differences between the HELIOS and KENO-VI models of Variant 14, differences in the representation of the scattering approximation (KENO-VI uses a "pure" P1 approximation, while HELIOS uses a transport-corrected P0 approximation), or unidentified errors in the HELIOS-to-AMPX library conversion.

Table 5.1. Comparison of HELIOS and KENO-VI k_{eff} results for Variant 14, State 1

Burnup (MWd/kg)	k_{eff}	
	HELIOS	KENO-VI (1 σ)
	1.0632	1.0494 (0.0025)
10	0.9757	0.9612 (0.0023)
20	0.9067	0.8932 (0.0021)
30	0.8487	0.8376 (0.0019)
40	0.7974	0.7848 (0.0017)
50	0.7519	0.7422 (0.0016)
60	0.7123	0.7005 (0.0018)

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6. DISCUSSION AND CONCLUSIONS

The series of VVER-1000 benchmark calculations were calculated with the HELIOS fuel assembly analysis code and the results documented. In calculating these benchmarks, we found the HELIOS system to be very flexible, allowing detailed modeling of complex systems.

In the preliminary analysis discussed in Chap. 3, it was shown that the 34-group library should be avoided for MOX systems based on a comparison of pin-cell k_{inf} values with the results from the 190-group library. The 89-group library compares favorably with the 190-group library and is therefore recommended for the analysis of MOX systems. Note that adequate convergence with the 89- and 190-group libraries may require reducing the ω_3 and ω_4 relaxation parameters to 1.0.

The fission distributions from the multiassembly variants (V13 and V14) also show an unusual behavior in that there appears to be a slight peak in the fission rate in the pin at the center of the MOX assembly. Fig. 6.1 shows a radial traverse through the MOX and UO_2 assemblies which demonstrates the peak at the central fuel pin for Variant 13 at 0 MWd/kg. Based on the system's geometry and material compositions, the current, and hence the derivative of the neutron flux, should vanish at this central point (given the uniform composition in the center of the assembly), resulting in a flat fission density profile. Several other calculational tests were performed, and other slight anomalies were noted. These results were provided to Studsvik Scandpower, Inc., for further investigation.

These benchmarks have been analyzed with calculational systems used in Russia at the Russian Research Center, "Kurchatov Institute," in Moscow and at the Institute of Physics and Power Engineering in Obninsk. The calculational results are given in Ref. 1 for Variants 1-13. Preliminary comparisons of the multiplication factor results show good agreement with values typically within 0.2-0.5 %. The results of all of the calculations will be compared and will be the topic of a separate report.

Fig. 6.1. Variant 14 relative pin power along assembly axis.

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