MOL.19980806.0608

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Calculation Cover Sheet

Complete only applicable items.

1. QA: L
Page: 1 Of: 59

2. Calculation Title: Principal Isotope Selection Calculation MOL.19980806.060

3. Document Identifier (including Revision Number): B00000000-01717-0210-00031 REV 00

4. Total Pages: 59

5. Total Attachments: 2

6. Attachment Numbers - Number of pages in each: See Box 10

	Print Name	Signature	Date
7. Originator	JR Worsham III	JR Worsham III	8/20/98
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10. Remarks

Attachments I and II are electronic attachments that were provided with REV00A of this document for checking. These attachments have been corrected per the checker's comments from review of REV00A. These attachments have been moved to Reference 7.6 of REV00 of this document. Attachments I and II each have a 1 page listing of their electronic media content provided in their corresponding hard-copy locations of this document.

EDITORIAL CHANGE: TIC # ADDED TO Pg 59 DW FOR JRW 5/13/99, DW 5/13/99

The electronic attachments have been checked. KDW 8/20/98

PCG compliance review by WSWallin 8/20/98

Revision History

11. Revision No.	12. Date Approved	13. Description of Revision
00		Initial Issuance

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1. Purpose

Utilizing nuclear fuel to produce power in commercial reactors results in the production of hundreds of fission product and trans-uranic isotopes in the spent nuclear fuel (SNF). When the SNF is disposed of in a repository, the criticality analyses could consider all of the isotopes, some principal isotopes affecting criticality, or none of the isotopes, other than the initial loading. The purpose of this calculation is to document the calculations that support the determination of the principal isotopes affecting criticality in the SNF. The principal isotopes will be the ones used in criticality analyses of the SNF to evaluate the reactivity of the fuel/waste package composition and configuration.

2. Method

The methods used in the calculations to support the selection of the principal isotopes are those of nuclear physics for critical systems, and systems with time dependent isotopics. These methods include neutron transport theory and the theory of nuclear reactions and disintegrations. Neutron transport theory is represented by the time-independent transport equation with a critical eigenvalue representing an asymptotic time period and a buckling eigenvalue representing spatial leakage. The nuclear reactions and disintegrations are represented by a set of coupled differential equations. The solution of the differential equations produces a set of coupled exponential equations (the Bateman equations). These exponential equations represent the time dependent changes in the isotopics with each product isotope dependent on its own reactions and disintegrations, and on the reactions and disintegrations of the parent and daughter isotopes.

The methods of determining solutions for the isotopic reactions and reactivity effects of the isotopes in the transport equation are based on the XSDRNPM-S computer code module of the SAS2H sequence in the SCALE 4.3 computer software package. The XSDRNPM-S results are utilized by the ORIGEN-S computer code. The ORIGEN-S module of the SAS2H sequence in the SCALE 4.3 software package uses the (Bateman) set of coupled exponential equations to determine the time dependent isotopics within the SNF. The ORIGEN-S results include the reaction rate density along with the isotopic concentration density. The reaction rates are primarily determined in XSDRNPM-S, and collapsed through the COUPLE code module of the SAS2H sequence. The ORIGEN-S edit provides a relative ranking of the isotopic absorption reaction rate density. This ranking provides the means of identifying the principal fission product isotopes affecting critical conditions. This ranking also provides the means of identifying the principal trans-uranic and actinide isotopes affecting critical conditions. The importance of the trans-uranic and actinide isotopes is evaluated using both the relative ranking of the absorption rate and the product of the relative absorption rate and the isotopic k_∞. The isotopic k_∞ is calculated using the following expression:

$$k_\infty = \left(\frac{\Sigma_{f_i}\nu_i}{\Sigma_{a_i}}\right) = \left(\frac{N_i\sigma_{f_i}\nu_i}{N_i\sigma_{a_i}}\right) = \left(\frac{\sigma_{f_i}\nu_i}{\sigma_{a_i}}\right)$$

where the values of σ_{f_i}, ν_i, and σ_{a_i} respresent the microscopic fission cross section of isotope i, the average number of neutrons resulting from thermal neutron induced fission of isotope i, and the

microscopic absorption cross section of isotope i, respectively. The isotopic k_∞ is determined with 2200 meter per second σ_{f_i}, ν_i, and σ_{a_i} values obtained from Reference 7.1.

3. Assumptions

As discussed in Section 1, the purpose of these calculations is to provide results which assist in the determination of the principal isotopes that affect the criticality of the SNF when it is disposed of in a repository. To identify the principal isotopes, it is necessary to identify and understand the characteristics of (a) the variables that affect the production and transmutation of the isotopes, and (b) those that affect criticality. These variables are identified from the methods discussed in Section 2.

Criticality is defined by the effective neutron multiplication factor (k_{eff}). The k_{eff} factor is formulated as the ratio of neutron productions to the sum of neutron absorptions plus leakage. Neutron production is affected by the isotopes that fission. The principal fissioning isotopes are those that produce the most neutrons from a fission reaction in the SNF. Neutron absorption is affected by all isotopes. The ones that have the largest net absorption (absorption minus production) are the principal absorber isotopes. Neutron leakage is affected by the isotopes having the largest scattering reactions.

3.1. Highly Reactive SNF Configuration Assumption

Since the purpose of these calculations is to provide results that assist in determining the principal isotopes which have the largest influence on the SNF reactivity, the calculations will be performed on a highly reactive SNF configuration. It is assumed throughout the calculations that the degraded fuel configuration is one of the most reactive SNF configurations. The basis for this assumption is that the degraded fuel configuration represents a geometrical arrangement of fuel and moderator which enhances neutron moderation and thermal neutron interaction within the fuel. Hence, the thermal neutron induced fission rate in the SNF is enhanced resulting in a highly reactive SNF configuration. The degraded fuel configuration is represented as having no grid or other structural material within the assembly lattice, and no material outside the assembly lattice other than a neighboring assembly or a moderator reflector of water. In the degraded configuration, the fuel clad is the only structure and the cladding is assumed to have degraded to the extent that water is between the pellet and clad. Also in the degraded configuration, the fuel rods and assemblies are further represented as having bowed to the maximum extent within the area of two assembly pitch gap widths. The assumption concerning the structural configuration of the degraded fuel is used throughout the calculations.

The degraded fuel configuration is also assumed to have the following characteristics: (a) no poisons or other elements in the water, (b) water and all material temperatures have decreased to 20 °C, and (c) the water density is assumed to be the maximum of 1.0 gram per cubic centimeter. The basis for these assumed degraded fuel configuration characteristics is that the lack of soluble poisons, the lack of moderator exclusion, the low temperature conditions, and the maximum hydrogen density all serve to maximize the neutron thermalization, thus increasing the thermal neutron population available to induce fission in the SNF. The assumption that the degraded fuel configuration has these described characteristics is used throughout the calculations.

3.2. Leakage Influence Assumption

Having defined the principal isotope selection process to be associated with the maximum reactivity of the SNF in a degraded fuel configuration, the assumptions noted above provide sufficient conditions for additional assumptions concerning the calculations which support the selection process. The highly moderated model has scattering reactions that are dominated by the water. This means that the neutron spectrum will be highly thermalized and the neutron leakage will be dominated by water scattering reactions. Therefore, it is assumed that the selection of the principal isotopes in the commercial SNF will not be affected by leakage. Consequently, the results of these analyses will be to identify the SNF isotopes that have the largest absorption and production reaction rates. This assumption is used throughout the evaluation of results in Section 6.

3.3. Dancoff Factor and Relative Neutron Production Rate Assumptions

Since the neutron spectrum will be highly thermalized, two other assumptions are used in the calculations that support the principal isotope selection process. The first concerns the Dancoff factor model for the degraded fuel and the second concerns the relative neutron production rate from fission.

The degraded fuel configuration includes degradation of the fuel rod cladding such that water has penetrated the cladding and filled the gap between the fuel pellet and clad. This has two affects on the neutron spectrum:

1. The material between fuel pellets in the radial plane is now greater than before, thereby making each pellet more isolated. The additional material reduces the Dancoff factor.

2. The additional water contributes to a more thermalized neutron spectrum.

The modified Dancoff factor could not be incorporated in the degraded SNF model due to limitations in the analysis code SAS2H. However, it is assumed that the relative decrease in resonance absorption will not affect the relative absorption rates of the various isotopes with the exceptions of Uranium-238 and Plutonium-239. The basis for this assumption is that the resonance absorption in the various isotopes other than Uranium-238 and Plutonium-239 is not significant with respect to relative thermal neutron absorption in a configuration characterized by a highly thermalized neutron spectrum. This assumption is used throughout the calculations.

The second assumption related to the highly thermalized neutron spectrum, is that the relative neutron production rate may be determined by the product of the 2200 meter per second isotopic k_∞ and the relative absorption rate density. The basis for this assumption is that with a highly thermalized neutron spectrum, the fast fission production rate is assumed to be small, compared to the thermal fission production rate. In addition, with a hardened Maxwellian spectrum, the ratio of fission rates to absorption rates for each isotope allows the spectrum to cancel from the numerator and denominator of the ratio. This assumption is an exact condition for the Maxwellian spectrum if the fission and absorption cross sections have an inverse proportionality to the neutron speed, without any thermal resonances. The assumptions concerning the relative neutron production rate are used throughout the calculations.

4. Use of Computer Software

4.1. Software Approved for QA Work

4.1.1. SAS2H and ORIGEN-S

Both the SAS2H sequence and the ORIGEN-S module of the SCALE computer code package were used together to calculate the reactivity and absorption fractions of various commercial fuel types with several different operating conditions at numerous decay times. The software specifications are as follow:

- Program Names: SAS2H of the SCALE Modular Code System, ORIGEN-S of the SCALE Modular Code System
- Version/Revision Number: SCALE, Version 4.3
- Computer Software Configuration Item (CSCI) Number: 30011 V4.3
- Computer Type: Hewlett Packard (HP) 9000 Series Workstations

The input and output files for the various SAS2H/ORIGEN-S calculations are provided in the attachments to this calculation as described in Sections 5 and 8. These attachments are contained on an attachment tape that has been moved to Reference 7.6 of this calculation. These attachments contain sufficient information such that an independent repetition of the software use could be performed. The SAS2H and ORIGEN-S software used was: (a) appropriate for the application of time-dependent SNF composition and reactivity calculations, (b) used only within the range of validation as documented throughout References 7.2 and 7.3, and (c) obtained from the Software Configuration Manager in accordance with appropriate procedures.

4.2. Software Routines

There were no software routines used.

5. Calculation

The calculations used to support the principal isotopes selection process include (a) 18 SAS2H depletion cases (each containing a final depletion pass which represents the SNF at the end of its reactor life in a degraded fuel configuration) and (b) 18 ORIGEN-S decay cases (one case immediately following each of the 18 SAS2H cases to calculate the decay of the SNF to a number of time periods). Table 5-1 lists the parameters that characterize each of the 18 different SAS2H fuel assembly depletion calculations.

Reviewing the methods in Section 2 provides the information necessary to perform an evaluation of the variables affecting the selection of the principal isotopes. The evaluation indicates that the isotope selection would be a function of the isotope concentrations and absorption reaction rates. The actinides, beyond Plutonium, and the fission products have small concentrations; therefore, resonance shielding effects will not be important. Hence, the reaction rates will be dominated by the very thermalized, but hardened, Maxwellian spectrum of the degraded fuel configuration.

In the thermal energy range, the absorption cross sections are predominantly a function of the inverse of the neutron velocity. This dominant cross section behavior results in a constant reaction rate in the Maxwellian spectrum. Therefore, the reaction rate dependency of the principal isotopes is simply dependent on the isotopes with the greatest 2200 meter per second cross sections.

The concentrations of the principal isotopes are affected by the transmutations to the trans-uranic elements, and by the fission product yields and asymptotic buildups. The transmutations to the trans-uranic elements are dependent on the neutron energy spectrum being shifted to the higher energy ranges during operation. The parameters for the fuel types and operating conditions in Table 5-1 are selected to evaluate the sensitivity of the principal isotopes to a high energy neutron spectrum.

The fission product yields are somewhat sensitive to high energy neutron fission versus thermal energy neutron fission. The yields however, are somewhat more sensitive to the fissioning isotopes, such as Plutonium versus Uranium. The various fission product disintegrations occur at a constant rate, but their neutron absorption rates are dependent on the neutron spectrum during operation. However, since the fission product cross sections are dominated by the linear inverse velocity functional behavior, all absorptions are increased or decreased by a shift in the spectrum. As the fission products approach an asymptotic buildup, it is simply the time at power that will have the greatest influence on their concentrations. The parameters for the fuel types and operating conditions in Table 5-1 are selected to evaluate the sensitivity of the principal isotopes to burnup and trans-uranic yields.

The parameters in Table 5-1 cover the range of variables that should affect the selection of the principal isotopes. Since the results of the calculations showed the expected trends of principal isotopic behavior versus the dependency on the various parameters, no other calculations with additional parameters were deemed necessary to support the selection of the principal isotopes.

The B&W 15 by 15 fuel assembly specifications correspond to the Fuel Batch 3 specifications from the Crystal River Unit 3 reactor as presented in Table 5.2.1-1 of Reference 7.4. The Westinghouse 17 by 17 OFA specifications correspond to the Fuel Batch 6B specifications from the McGuire Unit 1 reactor as presented in Table 5.2.1-1 of Reference 7.5. The Westinghouse 17 by 17 standard lattice fuel assembly specifications correspond to the Fuel Batch 2 specifications from the McGuire Unit 1 reactor as presented in Table 5.2.1-1 of Reference 7.5. The various SAS2H calculations were performed using input preparation techniques identical to those presented in Section 5.4 of References 7.4 and 7.5.

The SAS2H and ORIGEN-S input and output files for each of the 18 calculations described in Table 5-1 are provided in the attachments to this calculation (these attachments have been moved to Reference 7.6) as described in Section 8.

Table 5-1. Calculational Parameters

SAS2H/ ORIGEN-S Case Number	Fuel Type	Enrichment (wt% U-235 in U of UO_2)[3]	Burnup (MWd/MTU)[1]	Assembly Power	Control Rods
1	B&W 15 by 15	2.5	18.000	100% 14.5085 MW[2]	None
2	B&W 15 by 15	2.5	30.000	100% 14.5085 MW	None

Table 5-1. Calculational Parameters

SAS2H/ ORIGEN-S Case Number	Fuel Type	Enrichment (wt% U-235 in U of UO_2)[3]	Burnup (MWd/MTU)[1]	Assembly Power	Control Rods
3	B&W 15 by 15	5.0	30,000	50% 7.2542 MW	None
4	B&W 15 by 15	5.0	30,000	100% 14.5085 MW	None
5	B&W 15 by 15	5.0	30,000	100% 14.5085 MW	Inserted
6	B&W 15 by 15	5.0	63,000	100% 14.5085 MW	None
7	Westinghouse OFA 17 by 17	2.5	18,000	100% 17.6736 MW	None
8	Westinghouse OFA 17 by 17	2.5	30,000	100% 17.6736 MW	None
9	Westinghouse OFA 17 by 17	5.0	30,000	50% 8.8368 MW	None
10	Westinghouse OFA 17 by 17	5.0	30,000	100% 17.6736 MW	None
11	Westinghouse OFA 17 by 17	5.0	30,000	100% 17.6736 MW	Inserted
12	Westinghouse OFA 17 by 17	5.0	63,000	100% 17.6736 MW	None
13	Westinghouse Std. 17 by 17	2.5	18,000	100% 17.6736 MW	None
14	Westinghouse Std. 17 by 17	2.5	30,000	100% 17.6736 MW	None
15	Westinghouse Std. 17 by 17	5.0	30,000	50% 8.8368 MW	None
16	Westinghouse Std. 17 by 17	5.0	30,000	100% 17.6736 MW	None
17	Westinghouse Std. 17 by 17	5.0	30,000	100% 17.6736 MW	Inserted
18	Westinghouse Std. 17 by 17	5.0	63,000	100% 17.6736 MW	None

[1] MWd/MTU = megawatt days per tonne of Uranium
[2] MW = megawatt
[3] wt% = weight percent

6. Results

The following is a summary of the results of the calculations:

1. A ranking of the top 29 isotopes affecting the reactivity of the degraded SNF configuration was identified as a result of the calculations and evaluations documented herein. The top 29 isotopes in the ranking represent at least 96 percent of the absorption in the more reactive, degraded SNF, and at least 92 percent absorption in the less reactive, highly burned and degraded SNF.

2. The ranking of the top 29 isotopes, providing 96 and 92 percent of the respective absorption fractions, was independent of the fuel type and operational history.

3. The ranking of the top 29 isotopes contained 14 actinide and 15 fission product isotopes. A relative absorption fraction cutoff of 0.001 was used to screen the isotopes in the identification of the top ranking actinides. This relative absorption fraction cutoff resulted in the inclusion of isotopes which represented approximately 99 percent of the relative production fraction. The percentage (99%) of the relative production fraction included with the top ranked isotopes from the relative absorption fraction cutoff evaluation eliminated the need to use a relative production fraction cutoff evaluation in the ranking process.

4. Table 6.2-19 lists the 14 top ranked actinide isotopes affecting SNF reactivity. Table 6.2-20 lists the 15 top ranked fission product isotopes affecting SNF reactivity.

6.1. k_∞ Results

The purpose of eventually selecting a set of principal isotopes, is to reduce the number of SNF isotopes in the criticality calculations from hundreds, to a manageable number for the analyses. Consequently, the first key parameter in the ranking process to support the selection of the principal isotopes is the reactivity of the degraded SNF (in a degraded waste package environment). Tables 6.1-1 through 6.1-18 show the value of the ORIGEN-S k_∞ as a function of the SNF decaying. Below the title of each table is a subtitle describing the fuel type and operating conditions for the fuel.

For every fuel type, and all the various operating conditions, the reactivity of the decaying fuel decreased from the value at 5 years to the decay step of 100 years. Somewhere between 100 and 150 years, the reactivity stopped decreasing and began to increase. The increase in reactivity continued as the SNF decayed until it peaked when reaching the steps of either 10,000, 12,000, or 14,000 years. After the increasing reactivity peaked, it again began decreasing and did not show any indication of increasing through the remainder of the 250,000 years of decay.

The reactivity peak in the SNF at either 10,000, 12,000, or 14,000 years followed a well defined pattern as a function of fuel enrichment and burnup. The high and low initial enrichments are 5.0 wt% and 2.5 wt% U-235 in the uranium mass loading. The highly enriched fuel had a minimum burnup of 30,000 MWd/MTU and a maximum burnup of 63,000 MWd/MTU. The low enriched fuel had a minimum burnup of 18,000 MWd/MTU and a maximum burnup of 30,000 MWd/MTU.

The highly enriched fuel reached a decayed reactivity peak at the 14,000 year step, independent of either (a) burnup, (b) the various operating conditions, or (c) any other fuel type characteristics. The low enriched fuel reached a decayed reactivity peak at the 12,000 year step for a burnup of 30,000 MWd/MTU. When the burnup of the low enriched fuel was reduced to 18,000 MWd/MTU, it reach a decayed reactivity peak at the 10,000 year step.

All three fuel types showed the same pattern. Thus, the more highly enriched fuel appears to reach a decayed reactivity peak around 14,000 years, independent of any other parameter. The lower enriched fuels appear to reach a decayed reactivity peak before 14,000 years, and the peak period appears to be a function of burnup.

The reactivity tables for the 18 various fuel types and operating conditions indicate that the low burned, highly enriched fuel will be more reactive than the low burned, low enriched fuel. Thus, the isotopes should be ranked based on the more reactive, low burned, highly enriched fuel. In addition to burnup and enrichment, the SNF reactivity is affected by operation with burnable poisons or control rod poisons. These poisons significantly increase the reactivity of SNF that has experienced operation with relative assembly powers in the range of either 100 percent or 50 percent of full power to an equivalent exposure. Tables 6.1-3 through 6.1-5 for B&W fuel, Tables 6.1-9 through 6.1-11 for Westinghouse OFA fuel, and Tables 6.1-15 through 6.1-17 for Westinghouse standard fuel, indicate that the most reactive degraded configuration contains the previously poisoned SNF. The fuel with the largest fraction of poison is the Westinghouse 17 by 17 assembly.

The Westinghouse fuel with the highest conversion of U-238 to Pu-239 will be the most reactive. The less moderated standard lattice has a higher conversion ratio than the more moderated wet lattice (OFA). Consequently, the most reactive fuel type is the Westinghouse assembly with a standard 17 by 17 lattice of cells. The calculational representation of this assembly considered it to be initially loaded with 5.0 wt% U-235, and operated to 30,000 MWd/MTU, at 100% full power (3411 MW core power) with a complete assembly of 24 control rods inserted throughout the period of operation.

As noted from Table 6.1-17, the most reactive Westinghouse assembly, in a degraded condition, in a degraded waste package, would have a k_∞ of 1.272 following 5 years of decay, and a k_∞ of 1.267 following 14,000 years of decay. This is the highest reactivity of any fuel type and operational condition. Therefore, the ranking of the isotopes to support the principal isotope selection is based on evaluations of the results of this fuel type (ORIGEN-S calculation number 17 from Table 5-1).

Table 6.1-1. k_∞ Versus Decay
B&W Fuel, 2.5 wt%, 18,000 MWd/MTU Burnup, 100% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	1.024275E+00	10 y	1.012831E+00
15 y	1.003670E+00	20 y	9.964838E-01
30 y	9.865141E-01	50 y	9.768974E-01
100 y	9.727058E-01	150 y	9.736775E-01
200 y	9.750373E-01	250 y	9.763553E-01
500 y	9.818518E-01	1000 y	9.888984E-01
2000 y	9.957233E-01	4000 y	1.001835E+00
8000 y	1.007254E+00	10000 y	1.007961E+00
12000 y	1.007677E+00	14000 y	1.006606E+00
18000 y	1.002766E+00	20000 y	1.000260E+00
22000 y	9.975006E-01	24000 y	9.945675E-01
26000 y	9.915252E-01	28000 y	9.884253E-01
30000 y	9.853092E-01	32000 y	9.822093E-01
34000 y	9.791511E-01	35000 y	9.776441E-01
45000 y	9.637343E-01	100000 y	9.258115E-01
250000 y	9.176762E-01		

Table 6.1-2. k_∞ Versus Decay
B&W Fuel, 2.5 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

Decay	K_∞	Decay	k_∞
5 y	8.888044E-01	10 y	8.689522E-01
15 y	8.532933E-01	20 y	8.410578E-01
30 y	8.240705E-01	50 y	8.075551E-01
100 y	7.999142E-01	150 y	8.010873E-01
200 y	8.029529E-01	250 y	8.047782E-01
500 y	8.124278E-01	1000 y	8.223666E-01
2000 y	8.322365E-01	4000 y	8.415011E-01
8000 y	8.505786E-01	10000 y	8.522646E-01
12000 y	8.524988E-01	14000 y	8.515570E-01
18000 y	8.470716E-01	20000 y	8.439049E-01
22000 y	8.403230E-01	24000 y	8.364453E-01
26000 y	8.323683E-01	28000 y	8.281717E-01
30000 y	8.239189E-01	32000 y	8.196605E-01
34000 y	8.154365E-01	35000 y	8.133475E-01
45000 y	7.938966E-01	100000 y	7.400678E-01
250000 y	7.292808E-01		

Table 6.1-3. k_∞ Versus Decay
B&W Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 50% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	1.190401E+00	10 y	1.178764E+00
15 y	1.169515E+00	20 y	1.162292E+00
30 y	1.152313E+00	50 y	1.142770E+00
100 y	1.138908E+00	150 y	1.140241E+00
200 y	1.141948E+00	250 y	1.143595E+00
500 y	1.150465E+00	1000 y	1.159316E+00
2000 y	1.168019E+00	4000 y	1.176326E+00
8000 y	1.185530E+00	10000 y	1.188036E+00
12000 y	1.189494E+00	14000 y	1.190107E+00
18000 y	1.189462E+00	20000 y	1.188467E+00
22000 y	1.187159E+00	24000 y	1.185620E+00
26000 y	1.183915E+00	28000 y	1.182097E+00
30000 y	1.180207E+00	32000 y	1.178280E+00
34000 y	1.176342E+00	35000 y	1.175376E+00
45000 y	1.166228E+00	100000 y	1.140749E+00
250000 y	1.136965E+00		

Table 6.1-4. k_∞ Versus Decay
B&W Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	1.191294E+00	10 y	1.179478E+00
15 y	1.170004E+00	20 y	1.162583E+00
30 y	1.152314E+00	50 y	1.142481E+00
100 y	1.138456E+00	150 y	1.139777E+00
200 y	1.141483E+00	250 y	1.143129E+00
500 y	1.149989E+00	1000 y	1.158800E+00
2000 y	1.167429E+00	4000 y	1.175614E+00
8000 y	1.184617E+00	10000 y	1.187040E+00
12000 y	1.188423E+00	14000 y	1.188971E+00
18000 y	1.188215E+00	20000 y	1.187172E+00
22000 y	1.185821E+00	24000 y	1.184243E+00
26000 y	1.182502E+00	28000 y	1.180651E+00
30000 y	1.178730E+00	32000 y	1.176775E+00
34000 y	1.174810E+00	35000 y	1.173832E+00
45000 y	1.164577E+00	100000 y	1.138841E+00
250000 y	1.134966E+00		

Table 6.1-5. k_∞ Versus Decay
B&W Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, Inserted Control Rods

Decay	k_∞	Decay	k_∞
5 y	1.237542E+00	10 y	1.224625E+00
15 y	1.214329E+00	20 y	1.206274E+00
30 y	1.195128E+00	50 y	1.184446E+00
100 y	1.180074E+00	150 y	1.181517E+00
200 y	1.183382E+00	250 y	1.185185E+00
500 y	1.192717E+00	1000 y	1.202338E+00
2000 y	1.211473E+00	4000 y	1.219639E+00
8000 y	1.228247E+00	10000 y	1.230436E+00
12000 y	1.231569E+00	14000 y	1.231852E+00
18000 y	1.230533E+00	20000 y	1.229197E+00
22000 y	1.227551E+00	24000 y	1.225675E+00
26000 y	1.223637E+00	28000 y	1.221489E+00
30000 y	1.219276E+00	32000 y	1.217033E+00
34000 y	1.214786E+00	35000 y	1.213668E+00
45000 y	1.203127E+00	100000 y	1.173637E+00
250000 y	1.168747E+00		

Table 6.1-6. k_∞ Versus Decay
B&W Fuel, 5.0 wt%, 63,000 MWd/MTU Burnup, 100% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	8.780415E-01	10 y	8.519845E-01
15 y	8.316329E-01	20 y	8.158009E-01
30 y	7.938513E-01	50 y	7.724412E-01
100 y	7.623167E-01	150 y	7.636778E-01
200 y	7.659725E-01	250 y	7.682264E-01
500 y	7.777002E-01	1000 y	7.901694E-01
2000 y	8.029428E-01	4000 y	8.156936E-01
8000 y	8.297513E-01	10000 y	8.332965E-01
12000 y	8.350359E-01	14000 y	8.352948E-01
18000 y	8.324664E-01	20000 y	8.298321E-01
22000 y	8.266287E-01	24000 y	8.230019E-01
26000 y	8.190730E-01	28000 y	8.149408E-01
30000 y	8.106845E-01	32000 y	8.063700E-01
34000 y	8.020487E-01	35000 y	7.998982E-01
45000 y	7.795874E-01	100000 y	7.225299E-01
250000 y	7.136866E-01		

Table 6.1-7. k_∞ Versus Decay
Westinghouse OFA Fuel, 2.5 wt%, 18,000 MWd/MTU Burnup, 100% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	1.003388E+00	10 y	9.923797E-01
15 y	9.835361E-01	20 y	9.765914E-01
30 y	9.669542E-01	50 y	9.576547E-01
100 y	9.535785E-01	150 y	9.544912E-01
200 y	9.557800E-01	250 y	9.570315E-01
500 y	9.622564E-01	1000 y	9.689878E-01
2000 y	9.755990E-01	4000 y	9.816623E-01
8000 y	9.871373E-01	10000 y	9.878927E-01
12000 y	9.876681E-01	14000 y	9.866648E-01
18000 y	9.829810E-01	20000 y	9.805598E-01
22000 y	9.778877E-01	24000 y	9.750440E-01
26000 y	9.720926E-01	28000 y	9.690841E-01
30000 y	9.660587E-01	32000 y	9.630489E-01
34000 y	9.600795E-01	35000 y	9.586160E-01
45000 y	9.451141E-01	100000 y	9.083914E-01
250000 y	9.005430E-01		

Table 6.1-8. k_∞ Versus Decay
Westinghouse OFA Fuel, 2.5 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	8.558328E-01	10 y	8.365416E-01
15 y	8.212947E-01	20 y	8.093742E-01
30 y	7.928202E-01	50 y	7.767137E-01
100 y	7.691973E-01	150 y	7.702584E-01
200 y	7.719985E-01	250 y	7.737035E-01
500 y	7.808573E-01	1000 y	7.901846E-01
2000 y	7.995513E-01	4000 y	8.084927E-01
8000 y	8.172689E-01	10000 y	8.188748E-01
12000 y	8.190651E-01	14000 y	8.181117E-01
18000 y	8.136771E-01	20000 y	8.105649E-01
22000 y	8.070526E-01	24000 y	8.032563E-01
26000 y	7.992702E-01	28000 y	7.951717E-01
30000 y	7.910217E-01	32000 y	7.868702E-01
34000 y	7.827552E-01	35000 y	7.807214E-01
45000 y	7.618139E-01	100000 y	7.097495E-01
250000 y	6.993830E-01		

Table 6.1-9. k_∞ Versus Decay
Westinghouse OFA Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 50% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	1.174994E+00	10 y	1.163690E+00
15 y	1.154654E+00	20 y	1.147584E+00
30 y	1.137812E+00	50 y	1.128461E+00
100 y	1.124644E+00	150 y	1.125912E+00
200 y	1.127547E+00	250 y	1.129127E+00
500 y	1.135723E+00	1000 y	1.144250E+00
2000 y	1.152736E+00	4000 y	1.161002E+00
8000 y	1.170274E+00	10000 y	1.172833E+00
12000 y	1.174353E+00	14000 y	1.175037E+00
18000 y	1.174549E+00	20000 y	1.173638E+00
22000 y	1.172418E+00	24000 y	1.170968E+00
26000 y	1.169352E+00	28000 y	1.167623E+00
30000 y	1.165822E+00	32000 y	1.163982E+00
34000 y	1.162131E+00	35000 y	1.161207E+00
45000 y	1.152452E+00	100000 y	1.128103E+00
250000 y	1.124578E+00		

Table 6.1-10. k_∞ Versus Decay
Westinghouse OFA Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	1.174676E+00	10 y	1.163301E+00
15 y	1.154129E+00	20 y	1.146932E+00
30 y	1.136971E+00	50 y	1.127428E+00
100 y	1.123499E+00	150 y	1.124751E+00
200 y	1.126379E+00	250 y	1.127951E+00
500 y	1.134512E+00	1000 y	1.142969E+00
2000 y	1.151348E+00	4000 y	1.159448E+00
8000 y	1.168452E+00	10000 y	1.170901E+00
12000 y	1.172323E+00	14000 y	1.172921E+00
18000 y	1.172288E+00	20000 y	1.171315E+00
22000 y	1.170039E+00	24000 y	1.168539E+00
26000 y	1.166877E+00	28000 y	1.165105E+00
30000 y	1.163265E+00	32000 y	1.161390E+00
34000 y	1.159505E+00	35000 y	1.158565E+00
45000 y	1.149678E+00	100000 y	1.125012E+00
250000 y	1.121378E+00		

Table 6.1-11. k_∞ Versus Decay
Westinghouse OFA Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, Inserted Control Rods

Decay	k_∞	Decay	k_∞
5 y	1.233144E+00	10 y	1.220191E+00
15 y	1.209837E+00	20 y	1.201729E+00
30 y	1.190505E+00	50 y	1.179739E+00
100 y	1.175303E+00	150 y	1.176720E+00
200 y	1.178566E+00	250 y	1.180354E+00
500 y	1.187830E+00	1000 y	1.197394E+00
2000 y	1.206481E+00	4000 y	1.214608E+00
8000 y	1.223176E+00	10000 y	1.225355E+00
12000 y	1.226483E+00	14000 y	1.226765E+00
18000 y	1.225456E+00	20000 y	1.224129E+00
22000 y	1.222494E+00	24000 y	1.220630E+00
26000 y	1.218606E+00	28000 y	1.216474E+00
30000 y	1.214277E+00	32000 y	1.212050E+00
34000 y	1.209820E+00	35000 y	1.208711E+00
45000 y	1.198253E+00	100000 y	1.169032E+00
250000 y	1.164194E+00		

Table 6.1-12. k_∞ Versus Decay
Westinghouse OFA Fuel, 5.0 wt%, 63,000 MWd/MTU Burnup, 100% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	8.348894E-01	10 y	8.096495E-01
15 y	7.898999E-01	20 y	7.745323E-01
30 y	7.532267E-01	50 y	7.324279E-01
100 y	7.224780E-01	150 y	7.236547E-01
200 y	7.257441E-01	250 y	7.278029E-01
500 y	7.364697E-01	1000 y	7.479251E-01
2000 y	7.598199E-01	4000 y	7.719218E-01
8000 y	7.852392E-01	10000 y	7.885305E-01
12000 y	7.900805E-01	14000 y	7.902046E-01
18000 y	7.872416E-01	20000 y	7.845933E-01
22000 y	7.814044E-01	24000 y	7.778149E-01
26000 y	7.739422E-01	28000 y	7.698804E-01
30000 y	7.657073E-01	32000 y	7.614840E-01
34000 y	7.572610E-01	35000 y	7.551618E-01
45000 y	7.353889E-01	100000 y	6.802263E-01
250000 y	6.717318E-01		

Table 6.1-13. k_∞ Versus Decay
Westinghouse Std. Fuel, 2.5 wt%, 18,000 MWd/MTU Burnup, 100% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	1.045264E+00	10 y	1.034870E+00
15 y	1.026516E+00	20 y	1.019955E+00
30 y	1.010851E+00	50 y	1.002078E+00
100 y	9.982793E-01	150 y	9.991968E-01
200 y	1.000466E+00	250 y	1.001697E+00
500 y	1.006823E+00	1000 y	1.013378E+00
2000 y	1.019685E+00	4000 y	1.025251E+00
8000 y	1.030018E+00	10000 y	1.030535E+00
12000 y	1.030132E+00	14000 y	1.029002E+00
18000 y	1.025182E+00	20000 y	1.022735E+00
22000 y	1.020060E+00	24000 y	1.017230E+00
26000 y	1.014305E+00	28000 y	1.011332E+00
30000 y	1.008349E+00	32000 y	1.005386E+00
34000 y	1.002466E+00	35000 y	1.001029E+00
45000 y	9.877865E-01	100000 y	9.517866E-01
250000 y	9.439764E-01		

Table 6.1-14. k_∞ Versus Decay
Westinghouse Std. Fuel, 2.5 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	9.179580E-01	10 y	8.991604E-01
15 y	8.842890E-01	20 y	8.726576E-01
30 y	8.565072E-01	50 y	8.408247E-01
100 y	8.336424E-01	150 y	8.348361E-01
200 y	8.366813E-01	250 y	8.384823E-01
500 y	8.460135E-01	1000 y	8.557429E-01
2000 y	8.652870E-01	4000 y	8.740661E-01
8000 y	8.824950E-01	10000 y	8.839883E-01
12000 y	8.841027E-01	14000 y	8.831046E-01
18000 y	8.786559E-01	20000 y	8.755639E-01
22000 y	8.720850E-01	24000 y	8.683308E-01
26000 y	8.643939E-01	28000 y	8.603482E-01
30000 y	8.562543E-01	32000 y	8.521593E-01
34000 y	8.481011E-01	35000 y	8.460951E-01
45000 y	8.274432E-01	100000 y	7.759206E-01
250000 y	7.654725E-01		

Table 6.1-15. k_∞ Versus Decay
Westinghouse Std. Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 50% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	1.219460E+00	10 y	1.208876E+00
15 y	1.200411E+00	20 y	1.193786E+00
30 y	1.184629E+00	50 y	1.175878E+00
100 y	1.172365E+00	150 y	1.173621E+00
200 y	1.175217E+00	250 y	1.176757E+00
500 y	1.183181E+00	1000 y	1.191441E+00
2000 y	1.199543E+00	4000 y	1.207256E+00
8000 y	1.215770E+00	10000 y	1.218078E+00
12000 y	1.219415E+00	14000 y	1.219971E+00
18000 y	1.219358E+00	20000 y	1.218431E+00
22000 y	1.217218E+00	24000 y	1.215794E+00
26000 y	1.214217E+00	28000 y	1.212537E+00
30000 y	1.210792E+00	32000 y	1.209013E+00
34000 y	1.207226E+00	35000 y	1.206335E+00
45000 y	1.197906E+00	100000 y	1.174466E+00
250000 y	1.170956E+00		

Table 6.1-16. k_∞ Versus Decay
Westinghouse Std. Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	1.218973E+00	10 y	1.208297E+00
15 y	1.199686E+00	20 y	1.192927E+00
30 y	1.183573E+00	50 y	1.174623E+00
100 y	1.170995E+00	150 y	1.172236E+00
200 y	1.173829E+00	250 y	1.175363E+00
500 y	1.181761E+00	1000 y	1.189965E+00
2000 y	1.197976E+00	4000 y	1.205540E+00
8000 y	1.213813E+00	10000 y	1.216022E+00
12000 y	1.217270E+00	14000 y	1.217748E+00
18000 y	1.217001E+00	20000 y	1.216017E+00
22000 y	1.214753E+00	24000 y	1.213281E+00
26000 y	1.211661E+00	28000 y	1.209941E+00
30000 y	1.208159E+00	32000 y	1.206346E+00
34000 y	1.204528E+00	35000 y	1.203622E+00
45000 y	1.195066E+00	100000 y	1.171322E+00
250000 y	1.167710E+00		

Table 6.1-17. k_∞ Versus Decay
Westinghouse Std. Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup,
100% Power, Inserted Control Rods

Decay	k_∞	Decay	k_∞
5 y	1.272028E+00	10 y	1.260107E+00
15 y	1.250573E+00	20 y	1.243107E+00
30 y	1.232774E+00	50 y	1.222876E+00
100 y	1.218854E+00	150 y	1.220224E+00
200 y	1.221988E+00	250 y	1.223694E+00
500 y	1.230825E+00	1000 y	1.239918E+00
2000 y	1.248474E+00	4000 y	1.255984E+00
8000 y	1.263744E+00	10000 y	1.265653E+00
12000 y	1.266581E+00	14000 y	1.266721E+00
18000 y	1.265261E+00	20000 y	1.263909E+00
22000 y	1.262272E+00	24000 y	1.260425E+00
26000 y	1.258430E+00	28000 y	1.256339E+00
30000 y	1.254191E+00	32000 y	1.252018E+00
34000 y	1.249846E+00	35000 y	1.248766E+00
45000 y	1.238604E+00	100000 y	1.210193E+00
250000 y	1.205300E+00		

Table 6.1-18. k_∞ Versus Decay
Westinghouse Std. Fuel, 5.0 wt%, 63,000 MWd/MTU Burnup, 100% Power, No Control Rods

Decay	k_∞	Decay	k_∞
5 y	9.252483E-01	10 y	9.001721E-01
15 y	8.805192E-01	20 y	8.652142E-01
30 y	8.439966E-01	50 y	8.233472E-01
100 y	8.137521E-01	150 y	8.152427E-01
200 y	8.176162E-01	250 y	8.199375E-01
500 y	8.296583E-01	1000 y	8.423313E-01
2000 y	8.550423E-01	4000 y	8.673542E-01
8000 y	8.807796E-01	10000 y	8.841673E-01
12000 y	8.858414E-01	14000 y	8.861135E-01
18000 y	8.834986E-01	20000 y	8.810421E-01
22000 y	8.780506E-01	24000 y	8.746623E-01
26000 y	8.709907E-01	28000 y	8.671287E-01
30000 y	8.631514E-01	32000 y	8.591196E-01
34000 y	8.550820E-01	35000 y	8.530733E-01
45000 y	8.341069E-01	100000 y	7.809225E-01
250000 y	7.727818E-01		

6.2. Relative Absorption Fractions

Tables 6.2-1 through 6.2-18 provide a partial listing of the relative absorption and production fractions for the 18 combinations of fuel types and operating conditions. Each table lists 3 time periods, (a) 5 years, (b) the decayed reactivity peak (10,000, 12,000, or 14,000 years), and (c) 250,000 years. Table 6.2-17 provides the listing for the most reactive fuel (the Westinghouse standard 17 by 17 lattice) that was highly enriched (5.0 wt% U-235) when initially loaded, discharged with a low burnup (30,000 MWd/MTU), and operated with a control rod assembly for the entire burnup period.

During the decay period, when the reactivity is increasing, this fuel reaches a peak reactivity at 14,000 years with a k_∞ of 1.267. Thus, this case was used to evaluate the isotope's absorption and production rates to support the principal isotope selection process. For both the actinides and the fission products, a screening cutoff was defined for the isotopic absorption fraction. An isotope with an absorption fraction less than 0.001 (one-tenth of a percent) would not be included in the screening for the isotope ranking. Referring to Table 6.2-17, and using the absorption fractions for the 14,000 year decay period as an example, the last noted fission product is Ruthenium (Ru-101), with an absorption fraction of 0.00113. The isotope with the next lower absorption fraction is Gadolinium (Gd-157), with a fraction of 0.00058. Because the Gd-157 is below the absorption fraction cutoff of 0.001, it was not included in the top isotope ranking as a result of the screening process.

The actinide absorption fraction ranking used a screening cutoff of 0.001 as noted above, thus Plutonium (Pu-242) would be the last isotope selected from Table 6.2-17 for the 14,000 year decay period. However, the actinides also fission. Because of the importance of fissioning reactions to the fuel reactivity, the relative production fraction ranking used a screening cutoff that was defined by the first Curium isotope with an odd atomic weight.

The ranking of the most important isotopes affecting reactivity that was developed based on ORIGEN-S case number 17 (see Table 5-1) with a decay time of 14,000 years after discharge, is shown in Tables 6.2-19 and 6.2-20. Table 6.2-19 lists 8 of the 14 actinides in the top ranking under the column representing the 14,000 year decay period. The next column to the right, is the 5 year decay period for case number 17. In the 5 year column, 3 additional actinides are added to the top ranking. The 250,000 year column for case number 17 includes the buildup of U-233 from the decay of Am-241 through Np-237. In addition, the 250,000 year column includes the buildup of Thorium (Th-230) from the decay of Americium (Am-242m) through Pu-238 and U-234. While U-233 is included as one of the top ranked actinides, Th-230 is not included. The U-233 is an important thermal fissioning isotope while Th-230 is not.

The ranking of the remaining actinides is based on ORIGEN-S case number 18 (see Table 5-1) in addition to case number 17, as shown by Table 6.2-19. The case number 18 results are for the high burnup fuel of 63,000 MWd/MTU. The case number 18, 5 year decay step, shows that in high burnup SNF, Pu-238 and Am-243 are above the screening cutoff used in the ranking.

Table 6.2-20 lists 14 of the 15 top ranked fission products under the column representing the 14,000 year decay period for ORIGEN-S case number 17. In addition to these 14 fission products, the Xe-131 and Cs-133 fission products should be noted. Table 6.2-17 shows that Xe-131 and Cs-133 have high

absorption fractions in the degraded SNF. However, these 2 isotopes are not included in the top ranking of fission products because of their gaseous and soluble physical and chemical properties.

Xenon is always a gas, and Cesium is gaseous in the operating fuel, and forms gaseous oxide and halide compounds. With degraded fuel defined to include water between the fuel pellet and cladding, the concentration of the gaseous fission products cannot be adequately determined. Furthermore, the Cesium and Cesium compounds are part of a gaseous solution, and are very soluble and chemically active in water. Thus, the concentrations of Cesium cannot be adequately determined. Therefore, while Xe-131 and Cs-133 meet the ranking screening cutoff based on their respective absorption fractions, they are not suitable because of their physical and chemical properties.

The remaining fission product isotopes in the top ranking are based on ORIGEN-S case number 17 at the 5 year decay period. For this case, both Sm-151 and Promethium (Pm-147) passed the aborption fraction screening cutoff for the top ranking. Sm-151 is an important absorber in the 5 year decay period, so it is included in the top ranked fission products. However, Pm-147 is not an important absorber, just passing the top ranking screening cutoff, and decays with a half-life of 2.6 years. Therefore, Pm-147 was not included in the top isotope ranking.

Tables 6.2-19 and 6.2-20 show the top ranked isotopes which have the largest effect on SNF reactivity. Table 6.2-19 contains the 14 actinide isotopes in the top ranking, and Table 6.2-20 contains the 15 fission product isotopes in the top ranking. As indicated in the previous discussion, the ranking of the top isotopes was based on the most reactive case (case number 17 in Table 5-1) at the decayed reactivity peak (14,000 years). In addition to the decayed peak reactivity for this case, both the 5 year and 250,000 year decay periods contributed to the ranking of the top isotopes. As also noted, the 5 year decay period from the high burnup case (case number 18 in Table 5-1) contributed to the ranking of the top isotopes. The above discussion explains the process used to rank the isotopes that have the largest effect on SNF reactivity. However, there are two additional issues which need to be discussed:

1. The ranking of actinides based on neutron productions (Section 6.3).

2. How the top ranked isotopes cover the absorptions and reactivity in the 51 other combinations of decay periods, fuel types, and operational conditions (Section 6.4).

Table 6.2-1. Relative Isotopic Absorptions and Productions
B&W Fuel, 2.5 wt%, 18,000 MWd/MTU Burnup, 100% Power, No Control Rods

5 years			10,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
U-238	3.52E-01	0.00E+00	U-238	3.98E-01	0.00E+00	U-238	4.81E-01	0.00E+00
Pu-239	2.51E-01	5.32E-01	U-235	2.52E-01	5.22E-01	U-235	3.93E-01	8.14E-01
U-235	2.02E-01	4.18E-01	Pu-239	2.13E-01	4.52E-01	U-236	1.49E-02	4.47E-04
Pu-240	7.98E-02	0.00E+00	Pu-240	3.14E-02	0.00E+00	Np-237	1.33E-02	3.72E-03
Pu-241	2.73E-02	5.92E-02	Np-237	1.19E-02	3.33E-03	Pu-242	1.69E-03	3.38E-05
U-236	7.09E-03	2.13E-04	U-236	1.09E-02	3.27E-04	U-233	1.28E-03	2.94E-03
Am-241	6.62E-03	1.32E-04	Pu-242	2.18E-03	4.36E-05	U-234	1.24E-03	2.48E-05
Np-237	2.25E-03	6.30E-04	U-234	1.58E-03	3.16E-05			
Pu-242	1.96E-03	3.92E-05	U-233	6.78E-05	1.56E-04			
U-234	1.16E-03	2.32E-05	Cm-245	2.09E-06	6.63E-06			
Am-242m	4.82E-05	1.22E-04						
Cm-245	4.18E-06	1.33E-05						
Fission Products			Fission Products			Fission Products		
Sm-149	9.56E-03		Sm-149	1.08E-02		Sm-149	1.31E-02	
Rh-103	9.30E-03		Rh-103	1.05E-02		Rh-103	1.27E-02	
Nd-143	7.20E-03		Nd-143	8.15E-03		Nd-143	9.84E-03	
Xe-131	4.75E-03		Xe-131	5.37E-03		Xe-131	6.49E-03	
Cs-133	4.64E-03		Cs-133	5.25E-03		Cs-133	6.34E-03	
Tc-99	3.73E-03		Eu-151	4.19E-03		Eu-151	5.07E-03	
Sm-152	3.41E-03		Tc-99	4.09E-03		Sm-152	4.66E-03	
Sm-151	3.33E-03		Sm-152	3.86E-03		Gd-155	3.76E-03	
Eu-153	2.02E-03		Gd-155	3.11E-03		Sm-147	3.50E-03	
Sm-147	2.00E-03		Sm-147	2.90E-03		Eu-153	2.76E-03	
Nd-145	1.97E-03		Eu-153	2.28E-03		Nd-145	2.69E-03	
Mo-95	1.60E-03		Nd-145	2.23E-03		Tc-99	2.24E-03	
Gd-155	1.45E-03		Mo-95	1.81E-03		Mo-95	2.19E-03	
Pm-147	1.41E-03		Ag-109	1.54E-03		Ag-109	1.86E-03	
Ag-109	1.36E-03		Sm-150	1.49E-03		Sm-150	1.79E-03	
Sm-150	1.31E-03		Ru-101	1.18E-03		Ru-101	1.43E-03	
Ru-101	1.05E-03					Ru-99	1.27E-03	

Table 6.2-2. Relative Isotopic Absorptions and Productions
B&W Fuel, 2.5 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

5 years			12,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
U-238	3.34E-01	0.00E+00	U-238	4.05E-01	0.00E+00	U-238	5.04E-01	0.00E+00
Pu-239	2.65E-01	5.62E-01	Pu-239	2.32E-01	4.92E-01	U-235	2.92E-01	6.04E-01
Pu-240	1.23E-01	0.00E+00	U-235	1.55E-01	3.21E-01	Np-237	2.50E-02	7.00E-03
U-235	1.01E-01	2.09E-01	Pu-240	4.25E-02	0.00E+00	U-236	2.20E-02	6.60E-04
Pu-241	4.53E-02	9.83E-02	Np-237	2.17E-02	6.08E-03	Pu-242	5.92E-03	1.18E-04
Am-241	1.14E-02	2.28E-04	U-236	1.57E-02	4.71E-04	U-233	2.41E-03	5.54E-03
U-236	8.60E-03	2.58E-04	Pu-242	7.39E-03	1.48E-04	U-234	1.61E-03	3.22E-05
Pu-242	6.23E-03	1.25E-04	U-234	2.10E-03	4.20E-05	Pu-239	3.12E-04	6.61E-04
Np-237	4.11E-03	1.15E-03	U-233	1.49E-04	3.43E-04	Cm-247	3.39E-08	7.56E-08
Am-243	1.61E-03	1.61E-05	Cm-245	3.04E-05	9.64E-05			
Pu-238	1.46E-03	1.02E-04						
Am-242m	1.26E-04	3.19E-04						
Cm-245	6.67E-05	2.11E-04						
Fission Products			Fission Products			Fission Products		
Rh-103	1.38E-02		Rh-103	1.68E-02		Rh-103	2.09E-02	
Sm-149	9.66E-03		Sm-149	1.17E-02		Sm-149	1.46E-02	
Nd-143	9.46E-03		Nd-143	1.15E-02		Nd-143	1.43E-02	
Cs-133	6.97E-03		Cs-133	8.45E-03		Cs-133	1.05E-02	
Xe-131	6.63E-03		Xe-131	8.03E-03		Xe-131	1.00E-02	
Tc-99	5.63E-03		Gd-155	7.07E-03		Gd-155	8.80E-03	
Sm-152	5.16E-03		Tc-99	6.56E-03		Sm-152	7.79E-03	
Eu-153	3.99E-03		Sm-152	6.25E-03		Eu-151	6.65E-03	
Sm-151	3.95E-03		Eu-151	5.34E-03		Eu-153	6.02E-03	
Gd-155	3.07E-03		Eu-153	4.83E-03		Sm-147	4.82E-03	
Nd-145	2.89E-03		Sm-147	3.87E-03		Nd-145	4.36E-03	
Ag-109	2.66E-03		Nd-145	3.50E-03		Ag-109	4.01E-03	
Sm-147	2.56E-03		Ag-109	3.22E-03		Tc-99	3.74E-03	
Mo-95	2.38E-03		Mo-95	2.89E-03		Mo-95	3.60E-03	
Sm-150	2.18E-03		Sm-150	2.64E-03		Sm-150	3.29E-03	
Ru-101	1.66E-03		Ru-101	2.01E-03		Ru-101	2.50E-03	
Pm-147	1.56E-03		Pd-105	1.26E-03		Ru-99	2.11E-03	
Pd-105	1.04E-03					Pd-105	1.56E-03	
						Pd-108	1.19E-03	
						Pr-141	1.17E-03	

Table 6.2-3. Relative Isotopic Absorptions and Productions
B&W Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 50% Power, No Control Rods

5 years			14,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
U-235	3.13E-01	6.48E-01	U-235	3.90E-01	8.07E-01	U-235	5.26E-01	1.09E+00
U-238	2.51E-01	0.00E+00	U-238	2.87E-01	0.00E+00	U-238	3.34E-01	0.00E+00
Pu-239	2.36E-01	5.00E-01	Pu-239	1.82E-01	3.86E-01	U-236	1.84E-02	5.52E-04
Pu-240	6.80E-02	0.00E+00	Pu-240	1.78E-02	0.00E+00	Np-237	1.52E-02	4.26E-03
Pu-241	2.79E-02	6.05E-02	U-236	1.51E-02	4.53E-04	U-234	1.70E-03	3.40E-05
U-236	1.06E-02	3.18E-04	Np-237	1.41E-02	3.95E-03	Pu-242	1.60E-03	3.20E-05
Am-241	8.01E-03	1.60E-04	U-234	2.54E-03	5.08E-05	U-233	1.47E-03	3.38E-03
Np-237	3.55E-03	9.94E-04	Pu-242	2.14E-03	4.28E-05	Pu-239	2.40E-04	5.09E-04
Pu-242	1.91E-03	3.82E-05	U-233	1.14E-04	2.62E-04	Cm-247	1.59E-09	3.55E-09
U-234	1.71E-03	3.42E-05	Cm-245	3.73E-06	1.18E-05			
Am-242m	1.88E-04	4.76E-04						
Cm-245	1.02E-05	3.23E-05						
Fission Products			Fission Products			Fission Products		
Rh-103	9.91E-03		Rh-103	1.14E-02		Rh-103	1.32E-02	
Nd-143	9.21E-03		Nd-143	1.06E-02		Nd-143	1.23E-02	
Sm-149	7.99E-03		Sm-149	9.16E-03		Sm-149	1.06E-02	
Cs-133	5.58E-03		Cs-133	6.40E-03		Cs-133	7.43E-03	
Xe-131	5.40E-03		Xe-131	6.19E-03		Xe-131	7.19E-03	
Tc-99	4.47E-03		Eu-151	5.63E-03		Eu-151	6.53E-03	
Sm-151	4.39E-03		Tc-99	4.90E-03		Sm-152	4.83E-03	
Sm-152	3.62E-03		Sm-152	4.16E-03		Gd-155	4.16E-03	
Sm-147	2.59E-03		Gd-155	3.58E-03		Sm-147	4.05E-03	
Eu-153	2.45E-03		Sm-147	3.49E-03		Eu-153	3.26E-03	
Nd-145	2.44E-03		Eu-153	2.81E-03		Nd-145	3.25E-03	
Mo-95	1.99E-03		Nd-145	2.80E-03		Mo-95	2.64E-03	
Gd-155	1.67E-03		Mo-95	2.28E-03		Tc-99	2.62E-03	
Sm-150	1.49E-03		Sm-150	1.71E-03		Sm-150	1.99E-03	
Ru-101	1.26E-03		Ru-101	1.45E-03		Ru-101	1.68E-03	
Ag-109	1.26E-03		Ag-109	1.45E-03		Ag-109	1.68E-03	
Pm-147	1.13E-03					Ru-99	1.48E-03	

Table 6.2-6. Relative Isotopic Absorptions and Productions
B&W Fuel, 5.0 wt%, 63,000 MWd/MTU Burnup, 100% Power, No Control Rods

5 years			14,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
Pu-239	2.62E-01	5.55E-01	U-238	3.16E-01	0.00E+00	U-238	3.94E-01	0.00E+00
U-238	2.51E-01	0.00E+00	Pu-239	2.31E-01	4.90E-01	U-235	2.98E-01	6.17E-01
Pu-240	1.35E-01	0.00E+00	U-235	1.58E-01	3.27E-01	Np-237	3.86E-02	1.08E-02
U-235	9.52E-02	1.97E-01	Pu-240	4.04E-02	0.00E+00	U-236	3.41E-02	1.02E-03
Pu-241	5.68E-02	1.23E-01	Np-237	3.33E-02	9.32E-03	Pu-242	1.06E-02	2.12E-04
Am-241	1.53E-02	3.06E-04	U-236	2.56E-02	7.68E-04	U-233	3.72E-03	8.56E-03
U-236	1.50E-02	4.50E-04	Pu-242	1.32E-02	2.64E-04	U-234	3.48E-03	6.96E-05
Pu-242	1.08E-02	2.16E-04	U-234	5.10E-03	1.02E-04	Pu-239	3.36E-04	7.12E-04
Np-237	8.91E-03	2.49E-03	Am-243	1.45E-03	1.45E-05	Cm-247	8.54E-07	1.90E-06
Pu-238	5.04E-03	3.53E-04	U-233	2.70E-04	6.21E-04			
Am-243	4.30E-03	4.30E-05	Cm-245	2.21E-04	7.01E-04			
U-234	1.18E-03	2.36E-05						
Cm-245	5.52E-04	1.75E-03						
Fission Products			Fission Products			Fission Products		
Rh-103	1.76E-02		Rh-103	2.21E-02		Rh-103	2.76E-02	
Nd-143	1.40E-02		Nd-143	1.75E-02		Nd-143	2.19E-02	
Cs-133	1.05E-02		Gd-155	1.33E-02		Gd-155	1.66E-02	
Sm-149	9.84E-03		Cs-133	1.32E-02		Cs-133	1.64E-02	
Tc-99	8.58E-03		Sm-149	1.24E-02		Sm-149	1.54E-02	
Xe-131	8.51E-03		Xe-131	1.07E-02		Xe-131	1.33E-02	
Sm-152	6.75E-03		Tc-99	1.03E-02		Sm-152	1.06E-02	
Eu-153	6.59E-03		Sm-152	8.48E-03		Eu-153	1.03E-02	
Sm-151	5.72E-03		Eu-153	8.27E-03		Eu-151	9.99E-03	
Gd-155	5.59E-03		Eu-151	8.01E-03		Nd-145	6.98E-03	
Nd-145	4.45E-03		Nd-145	5.59E-03		Sm-147	6.11E-03	
Mo-95	3.80E-03		Sm-147	4.90E-03		Mo-95	5.95E-03	
Ag-109	3.71E-03		Mo-95	4.77E-03		Tc-99	5.91E-03	
Sm-150	3.37E-03		Ag-109	4.66E-03		Ag-109	5.81E-03	
Sm-147	3.30E-03		Sm-150	4.23E-03		Sm-150	5.28E-03	
Ru-101	2.65E-03		Ru-101	3.33E-03		Ru-101	4.15E-03	
Eu-154	1.81E-03		Pd-105	2.10E-03		Ru-99	3.34E-03	
Pd-105	1.67E-03		Pr-141	1.60E-03		Pd-105	2.62E-03	
Pm-147	1.50E-03		Pd-108	1.56E-03		Pr-141	2.00E-03	
Pr-141	1.27E-03		Cs-135	1.24E-03		Pd-108	1.95E-03	
Pd-108	1.24E-03		La-139	1.21E-03		La-139	1.51E-03	
			Kr-83	1.16E-03		Kr-83	1.45E-03	
			Gd-157	1.09E-03		Cs-135	1.44E-03	
			Zr-93	1.04E-03		Gd-157	1.36E-03	
						Zr-93	1.17E-03	
						Pd-107	1.13E-03	

Table 6.2-9. Relative Isotopic Absorptions and Productions
Westinghouse OFA Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 50% Power, No Control Rods

5 years			14,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
U-235	3.17E-01	6.56E-01	U-235	3.91E-01	8.09E-01	U-235	5.18E-01	1.07E+00
U-238	2.59E-01	0.00E+00	U-238	2.95E-01	0.00E+00	U-238	3.41E-01	0.00E+00
Pu-239	2.24E-01	4.75E-01	Pu-239	1.72E-01	3.65E-01	U-236	1.86E-02	5.58E-04
Pu-240	6.83E-02	0.00E+00	Pu-240	1.78E-02	0.00E+00	Np-237	1.44E-02	4.03E-03
Pu-241	2.72E-02	5.90E-02	U-236	1.54E-02	4.62E-04	U-234	1.68E-03	3.36E-05
U-236	1.09E-02	3.27E-04	Np-237	1.35E-02	3.78E-03	Pu-242	1.62E-03	3.24E-05
Am-241	7.37E-03	1.47E-04	U-234	2.53E-03	5.06E-05	U-233	1.39E-03	3.20E-03
Np-237	3.40E-03	9.52E-04	Pu-242	2.18E-03	4.36E-05	Pu-239	2.25E-04	4.77E-04
Pu-242	1.95E-03	3.90E-05	U-233	1.09E-04	2.51E-04			
U-234	1.79E-03	3.58E-05	Cm-245	2.88E-06	9.13E-06			
Am-242m	1.30E-04	3.29E-04						
Cm-245	7.89E-06	2.50E-05						
Fission Products			Fission Products			Fission Products		
Rh-103	1.03E-02		Rh-103	1.17E-02		Rh-103	1.35E-02	
Nd-143	9.47E-03		Nd-143	1.08E-02		Nd-143	1.25E-02	
Sm-149	8.09E-03		Sm-149	9.24E-03		Sm-149	1.07E-02	
Cs-133	5.79E-03		Cs-133	6.61E-03		Cs-133	7.62E-03	
Xe-131	5.65E-03		Xe-131	6.45E-03		Xe-131	7.44E-03	
Tc-99	4.64E-03		Eu-151	5.38E-03		Eu-151	6.20E-03	
Sm-151	4.22E-03		Tc-99	5.06E-03		Sm-152	5.03E-03	
Sm-152	3.82E-03		Sm-152	4.37E-03		Gd-155	4.19E-03	
Sm-147	2.63E-03		Gd-155	3.63E-03		Sm-147	4.17E-03	
Nd-145	2.53E-03		Sm-147	3.62E-03		Nd-145	3.34E-03	
Eu-153	2.49E-03		Nd-145	2.89E-03		Eu-153	3.28E-03	
Mo-95	2.06E-03		Eu-153	2.84E-03		Mo-95	2.72E-03	
Gd-155	1.69E-03		Mo-95	2.36E-03		Tc-99	2.69E-03	
Sm-150	1.61E-03		Sm-150	1.83E-03		Sm-150	2.11E-03	
Pm-147	1.34E-03		Ru-101	1.49E-03		Ru-101	1.72E-03	
Ru-101	1.30E-03		Ag-109	1.45E-03		Ag-109	1.67E-03	
Ag-109	1.27E-03					Ru-99	1.52E-03	

Table 6.2-10. Relative Isotopic Absorptions and Productions
Westinghouse OFA Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

5 years			14,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
U-235	3.15E-01	6.52E-01	U-235	3.89E-01	8.05E-01	U-235	5.17E-01	1.07E+00
U-238	2.57E-01	0.00E+00	U-238	2.93E-01	0.00E+00	U-238	3.38E-01	0.00E+00
Pu-239	2.25E-01	4.77E-01	Pu-239	1.73E-01	3.67E-01	U-236	1.85E-02	5.55E-04
Pu-240	6.78E-02	0.00E+00	Pu-240	1.77E-02	0.00E+00	Np-237	1.44E-02	4.03E-03
Pu-241	2.77E-02	6.01E-02	U-236	1.53E-02	4.59E-04	U-234	1.64E-03	3.28E-05
U-236	1.08E-02	3.24E-04	Np-237	1.35E-02	3.78E-03	Pu-242	1.62E-03	3.24E-05
Am-241	6.84E-03	1.37E-04	U-234	2.46E-03	4.92E-05	U-233	1.39E-03	3.20E-03
Np-237	3.39E-03	9.49E-04	Pu-242	2.18E-03	4.36E-05	Pu-239	2.26E-04	4.79E-04
Pu-242	1.96E-03	3.92E-05	U-233	1.09E-04	2.51E-04			
U-234	1.77E-03	3.54E-05	Cm-245	2.93E-06	9.29E-06			
Am-242m	6.62E-05	1.67E-04						
Cm-245	8.03E-06	2.55E-05						
Fission Products			Fission Products			Fission Products		
Sm-149	1.14E-02		Sm-149	1.30E-02		Sm-149	1.50E-02	
Rh-103	1.04E-02		Rh-103	1.18E-02		Rh-103	1.36E-02	
Nd-143	9.36E-03		Nd-143	1.07E-02		Nd-143	1.23E-02	
Cs-133	5.76E-03		Cs-133	6.58E-03		Cs-133	7.59E-03	
Xe-131	5.62E-03		Xe-131	6.42E-03		Xe-131	7.41E-03	
Tc-99	4.64E-03		Eu-151	5.45E-03		Eu-151	6.29E-03	
Sm-151	4.29E-03		Tc-99	5.06E-03		Sm-152	5.00E-03	
Sm-152	3.79E-03		Sm-152	4.33E-03		Gd-155	4.22E-03	
Nd-145	2.51E-03		Gd-155	3.66E-03		Sm-147	4.03E-03	
Eu-153	2.47E-03		Sm-147	3.50E-03		Nd-145	3.31E-03	
Sm-147	2.42E-03		Nd-145	2.87E-03		Eu-153	3.25E-03	
Mo-95	2.05E-03		Eu-153	2.82E-03		Mo-95	2.71E-03	
Gd-155	1.69E-03		Mo-95	2.35E-03		Tc-99	2.69E-03	
Sm-150	1.64E-03		Sm-150	1.87E-03		Sm-150	2.16E-03	
Pm-147	1.61E-03		Ru-101	1.48E-03		Ru-101	1.70E-03	
Ru1-01	1.29E-03		Ag-109	1.44E-03		Ag-109	1.66E-03	
Ag-109	1.26E-03					Ru-99	1.52E-03	

Table 6.2-11. Relative Isotopic Absorptions and Productions Westinghouse OFA Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, Inserted Control Rods

5 years			14,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
U-235	2.99E-01	6.19E-01	U-235	3.83E-01	7.93E-01	U-235	5.43E-01	1.12E+00
Pu-239	2.75E-01	5.83E-01	U-238	2.58E-01	0.00E+00	U-238	3.07E-01	0.00E+00
U-238	2.23E-01	0.00E+00	Pu-239	2.14E-01	4.54E-01	U-236	1.74E-02	5.22E-04
Pu-240	6.66E-02	0.00E+00	Pu-240	1.77E-02	0.00E+00	Np-237	1.69E-02	4.73E-03
Pu-241	3.14E-02	6.81E-02	Np-237	1.54E-02	4.31E-03	U-233	1.63E-03	3.75E-03
U-236	9.42E-03	2.83E-04	U-236	1.38E-02	4.14E-04	U-234	1.55E-03	3.10E-05
Am-241	7.77E-03	1.55E-04	U-234	2.27E-03	4.54E-05	Pu-242	1.54E-03	3.08E-05
Np-237	3.72E-03	1.04E-03	Pu-242	2.01E-03	4.02E-05	Pu-239	2.88E-04	6.11E-04
Pu-242	1.78E-03	3.56E-05	U-233	1.24E-04	2.85E-04			
U-234	1.48E-03	2.96E-05	Cm-245	5.03E-06	1.59E-05			
Am-242m	8.84E-05	2.24E-04						
Cm-245	1.36E-05	4.31E-05						
Fission Products			Fission Products			Fission Products		
Sm-149	1.30E-02		Sm-149	1.51E-02		Sm-149	1.79E-02	
Rh-103	9.25E-03		Rh-103	1.07E-02		Rh-103	1.28E-02	
Nd-143	8.16E-03		Nd-143	9.47E-03		Nd-143	1.13E-02	
Sm-151	5.01E-03		Eu-151	6.47E-03		Eu-151	7.70E-03	
Cs-133	4.87E-03		Cs-133	5.64E-03		Cs-133	6.72E-03	
Xe-131	4.66E-03		Xe-131	5.40E-03		Xe-131	6.43E-03	
Tc-99	3.92E-03		Tc-99	4.35E-03		Sm-152	4.26E-03	
Sm-152	3.08E-03		Sm-152	3.58E-03		Gd-155	4.24E-03	
Eu-153	2.25E-03		Gd-155	3.57E-03		Sm-147	3.40E-03	
Nd-145	2.11E-03		Sm-147	2.85E-03		Eu-153	3.11E-03	
Sm-147	1.94E-03		Eu-153	2.61E-03		Nd-145	2.91E-03	
Mo-95	1.73E-03		Nd-145	2.45E-03		Mo-95	2.38E-03	
Gd-155	1.63E-03		Mo-95	2.00E-03		Tc-99	2.38E-03	
Ag-109	1.55E-03		Ag-109	1.80E-03		Ag-109	2.14E-03	
Sm-150	1.43E-03		Sm-150	1.66E-03		Sm-150	1.97E-03	
Pm-147	1.30E-03		Ru-101	1.29E-03		Ru-101	1.53E-03	
Ru-101	1.11E-03					Ru-99	1.34E-03	

Table 6.2-12. Relative Isotopic Absorptions and Productions
Westinghouse OFA Fuel, 5.0 wt%, 63,000 MWd/MTU Burnup, 100% Power, No Control Rods

5 years			14,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
U-238	2.67E-01	0.00E+00	U-238	3.33E-01	0.00E+00	U-238	4.10E-01	0.00E+00
Pu-239	2.46E-01	5.22E-01	Pu-239	2.16E-01	4.58E-01	U-235	2.74E-01	5.67E-01
Pu-240	1.36E-01	0.00E+00	U-235	1.47E-01	3.04E-01	Np-237	3.67E-02	1.03E-02
U-235	8.91E-02	1.84E-01	Pu-240	4.04E-02	0.00E+00	U-236	3.49E-02	1.05E-03
Pu-241	5.49E-02	1.19E-01	Np-237	3.21E-02	8.99E-03	Pu-242	1.15E-02	2.30E-04
U-236	1.59E-02	4.77E-04	U-236	2.65E-02	7.95E-04	U-233	3.54E-03	8.14E-03
Am-241	1.41E-02	2.82E-04	Pu-242	1.44E-02	2.88E-04	U-234	3.29E-03	6.58E-05
Pu-242	1.19E-02	2.38E-04	U-234	4.84E-03	9.68E-05	Pu-239	3.11E-04	6.59E-04
Np-237	8.90E-03	2.49E-03	Am-243	1.49E-03	4.22E-03	Cm-247	7.29E-07	1.63E-06
Pu-238	4.64E-03	3.25E-04	U-233	2.60E-04	5.98E-04			
Am-243	4.45E-03	4.45E-05	Cm-245	1.89E-04	5.99E-04			
U-234	1.25E-03	2.50E-05						
Cm-245	4.75E-04	1.51E-03						
Fission Products			**Fission Products**			**Fission Products**		
Rh-103	1.87E-02		Rh-103	2.34E-02		Rh-103	2.88E-02	
Nd-143	1.40E-02		Nd-143	1.75E-02		Nd-143	2.16E-02	
Sm-149	1.12E-02		Sm-149	1.40E-02		Sm-149	1.73E-02	
Cs-133	1.12E-02		Cs-133	1.40E-02		Cs-133	1.72E-02	
Xe-131	9.18E-03		Gd-155	1.39E-02		Gd-155	1.71E-02	
Tc-99	9.18E-03		Xe-131	1.15E-02		Xe-131	1.41E-02	
Sm-152	7.42E-03		Tc-99	1.09E-02		Sm-152	1.14E-02	
Eu-153	7.07E-03		Sm-152	9.26E-03		Eu-153	1.09E-02	
Gd-155	5.86E-03		Eu-153	8.82E-03		Eu-151	9.39E-03	
Sm-151	5.48E-03		Eu-151	7.62E-03		Nd-145	7.31E-03	
Nd-145	4.75E-03		Nd-145	5.93E-03		Sm-147	6.33E-03	
Mo-95	4.07E-03		Sm-147	5.14E-03		Mo-95	6.25E-03	
Ag-109	3.90E-03		Mo-95	5.07E-03		Tc-99	6.21E-03	
Sm-150	3.73E-03		Ag-109	4.86E-03		Ag-109	6.00E-03	
Sm-147	3.41E-03		Sm-150	4.66E-03		Sm-150	5.74E-03	
Ru-101	2.82E-03		Ru-101	3.51E-03		Ru-101	4.33E-03	
Pm-147	1.77E-03		Pd-105	2.13E-03		Ru-99	3.50E-03	
Eu-154	1.76E-03		Pr-141	1.69E-03		Pd-105	2.63E-03	
Pd-105	1.71E-03		Pd-108	1.63E-03		Pr-141	2.08E-03	
Pr-141	1.35E-03		La-139	1.27E-03		Pd-108	2.01E-03	
Pd-108	1.31E-03		Kr-83	1.20E-03		La-139	1.57E-03	
La-139	1.02E-03		Gd-157	1.12E-03		Kr-83	1.48E-03	
			Zr-93	1.10E-03		Gd-157	1.38E-03	
			Cs-135	1.03E-03		Zr-93	1.22E-03	
						Cs-135	1.18E-03	
						Pd-107	1.16E-03	
						Mo-97	1.04E-03	

Table 6.2-13. Relative Isotopic Absorptions and Productions
Westinghouse Std. Fuel, 2.5 wt%, 18,000 MWd/MTU Burnup, 100% Power, No Control Rods

5 years			10,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
U-238	3.52E-01	0.00E+00	U-238	3.96E-01	0.00E+00	U-238	4.75E-01	0.00E+00
Pu-239	2.48E-01	5.26E-01	U-235	2.68E-01	5.55E-01	U-235	4.08E-01	8.45E-01
U-235	2.17E-01	4.49E-01	Pu-239	2.09E-01	4.43E-01	U-236	1.38E-02	4.14E-04
Pu-240	7.34E-02	0.00E+00	Pu-240	2.87E-02	0.00E+00	Np-237	1.19E-02	3.33E-03
Pu-241	2.50E-02	5.43E-02	Np-237	1.07E-02	3.00E-03	Pu-242	1.37E-03	2.74E-05
U-236	6.74E-03	2.02E-04	U-236	1.02E-02	3.06E-04	U-234	1.20E-03	2.40E-05
Am-241	5.94E-03	1.19E-04	Pu-242	1.78E-03	3.56E-05	U-233	1.15E-03	2.65E-03
Np-237	2.02E-03	5.66E-04	U-234	1.54E-03	3.08E-05	Pu-239	2.54E-04	5.38E-04
Pu-242	1.61E-03	3.22E-05	Am-243	9.73E-05	9.73E-07	Cm-247	2.64E-10	5.89E-10
U-234	1.18E-03	2.36E-05	U-233	6.12E-05	1.41E-04			
Pu-238	3.61E-04	2.53E-05	Cm-245	1.31E-06	4.15E-06			
Am-243	2.22E-04	2.22E-06						
Am-242m	3.29E-05	8.32E-05						
Cm-244	8.67E-06	1.47E-06						
Cm-245	2.64E-06	8.37E-06						
Fission Products			Fission Products			Fission Products		
Sm-149	1.06E-02		Sm-149	1.19E-02		Sm-149	1.43E-02	
Rh-103	8.70E-03		Rh-103	9.77E-03		Rh-103	1.17E-02	
Nd-143	6.80E-03		Nd-143	7.64E-03		Nd-143	9.16E-03	
Xe-131	4.45E-03		Xe-131	4.99E-03		Xe-131	5.99E-03	
Cs-133	4.31E-03		Cs-133	4.84E-03		Cs-133	5.80E-03	
Tc-99	3.46E-03		Eu-151	4.11E-03		Eu-151	4.94E-03	
Sm-151	3.29E-03		Tc-99	3.76E-03		Sm-152	4.24E-03	
Sm-152	3.15E-03		Sm-152	3.53E-03		Gd-155	3.28E-03	
Sm-147	1.87E-03		Gd-155	2.74E-03		Sm-147	3.28E-03	
Nd-145	1.83E-03		Sm-147	2.73E-03		Nd-145	2.47E-03	
Eu-153	1.79E-03		Nd-145	2.06E-03		Eu-153	2.42E-03	
Mo-95	1.49E-03		Eu-153	2.01E-03		Tc-99	2.05E-03	
Pm-147	1.41E-03		Mo-95	1.67E-03		Mo-95	2.00E-03	
Gd-155	1.28E-03		Ag-109	1.37E-03		Ag-109	1.64E-03	
Ag-109	1.22E-03		Sm-150	1.36E-03		Sm-150	1.64E-03	
Sm-150	1.21E-03		Ru-101	1.08E-03		Ru-101	1.30E-03	
						Ru-99	1.16E-03	

Table 6.2-14. Relative Isotopic Absorptions and Productions
Westinghouse Std. Fuel, 2.5 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

5 years			12,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
U-238	3.33E-01	0.00E+00	U-238	4.01E-01	0.00E+00	U-238	4.97E-01	0.00E+00
Pu-239	2.67E-01	5.66E-01	Pu-239	2.31E-01	4.90E-01	U-235	3.12E-01	6.46E-01
U-235	1.16E-01	2.40E-01	U-235	1.72E-01	3.56E-01	Np-237	2.33E-02	6.52E-03
Pu-240	1.15E-01	0.00E+00	Pu-240	3.94E-02	0.00E+00	U-236	2.07E-02	6.21E-04
Pu-241	4.33E-02	9.40E-02	Np-237	2.03E-02	5.68E-03	Pu-242	4.96E-03	9.92E-05
Am-241	1.06E-02	2.12E-04	U-236	1.49E-02	4.47E-04	U-233	2.24E-03	5.15E-03
U-236	8.31E-03	2.49E-04	Pu-242	6.22E-03	1.24E-04	U-234	1.49E-03	2.98E-05
Pu-242	5.29E-03	1.06E-04	U-234	1.92E-03	3.84E-05	Pu-239	3.08E-04	6.53E-04
Np-237	3.74E-03	1.05E-03	Am-243	4.90E-04	1.39E-03	Cm-247	1.76E-08	3.92E-08
Am-243	1.26E-03	1.26E-05	U-233	1.40E-04	3.22E-04			
Pu-238	1.17E-03	8.19E-05	Cm-245	2.01E-05	6.37E-05			
U-234	9.35E-04	1.87E-05						
Am-242m	9.34E-05	2.36E-04						
Cm-245	4.46E-05	1.41E-04						
Fission Products			Fission Products			Fission Products		
Rh-103	1.31E-02		Rh-103	1.58E-02		Rh-103	1.95E-02	
Sm-149	1.10E-02		Sm-149	1.32E-02		Sm-149	1.64E-02	
Nd-143	9.10E-03		Nd-143	1.09E-02		Nd-143	1.36E-02	
Cs-133	6.48E-03		Cs-133	7.80E-03		Cs-133	9.66E-03	
Xe-131	6.28E-03		Xe-131	7.55E-03		Xe-131	9.35E-03	
Tc-99	5.23E-03		Gd-155	6.19E-03		Gd-155	7.67E-03	
Sm-152	4.81E-03		Tc-99	6.05E-03		Sm-152	7.17E-03	
Sm-151	3.91E-03		Sm-152	5.79E-03		Eu-151	6.49E-03	
Eu-153	3.58E-03		Eu-151	5.24E-03		Eu-153	5.33E-03	
Gd-155	2.71E-03		Eu-153	4.30E-03		Sm-147	4.55E-03	
Nd-145	2.70E-03		Sm-147	3.67E-03		Nd-145	4.02E-03	
Sm-147	2.41E-03		Nd-145	3.25E-03		Ag-109	3.57E-03	
Ag-109	2.39E-03		Ag-109	2.88E-03		Tc-99	3.43E-03	
Mo-95	2.22E-03		Mo-95	2.67E-03		Mo-95	3.31E-03	
Sm-150	2.04E-03		Sm-150	2.45E-03		Sm-150	3.04E-03	
Pm-147	1.61E-03		Ru-101	1.84E-03		Ru-101	2.28E-03	
Ru-101	1.53E-03		Pd-105	1.10E-03		Ru-99	1.94E-03	
						Pd-105	1.36E-03	
						Pr-141	1.07E-03	
						Pd-108	1.03E-03	

Table 6.2-15. Relative Isotopic Absorptions and Productions
Westinghouse Std. Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 50% Power, No Control Rods

5 years			14,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
U-235	3.35E-01	6.93E-01	U-235	4.11E-01	8.51E-01	U-235	5.44E-01	1.13E+00
U-238	2.49E-01	0.00E+00	U-238	2.83E-01	0.00E+00	U-238	3.27E-01	0.00E+00
Pu-239	2.32E-01	4.92E-01	Pu-239	1.77E-01	3.75E-01	U-236	1.70E-02	5.10E-04
Pu-240	6.21E-02	0.00E+00	Pu-240	1.61E-02	0.00E+00	Np-237	1.35E-02	3.78E-03
Pu-241	2.57E-02	5.58E-02	U-236	1.40E-02	4.20E-04	U-234	1.61E-03	3.22E-05
U-236	9.97E-03	2.99E-04	Np-237	1.27E-02	3.56E-03	U-233	1.31E-03	3.01E-03
Am-241	6.98E-03	1.40E-04	U-234	2.41E-03	4.82E-05	Pu-242	1.29E-03	2.58E-05
Np-237	3.17E-03	8.88E-04	Pu-242	1.74E-03	3.48E-05	Pu-239	2.32E-04	4.92E-04
U-234	1.74E-03	3.48E-05	U-233	1.02E-04	2.35E-04	Cm-247	8.00E-10	1.78E-09
Pu-242	1.57E-03	3.14E-05	Cm-245	2.35E-06	7.45E-06			
Am-242m	1.30E-04	3.29E-04						
Cm-245	6.47E-06	2.05E-05						
Fission Products			Fission Products			Fission Products		
Rh-103	9.21E-03		Rh-103	1.05E-02		Rh-103	1.21E-02	
Nd-143	8.60E-03		Nd-143	9.78E-03		Nd-143	1.13E-02	
Sm-149	8.41E-03		Sm-149	9.56E-03		Sm-149	1.10E-02	
Cs-133	5.14E-03		Cs-133	5.84E-03		Cs-133	6.74E-03	
Xe-131	5.03E-03		Xe-131	5.72E-03		Xe-131	6.60E-03	
Sm-151	4.36E-03		Eu-151	5.53E-03		Eu-151	6.38E-03	
Tc-99	4.11E-03		Tc-99	4.47E-03		Sm-152	4.39E-03	
Sm-152	3.34E-03		Sm-152	3.80E-03		Sm-147	3.72E-03	
Sm-147	2.35E-03		Sm-147	3.22E-03		Gd-155	3.60E-03	
Nd-145	2.25E-03		Gd-155	3.12E-03		Nd-145	2.95E-03	
Eu-153	2.17E-03		Nd-145	2.56E-03		Eu-153	2.85E-03	
Mo-95	1.83E-03		Eu-153	2.47E-03		Mo-95	2.40E-03	
Gd-155	1.46E-03		Mo-95	2.08E-03		Tc-99	2.38E-03	
Sm-150	1.40E-03		Sm-150	1.60E-03		Sm-150	1.84E-03	
Pm-147	1.20E-03		Ru-101	1.31E-03		Ru-101	1.52E-03	
Ru-101	1.15E-03		Ag-109	1.27E-03		Ag-109	1.47E-03	
Ag-109	1.12E-03					Ru-99	1.34E-03	

Table 6.2-16. Relative Isotopic Absorptions and Productions
Westinghouse Std. Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

5 years			14,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
U-235	3.33E-01	6.89E-01	U-235	4.09E-01	8.47E-01	U-235	5.43E-01	1.12E+00
U-238	2.47E-01	0.00E+00	U-238	2.81E-01	0.00E+00	U-238	3.24E-01	0.00E+00
Pu-239	2.34E-01	4.96E-01	Pu-239	1.79E-01	3.79E-01	U-236	1.68E-02	5.04E-04
Pu-240	6.16E-02	0.00E+00	Pu-240	1.60E-02	0.00E+00	Np-237	1.35E-02	3.78E-03
Pu-241	2.62E-02	5.69E-02	U-236	1.39E-02	4.17E-04	U-234	1.57E-03	3.14E-05
U-236	9.90E-03	2.97E-04	Np-237	1.26E-02	3.53E-03	U-233	1.30E-03	2.99E-03
Am-241	6.48E-03	1.30E-04	U-234	2.35E-03	4.70E-05	Pu-242	1.30E-03	2.60E-05
Np-237	3.16E-03	8.85E-04	Pu-242	1.74E-03	3.48E-05	Pu-239	2.34E-04	4.96E-04
U-234	1.73E-03	3.46E-05	U-233	1.02E-04	2.35E-04			
Pu-242	1.57E-03	3.14E-05	Cm-245	2.40E-06	7.61E-06			
Am-242m	6.64E-05	1.68E-04						
Cm-245	6.61E-06	2.10E-05						
Fission Products			**Fission Products**			**Fission Products**		
Sm-149	1.15E-02		Sm-149	1.30E-02		Sm-149	1.51E-02	
Rh-103	9.30E-03		Rh-103	1.06E-02		Rh-103	1.22E-02	
Nd-143	8.50E-03		Nd-143	9.66E-03		Nd-143	1.12E-02	
Cs-133	5.11E-03		Cs-133	5.81E-03		Cs-133	6.72E-03	
Xe-131	5.01E-03		Xe-131	5.69E-03		Xe-131	6.58E-03	
Sm-151	4.42E-03		Eu-151	5.61E-03		Eu-151	6.48E-03	
Tc-99	4.12E-03		Tc-99	4.47E-03		Sm-152	4.36E-03	
Sm-152	3.32E-03		Sm-152	3.77E-03		Gd-155	3.63E-03	
Nd-145	2.23E-03		Gd-155	3.14E-03		Sm-147	3.60E-03	
Sm-147	2.16E-03		Sm-147	3.12E-03		Nd-145	2.93E-03	
Eu-153	2.15E-03		Nd-145	2.53E-03		Eu-153	2.82E-03	
Mo-95	1.82E-03		Eu-153	2.44E-03		Mo-95	2.39E-03	
Gd-155	1.46E-03		Mo-95	2.07E-03		Tc-99	2.38E-03	
Pm-147	1.45E-03		Sm-150	1.64E-03		Sm-150	1.90E-03	
Sm-150	1.44E-03		Ru-101	1.30E-03		Ru-101	1.50E-03	
Ru-101	1.14E-03		Ag-109	1.26E-03		Ag-109	1.46E-03	
Ag-109	1.11E-03					Ru-99	1.34E-03	

Table 6.2-17. Relative Isotopic Absorptions and Productions Westinghouse Std. Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, Inserted Control Rods

5 years			14,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
U-235	3.12E-01	6.46E-01	U-235	3.98E-01	8.24E-01	U-235	5.66E-01	1.17E+00
Pu-239	2.86E-01	6.06E-01	U-238	2.48E-01	0.00E+00	U-238	2.96E-01	0.00E+00
U-238	2.14E-01	0.00E+00	Pu-239	2.22E-01	4.71E-01	U-236	1.60E-02	4.80E-04
Pu-240	6.08E-02	0.00E+00	Pu-240	1.61E-02	0.00E+00	Np-237	1.57E-02	4.40E-03
Pu-241	2.91E-02	6.31E-02	Np-237	1.42E-02	3.98E-03	U-233	1.52E-03	3.50E-03
U-236	8.69E-03	2.61E-04	U-236	1.27E-02	3.81E-04	Pu-242	1.21E-03	2.42E-05
Am-241	7.21E-03	1.44E-04	U-234	2.15E-03	4.30E-05	Pu-239	3.00E-04	6.36E-04
Np-237	3.48E-03	9.74E-04	Pu-242	1.57E-03	3.14E-05	Cm-247	1.38E-09	3.08E-09
U-234	1.45E-03	2.90E-05	U-233	1.15E-04	2.65E-04			
Pu-242	1.40E-03	2.80E-05	Am-243	9.40E-05	9.40E-07			
Pu-238	8.07E-04	5.65E-05	Cm-245	3.87E-06	1.23E-05			
Am-243	3.04E-04	3.04E-06						
Am-242m	8.61E-05	2.18E-04						
Cm-244	1.78E-05	3.03E-06						
Cm-245	1.05E-05	3.33E-05						
Fission Products			Fission Products			Fission Products		
Sm-149	1.35E-02		Sm-149	1.55E-02		Sm-149	1.86E-02	
Rh-103	8.32E-03		Rh-103	9.60E-03		Rh-103	1.15E-02	
Nd-143	7.38E-03		Nd-143	8.52E-03		Nd-143	1.02E-02	
Sm-151	5.15E-03		Eu-151	6.62E-03		Eu-151	7.91E-03	
Cs-133	4.32E-03		Cs-133	4.99E-03		Cs-133	5.96E-03	
Xe-131	4.15E-03		Xe-131	4.79E-03		Xe-131	5.72E-03	
Tc-99	3.48E-03		Tc-99	3.84E-03		Sm-152	3.71E-03	
Sm-152	2.69E-03		Sm-152	3.11E-03		Gd-155	3.70E-03	
Eu-153	1.96E-03		Gd-155	3.10E-03		Sm-147	3.05E-03	
Nd-145	1.88E-03		Sm-147	2.55E-03		Eu-153	2.70E-03	
Sm-147	1.74E-03		Eu-153	2.26E-03		Nd-145	2.59E-03	
Mo-95	1.53E-03		Nd-145	2.17E-03		Tc-99	2.11E-03	
Gd-155	1.42E-03		Mo-95	1.77E-03		Mo-95	2.11E-03	
Ag-109	1.36E-03		Ag-109	1.57E-03		Ag-109	1.87E-03	
Sm-150	1.25E-03		Sm-150	1.44E-03		Sm-150	1.72E-03	
Pm-147	1.17E-03		Ru-101	1.13E-03		Ru-101	1.35E-03	
						Ru-99	1.19E-03	

Table 6.2-18. Relative Isotopic Absorptions and Productions
Westinghouse Std. Fuel, 5.0 wt%, 63,000 MWd/MTU Burnup, 100% Power, No Control Rods

5 years			14,000 years			250,000 years		
Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction	Actinides	Absorp. Fraction	Prod. Fraction
Pu-239	2.66E-01	5.64E-01	U-238	3.09E-01	0.00E+00	U-238	3.83E-01	0.00E+00
U-238	2.48E-01	0.00E+00	Pu-239	2.30E-01	4.88E-01	U-235	3.30E-01	6.83E-01
Pu-240	1.26E-01	0.00E+00	U-235	1.86E-01	3.85E-01	Np-237	3.62E-02	1.01E-02
U-235	1.18E-01	2.44E-01	Pu-240	3.71E-02	0.00E+00	U-236	3.21E-02	9.63E-04
Pu-241	5.57E-02	1.21E-01	Np-237	3.15E-02	8.82E-03	Pu-242	8.90E-03	1.78E-04
U-236	1.45E-02	4.35E-04	U-236	2.42E-02	7.26E-04	U-233	3.49E-03	8.03E-03
Am-241	1.45E-02	2.90E-04	Pu-242	1.11E-02	2.22E-04	U-234	3.03E-03	6.06E-05
Pu-242	9.14E-03	1.83E-04	U-234	4.44E-03	8.88E-05	Pu-239	3.31E-04	7.02E-04
Np-237	8.17E-03	2.29E-03	Am-243	1.15E-03	1.15E-05	Th-232	9.34E-05	0.00E+00
Pu-238	4.11E-03	2.88E-04	U-233	2.55E-04	5.87E-04	Cm-247	4.39E-07	9.79E-07
Am-243	3.43E-03	3.43E-05	Cm-245	1.53E-04	4.85E-04			
U-234	1.22E-03	2.44E-05						
Cm-245	3.84E-04	1.22E-03						
Fission Products			Fission Products			Fission Products		
Rh-103	1.68E-02		Rh-103	2.09E-02		Rh-103	2.60E-02	
Nd-143	1.34E-02		Nd-143	1.67E-02		Nd-143	2.07E-02	
Sm-149	1.12E-02		Sm-149	1.40E-02		Sm-149	1.74E-02	
Cs-133	9.73E-03		Cs-133	1.21E-02		Cs-133	1.50E-02	
Xe-131	8.13E-03		Gd-155	1.17E-02		Gd-155	1.46E-02	
Tc-99	7.94E-03		Xe-131	1.01E-02		Xe-131	1.26E-02	
Sm-152	6.30E-03		Tc-99	9.45E-03		Eu-151	9.93E-03	
Eu-153	5.96E-03		Eu-151	8.01E-03		Sm-152	9.75E-03	
Sm-151	5.77E-03		Sm-152	7.86E-03		Eu-153	9.22E-03	
Gd-155	4.97E-03		Eu-153	7.44E-03		Nd-145	6.40E-03	
Nd-145	4.14E-03		Nd-145	5.16E-03		Sm-147	5.76E-03	
Mo-95	3.51E-03		Sm-147	4.65E-03		Mo-95	5.43E-03	
Ag-109	3.30E-03		Mo-95	4.37E-03		Tc-99	5.40E-03	
Sm-150	3.19E-03		Ag-109	4.12E-03		Ag-109	5.11E-03	
Sm-147	3.08E-03		Sm-150	3.98E-03		Sm-150	4.94E-03	
Ru-101	2.41E-03		Ru-101	3.01E-03		Ru-101	3.73E-03	
Eu-154	1.64E-03		Pd-105	1.83E-03		Ru-99	3.05E-03	
Pm-147	1.60E-03		Pr-141	1.45E-03		Pd-105	2.26E-03	
Pd-105	1.46E-03		Pd-108	1.34E-03		Pr-141	1.80E-03	
Pr-141	1.16E-03		Kr-83	1.11E-03		Pd-108	1.66E-03	
Pd-108	1.08E-03		La-139	1.09E-03		Kr-83	1.38E-03	
			Gd-157	1.07E-03		La-139	1.36E-03	
			Cs-135	1.01E-03		Gd-157	1.33E-03	
						Cs-135	1.16E-03	
						Zr-93	1.06E-03	

Table 6.2-19. Top Ranked Actinides Affecting SNF Reactivity

ORIGEN-S Case Number from Table 5-1 and Decay Time After Discharge				Top Ranked Actinides
Case Number 17 14,000 years	Case Number 17 5 years	Case Number 17 250,000 years	Case Number 18 5 years	
		U-233		U-233
U-234				U-234
U-235				U-235
U-236				U-236
U-238				U-238
Np-237				Np-237
			Pu-238	Pu-238
Pu-239				Pu-239
Pu-240				Pu-240
	Pu-241			Pu-241
Pu-242				Pu-242
	Am-241			Am-241
	Am-242m			Am-242m
			Am-243	Am-243
		Th-230		

Table 6.2-20. Top Ranked Fission Products Affecting SNF Reactivity

ORIGEN-S Case Number from Table 5-1 and Decay Time After Discharge		Top Ranked Fission Products
Case Number 17 14,000 years	Case Number 17 5 years	
Mo-95		Mo-95
Tc-99		Tc-99
Ru-101		Ru-101
Rh-103		Rh-103
Ag-109		Ag-109
Nd-143		Nd-143
Nd-145		Nd-145
Sm-147		Sm-147
Sm-149		Sm-149
Sm-150		Sm-150
	Sm-151	Sm-151
Sm-152		Sm-152
Eu-151		Eu-151
Eu-153		Eu-153
Gd-155		Gd-155
	Pm-147	
Xe-131		
Cs-133		

6.3. Relative Production Fractions

Tables 6.2-1 through 6.2-18 include both the relative absorption fractions and relative production fractions for the top ranked actinides. The data is listed for the 3 decay periods of interest, and for the 18 combinations of fuel types and operating conditions. The absorption fractions are calculated as part of the ORIGEN-S output results. The relative production fractions, however, are calculated from the 2200 meter per second isotopic k_∞ values. The isotopic k_∞ values for the Thorium and trans-uranic actinides are given in Table 6.3-1. The product of the isotopic k_∞ values and the relative absorption fractions gives the relative production fractions. As shown by Tables 6.2-1 through 6.2-18, the importance of the relative thermal production fractions to the reactivity of the degraded SNF configuration follows a pattern that is bounded by the relative absorption fractions.

In Section 6.2, the relative absorption fraction screening cutoff used in the ranking evaluation was noted to be 0.001. The relative production fraction screening cutoff used in the ranking evaluation was defined as the first Curium isotope with an odd atomic weight. Evaluations of Tables 6.2-1 through 6.2-18 indicated that the Curium isotopes never made a significant contribution to the reactivity of the fuel, with respect to the relative absorption fraction cutoff of 0.001. When the isotopes with relative absorption values above the screening cutoff were evaluated for relative production fractions, more than 99 percent of the relative production fractions appeared to be represented. The relative production fractions from isotopes below the absorption screening cutoff of 0.001 were not significant. Therefore, the isotopes identified by the absorption screening process bounded the isotopes that represented those having significant production fractions above a screening cutoff of 0.001.

The actinides that are more prevalent than the Curium isotopes, with respect to relative absorption fractions and relative production fractions, are the Americium isotopes. The thermal neutron induced fissions in the Americium isotopes occur in those with even atomic weights. As shown in Table 6.3-1, the only fissionable Americium isotope is Am-242m. In the top actinide ranking evaluation, Am-241 and Am-243 passed the relative absorption fraction screening cutoff, but Am-242m met neither the relative absorption fraction nor the relative production fraction cutoff. Nonetheless, Am-242m was included in the top actinide ranking because the other Americium isotopes met the absorption fraction screening cutoff, and Am-242m is sensitive to thermal neutron induced fission.

Table 6.3-1. Isotopic k_∞

Isotope	$\left(\nu \ \sigma_f / \sigma_a\right)$ (See Section 2)	Half-Life
Th-232	≈ 0.00	
U-232	= 1.59	
U-233	= 2.30	
U-234	≈ 0.02	
U-235	= 2.07	
U-236	= 0.03	
U-237		Short
U-238	≈ 0.00	
U-239		Short
Np-236	≈ 3.12	
Np-237	= 0.28	
Np-238		Short
Np-239		Short
Pu-236	≈ 2.21	
Pu-237		Short
Pu-238	≈ 0.07	
Pu-239	= 2.12	
Pu-240	≈ 0.00	
Pu-241	= 2.17	
Pu-242	≈ 0.02	
Pu-243		Short
Pu-244	≈ 0.00	
Am-241	≈ 0.02	
Am-242m	= 2.53	
Am-243	≈ 0.01	
Cm-242		Short
Cm-243	= 2.83	
Cm-244	= 0.17	
Cm-245	= 3.17	
Cm-246	= 0.30	
Cm-247	= 2.23	
Cm-248	= 0.39	
Cm-249		Short
Bk-249		Short
Bk-250		Short
Cf-248		Short
Cf-249	= 3.12	
Cf-250		Short
Cf-251	≈ 2.53	
Cf-252	= 2.30	

6.4. Sum of the Top Ranked Isotope Absorptions

The calculations and evaluations to support the principal isotope selection process focused on the most reactive fuel types and operational conditions. Thus, it is expected that for the most reactive case, the sum of the absorption fractions for the 29 top ranked isotopes would be within a couple of percent of all the isotopes. The total reactivity effect of the 29 top ranked isotopes is also expected to be within a couple of percent of all the isotopes. However, the overall effect of the 29 top ranked isotopes in the other 53 combinations of decay periods, fuel types, and operational conditions, needs to be quantitatively evaluated. Since the isotopic effects on reactivity are directly related to the relative absorption fractions, the sum of the relative absorption fractions for the top ranked isotopes for all 54 combinations of decay periods, fuel types, and operational conditions was evaluated. Tables 6.4-1 through 6.4-18 list the sum of the relative absorption fractions from the 18 variations of fuel types and operating conditions for the 3 bounding decay periods.

Table 6.4-17 provides the sum of the absorption fractions for the 29 top ranked isotopes, for the most reactive case (Westinghouse, 17 by 17 standard lattice, initially loaded with 5.0 wt% U-235, and burned to 30,000 MWd/MTU, with a control rod assembly fully inserted during the entire burnup period). The most reactive decay periods for the most reactive case are at 5 years and 14,000 years. The sum of relative absorption fractions of the top ranked isotopes at these time periods is 98 percent. Following the 14,000 year decay period, the reactivity decreases and the relative absorption of the top ranked isotopes decreases. At 250,000 years, the sum of the 29 top ranked isotope's relative absorption fractions has decreased to 97 percent.

For all 3 decay periods, eliminating Xe-131 and Cs-133 from the top ranked isotopes decreases the total top ranked isotope absorption fraction by about 1.0 percent. If physical and chemical properties allowed Xe-131 and Cs-133 to be within the top ranked isotope set, this set would represent 99 percent of the absorptions for the more reactive time periods, and 98 percent of the absorptions for the less reactive time periods (following the decayed reactivity peak).

The more reactive cases for all fuel types, and operating conditions, are represented by the lower burnups. With the low enriched (2.5 wt%) fuel, the lower burnup is 18,000 MWd/MTU. With the high enriched (5.0 wt%) fuel, the lower burnup is 30,000 MWd/MTU. The calculational cases that are representative of the more reactive conditions are: 1, 3, 4, 5, 7, 9, 10, 11, 13, 15, 16, and 17 (see Table 5-1). For each of these cases, as shown by the respective tables (Tables 6.4-1 through 6.4-17), the sum of the 29 top ranked isotope relative absorption fractions is either 97 or 98 percent. Therefore, for the more reactive degraded SNF configuration, the 29 top ranked isotopes represent more than 96 percent of the total absorption from all the hundreds of fission products and actinides. In general, the 29 top ranked isotopes represent 98 percent of the total absorption in the more reactive degraded SNF configuration.

The less reactive cases represent the highly burned SNF. The calculational cases that are representative of the less reactive conditions are: 2, 6, 8, 12, 14, and 18 (see Table 5-1). For these cases, the 29 top ranked isotopes represent at least 92 percent of the total absorption from all the hundreds of fission products and actinides. This low total absorption fraction is acceptable because the k_∞ of this fuel is low compared to the more reactive fuel (see Tables 6.1-1 through 6.1-18).

Table 6.4-1. Absorption of the 29 Top Ranked Isotopes
B&W Fuel, 2.5 wt%, 18,000 MWd/MTU Burnup, 100% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	10,000 years	250,000 years
1	Actinides	0.93	0.92	0.91
	Fission Products	0.05	0.06	0.07
	Sum	0.98	0.98	0.97

Table 6.4-2. Absorption of the 29 Top Ranked Isotopes
B&W Fuel, 2.5 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	12,000 years	250,000 years
2	Actinides	0.90	0.88	0.85
	Fission Products	0.07	0.09	0.11
	Sum	0.97	0.97	0.96

Table 6.4-3. Absorption of the 29 Top Ranked Isotopes
B&W Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 50% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	14,000 years	250,000 years
3	Actinides	0.92	0.91	0.90
	Fission Products	0.05	0.07	0.07
	Sum	0.98	0.98	0.97

Table 6.4-4. Absorption of the 29 Top Ranked Isotopes
B&W Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	14,000 years	250,000 years
4	Actinides	0.92	0.91	0.90
	Fission Products	0.06	0.07	0.08
	Sum	0.98	0.98	0.97

Table 6.4-5. Absorption of the 29 Top Ranked Isotopes
B&W Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, Inserted Control Rods

ORIGEN-S Case Number	Absorption	5 years	14,000 years	250,000 years
5	Actinides	0.92	0.91	0.89
	Fission Products	0.05	0.07	0.08
	Sum	0.98	0.98	0.97

Table 6.4-6. Absorption of the 29 Top Ranked Isotopes
B&W Fuel, 5.0 wt%, 63,000 MWd/MTU Burnup, 100% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	14,000 years	250,000 years
6	Actinides	0.86	0.82	0.78
	Fission Products	0.10	0.13	0.15
	Sum	0.96	0.95	0.94

Table 6.4-7. Absorption of the 29 Top Ranked Isotopes
Westinghouse OFA Fuel, 2.5 wt%, 18,000 MWd/MTU Burnup, 100% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	10,000 years	250,000 years
7	Actinides	0.93	0.92	0.90
	Fission Products	0.05	0.06	0.07
	Sum	0.98	0.98	0.97

Table 6.4-8. Absorption of the 29 Top Ranked Isotopes
Westinghouse OFA Fuel, 2.5 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	12,000 years	250,000 years
8	Actinides	0.90	0.88	0.85
	Fission Products	0.07	0.09	0.11
	Sum	0.97	0.97	0.96

Table 6.4-9. Absorption of the 29 Top Ranked Isotopes
Westinghouse OFA Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 50% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	14,000 years	250,000 years
9	Actinides	0.92	0.91	0.90
	Fission Products	0.06	0.07	0.07
	Sum	0.98	0.98	0.97

Table 6.4-10. Absorption of the 29 Top Ranked Isotopes Westinghouse OFA Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	14,000 years	250,000 years
10	Actinides	0.92	0.91	0.89
	Fission Products	0.06	0.07	0.08
	Sum	0.98	0.98	0.97

Table 6.4-11. Absorption of the 29 Top Ranked Isotopes Westinghouse OFA Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, Inserted Control Rods

ORIGEN-S Case Number	Absorption	5 years	14,000 years	250,000 years
11	Actinides	0.92	0.91	0.89
	Fission Products	0.06	0.07	0.08
	Sum	0.98	0.97	0.97

Table 6.4-12. Absorption of the 29 Top Ranked Isotopes Westinghouse OFA Fuel, 5.0 wt%, 63,000 MWd/MTU Burnup, 100% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	14,000 years	250,000 years
12	Actinides	0.85	0.82	0.77
	Fission Products	0.10	0.13	0.16
	Sum	0.96	0.95	0.93

Table 6.4-13. Absorption of the 29 Top Ranked Isotopes
Westinghouse Std. Fuel, 2.5 wt%, 18,000 MWd/MTU Burnup, 100% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	10,000 years	250,000 years
13	Actinides	0.93	0.93	0.91
	Fission Products	0.05	0.06	0.06
	Sum	0.98	0.98	0.98

Table 6.4-14. Absorption of the 29 Top Ranked Isotopes
Westinghouse Std. Fuel, 2.5 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	12,000 years	250,000 years
14	Actinides	0.91	0.89	0.86
	Fission Products	0.07	0.08	0.10
	Sum	0.97	0.97	0.96

Table 6.4-15. Absorption of the 29 Top Ranked Isotopes
Westinghouse Std. Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 50% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	14,000 years	250,000 years
15	Actinides	0.93	0.92	0.91
	Fission Products	0.05	0.06	0.07
	Sum	0.98	0.98	0.97

Table 6.4-16. Absorption of the 29 Top Ranked Isotopes Westinghouse Std. Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	14,000 years	250,000 years
16	Actinides	0.92	0.92	0.90
	Fission Products	0.05	0.06	0.07
	Sum	0.98	0.98	0.97

Table 6.4-17. Absorption of the 29 Top Ranked Isotopes Westinghouse Std. Fuel, 5.0 wt%, 30,000 MWd/MTU Burnup, 100% Power, Inserted Control Rods

ORIGEN-S Case Number	Absorption	5 years	14,000 years	250,000 years
17	Actinides	0.93	0.91	0.90
	Fission Products	0.05	0.06	0.07
	Sum	0.98	0.98	0.97

Table 6.4-18. Absorption of the 29 Top Ranked Isotopes Westinghouse Std. Fuel, 5.0 wt%, 63,000 MWd/MTU Burnup, 100% Power, No Control Rods

ORIGEN-S Case Number	Absorption	5 years	14,000 years	250,000 years
18	Actinides	0.87	0.83	0.80
	Fission Products	0.09	0.12	0.14
	Sum	0.96	0.96	0.94

7. References

7.1 *Neutron Cross Sections, Volume 1, Neutron Resonance Parameters and Thermal Cross Sections,* Part B: *Z = 61 - 100.* S.F. Mughabghab (Editor), National Nuclear Data Center; Brookhaven National Laboratory, Upton, New York, Academic Press Inc. TIC#: 239940. [J. R. W. 5/13/99]

7.2 *SCALE 4.3: Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation.* User Manual Volumes 0 through 3, Radiation Shielding and Information Center (RSIC), Oak Ridge National Laboratory, RSIC Document Number: CCC-545. TIC#: 235920.

7.3 *Software Qualification Report for the SCALE Modular Code System Version 4.3.* Document Identifier Number (DI#): 30011.2002 REV 01, Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O). Accession Number: MOL.19970731.0884.

7.4 *CRC Depletion Calculations for Crystal River Unit 3.* DI#: B00000000-01717-0210-00001 REV 00, CRWMS M&O. Accession Number: MOL.19980810.0299.

7.5 *CRC Depletion Calculations for McGuire Unit 1.* DI#: B00000000-01717-0210-00003 REV 00, CRWMS M&O. Accession Number: MOL.19980626.0579.

7.6 *Principal Isotope Selection Calculation (DI#: B00000000-01717-0210-00031 REV 00)-1 Attachment Tape with listing of tape content (2 copies of tape).* CRWMS M&O. Accession Number: MOL.19980806.0605.

8. Attachments

Table 8-1 presents the attachment specifications for this calculation. These attachments were written to an attachment tape that has been moved to Reference 7.6.

Table 8-1. Attachment Listing

Attachment Number	Number of Pages	Date Written to Tape	Description
I	1 page hard-copy listing of tape content for Attachment I	8/19/98	SAS2H/ORIGEN-S Input Files for 18 Different Calculations
II	1 page hard-copy listing of tape content for Attachment II	8/19/98	SAS2H/ORIGEN-S Output Files for 18 Different Calculations

This attachment contains the SAS2H and ORIGEN-S input files for the depletion and decay calculations documented in this calculation. The input files are contained on an attachment tape (moved to Reference 7.6) of this calculation. The information contained in this hard-copy representation of Attachment I is a listing of the various SAS2H and ORIGEN-S input files and their attributes. The SAS2H input files begin with the letters "calc", and the ORIGEN-S input files begin with the letters "orig". The file sizes listed in the following table are the file sizes as contained on the attachment tape (moved to Reference 7.6). The tape containing Attachment I was written using the HP Colorado Model T1000e External Parallel Port Backup System for personal computers.

Filename	File Type	File Size on Tape (bytes)	Date Written to Tape
calc1.inp	ASCII	9387	08/19/98
calc2.inp	ASCII	10641	08/19/98
calc3.inp	ASCII	10652	08/19/98
calc4.inp	ASCII	10639	08/19/98
calc5.inp	ASCII	11559	08/19/98
calc6.inp	ASCII	12981	08/19/98
calc7.inp	ASCII	9091	08/19/98
calc8.inp	ASCII	9951	08/19/98
calc9.inp	ASCII	9954	08/19/98
calc10.inp	ASCII	9952	08/19/98
calc11.inp	ASCII	10853	08/19/98
calc12.inp	ASCII	12533	08/19/98
calc13.inp	ASCII	9235	08/19/98
calc14.inp	ASCII	10095	08/19/98
calc15.inp	ASCII	10094	08/19/98
calc16.inp	ASCII	10095	08/19/98
calc17.inp	ASCII	10996	08/19/98
calc18.inp	ASCII	12676	08/19/98
orig1.inp	ASCII	13290	08/19/98
orig2.inp	ASCII	13290	08/19/98
orig3.inp	ASCII	13290	08/19/98
orig4.inp	ASCII	13290	08/19/98
orig5.inp	ASCII	13290	08/19/98
orig6.inp	ASCII	13292	08/19/98
orig7.inp	ASCII	13290	08/19/98
orig8.inp	ASCII	13290	08/19/98
orig9.inp	ASCII	13290	08/19/98
orig10.inp	ASCII	13290	08/19/98
orig11.inp	ASCII	13290	08/19/98
orig12.inp	ASCII	13290	08/19/98
orig13.inp	ASCII	13290	08/19/98
orig14.inp	ASCII	13290	08/19/98
orig15.inp	ASCII	13290	08/19/98
orig16.inp	ASCII	13290	08/19/98
orig17.inp	ASCII	13290	08/19/98
orig18.inp	ASCII	13290	08/19/98

This attachment contains the SAS2H and ORIGEN-S output files for the depletion and decay calculations documented in this calculation. The output files are contained on an attachment tape (moved to Reference 7.6) of this calculation. The information contained in this hard-copy representation of Attachment II is a listing of the various SAS2H and ORIGEN-S output files and their attributes. The SAS2H output files begin with the letters "calc", and the ORIGEN-S output files begin with the letters "orig". The file sizes listed in the following table are the file sizes as contained on the attachment tape (moved to Reference 7.6). The tape containing Attachment II was written using the HP Colorado Model T1000e External Parallel Port Backup System for personal computers.

Filename	File Type	File Size on Tape (bytes)	Date Written to Tape
calc1.out	ASCII	14360973	08/19/98
calc2.out	ASCII	20972058	08/19/98
calc3.out	ASCII	20967834	08/19/98
calc4.out	ASCII	20953667	08/19/98
calc5.out	ASCII	22820628	08/19/98
calc6.out	ASCII	33254775	08/19/98
calc7.out	ASCII	11436712	08/19/98
calc8.out	ASCII	16115522	08/19/98
calc9.out	ASCII	16113055	08/19/98
calc10.out	ASCII	16098731	08/19/98
calc11.out	ASCII	17550502	08/19/98
calc12.out	ASCII	30143021	08/19/98
calc13.out	ASCII	11453174	08/19/98
calc14.out	ASCII	16138063	08/19/98
calc15.out	ASCII	16164413	08/19/98
calc16.out	ASCII	16150944	08/19/98
calc17.out	ASCII	17609648	08/19/98
calc18.out	ASCII	30236955	08/19/98
orig1.out	ASCII	2039678	08/19/98
orig2.out	ASCII	2049434	08/19/98
orig3.out	ASCII	2041762	08/19/98
orig4.out	ASCII	2040174	08/19/98
orig5.out	ASCII	2092670	08/19/98
orig6.out	ASCII	2068466	08/19/98
orig7.out	ASCII	2039642	08/19/98
orig8.out	ASCII	2048650	08/19/98
orig9.out	ASCII	2039966	08/19/98
orig10.out	ASCII	2039894	08/19/98
orig11.out	ASCII	2092814	08/19/98
orig12.out	ASCII	2067998	08/19/98
orig13.out	ASCII	2039606	08/19/98
orig14.out	ASCII	2047470	08/19/98
orig15.out	ASCII	2039390	08/19/98
orig16.out	ASCII	2039318	08/19/98
orig17.out	ASCII	2091670	08/19/98
orig18.out	ASCII	[illegible]	[illegible]