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Multirecycling of Plutonium from LMFBR Blanket in Standard PWRs Loaded with MOX Fuel

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SUMMARY

It is now well-known that, from a physics standpoint, Pu, or even TRU (i.e. Pu+M.A.), originating from LEU fuel irradiated in PWRs can be multirecycled also in PWRs using MOX fuel. However, the degradation of the isotopic composition during irradiation necessitates using enriched U in conjunction with the MOX fuel either homogeneously or heterogeneously to maintain the Pu (or TRU) content at a level allowing safe operation of the reactor, i.e. below about 10%.

The study is related to another possible utilization of the excess Pu produced in the blanket of a LMFBR, namely in a PWR(MOX). In this case the more Pu is bred in the LMFBR, the more PWR(MOX) it can sustain. The important difference between the Pu coming from the blanket of a LMFBR and that coming from a PWR(LEU) is its isotopic composition. The first one contains about 95% of fissile isotopes whereas the second one contains only about 65% of fissile isotopes. As it will be shown later, this difference allows the PWR fed by Pu from the LMFBR blanket to operate with natural U instead of enriched U when it is fed by Pu from PWR(LEU).

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ACRONYMS

BOL	Beginning of Life
EOL	End of Life
GWd/tHM	Gigawatt-days per tonne of initial heavy metal
INL	Idaho National Laboratory
LEU	Low-Enriched Uranium
LMFBR	Liquid Metal Fast Breeder Reactor
MA	Minor Actinide
MOX	Mixed Oxide Fuel
MOX-NU	Mixed Oxide Fuel with Natural Uranium Support
MOX-UE	Mixed Oxide Fuel with Enriched Uranium Support
PWR	Pressurized Water Reactor
TRU	Transuranics

MULTIRECYCLING OF PLUTONIUM FROM LMFBR BLANKET IN STANDARD PWRS LOADED WITH MOX FUEL

1 INTRODUCTION

It is now well-known that, from a physics standpoint, Pu, or even TRU (i.e. Pu+M.A.), originating from LEU fuel irradiated in PWRs can be multirecycled also in PWRs using MOX fuel. However, the degradation of the isotopic composition during irradiation necessitates using enriched U in conjunction with the MOX fuel either homogeneously (MOX-UE approach [1]) or heterogeneously (CORAIL approach [2]) to maintain the Pu (or TRU) content at a level allowing safe operation of the reactor, i.e. below about 10%.

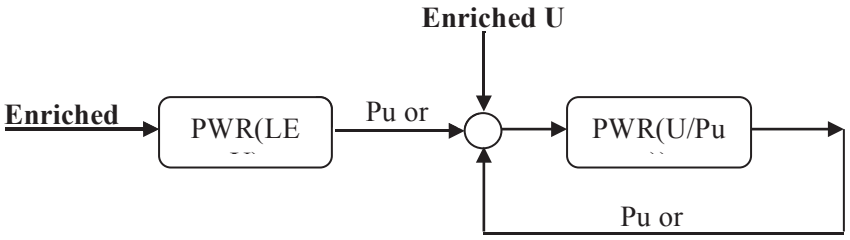

Figure 1-1. Schematic of the multirecycling of Pu or TRU originating from PWR(LEU) in PWR(MOX) using enriched U

It is also well-known that a LMFBR using U blankets can produce more Pu than it actually needs and that this Pu can be used to start another LMFBR. The more Pu it breeds, the less time it takes to have enough Pu to start a second LMFBR, i.e. the shorter the doubling time.

The results presented in this report are related to another possible utilization of the excess Pu produced in the blanket of a LMFBR, namely in a PWR(MOX). In this case the more Pu is bred in the LMFBR, the more PWR(MOX) it can sustain. The important difference between the Pu coming from the blanket of a LMFBR and that coming from a PWR(LEU) is its isotopic composition. The first one contains about 95% of fissile isotopes whereas the second one contains only about 65% of fissile isotopes. As it will be shown later, this difference allows the PWR fed by Pu from the LMFBR blanket to operate with natural U instead of enriched U when it is fed by Pu from PWR(LEU).

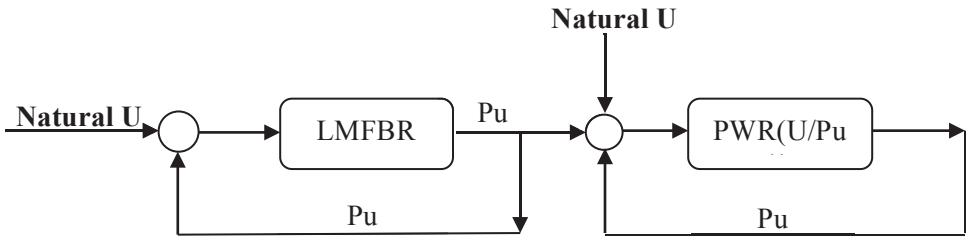

Figure 1-2. Schematic of the multirecycling of the excess Pu originating from LMFBR in PWR(MOX) using natural U

2 CALCULATION METHODOLOGY

The calculations needed by this study have been performed through the code SCALE 6.1/TRITON. A small overview on the main capabilities and models used is reported in the following paragraphs.

2.1 SCALE 6.1 CODE SYSTEMS.

The reactor physics calculations have been performed by the lattice physics capabilities of the SCALE 6.1 code systems. The calculation flow consists of the use of several modules mutually coupled. The discrete-ordinates code NEWT (**N**ew **E**SC-based **W**eighting **T**ransport code) coupled to the depletion code ORIGEN [3] via the TRITON control module [4]. Using the discrete-ordinates approximation to the transport equation on an arbitrary grid, together with a 238-group neutron cross-section library based on ENDF/B-VII, NEWT provides a robust and rigorous deterministic solution for non-orthogonal configurations. The differencing scheme employed by NEWT, the Extended Step Characteristic Approximation, allows a computational two-dimensional mesh based on arbitrary polygons. Such a mesh can be used to closely approximate curved or irregular surfaces to provide the capability to model problems that were formerly difficult or impractical to model directly with discrete-ordinates methods.

The TRITON control module performs the task of coordination of data transfer between various physics codes available within SCALE 6.1 and of invoking those codes in the proper sequence for a desired type of calculation. The high-fidelity nature of the NEWT solution in estimating angular flux distributions combined with the rigor of the ORIGEN depletion solver gives TRITON the capability to perform precise burnup-dependent physics calculations with few implicit approximations, and limited primarily by the accuracy of nuclide cross-sectional data. Such rigor may be necessary to capture the unique attributes of MOX-NU fuel behavior as well as that of advanced, highly heterogeneous fuel assembly designs being deployed in current-generation reactors. Cross-sectional self-shielding is carried out by BONAMI for unresolved-range resonance data; the resolved resonance processor module CENTRM performs a 1-D discrete-ordinates code that uses point-wise cross-section data to produce a set of continuous-energy fluxes at discrete spatial intervals for each unit cell. Following a CENTRM calculation, the code PMC uses the resulting flux to collapse the point-wise continuous-energy cross sections into multi-group cross sections for each nuclide in each material in a unit (e.g., pin cell). The result is a multi-group library in which point cross-sectional data are weighted using the explicit point-wise spectrum representative of the nuclides present in a pin cell. Effects from overlapping resonances, fissile material in the fuel and surrounding moderator, anisotropic scattering, and inelastic level scattering are explicitly handled by this approach.

For the physics calculations carried out during this study, a TRITON model of one fourth standard (17x17) fuel assembly has been used (Figure 2-1). All the MOX-NU rods have the same Uranium and Plutonium content. The 0.5 mm water gap at the periphery is explicitly represented. The model uses three different burn-up zones to take into account the different local moderating

ratios: 1 for the corner rods (green), 1 for the other rods located at the periphery (cyan) and 1 for the internal rods (red).

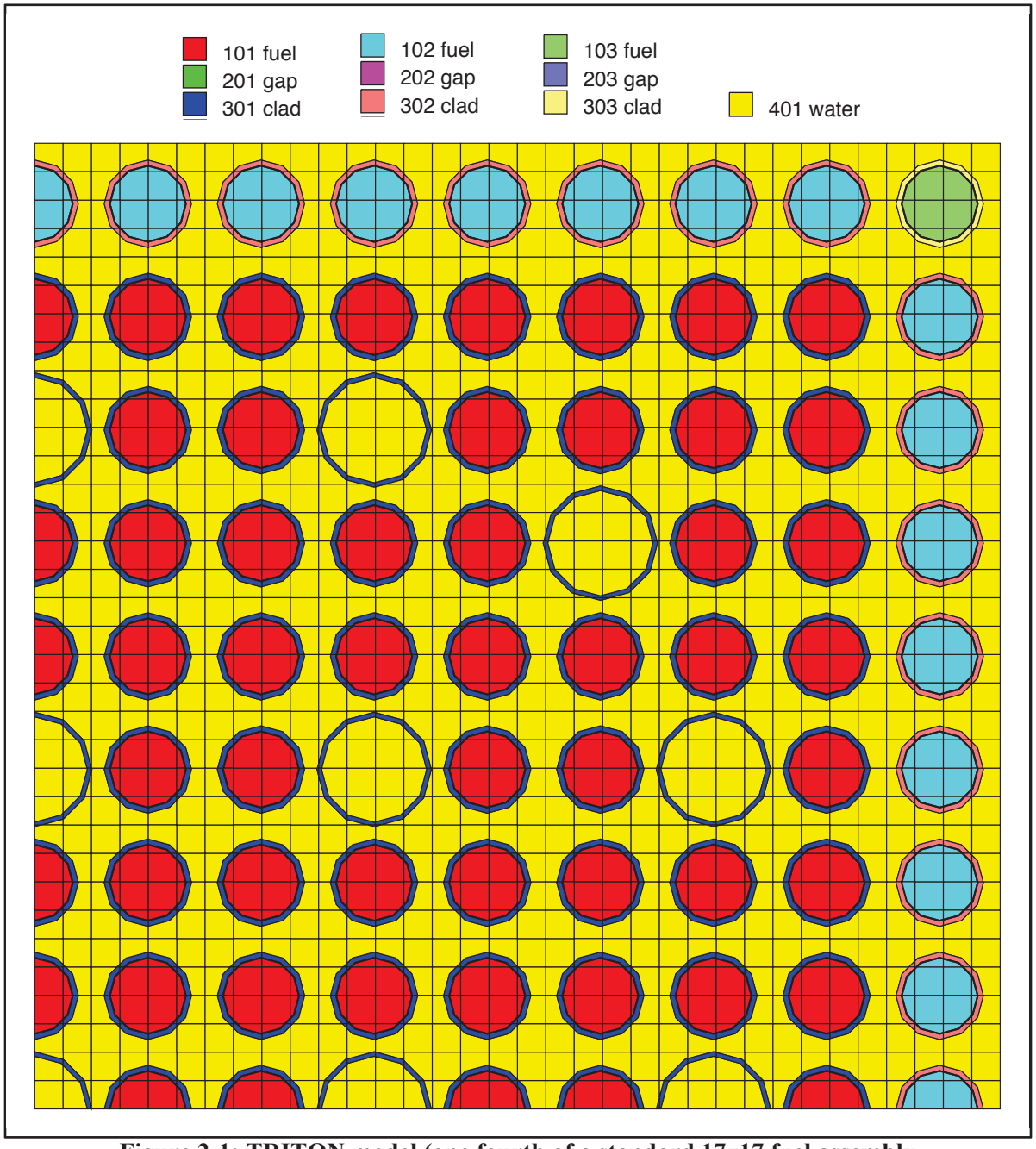

Figure 2-1: TRITON model (one fourth of a standard 17x17 fuel assembly

The calculations carried out to simulate the fuel cycle represented on the Figure 2-2. After each cycle, the amount of fissile Pu initially loaded that disappeared by either fission, capture or decay is replaced with Pu coming from LMFBR blanket with the amount required to achieve target burnup. The percentage of Pu coming from LMFBR blanket used in the manufacturing process decreases after the first cycle and reaches to an equilibrium.

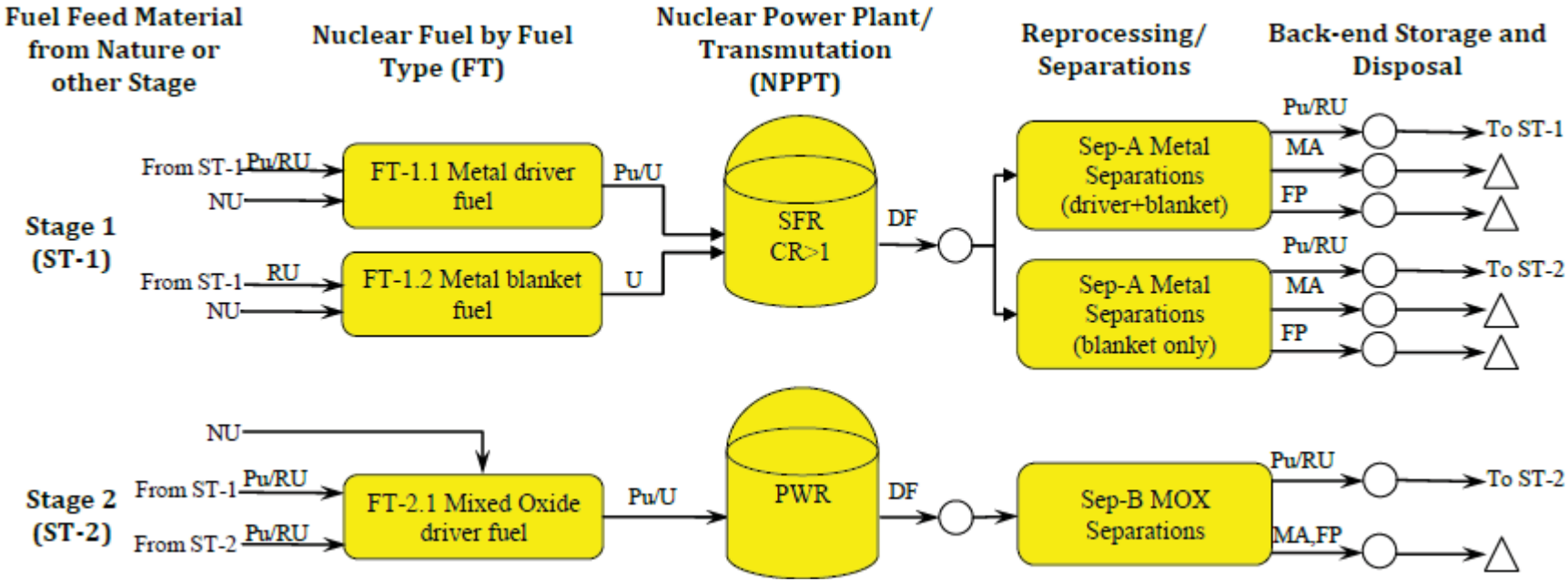

Figure 2-2: Representative Fuel cycle

The Pu content in the MOX-NU fuel assemblies has been tuned to maintain the same average discharge burn-up and a **constant cycle length**. The calculations have been run considering a 3-batch core with an average discharge burn-up of **50.0 GWd/tHM** and a fuel power density of ~ **35.36 MW/tHM**. The model takes in account 2 year fuel aging (time needed by the fabrication and transport operations) and 5 years of cooling time (time needed in order to reduce the decay heat generation to levels compatible with the separation operations). The burn-up level above specified is reached after ~ 1414 days of irradiation. **One cycle then corresponds to 2 years + 50 GWd/tHM (1414 days) + 5 years cooling time ≅ 10.9 years.**

The necessary *Pu* enrichment are determined with a methodology that is standard for this kind of application: the k-infinity of the assembly at the average end of cycle burn-up (33.33 GWd/tHM), without soluble boron, is equal to that of the reference 4.2% UOX assembly calculated using the same code (SCALE 6.1), methods (SN), nuclear data (238 group library based on ENDF/B - VII), etc., i.e. **k-inf = 1.029643** in our case. Figure 2-3, below, shows the k-infinity trends for the first 10 cycles as a function of burnup in GWd/tHM. The vertical line in Figure 2-3 corresponds to 33.33 GWd/tHM, where k-infinity for all the cases is equal to each other.

MOX-NU density of 10 g/cm^3 is used throughout the analysis.

The isotopic percentages of the Pu coming from the LMFBR blanket are given in Table 2-1.

Table 2-1: Contents of the LMFBR Blanket [5]

Isotope	Percentage
Pu-238	0.08%
Pu-239	94.29%
Pu-240	5.31%
Pu-241	0.24%
Pu-242	0.09%

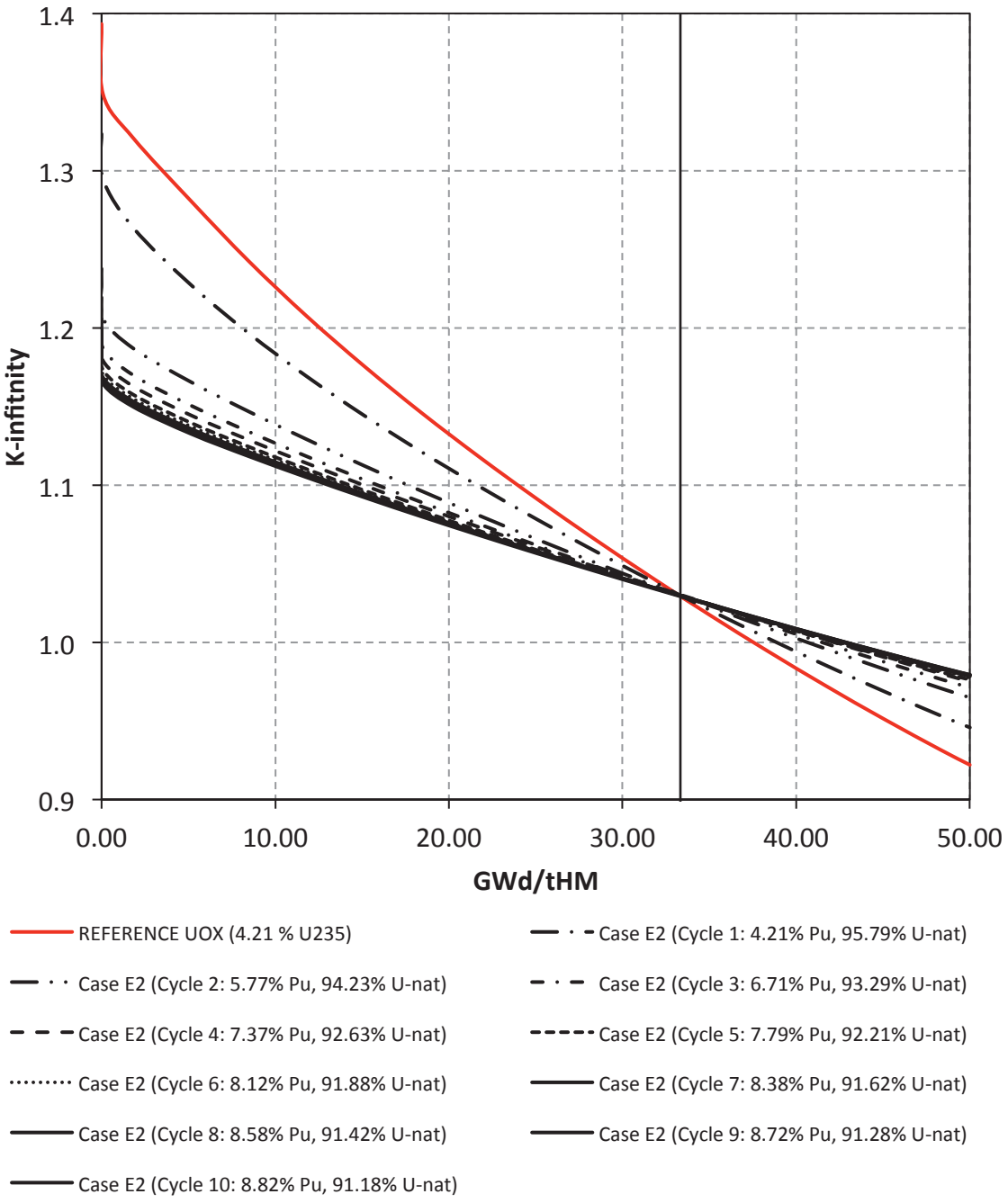

Figure 2-3: K-infinity trends vs. burnup showing the intersection point at 33.33 GWd/tHM.

3 RESULTS

3.1 Plutonium contents

The plutonium content considered for the first cycle is coming from the LMFBR blanket. Since the isotopic composition of the LMFBR blanket is highly fissile (~95%), the required amount of Pu for the first cycle is slightly over 4% by weight. The amount of Pu is steadily increased in the PWR MOX-NU assemblies after each cycle, since the fissile content of the Pu is reduced after each cycle and more Pu-240, Pu-241 and Pu-242 is produced in each cycle. The amount of Pu reaches to an equilibrium roughly after 10^{th} cycle.

Table 3-1 and Figure 3-1 below show the calculated *Pu* content in the fuel assemblies necessary to maintain the same average burn-up at discharge of 50 GWd/tHM as a function of cycle number. Figure 3-2 shows the weight percent of each Pu isotope at the BOL for each cycle whereas Figure 3-3 shows the Pu isotopic compositions at BOL for each cycle. Figure 3-4 shows the isotopic composition Pu at BOL and EOL for each cycle. For the first cycle the destruction of Pu-239 is about 50% of its initial value, after reaching the equilibrium the destruction of Pu-239 per cycle reduces to about 30% of its initial value. Figure 3-5 shows the weight percentages of Pu at the BOL and EOL per cycle, it also shows the weight percentage of the Pu from LMFBR blanket, which is required to be mixed with the recycled Pu from the previous cycle to achieve the target burnup. Figure 3-6 shows the percentage of the Pu according to their origins (i.e. either from previous cycle or LMFBR blanket) that is loaded to the PWR MOX-NU assemblies per cycle.

Table 3-1: Pu and U percentages in the fresh fuel per cycle

Cycle	*Pu*	U
1	4.21%	95.79%
2	5.77%	94.23%
3	6.71%	93.29%
4	7.37%	92.63%
5	7.79%	92.21%
6	8.12%	91.88%
7	8.38%	91.62%
8	8.58%	91.42%
9	8.72%	91.28%
10	8.82%	91.18%
11	8.90%	91.10%
12	8.97%	91.03%
13	9.03%	90.97%
14	9.08%	90.92%
15	9.13%	90.87%

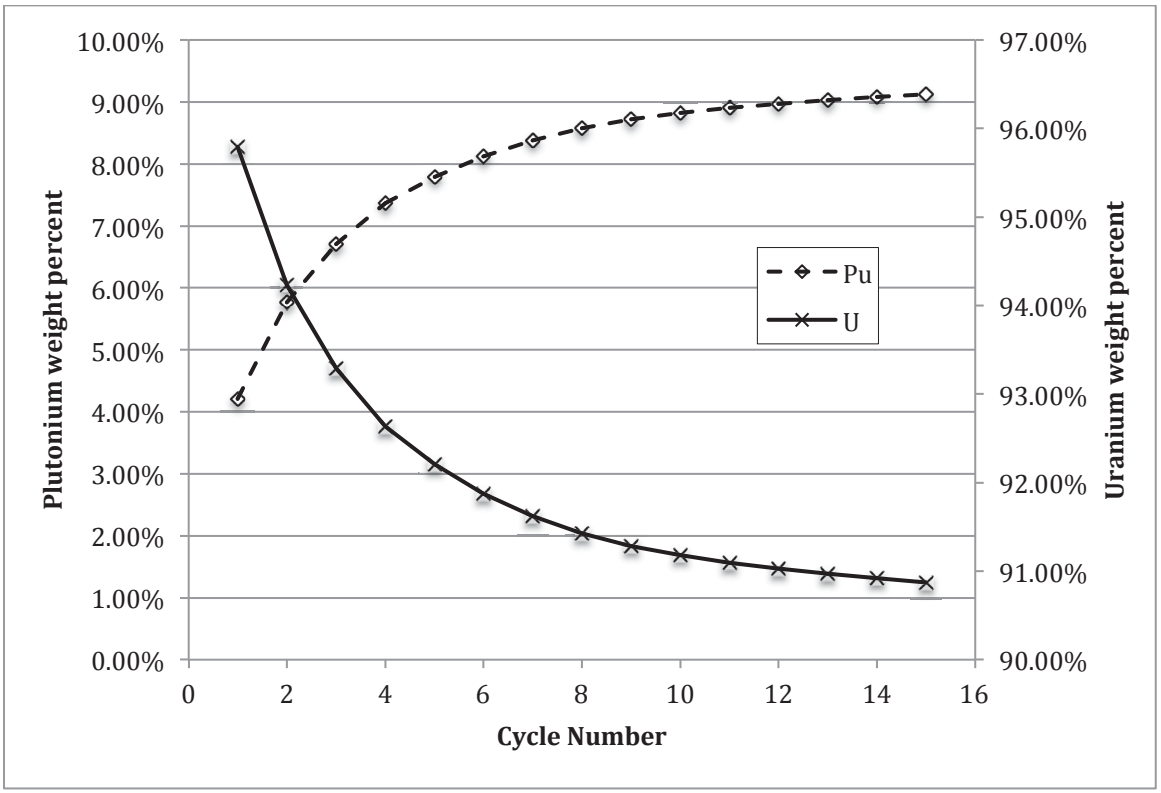

Figure 3-1: U and Pu percentages in PWR MOX-NU fuel assemblies per cycle.

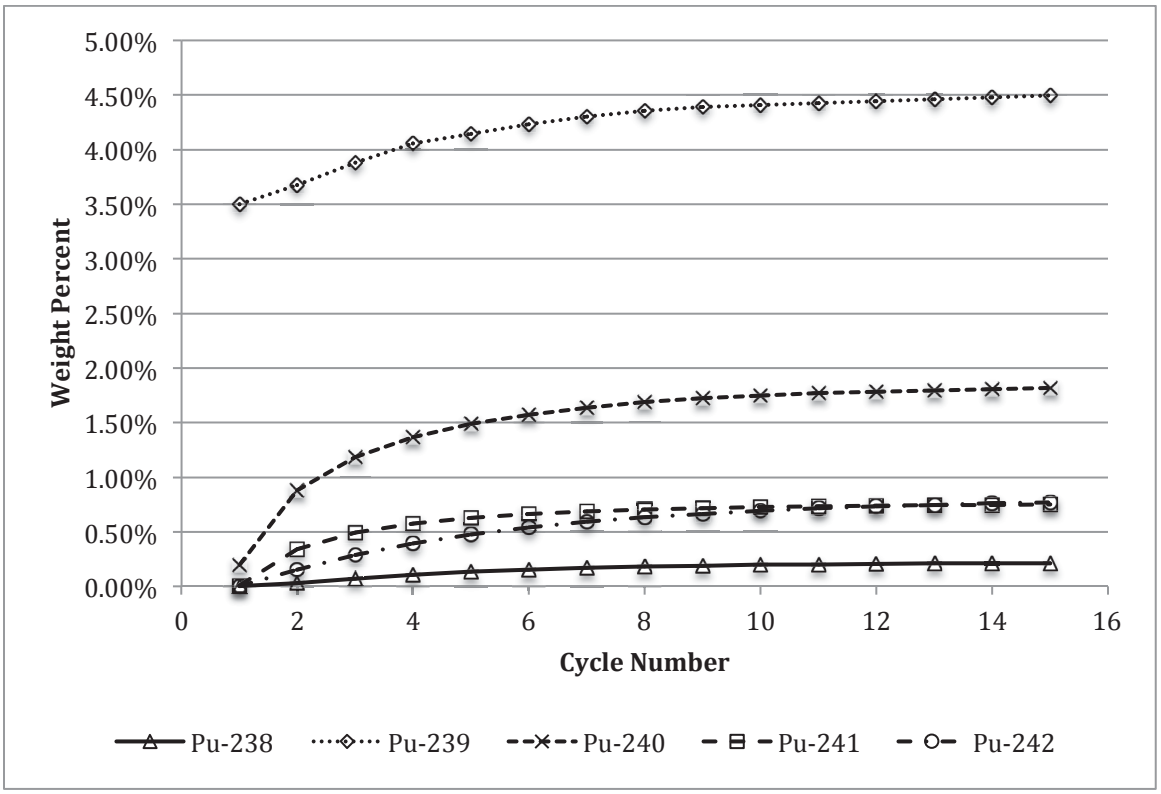

Figure 3-2: Weight percent of Pu isotopes in PWR MOX-NU assemblies per cycle

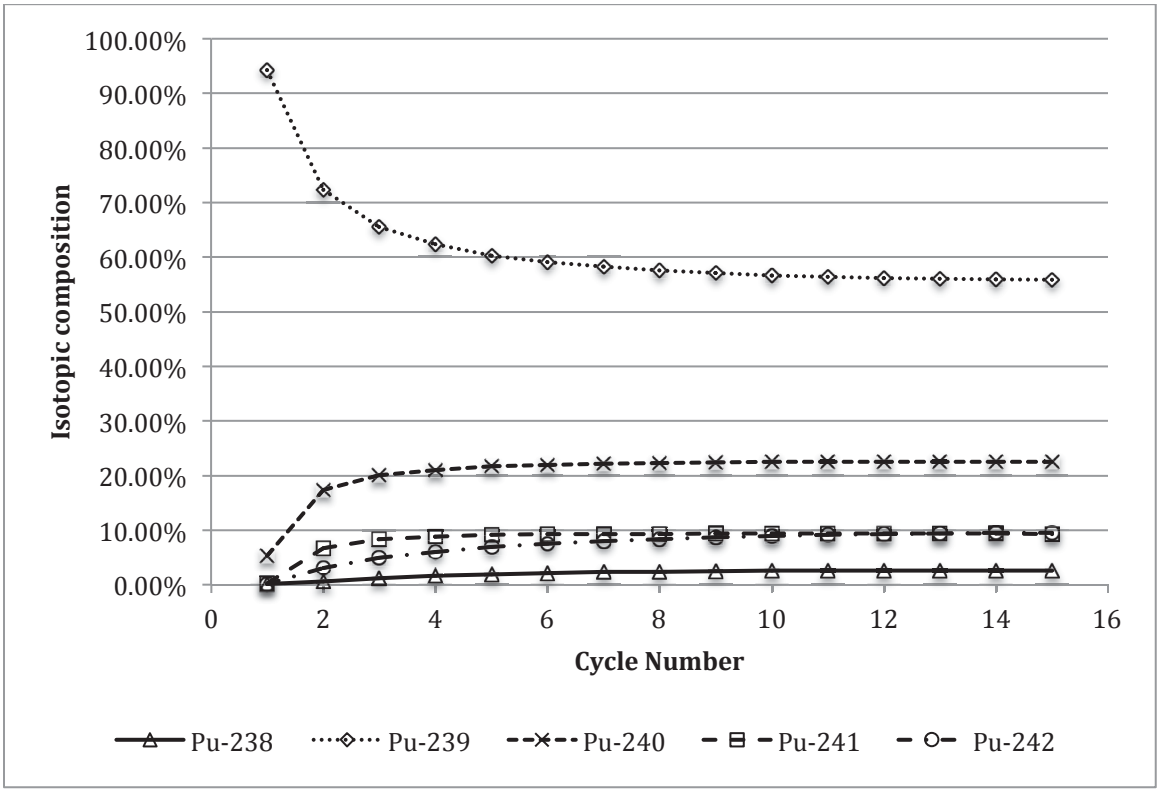

Figure 3-3: Isotopic composition of Pu in PWR MOX-NU assemblies per cycle (BOL only)

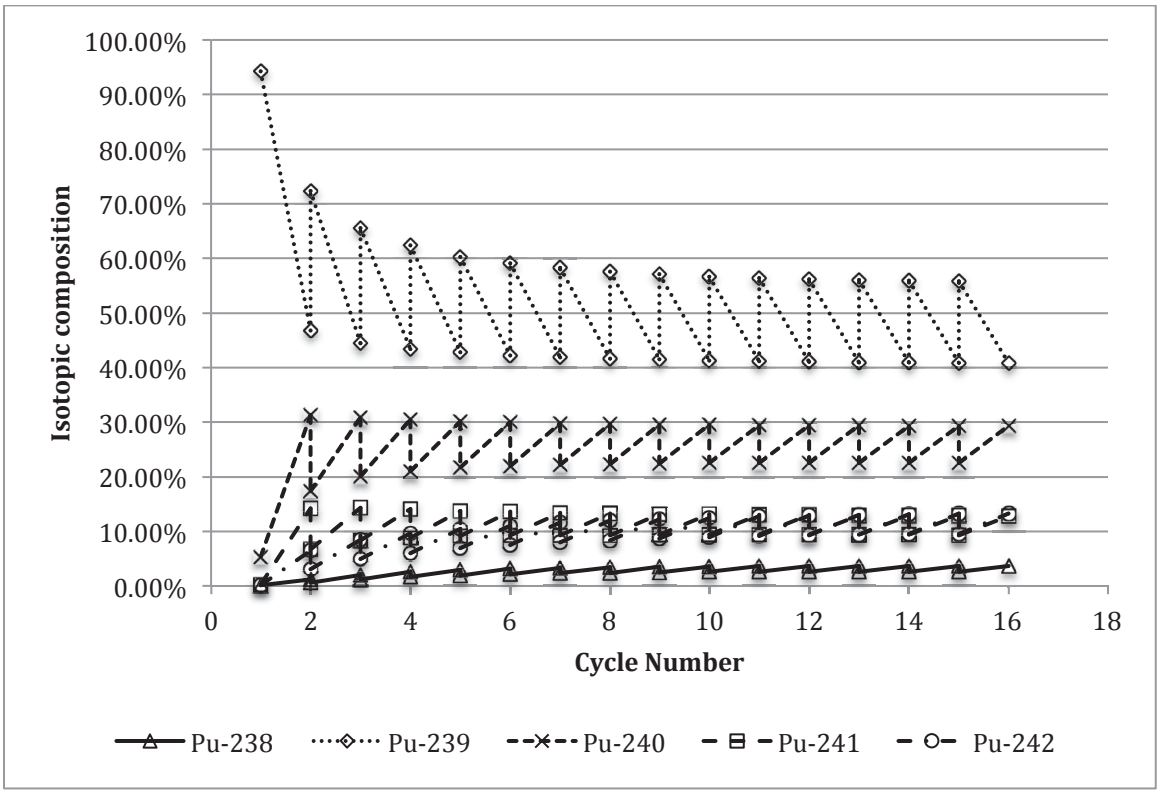

Figure 3-4: Isotopic composition of Pu in PWR MOX-NU assemblies per cycle (BOL and EOL)

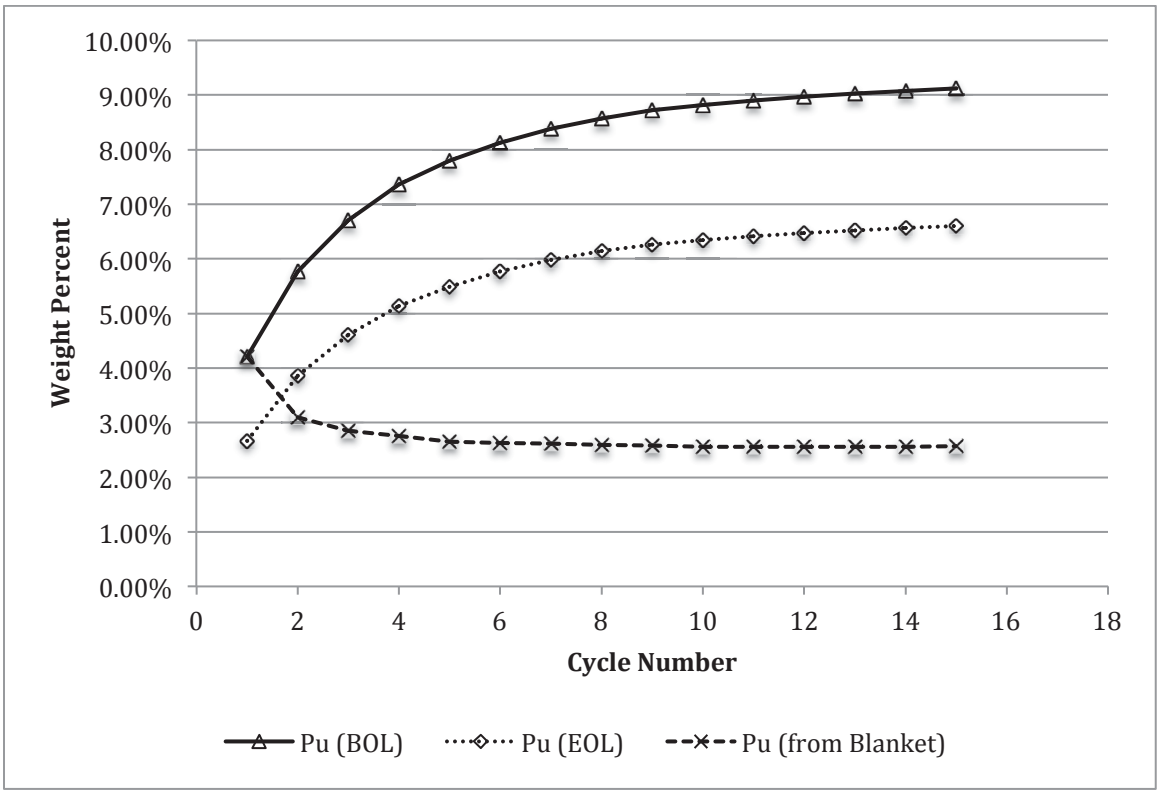

Figure 3-5: Weight percentages of Pu in PWR MOX-NU assemblies per cycle

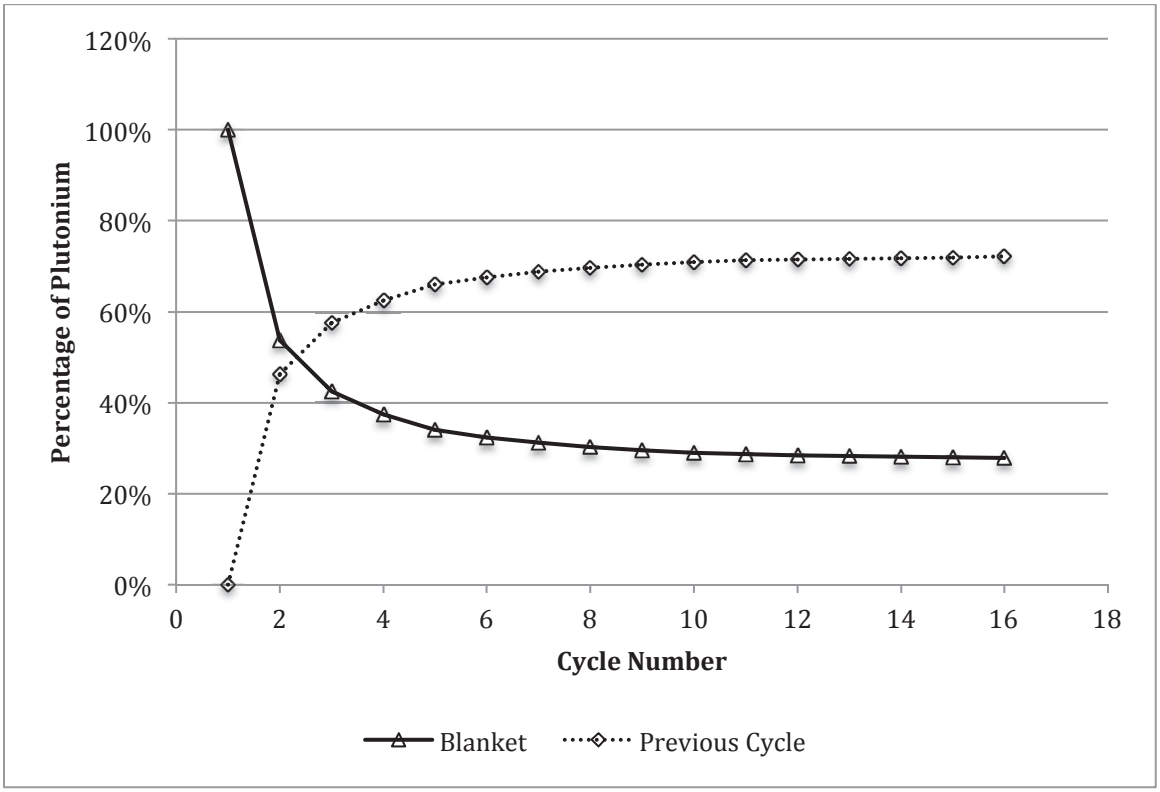

Figure 3-6: The origin of Pu in PWR MOX-NU assemblies per cycle

Figure 3-7 shows the infinite multiplication factor trends for each cycle step (initial fuel aging, burning) against the 50 GWd/tHM UOX (4.2%) reference case.

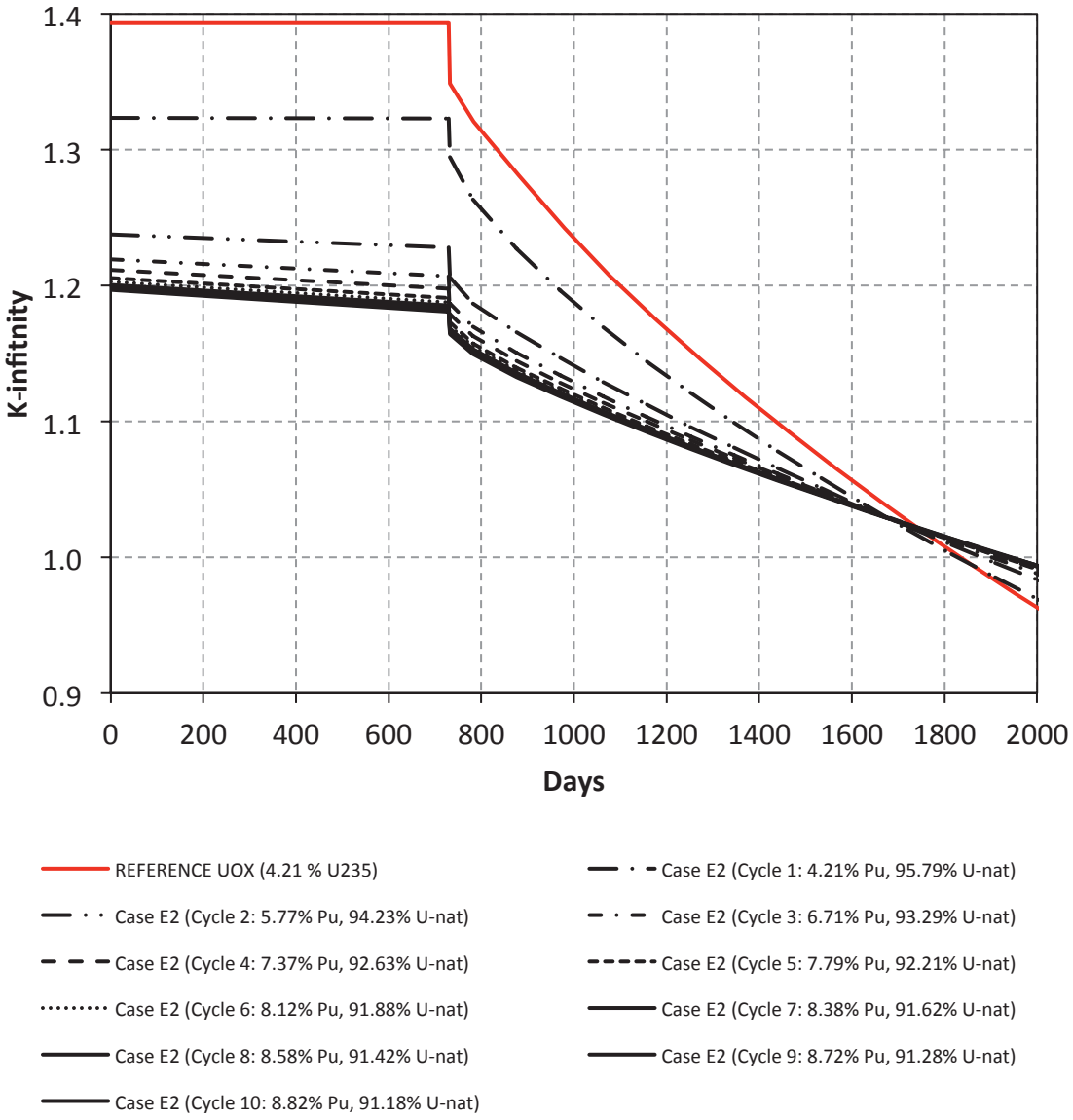

Figure 3-7: *k-infinitive* trends for the first 10 cycles.

Table 3-2 summarizes the isotopic input, after 2 years aging, and output compositions, at the average discharged burn-up of 50 GWd/tHM, for the four cases taken in exam.

Table 3-2: Mass Fraction input and output (summary).

Isotopic input (2 yrs aging) and output mass vectors								
Isotope	1st Cycle		2nd Cycle		5th Cycle		10th Cycle	
	kg/tIHM		kg/tIHM		kg/tIHM		kg/tIHM	
IDs	Input	Output	Input	Output	Input	Output	Input	Output
U232	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
U233	5.196E-09	1.210E-03	1.264E-07	1.585E-03	2.327E-07	2.472E-03	2.692E-07	3.003E-03
U234	5.221E+01	3.011E+01	5.594E+01	4.152E+01	7.316E+01	7.660E+01	8.382E+01	9.801E+01
U235	6.812E+03	2.385E+03	6.701E+03	2.850E+03	6.557E+03	3.216E+03	6.484E+03	3.335E+03
U236	4.646E-01	8.478E+02	2.078E+00	7.933E+02	3.510E+00	7.386E+02	4.123E+00	7.161E+02
U238	9.508E+05	9.167E+05	9.354E+05	9.026E+05	9.153E+05	8.839E+05	9.051E+05	8.743E+05
Np237	1.528E-02	2.410E+02	5.776E-01	2.429E+02	1.069E+00	2.418E+02	1.238E+00	2.407E+02
Pu238	3.148E+01	2.388E+02	3.200E+02	6.670E+02	1.493E+03	1.620E+03	2.210E+03	2.172E+03
Pu239	3.968E+04	1.241E+04	4.169E+04	1.706E+04	4.699E+04	2.310E+04	4.999E+04	2.604E+04
Pu240	2.233E+03	8.333E+03	1.000E+04	1.181E+04	1.690E+04	1.629E+04	1.985E+04	1.852E+04
Pu241	9.255E+01	4.816E+03	3.498E+03	7.035E+03	6.475E+03	9.499E+03	7.495E+03	1.055E+04
Pu242	3.652E+01	1.738E+03	1.765E+03	3.254E+03	5.369E+03	6.084E+03	7.849E+03	8.085E+03
Am241	9.405E+00	2.689E+02	3.555E+02	5.740E+02	6.581E+02	9.670E+02	7.618E+02	1.146E+03
Am242m	2.414E-06	4.628E+00	4.457E-05	1.151E+01	7.145E-05	2.169E+01	7.800E-05	2.666E+01
Am243	1.186E-06	4.558E+02	2.969E-06	1.053E+03	4.786E-06	1.755E+03	5.541E-06	2.097E+03
Cm242	5.848E-08	7.484E+01	2.209E-07	1.379E+02	3.225E-07	1.876E+02	3.467E-07	2.031E+02
Cm243	1.081E-06	2.290E+00	1.081E-06	5.762E+00	1.081E-06	8.452E+00	1.081E-06	9.248E+00
Cm244	1.051E-06	1.981E+02	1.051E-06	6.460E+02	1.051E-06	1.032E+03	1.051E-06	1.182E+03
Cm245	1.134E-06	1.880E+01	1.134E-06	8.193E+01	1.134E-06	1.347E+02	1.134E-06	1.535E+02
Cm246	1.134E-06	1.623E+00	1.134E-06	7.381E+00	1.134E-06	9.519E+00	1.134E-06	9.834E+00
Cm247	1.134E-06	2.720E-02	1.134E-06	1.539E-01	1.134E-06	1.983E-01	1.134E-06	2.036E-01
Cm248	1.134E-06	2.018E-03	1.134E-06	1.248E-02	1.134E-06	1.428E-02	1.134E-06	1.393E-02
Bk249	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cf249	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Element input and output summary								
IDs	%	%	%	%	%	%	%	%
U	95.77%	92.00%	94.22%	90.63%	92.19%	88.79%	91.17%	87.84%
Np	0.00%	0.02%	0.00%	0.02%	0.00%	0.02%	0.00%	0.02%
Pu	4.21%	2.75%	5.73%	3.98%	7.72%	5.66%	8.74%	6.54%
Am	0.00%	0.07%	0.04%	0.16%	0.07%	0.27%	0.08%	0.33%

Cm	0.00%	0.03%	0.00%	0.09%	0.00%	0.14%	0.00%	0.16%
Bk	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cf	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
FP	0.00%	5.11%	0.00%	5.11%	0.00%	5.10%	0.00%	5.10%

3.2 Reactivity Coefficients

The reactivity coefficients are very important for reactor safety and should be negative to ensure negative feedback. This section presents the results of a reactivity coefficient analysis of the MOX-NU fueled PWR. The fuel and moderator temperature, and void coefficients are looked at. For MOX fueled PWRs the void coefficient tends to become less negative when the total plutonium content is increased. In the conventional PWR lattice changes sign from negative to positiove at a total plutonium content of between 10% and 12% depending on its isotopic composition [6]. Since the Pu content at the equilibrium has not been reached to these levels, only the results is shown here and no attempt to make the void coefficient more negative has been done. For a more detailed analysis on the void coefficient issue refer [1].
Only the reactivity coefficients for the 15th cycle will be presented here since the Pu content is the highest for this cycle. Table 3-3 shows the reactivity coefficients at the BOL (after 2 years of aging).

Table 3-3: Reactivity Coefficients calculated for the 15th cycle.

Coefficient	Value
Fuel Temperature (pcm/^{o}C)	-2.669
Moderator Temperature (pcm/^{o}C)	-41.069
Void (90%) (pcm)	-13143.513

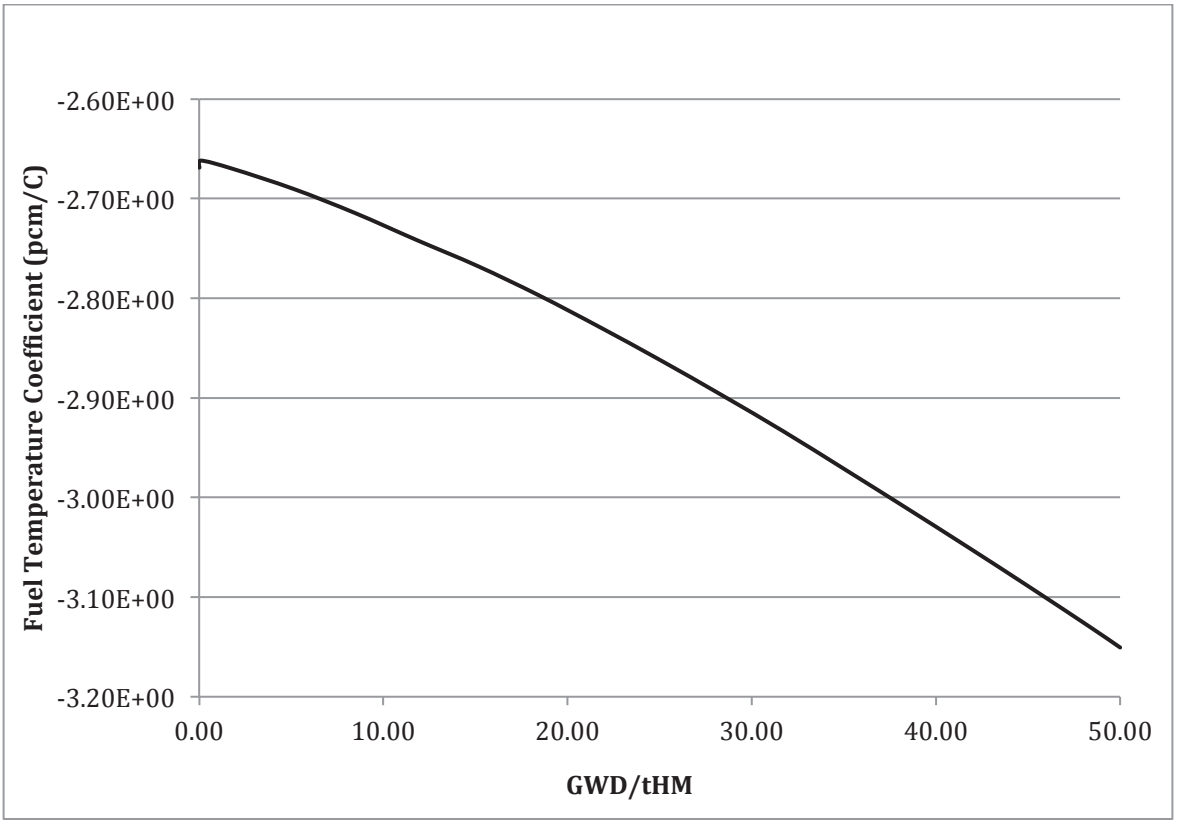

Figure 3-8: Fuel Temperature coefficient for the 15th Cycle

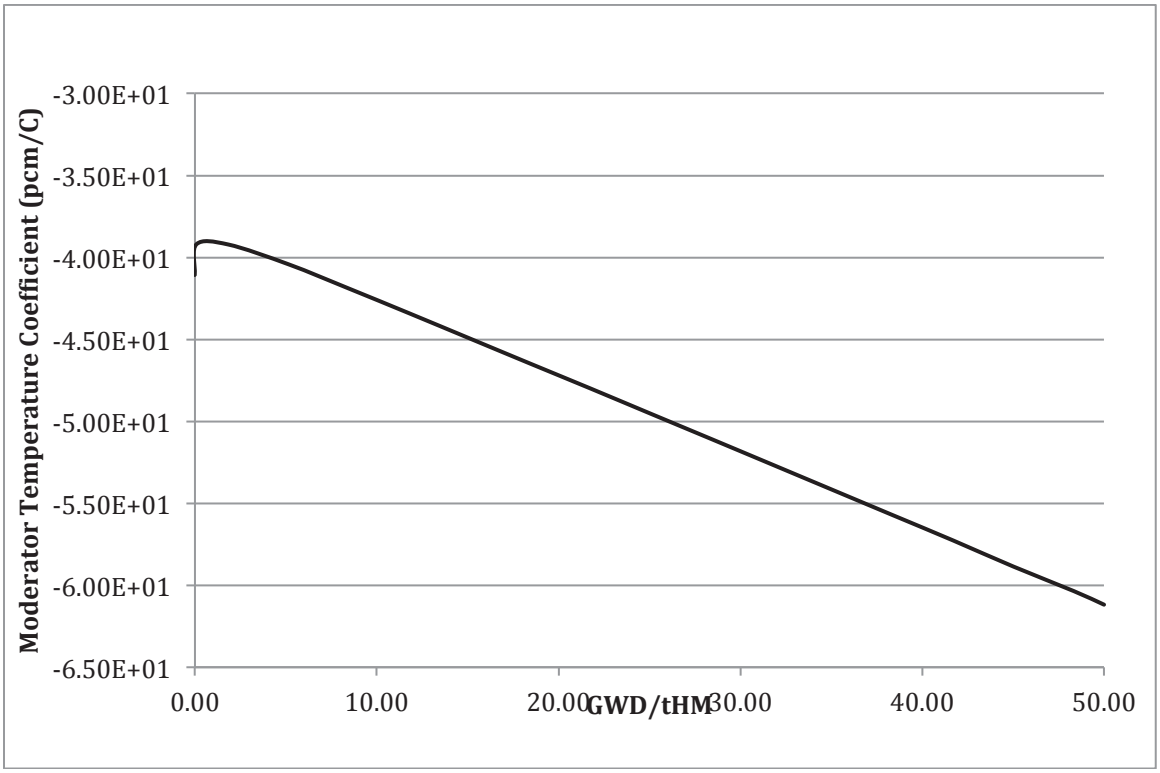

Figure 3-9: Moderator Temperature coefficient for the 15th Cycle

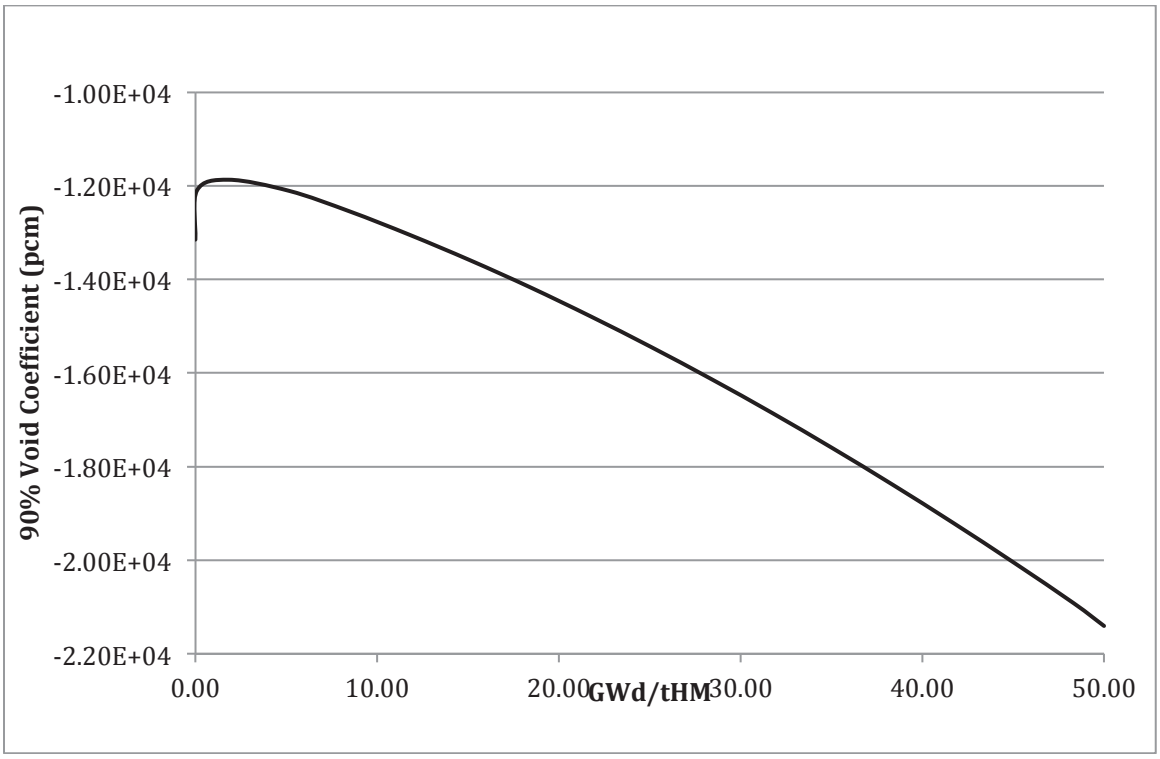

Figure 3-10: 90% Void coefficient for the 15th cycle

4 CONCLUSIONS.

This report presents the results of a neutronics analysis in which the option of a MOX-NU based fuel cycle has been shown.

The main objective of these calculations is to quantify the Pu content needed to operate a MOX-NU based reactor (PWR) in order to maintain the same average burnup at discharge (50 GWd/tHM) and, consequently, collect the data needed for further analysis.

It is important to recognize that these results are based on infinite lattice assembly calculations, assuming standard UOX fuel assembly parameters with homogeneously loaded fuel. While this approach increases the ability to retrofit MOX based fuels into existing commercial PWRs with minimal or no changes required to reactor hardware, it **does not** represent the optimum performance achievable. Additionally more detailed studies (i.e. optimization of assembly and reactor parameters, calculation of void coefficients, etc.) would be required.

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Appendix 1: Detailed isotopic mass fraction input (after 2-yrs fuel aging).

Isotopic input mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
IDs	***kg/tIHM***	***kg/tIHM***	***kg/tIHM***	***kg/tIHM***	***kg/tIHM***
He4	5.47E-02	1.71E-01	5.23E-01	7.31E-01	7.81E-01
Ra228	4.11E-19	1.84E-18	3.11E-18	3.65E-18	3.79E-18
Th228	1.13E-16	1.28E-16	1.54E-16	1.69E-16	1.72E-16
Th229	5.40E-14	3.19E-13	5.56E-13	6.39E-13	6.58E-13
Th230	2.88E-04	2.96E-04	3.41E-04	3.69E-04	3.76E-04
Th231	2.78E-08	2.74E-08	2.68E-08	2.65E-08	2.65E-08
Th232	1.40E-08	6.08E-08	1.02E-07	1.20E-07	1.25E-07
Pa231	1.33E-05	1.30E-05	1.28E-05	1.26E-05	1.26E-05
Pa233	5.18E-10	1.96E-08	3.62E-08	4.19E-08	4.32E-08
Pa234	1.60E-07	1.57E-07	1.54E-07	1.52E-07	1.52E-07
U232	8.55E-13	9.84E-13	1.30E-12	1.48E-12	1.53E-12
U233	5.20E-09	1.26E-07	2.33E-07	2.69E-07	2.78E-07
U234	5.22E+01	5.59E+01	7.32E+01	8.38E+01	8.64E+01
U235	6.81E+03	6.70E+03	6.56E+03	6.48E+03	6.46E+03
U236	4.65E-01	2.08E+00	3.51E+00	4.12E+00	4.28E+00
U237	1.48E-04	2.64E-04	3.59E-04	3.91E-04	3.98E-04
U238	9.51E+05	9.35E+05	9.15E+05	9.05E+05	9.02E+05
Np236	1.06E-13	4.34E-12	8.33E-12	9.74E-12	1.01E-11
Np237	1.53E-02	5.78E-01	1.07E+00	1.24E+00	1.28E+00

Isotopic input mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
Np238	8.81E-09	3.18E-07	5.47E-07	6.12E-07	6.25E-07
Np239	4.14E-04	4.23E-04	4.14E-04	4.09E-04	4.07E-04
Pu236	2.97E-11	3.31E-10	1.62E-09	2.43E-09	2.63E-09
Pu237	4.35E-09	1.93E-08	8.13E-08	1.20E-07	1.29E-07
Pu238	3.15E+01	3.20E+02	1.49E+03	2.21E+03	2.38E+03
Pu239	3.97E+04	4.17E+04	4.70E+04	5.00E+04	5.10E+04
Pu240	2.23E+03	1.00E+04	1.69E+04	1.99E+04	2.06E+04
Pu241	9.26E+01	3.50E+03	6.48E+03	7.50E+03	7.73E+03
Pu242	3.65E+01	1.77E+03	5.37E+03	7.85E+03	8.73E+03
Pu243	2.90E-05	1.03E-03	2.04E-03	2.47E-03	2.59E-03
Pu244	4.07E-12	4.07E-12	4.07E-12	4.07E-12	4.07E-12
Am241	9.41E+00	3.56E+02	6.58E+02	7.62E+02	7.85E+02
Am242	1.10E-05	3.66E-04	5.88E-04	6.41E-04	6.50E-04
Am242M	2.41E-06	4.46E-05	7.15E-05	7.80E-05	7.91E-05
Am243	1.19E-06	2.97E-06	4.79E-06	5.54E-06	5.76E-06
Cm242	5.85E-08	2.21E-07	3.23E-07	3.47E-07	3.51E-07
Cm243	1.08E-06	1.08E-06	1.08E-06	1.08E-06	1.08E-06
Cm244	1.05E-06	1.05E-06	1.05E-06	1.05E-06	1.05E-06
Cm245	1.13E-06	1.13E-06	1.13E-06	1.13E-06	1.13E-06
Cm246	1.13E-06	1.13E-06	1.13E-06	1.13E-06	1.13E-06
Cm247	1.13E-06	1.13E-06	1.13E-06	1.13E-06	1.13E-06
Cm248	1.13E-06	1.13E-06	1.13E-06	1.13E-06	1.13E-06

Isotopic input mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
Bk249	1.41E-15	1.47E-15	1.46E-15	1.45E-15	1.44E-15
Cf249	4.62E-21	4.78E-21	4.73E-21	4.68E-21	4.67E-21
Zn70	1.26E-09	1.26E-09	1.27E-09	1.27E-09	1.28E-09
Ga71	5.67E-10	5.97E-10	6.19E-10	6.27E-10	6.29E-10
Ge72	1.49E-12	1.37E-12	1.30E-12	1.29E-12	1.29E-12
Ge73	6.36E-11	5.96E-11	5.75E-11	5.71E-11	5.70E-11
Ge74	4.36E-09	4.06E-09	3.91E-09	3.89E-09	3.89E-09
Ge76	2.27E-07	2.15E-07	2.09E-07	2.08E-07	2.08E-07
As75	1.72E-10	1.61E-10	1.55E-10	1.54E-10	1.54E-10
Se77	2.95E-11	2.70E-11	2.56E-11	2.53E-11	2.53E-11
Se78	1.96E-09	1.83E-09	1.76E-09	1.74E-09	1.74E-09
Se79	4.64E-08	4.31E-08	4.13E-08	4.09E-08	4.08E-08
Se80	6.60E-06	6.17E-06	5.91E-06	5.84E-06	5.83E-06
Se82	2.58E-05	2.46E-05	2.39E-05	2.38E-05	2.37E-05
Br79	3.31E-11	3.03E-11	2.87E-11	2.83E-11	2.83E-11
Br81	2.63E-07	2.46E-07	2.36E-07	2.33E-07	2.33E-07
Kr82	6.26E-10	5.73E-10	5.43E-10	5.36E-10	5.35E-10
Kr83	1.46E-08	1.33E-08	1.25E-08	1.24E-08	1.23E-08
Kr84	9.69E-07	9.04E-07	8.66E-07	8.57E-07	8.55E-07
Kr85	1.81E-06	1.67E-06	1.58E-06	1.56E-06	1.55E-06
Kr86	4.82E-05	4.64E-05	4.52E-05	4.48E-05	4.47E-05
Rb85	3.85E-08	3.44E-08	3.07E-08	2.93E-08	2.90E-08

Isotopic input mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
Rb87	2.33E-06	2.15E-06	2.04E-06	2.02E-06	2.01E-06
Sr86	1.21E-10	1.09E-10	1.03E-10	1.01E-10	1.01E-10
Sr87	2.98E-09	2.71E-09	2.55E-09	2.51E-09	2.51E-09
Sr88	3.09E-07	2.85E-07	2.72E-07	2.69E-07	2.68E-07
Sr89	4.14E-06	3.84E-06	3.65E-06	3.59E-06	3.58E-06
Sr90	4.52E-05	4.28E-05	4.12E-05	4.07E-05	4.06E-05
Y89	8.85E-10	8.03E-10	7.56E-10	7.45E-10	7.43E-10
Y90	1.21E-08	1.10E-08	1.04E-08	1.02E-08	1.02E-08
Y91	2.18E-07	2.02E-07	1.92E-07	1.90E-07	1.89E-07
Zr90	9.76E-12	8.87E-12	8.36E-12	8.24E-12	8.22E-12
Zr91	4.77E-10	4.33E-10	4.07E-10	4.01E-10	4.00E-10
Zr92	1.67E-07	1.47E-07	1.27E-07	1.20E-07	1.18E-07
Zr93	2.63E-07	2.41E-07	2.28E-07	2.25E-07	2.25E-07
Zr94	1.06E-05	9.99E-06	9.60E-06	9.50E-06	9.48E-06
Zr95	4.33E-05	4.10E-05	3.96E-05	3.93E-05	3.92E-05
Zr96	7.32E-04	7.22E-04	7.15E-04	7.12E-04	7.12E-04
Nb94	1.32E-09	1.20E-09	1.13E-09	1.12E-09	1.12E-09
Nb95	7.56E-08	6.85E-08	6.43E-08	6.32E-08	6.31E-08
Nb95M	1.76E-08	1.59E-08	1.50E-08	1.47E-08	1.47E-08
Mo95	3.43E-11	3.26E-11	3.16E-11	3.13E-11	3.13E-11
Mo96	7.90E-10	7.73E-10	7.65E-10	7.63E-10	7.63E-10
Mo97	8.59E-08	7.83E-08	7.39E-08	7.28E-08	7.26E-08

Isotopic input mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
Mo98	5.12E-04	5.04E-04	4.99E-04	4.97E-04	4.97E-04
Mo100	1.05E-03	1.03E-03	1.03E-03	1.03E-03	1.02E-03
Tc98	6.76E-11	6.09E-11	5.66E-11	5.54E-11	5.51E-11
Tc99	1.11E-08	1.10E-08	1.09E-08	1.08E-08	1.08E-08
Ru99	1.22E-13	1.11E-13	1.05E-13	1.03E-13	1.03E-13
Ru100	3.24E-08	2.94E-08	2.78E-08	2.74E-08	2.73E-08
Ru101	6.92E-07	6.85E-07	6.82E-07	6.82E-07	6.81E-07
Ru102	4.25E-05	4.22E-05	4.21E-05	4.21E-05	4.21E-05
Ru103	1.40E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04
Ru104	1.27E-05	1.24E-05	1.23E-05	1.23E-05	1.23E-05
Ru106	3.50E-04	3.59E-04	3.67E-04	3.69E-04	3.70E-04
Rh103	4.92E-11	4.86E-11	4.84E-11	4.83E-11	4.83E-11
Rh103M	7.71E-10	7.60E-10	7.55E-10	7.55E-10	7.55E-10
Rh106	1.49E-08	1.42E-08	1.40E-08	1.41E-08	1.41E-08
Pd104	1.55E-10	1.42E-10	1.34E-10	1.32E-10	1.32E-10
Pd105	4.21E-11	4.16E-11	4.13E-11	4.13E-11	4.13E-11
Pd106	2.14E-08	2.04E-08	2.01E-08	2.02E-08	2.03E-08
Pd107	8.99E-07	8.85E-07	8.81E-07	8.81E-07	8.81E-07
Pd108	2.31E-05	2.42E-05	2.50E-05	2.53E-05	2.53E-05
Pd110	7.97E-05	8.75E-05	9.30E-05	9.45E-05	9.48E-05
Ag109	3.39E-09	3.60E-09	3.74E-09	3.78E-09	3.79E-09
Ag110M	4.51E-13	6.58E-12	1.24E-11	1.46E-11	1.52E-11

Isotopic input mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
In115	7.80E-13	9.42E-13	1.44E-12	1.73E-12	1.80E-12
Sn115	1.23E-14	1.24E-14	1.27E-14	1.28E-14	1.28E-14
Sn116	9.91E-12	9.85E-12	1.21E-11	1.36E-11	1.40E-11
Sn117	4.69E-11	4.45E-11	4.45E-11	4.52E-11	4.54E-11
Sn118	7.00E-08	6.93E-08	6.96E-08	7.01E-08	7.03E-08
Sn119	1.22E-07	1.19E-07	1.18E-07	1.18E-07	1.18E-07
Sn120	2.92E-06	2.94E-06	2.96E-06	2.98E-06	2.98E-06
Sn121	3.31E-06	3.27E-06	3.26E-06	3.26E-06	3.27E-06
Sn121M	3.30E-07	3.19E-07	3.16E-07	3.17E-07	3.17E-07
Sn122	9.15E-06	9.01E-06	8.97E-06	8.98E-06	8.99E-06
Sn123	3.14E-06	3.05E-06	3.01E-06	3.01E-06	3.01E-06
Sn124	1.59E-05	1.53E-05	1.50E-05	1.50E-05	1.50E-05
Sn126	3.92E-05	3.76E-05	3.68E-05	3.67E-05	3.67E-05
Sb121	8.41E-10	8.31E-10	8.49E-10	8.63E-10	8.67E-10
Sb123	1.41E-07	1.34E-07	1.30E-07	1.29E-07	1.29E-07
Sb124	8.75E-09	1.01E-08	1.10E-08	1.13E-08	1.13E-08
Sb125	5.18E-07	4.95E-07	4.83E-07	4.81E-07	4.81E-07
Sb126	2.64E-07	2.43E-07	2.32E-07	2.29E-07	2.29E-07
Te122	6.45E-12	6.05E-12	6.35E-12	6.65E-12	6.73E-12
Te124	8.51E-10	9.90E-10	1.09E-09	1.12E-09	1.12E-09
Te125	1.82E-12	2.36E-12	2.92E-12	3.18E-12	3.25E-12
Te125M	6.98E-12	1.03E-11	1.38E-11	1.55E-11	1.59E-11

Isotopic input mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
Te126	1.05E-08	9.62E-09	9.13E-09	9.02E-09	9.01E-09
Te127	9.40E-10	9.16E-10	9.12E-10	9.17E-10	9.19E-10
Te127M	1.07E-09	1.20E-09	1.31E-09	1.36E-09	1.38E-09
Te128	5.32E-07	4.95E-07	4.75E-07	4.70E-07	4.69E-07
Te129M	1.14E-07	1.10E-07	1.12E-07	1.14E-07	1.14E-07
Te130	5.03E-05	4.63E-05	4.41E-05	4.36E-05	4.35E-05
I127	3.61E-12	4.30E-12	5.15E-12	5.58E-12	5.69E-12
I129	1.36E-09	1.34E-09	1.36E-09	1.38E-09	1.39E-09
Xe128	3.16E-10	2.85E-10	2.67E-10	2.62E-10	2.61E-10
Xe130	3.33E-09	3.01E-09	2.84E-09	2.79E-09	2.79E-09
Xe131	2.52E-09	2.30E-09	2.18E-09	2.15E-09	2.15E-09
Xe132	4.01E-07	3.68E-07	3.49E-07	3.45E-07	3.44E-07
Xe134	5.10E-05	4.71E-05	4.50E-05	4.45E-05	4.44E-05
Xe136	1.01E-03	9.73E-04	9.53E-04	9.48E-04	9.47E-04
Cs133	4.00E-09	3.65E-09	3.46E-09	3.42E-09	3.42E-09
Cs134	6.33E-08	5.79E-08	5.50E-08	5.44E-08	5.43E-08
Cs135	1.28E-06	1.17E-06	1.11E-06	1.09E-06	1.09E-06
Cs136	9.41E-06	8.70E-06	8.33E-06	8.25E-06	8.25E-06
Cs137	2.55E-04	2.45E-04	2.40E-04	2.39E-04	2.39E-04
Ba134	3.83E-11	3.53E-11	3.40E-11	3.38E-11	3.39E-11
Ba135	1.16E-09	1.05E-09	9.98E-10	9.86E-10	9.85E-10
Ba136	6.80E-06	6.29E-06	6.02E-06	5.96E-06	5.96E-06

Isotopic input mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
Ba137	5.13E-07	4.67E-07	4.42E-07	4.36E-07	4.35E-07
Ba137M	7.11E-07	6.48E-07	6.14E-07	6.06E-07	6.05E-07
Ba138	1.56E-05	1.44E-05	1.38E-05	1.37E-05	1.37E-05
Ba140	5.97E-04	5.77E-04	5.67E-04	5.64E-04	5.63E-04
La138	1.24E-08	1.13E-08	1.07E-08	1.05E-08	1.05E-08
La139	6.62E-07	6.18E-07	5.94E-07	5.89E-07	5.88E-07
La140	2.11E-06	1.92E-06	1.82E-06	1.80E-06	1.79E-06
Ce140	3.04E-09	2.76E-09	2.61E-09	2.58E-09	2.58E-09
Ce141	1.10E-07	1.02E-07	9.82E-08	9.73E-08	9.72E-08
Ce142	1.28E-06	1.19E-06	1.14E-06	1.13E-06	1.13E-06
Ce144	3.92E-04	3.90E-04	3.88E-04	3.87E-04	3.87E-04
Pr141	3.94E-11	3.86E-11	3.82E-11	3.81E-11	3.80E-11
Pr143	1.28E-08	1.20E-08	1.15E-08	1.15E-08	1.14E-08
Pr144	1.22E-08	1.12E-08	1.07E-08	1.07E-08	1.06E-08
Nd142	5.85E-14	5.36E-14	5.14E-14	5.11E-14	5.11E-14
Nd143	3.06E-11	3.04E-11	3.03E-11	3.03E-11	3.03E-11
Nd144	3.79E-10	3.49E-10	3.35E-10	3.32E-10	3.32E-10
Nd145	5.78E-08	5.66E-08	5.60E-08	5.58E-08	5.58E-08
Nd146	3.85E-07	3.76E-07	3.71E-07	3.70E-07	3.70E-07
Nd147	6.56E-06	6.45E-06	6.38E-06	6.36E-06	6.35E-06
Nd148	4.68E-05	4.52E-05	4.43E-05	4.41E-05	4.41E-05
Nd150	2.12E-04	2.15E-04	2.17E-04	2.18E-04	2.18E-04

Isotopic input mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
Pm147	2.69E-10	2.54E-10	2.47E-10	2.46E-10	2.45E-10
Pm148	2.74E-10	2.55E-10	2.51E-10	2.52E-10	2.53E-10
Pm148M	9.64E-10	8.92E-10	8.69E-10	8.71E-10	8.73E-10
Sm147	5.83E-12	5.86E-12	5.89E-12	5.89E-12	5.89E-12
Sm148	7.01E-13	6.70E-13	6.61E-13	6.63E-13	6.63E-13
Sm149	5.54E-11	5.30E-11	5.20E-11	5.19E-11	5.19E-11
Sm150	1.35E-09	1.24E-09	1.19E-09	1.18E-09	1.18E-09
Sm151	9.98E-09	9.20E-09	8.83E-09	8.77E-09	8.77E-09
Sm152	1.16E-06	1.11E-06	1.09E-06	1.09E-06	1.08E-06
Sm154	9.73E-06	9.69E-06	9.72E-06	9.74E-06	9.75E-06
Eu151	1.34E-12	1.29E-12	1.28E-12	1.29E-12	1.29E-12
Eu152	9.78E-12	9.04E-12	8.76E-12	8.76E-12	8.78E-12
Eu153	1.13E-09	1.08E-09	1.07E-09	1.07E-09	1.07E-09
Eu154	3.10E-09	2.84E-09	2.72E-09	2.71E-09	2.71E-09
Eu155	4.14E-07	4.15E-07	4.18E-07	4.20E-07	4.20E-07
Eu156	2.79E-07	2.58E-07	2.48E-07	2.46E-07	2.46E-07
Gd152	3.01E-13	3.00E-13	3.00E-13	3.00E-13	3.00E-13
Gd154	2.39E-12	2.28E-12	2.27E-12	2.30E-12	2.31E-12
Gd155	3.84E-11	3.60E-11	3.55E-11	3.58E-11	3.59E-11
Gd156	8.58E-10	7.82E-10	7.45E-10	7.39E-10	7.38E-10
Gd157	7.37E-09	6.84E-09	6.60E-09	6.58E-09	6.58E-09
Gd158	5.48E-08	5.21E-08	5.12E-08	5.12E-08	5.12E-08

Isotopic input mass vector					
Isotope	**1st Cycle**	**2nd Cycle**	**5th Cycle**	**10th Cycle**	**15th Cycle**
Gd160	1.18E-06	1.27E-06	1.35E-06	1.37E-06	1.37E-06
Tb159	3.82E-10	3.61E-10	3.55E-10	3.57E-10	3.57E-10
Tb160	1.50E-09	1.43E-09	1.43E-09	1.44E-09	1.44E-09
Dy160	1.13E-12	1.08E-12	1.10E-12	1.12E-12	1.13E-12
Dy161	1.69E-11	1.65E-11	1.67E-11	1.70E-11	1.71E-11
Dy162	2.33E-09	2.18E-09	2.13E-09	2.14E-09	2.15E-09
Dy163	2.40E-09	2.26E-09	2.22E-09	2.24E-09	2.24E-09
Dy164	8.11E-09	7.78E-09	7.77E-09	7.86E-09	7.89E-09
Ho165	5.47E-11	5.35E-11	5.48E-11	5.60E-11	5.64E-11
Er166	1.21E-13	1.43E-13	1.73E-13	1.89E-13	1.93E-13
Er167	1.47E-12	1.60E-12	1.81E-12	1.92E-12	1.96E-12
Er168	3.05E-11	3.37E-11	3.75E-11	3.94E-11	3.99E-11

Appendix 2: Detailed isotopic mass fraction output (discharged burn-up 50 GWd/ tHM).

Isotopic output mass vector					
Isotope	**1st Cycle**	**2nd Cycle**	**5th Cycle**	**10th Cycle**	**15th Cycle**
IDs	***kg/tIHM***	***kg/tIHM***	***kg/tIHM***	***kg/tIHM***	***kg/tIHM***
He4	8.68E+00	1.53E+01	2.06E+01	2.24E+01	2.28E+01
Ra228	5.29E-14	4.50E-14	3.83E-14	3.59E-14	3.53E-14
Th228	3.45E-06	4.55E-06	8.08E-06	1.03E-05	1.09E-05
Th229	9.25E-07	1.16E-06	2.04E-06	2.57E-06	2.69E-06
Th230	4.02E-04	4.84E-04	7.47E-04	9.10E-04	9.51E-04
Th231	4.16E-07	4.46E-07	6.11E-07	7.07E-07	7.29E-07
Th232	6.21E-04	5.26E-04	4.44E-04	4.13E-04	4.05E-04
Th233	1.19E-09	9.44E-10	7.58E-10	6.94E-10	6.77E-10
Pa231	1.87E-04	2.09E-04	2.79E-04	3.20E-04	3.29E-04
Pa233	9.84E-06	9.50E-06	9.15E-06	9.01E-06	8.97E-06
Pa234	1.57E-07	1.54E-07	1.51E-07	1.50E-07	1.49E-07
U232	5.19E-04	6.54E-04	1.06E-03	1.31E-03	1.38E-03
U233	1.21E-03	1.59E-03	2.47E-03	3.00E-03	3.14E-03
U234	3.01E+01	4.15E+01	7.66E+01	9.80E+01	1.03E+02
U235	2.39E+03	2.85E+03	3.22E+03	3.34E+03	3.37E+03
U236	8.48E+02	7.93E+02	7.39E+02	7.16E+02	7.10E+02
U237	3.49E+00	3.23E+00	3.00E+00	2.91E+00	2.88E+00
U238	9.17E+05	9.03E+05	8.84E+05	8.74E+05	8.72E+05
Np236	2.58E-04	3.26E-04	3.97E-04	4.27E-04	4.35E-04
Np236M	1.10E-05	1.09E-05	1.08E-05	1.07E-05	1.07E-05
Np237	2.41E+02	2.43E+02	2.42E+02	2.41E+02	2.40E+02
Np238	5.87E-01	5.07E-01	4.39E-01	4.14E-01	4.07E-01
Np239	8.38E+01	7.69E+01	7.15E+01	6.94E+01	6.89E+01
Pu236	1.53E-03	1.90E-03	2.78E-03	3.31E-03	3.44E-03
Pu237	6.70E-04	1.94E-03	4.95E-03	6.78E-03	7.23E-03
Pu238	2.39E+02	6.67E+02	1.62E+03	2.17E+03	2.31E+03
Pu239	1.24E+04	1.71E+04	2.31E+04	2.60E+04	2.69E+04
Pu240	8.33E+03	1.18E+04	1.63E+04	1.85E+04	1.92E+04
Pu241	4.82E+03	7.04E+03	9.50E+03	1.06E+04	1.08E+04
Pu242	1.74E+03	3.25E+03	6.08E+03	8.09E+03	8.80E+03
Pu243	3.88E-01	5.50E-01	7.36E-01	8.30E-01	8.59E-01
Pu244	7.80E-02	2.68E-01	4.25E-01	4.84E-01	5.00E-01
Am240	1.22E-05	2.57E-05	4.31E-05	5.11E-05	5.32E-05

Isotopic output mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
Am241	2.69E+02	5.74E+02	9.67E+02	1.15E+03	1.19E+03
Am242	4.70E-01	7.74E-01	1.03E+00	1.11E+00	1.13E+00
Am242M	4.63E+00	1.15E+01	2.17E+01	2.67E+01	2.80E+01
Am243	4.56E+02	1.05E+03	1.76E+03	2.10E+03	2.20E+03
Am244	2.23E-02	4.40E-02	6.31E-02	7.08E-02	7.31E-02
Am244M	1.38E-02	2.73E-02	3.91E-02	4.39E-02	4.53E-02
Cm242	7.48E+01	1.38E+02	1.88E+02	2.03E+02	2.06E+02
Cm243	2.29E+00	5.76E+00	8.45E+00	9.25E+00	9.41E+00
Cm244	1.98E+02	6.46E+02	1.03E+03	1.18E+03	1.23E+03
Cm245	1.88E+01	8.19E+01	1.35E+02	1.54E+02	1.59E+02
Cm246	1.62E+00	7.38E+00	9.52E+00	9.83E+00	9.89E+00
Cm247	2.72E-02	1.54E-01	1.98E-01	2.04E-01	2.04E-01
Cm248	2.02E-03	1.25E-02	1.43E-02	1.39E-02	1.37E-02
Bk249	3.14E-05	2.28E-04	2.73E-04	2.69E-04	2.66E-04
Cf249	6.65E-06	6.01E-05	7.81E-05	7.90E-05	7.85E-05
Zn70	4.16E-03	4.18E-03	4.22E-03	4.24E-03	4.25E-03
Zn72	3.41E-05	3.42E-05	3.48E-05	3.52E-05	3.53E-05
Ga71	7.79E-03	8.06E-03	8.29E-03	8.37E-03	8.39E-03
Ge72	1.94E-02	1.90E-02	1.90E-02	1.91E-02	1.92E-02
Ge73	3.99E-02	3.91E-02	3.90E-02	3.91E-02	3.91E-02
Ge74	9.75E-02	9.41E-02	9.32E-02	9.34E-02	9.35E-02
Ge76	4.51E-01	4.37E-01	4.33E-01	4.33E-01	4.33E-01
Ge77	4.44E-04	4.42E-04	4.44E-04	4.47E-04	4.48E-04
Ge78	1.65E-04	1.64E-04	1.64E-04	1.64E-04	1.65E-04
Ge80	4.71E-07	4.63E-07	4.59E-07	4.58E-07	4.58E-07
As75	1.96E-01	1.89E-01	1.87E-01	1.87E-01	1.87E-01
As77	1.60E-03	1.59E-03	1.60E-03	1.61E-03	1.61E-03
As78	1.78E-04	1.78E-04	1.78E-04	1.78E-04	1.78E-04
As79	3.63E-05	3.59E-05	3.59E-05	3.59E-05	3.60E-05
As80	4.74E-07	4.66E-07	4.62E-07	4.61E-07	4.61E-07
As81	1.85E-06	1.83E-06	1.81E-06	1.81E-06	1.81E-06
As82	2.37E-07	2.35E-07	2.32E-07	2.31E-07	2.30E-07
As82M	2.36E-08	2.36E-08	2.36E-08	2.37E-08	2.37E-08
As83	7.05E-08	6.96E-08	6.88E-08	6.85E-08	6.85E-08
Se77	1.05E+00	1.02E+00	1.01E+00	1.01E+00	1.01E+00
Se78	3.03E+00	2.96E+00	2.92E+00	2.92E+00	2.92E+00
Se79	6.66E+00	6.43E+00	6.32E+00	6.31E+00	6.31E+00

Isotopic output mass vector					
Isotope	**1st Cycle**	**2nd Cycle**	**5th Cycle**	**10th Cycle**	**15th Cycle**
Se79M	1.58E-05	1.56E-05	1.56E-05	1.56E-05	1.57E-05
Se80	1.48E+01	1.41E+01	1.37E+01	1.36E+01	1.36E+01
Se81	3.21E-04	3.16E-04	3.13E-04	3.13E-04	3.13E-04
Se81M	9.98E-05	9.80E-05	9.73E-05	9.73E-05	9.73E-05
Se82	3.93E+01	3.81E+01	3.75E+01	3.73E+01	3.72E+01
Se83	6.84E-04	6.77E-04	6.72E-04	6.70E-04	6.70E-04
Se83M	1.89E-06	1.87E-06	1.86E-06	1.85E-06	1.85E-06
Se84	1.32E-04	1.31E-04	1.29E-04	1.29E-04	1.29E-04
Se85	5.34E-06	5.25E-06	5.18E-06	5.16E-06	5.15E-06
Se86	3.61E-07	3.54E-07	3.48E-07	3.46E-07	3.45E-07
Se87	1.26E-10	1.23E-10	1.21E-10	1.20E-10	1.20E-10
Br79	3.39E-03	3.27E-03	3.22E-03	3.22E-03	3.22E-03
Br81	2.73E+01	2.61E+01	2.55E+01	2.53E+01	2.53E+01
Br82	3.46E-03	3.16E-03	2.97E-03	2.91E-03	2.90E-03
Br83	5.30E-03	5.24E-03	5.20E-03	5.19E-03	5.19E-03
Br84	1.88E-03	1.86E-03	1.84E-03	1.84E-03	1.84E-03
Br84M	2.23E-05	2.20E-05	2.20E-05	2.20E-05	2.20E-05
Br85	1.77E-04	1.75E-04	1.73E-04	1.72E-04	1.72E-04
Br86	3.85E-05	3.80E-05	3.76E-05	3.74E-05	3.73E-05
Br87	3.79E-05	3.74E-05	3.70E-05	3.68E-05	3.67E-05
Br88	8.12E-07	8.02E-07	7.91E-07	7.87E-07	7.86E-07
Br89	1.80E-11	1.78E-11	1.75E-11	1.74E-11	1.74E-11
Kr82	1.15E+00	1.07E+00	1.01E+00	9.98E-01	9.94E-01
Kr83	4.49E+01	4.54E+01	4.58E+01	4.60E+01	4.60E+01
Kr84	1.06E+02	1.02E+02	9.87E+01	9.78E+01	9.76E+01
Kr85	2.59E+01	2.51E+01	2.46E+01	2.44E+01	2.44E+01
Kr85M	1.93E-02	1.90E-02	1.88E-02	1.88E-02	1.87E-02
Kr86	1.57E+02	1.53E+02	1.50E+02	1.50E+02	1.49E+02
Kr87	1.06E-02	1.04E-02	1.03E-02	1.02E-02	1.02E-02
Kr88	3.07E-02	3.03E-02	2.99E-02	2.97E-02	2.97E-02
Kr89	5.18E-04	5.10E-04	5.03E-04	5.00E-04	5.00E-04
Kr90	2.10E-05	2.07E-05	2.04E-05	2.03E-05	2.02E-05
Kr91	3.46E-08	3.41E-08	3.36E-08	3.34E-08	3.33E-08
Kr92	7.96E-14	7.88E-14	7.77E-14	7.72E-14	7.71E-14
Rb85	8.82E+01	8.55E+01	8.37E+01	8.31E+01	8.30E+01
Rb87	2.11E+02	2.05E+02	2.00E+02	1.99E+02	1.99E+02
Rb88	3.31E-03	3.26E-03	3.22E-03	3.21E-03	3.21E-03

Isotopic output mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
Rb89	3.65E-03	3.60E-03	3.55E-03	3.53E-03	3.53E-03
Rb90	5.07E-04	4.99E-04	4.92E-04	4.89E-04	4.88E-04
Rb90M	2.24E-04	2.20E-04	2.19E-04	2.19E-04	2.19E-04
Rb91	1.31E-04	1.30E-04	1.28E-04	1.28E-04	1.28E-04
Rb92	1.24E-10	1.23E-10	1.22E-10	1.21E-10	1.21E-10
Rb93	1.94E-09	1.92E-09	1.91E-09	1.90E-09	1.90E-09
Rb94	2.07E-13	2.07E-13	2.05E-13	2.05E-13	2.05E-13
Sr86	4.70E-01	4.45E-01	4.28E-01	4.22E-01	4.21E-01
Sr87	5.79E-03	5.43E-03	5.24E-03	5.19E-03	5.18E-03
Sr88	2.81E+02	2.73E+02	2.67E+02	2.65E+02	2.64E+02
Sr89	1.81E+01	1.77E+01	1.75E+01	1.74E+01	1.74E+01
Sr90	4.36E+02	4.22E+02	4.13E+02	4.10E+02	4.09E+02
Sr91	2.06E-01	2.03E-01	2.01E-01	2.01E-01	2.01E-01
Sr92	6.69E-02	6.62E-02	6.57E-02	6.55E-02	6.55E-02
Sr93	3.38E-03	3.35E-03	3.33E-03	3.33E-03	3.33E-03
Sr94	3.17E-04	3.15E-04	3.13E-04	3.13E-04	3.13E-04
Sr95	1.87E-05	1.86E-05	1.85E-05	1.85E-05	1.85E-05
Sr96	1.77E-13	1.76E-13	1.76E-13	1.75E-13	1.75E-13
Y89	3.53E+02	3.42E+02	3.34E+02	3.31E+02	3.31E+02
Y90	1.13E-01	1.09E-01	1.06E-01	1.05E-01	1.05E-01
Y91	3.03E+01	2.99E+01	2.95E+01	2.94E+01	2.94E+01
Y91M	1.02E-02	1.00E-02	9.93E-03	9.89E-03	9.88E-03
Y92	9.05E-02	8.95E-02	8.88E-02	8.85E-02	8.85E-02
Y93	3.22E-01	3.20E-01	3.18E-01	3.17E-01	3.17E-01
Y94	1.08E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02
Y95	6.31E-03	6.28E-03	6.26E-03	6.25E-03	6.25E-03
Y96	1.29E-09	1.29E-09	1.29E-09	1.28E-09	1.28E-09
Y96M	1.36E-07	1.36E-07	1.35E-07	1.35E-07	1.35E-07
Y97	1.04E-11	1.04E-11	1.03E-11	1.03E-11	1.03E-11
Y97M	1.15E-13	1.15E-13	1.15E-13	1.15E-13	1.15E-13
Y98	7.96E-14	7.96E-14	7.94E-14	7.93E-14	7.93E-14
Y98M	1.76E-13	1.76E-13	1.76E-13	1.76E-13	1.76E-13
Y99	2.08E-13	2.08E-13	2.08E-13	2.07E-13	2.07E-13
Zr90	2.14E+01	2.06E+01	2.00E+01	1.98E+01	1.98E+01
Zr91	5.04E+02	4.90E+02	4.80E+02	4.77E+02	4.77E+02
Zr92	6.37E+02	6.22E+02	6.12E+02	6.09E+02	6.09E+02
Zr93	7.76E+02	7.60E+02	7.51E+02	7.48E+02	7.47E+02

Isotopic output mass vector					
Isotope	**1st Cycle**	**2nd Cycle**	**5th Cycle**	**10th Cycle**	**15th Cycle**
Zr94	8.89E+02	8.72E+02	8.61E+02	8.58E+02	8.58E+02
Zr95	6.20E+01	6.15E+01	6.12E+01	6.11E+01	6.11E+01
Zr96	1.03E+03	1.02E+03	1.01E+03	1.01E+03	1.01E+03
Zr97	7.73E-01	7.71E-01	7.70E-01	7.70E-01	7.70E-01
Zr98	6.87E-05	6.86E-05	6.85E-05	6.85E-05	6.85E-05
Zr99	7.98E-13	7.98E-13	7.98E-13	7.98E-13	7.98E-13
Zr100	3.89E-08	3.89E-08	3.89E-08	3.88E-08	3.88E-08
Zr101	5.16E-13	5.20E-13	5.21E-13	5.21E-13	5.21E-13
Zr102	4.66E-13	4.69E-13	4.69E-13	4.69E-13	4.68E-13
Zr103	6.20E-14	6.27E-14	6.27E-14	6.26E-14	6.25E-14
Nb94	3.37E-03	3.26E-03	3.21E-03	3.20E-03	3.20E-03
Nb95	3.39E+01	3.36E+01	3.34E+01	3.34E+01	3.33E+01
Nb95M	3.78E-02	3.75E-02	3.73E-02	3.73E-02	3.73E-02
Nb96	3.40E-03	3.22E-03	3.08E-03	3.02E-03	3.01E-03
Nb97	5.61E-02	5.59E-02	5.58E-02	5.58E-02	5.58E-02
Nb98	7.06E-06	7.04E-06	7.03E-06	7.03E-06	7.03E-06
Nb98M	2.30E-04	2.27E-04	2.26E-04	2.26E-04	2.26E-04
Nb99	6.58E-06	6.59E-06	6.58E-06	6.58E-06	6.58E-06
Nb99M	1.64E-04	1.62E-04	1.62E-04	1.62E-04	1.62E-04
Nb100	1.04E-08	1.04E-08	1.04E-08	1.04E-08	1.04E-08
Nb100M	1.64E-13	1.63E-13	1.64E-13	1.64E-13	1.65E-13
Nb101	5.41E-08	5.43E-08	5.44E-08	5.44E-08	5.44E-08
Nb102	3.75E-13	3.78E-13	3.79E-13	3.79E-13	3.79E-13
Nb103	3.99E-13	4.03E-13	4.05E-13	4.05E-13	4.05E-13
Nb104	1.77E-10	1.80E-10	1.81E-10	1.81E-10	1.81E-10
Nb105	2.25E-13	2.28E-13	2.29E-13	2.29E-13	2.29E-13
Mo95	8.31E+02	8.20E+02	8.15E+02	8.13E+02	8.13E+02
Mo96	5.76E+01	5.34E+01	5.00E+01	4.88E+01	4.84E+01
Mo97	1.12E+03	1.11E+03	1.10E+03	1.10E+03	1.10E+03
Mo98	1.20E+03	1.19E+03	1.19E+03	1.18E+03	1.18E+03
Mo99	3.61E+00	3.61E+00	3.61E+00	3.61E+00	3.61E+00
Mo100	1.42E+03	1.41E+03	1.41E+03	1.41E+03	1.41E+03
Mo101	1.27E-02	1.27E-02	1.28E-02	1.28E-02	1.28E-02
Mo102	9.76E-03	9.82E-03	9.86E-03	9.87E-03	9.88E-03
Mo103	5.00E-04	5.02E-04	5.04E-04	5.05E-04	5.05E-04
Mo104	3.55E-04	3.59E-04	3.61E-04	3.62E-04	3.62E-04
Mo105	8.39E-05	8.49E-05	8.55E-05	8.57E-05	8.57E-05

Isotopic output mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
Mo106	8.12E-08	8.27E-08	8.36E-08	8.38E-08	8.38E-08
Mo107	1.55E-12	1.59E-12	1.62E-12	1.62E-12	1.62E-12
Tc98	1.28E-02	1.30E-02	1.32E-02	1.33E-02	1.33E-02
Tc99	1.13E+03	1.14E+03	1.14E+03	1.15E+03	1.15E+03
Tc99M	2.92E-01	2.91E-01	2.91E-01	2.91E-01	2.91E-01
Tc101	1.30E-02	1.31E-02	1.31E-02	1.31E-02	1.31E-02
Tc102	7.66E-05	7.71E-05	7.74E-05	7.75E-05	7.75E-05
Tc102M	1.12E-05	1.10E-05	1.09E-05	1.09E-05	1.09E-05
Tc103	7.04E-04	7.07E-04	7.10E-04	7.11E-04	7.12E-04
Tc104	1.68E-02	1.70E-02	1.71E-02	1.72E-02	1.72E-02
Tc105	5.92E-03	5.98E-03	6.03E-03	6.04E-03	6.05E-03
Tc106	9.72E-05	9.89E-05	9.99E-05	1.00E-04	1.00E-04
Tc107	1.22E-05	1.25E-05	1.26E-05	1.27E-05	1.27E-05
Tc108	4.35E-10	4.50E-10	4.58E-10	4.60E-10	4.60E-10
Tc109	4.03E-14	4.16E-14	4.22E-14	4.23E-14	4.23E-14
Ru99	4.75E-02	4.74E-02	4.75E-02	4.75E-02	4.75E-02
Ru100	1.93E+02	1.81E+02	1.71E+02	1.67E+02	1.66E+02
Ru101	1.22E+03	1.23E+03	1.23E+03	1.23E+03	1.23E+03
Ru102	1.41E+03	1.41E+03	1.42E+03	1.42E+03	1.42E+03
Ru103	5.84E+01	5.86E+01	5.88E+01	5.88E+01	5.88E+01
Ru104	1.31E+03	1.33E+03	1.34E+03	1.34E+03	1.34E+03
Ru105	2.27E-01	2.29E-01	2.31E-01	2.31E-01	2.31E-01
Ru106	3.41E+02	3.49E+02	3.54E+02	3.56E+02	3.56E+02
Ru107	1.70E-03	1.74E-03	1.76E-03	1.77E-03	1.77E-03
Ru108	1.40E-03	1.44E-03	1.46E-03	1.46E-03	1.47E-03
Ru109	2.90E-05	2.97E-05	3.02E-05	3.03E-05	3.03E-05
Ru110	1.99E-07	2.06E-07	2.10E-07	2.11E-07	2.11E-07
Ru111	5.17E-14	5.37E-14	5.48E-14	5.51E-14	5.52E-14
Rh103	9.24E+02	9.95E+02	1.06E+03	1.08E+03	1.09E+03
Rh103M	5.73E-02	5.75E-02	5.77E-02	5.78E-02	5.78E-02
Rh105	1.71E+00	1.75E+00	1.77E+00	1.78E+00	1.79E+00
Rh105M	1.72E-04	1.73E-04	1.74E-04	1.75E-04	1.75E-04
Rh106	3.18E-04	3.25E-04	3.29E-04	3.31E-04	3.31E-04
Rh106M	5.85E-04	4.59E-04	3.72E-04	3.44E-04	3.37E-04
Rh107	1.18E-02	1.20E-02	1.21E-02	1.22E-02	1.22E-02
Rh108	9.13E-05	9.37E-05	9.51E-05	9.56E-05	9.57E-05
Rh108M	1.14E-05	1.16E-05	1.18E-05	1.19E-05	1.20E-05

Isotopic output mass vector					
Isotope	**1st Cycle**	**2nd Cycle**	**5th Cycle**	**10th Cycle**	**15th Cycle**
Rh109	2.49E-04	2.55E-04	2.59E-04	2.60E-04	2.61E-04
Rh110	7.56E-08	7.83E-08	7.98E-08	8.02E-08	8.03E-08
Rh111	8.24E-08	8.65E-08	8.88E-08	8.95E-08	8.97E-08
Rh112	3.17E-13	3.31E-13	3.40E-13	3.42E-13	3.43E-13
Pd104	4.82E+02	4.12E+02	3.53E+02	3.31E+02	3.25E+02
Pd105	1.06E+03	1.09E+03	1.11E+03	1.12E+03	1.12E+03
Pd106	7.31E+02	7.39E+02	7.42E+02	7.42E+02	7.42E+02
Pd107	6.82E+02	7.08E+02	7.24E+02	7.29E+02	7.30E+02
Pd108	4.74E+02	4.99E+02	5.13E+02	5.18E+02	5.18E+02
Pd109	2.94E-01	2.98E-01	3.00E-01	3.00E-01	3.00E-01
Pd110	1.56E+02	1.68E+02	1.74E+02	1.76E+02	1.76E+02
Pd111	1.33E-03	1.41E-03	1.45E-03	1.46E-03	1.47E-03
Pd111M	4.36E-05	7.62E-05	9.14E-05	9.49E-05	9.57E-05
Pd112	3.24E-02	3.48E-02	3.61E-02	3.65E-02	3.66E-02
Pd113	1.55E-05	1.66E-05	1.71E-05	1.73E-05	1.73E-05
Pd114	1.90E-05	2.00E-05	2.05E-05	2.06E-05	2.07E-05
Pd115	3.77E-07	3.90E-07	3.98E-07	4.00E-07	4.01E-07
Pd116	1.35E-08	1.36E-08	1.38E-08	1.38E-08	1.39E-08
Ag109	2.30E+02	2.48E+02	2.60E+02	2.65E+02	2.66E+02
Ag110M	1.91E+00	1.94E+00	1.94E+00	1.93E+00	1.92E+00
Ag111	6.71E-01	7.03E-01	7.19E-01	7.23E-01	7.24E-01
Ag111M	6.20E-05	6.54E-05	6.72E-05	6.77E-05	6.78E-05
Ag112	4.85E-03	5.21E-03	5.41E-03	5.47E-03	5.48E-03
Ag113	3.72E-03	3.99E-03	4.12E-03	4.16E-03	4.17E-03
Ag113M	1.66E-05	1.78E-05	1.84E-05	1.85E-05	1.86E-05
Ag115	1.60E-04	1.66E-04	1.69E-04	1.70E-04	1.71E-04
Ag116	1.62E-05	1.63E-05	1.65E-05	1.66E-05	1.66E-05
Ag117	3.70E-06	3.74E-06	3.77E-06	3.79E-06	3.80E-06
Cd110	1.61E+02	1.63E+02	1.60E+02	1.58E+02	1.57E+02
Cd111	7.56E+01	8.08E+01	8.38E+01	8.46E+01	8.47E+01
Cd112	3.60E+01	3.82E+01	3.94E+01	3.98E+01	3.99E+01
Cd113	3.21E-01	5.14E-01	7.73E-01	9.05E-01	9.44E-01
Cd113M	4.81E-03	7.52E-03	1.11E-02	1.30E-02	1.35E-02
Cd114	3.74E+01	3.94E+01	4.04E+01	4.06E+01	4.07E+01
Cd115	2.70E-02	2.79E-02	2.85E-02	2.86E-02	2.87E-02
Cd115M	3.48E-02	3.59E-02	3.66E-02	3.68E-02	3.68E-02
Cd116	1.24E+01	1.22E+01	1.22E+01	1.23E+01	1.23E+01

Isotopic output mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
Cd117	1.09E-03	1.10E-03	1.11E-03	1.12E-03	1.12E-03
Cd117M	3.64E-05	3.62E-05	3.69E-05	3.74E-05	3.76E-05
Cd118	3.29E-04	3.31E-04	3.34E-04	3.36E-04	3.36E-04
Cd119	1.04E-05	1.04E-05	1.05E-05	1.06E-05	1.06E-05
Cd119M	1.45E-06	1.45E-06	1.46E-06	1.48E-06	1.48E-06
Cd120	1.76E-06	1.77E-06	1.79E-06	1.79E-06	1.80E-06
In115	3.41E+00	3.91E+00	4.40E+00	4.62E+00	4.68E+00
In117	1.94E-04	1.95E-04	1.98E-04	1.99E-04	1.99E-04
In117M	6.62E-04	6.67E-04	6.74E-04	6.78E-04	6.79E-04
In119	7.17E-06	7.19E-06	7.26E-06	7.30E-06	7.31E-06
In119M	6.26E-05	6.29E-05	6.33E-05	6.36E-05	6.37E-05
In121	3.01E-07	3.01E-07	3.03E-07	3.05E-07	3.05E-07
In121M	6.99E-06	6.99E-06	7.02E-06	7.04E-06	7.04E-06
Sn115	5.39E-01	5.54E-01	5.65E-01	5.70E-01	5.71E-01
Sn116	4.58E+00	4.41E+00	4.21E+00	4.13E+00	4.11E+00
Sn117	1.10E+01	1.09E+01	1.09E+01	1.09E+01	1.09E+01
Sn118	9.63E+00	9.62E+00	9.68E+00	9.72E+00	9.74E+00
Sn119	9.24E+00	9.24E+00	9.30E+00	9.34E+00	9.35E+00
Sn120	9.28E+00	9.33E+00	9.41E+00	9.46E+00	9.47E+00
Sn121	1.14E-02	1.15E-02	1.15E-02	1.16E-02	1.16E-02
Sn121M	6.05E-01	6.00E-01	6.05E-01	6.08E-01	6.10E-01
Sn122	1.23E+01	1.22E+01	1.22E+01	1.23E+01	1.23E+01
Sn123	7.13E-01	7.13E-01	7.17E-01	7.20E-01	7.21E-01
Sn123M	1.89E-04	1.89E-04	1.91E-04	1.92E-04	1.93E-04
Sn124	1.99E+01	1.95E+01	1.94E+01	1.94E+01	1.94E+01
Sn125M	5.35E-05	5.32E-05	5.32E-05	5.33E-05	5.34E-05
Sn126	4.70E+01	4.58E+01	4.55E+01	4.55E+01	4.55E+01
Sn127	6.79E-03	6.77E-03	6.79E-03	6.80E-03	6.81E-03
Sn127M	5.83E-05	5.81E-05	5.83E-05	5.85E-05	5.85E-05
Sn128	5.79E-03	5.79E-03	5.81E-03	5.83E-03	5.84E-03
Sn129	1.82E-04	1.82E-04	1.83E-04	1.84E-04	1.84E-04
Sn129M	2.98E-04	2.98E-04	2.98E-04	2.98E-04	2.99E-04
Sn130	3.27E-04	3.28E-04	3.28E-04	3.28E-04	3.28E-04
Sn131	3.12E-05	3.14E-05	3.14E-05	3.14E-05	3.14E-05
Sn132	1.99E-05	1.97E-05	1.96E-05	1.95E-05	1.95E-05
Sb121	9.22E+00	9.23E+00	9.31E+00	9.36E+00	9.37E+00
Sb122	5.39E-03	5.04E-03	4.78E-03	4.69E-03	4.67E-03

Isotopic output mass vector					
Isotope	**1st Cycle**	**2nd Cycle**	**5th Cycle**	**10th Cycle**	**15th Cycle**
Sb123	1.12E+01	1.12E+01	1.13E+01	1.13E+01	1.13E+01
Sb124	8.27E-02	7.76E-02	7.40E-02	7.27E-02	7.24E-02
Sb125	1.73E+01	1.69E+01	1.69E+01	1.69E+01	1.69E+01
Sb126	5.89E-03	5.72E-03	5.64E-03	5.63E-03	5.63E-03
Sb127	4.17E-01	4.16E-01	4.17E-01	4.18E-01	4.18E-01
Sb128	5.82E-02	5.81E-02	5.83E-02	5.84E-02	5.85E-02
Sb128M	7.09E-05	7.04E-05	7.04E-05	7.06E-05	7.07E-05
Sb129	5.91E-02	5.91E-02	5.93E-02	5.94E-02	5.95E-02
Sb130	7.68E-03	7.68E-03	7.69E-03	7.69E-03	7.69E-03
Sb130M	1.15E-03	1.15E-03	1.16E-03	1.16E-03	1.16E-03
Sb131	1.17E-02	1.17E-02	1.18E-02	1.18E-02	1.18E-02
Sb132	9.56E-04	9.52E-04	9.48E-04	9.47E-04	9.47E-04
Sb132M	4.98E-04	5.04E-04	5.07E-04	5.07E-04	5.07E-04
Sb133	6.38E-04	6.43E-04	6.43E-04	6.42E-04	6.41E-04
Sb134M	5.16E-08	5.18E-08	5.17E-08	5.15E-08	5.15E-08
Te122	8.68E-01	8.29E-01	7.97E-01	7.86E-01	7.83E-01
Te124	5.97E-01	5.72E-01	5.52E-01	5.44E-01	5.42E-01
Te125	9.72E+00	9.43E+00	9.34E+00	9.34E+00	9.34E+00
Te125M	2.21E-01	2.16E-01	2.15E-01	2.15E-01	2.15E-01
Te126	1.01E+00	9.54E-01	9.25E-01	9.19E-01	9.18E-01
Te127	4.14E-02	4.14E-02	4.16E-02	4.18E-02	4.18E-02
Te127M	3.59E-01	4.03E-01	4.41E-01	4.54E-01	4.58E-01
Te128	1.79E+02	1.74E+02	1.72E+02	1.72E+02	1.72E+02
Te129M	6.66E-03	6.68E-03	6.86E-03	6.97E-03	7.00E-03
Te130	6.20E+02	6.12E+02	6.08E+02	6.08E+02	6.08E+02
Te131	1.51E-02	1.51E-02	1.52E-02	1.52E-02	1.52E-02
Te131M	2.03E-01	2.01E-01	2.00E-01	2.01E-01	2.01E-01
Te132	4.48E+00	4.48E+00	4.48E+00	4.49E+00	4.49E+00
Te133	9.20E-03	9.22E-03	9.22E-03	9.21E-03	9.21E-03
Te133M	3.04E-02	3.05E-02	3.05E-02	3.05E-02	3.05E-02
Te134	4.52E-02	4.53E-02	4.53E-02	4.53E-02	4.52E-02
Te135	1.04E-05	1.04E-05	1.04E-05	1.04E-05	1.04E-05
Te136	2.89E-06	2.92E-06	2.91E-06	2.91E-06	2.90E-06
Te137	8.76E-14	8.78E-14	8.72E-14	8.68E-14	8.67E-14
I127	1.06E+02	1.04E+02	1.03E+02	1.03E+02	1.03E+02
I128	3.72E-04	3.44E-04	3.27E-04	3.21E-04	3.20E-04
I129	3.27E+02	3.23E+02	3.22E+02	3.22E+02	3.23E+02

Isotopic output mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
I130	1.33E-02	1.06E-02	8.86E-03	8.34E-03	8.22E-03
I130M	9.14E-05	7.23E-05	6.03E-05	5.67E-05	5.58E-05
I132	1.38E-01	1.38E-01	1.38E-01	1.38E-01	1.38E-01
I133	1.70E+00	1.70E+00	1.70E+00	1.70E+00	1.70E+00
I133M	2.23E-08	2.20E-08	2.20E-08	2.21E-08	2.21E-08
I134	7.89E-02	7.91E-02	7.91E-02	7.91E-02	7.91E-02
I134M	4.94E-04	4.92E-04	4.94E-04	4.95E-04	4.95E-04
I135	5.26E-01	5.27E-01	5.28E-01	5.28E-01	5.28E-01
I136	4.15E-04	4.19E-04	4.20E-04	4.20E-04	4.20E-04
I136M	8.25E-05	8.30E-05	8.33E-05	8.33E-05	8.34E-05
I137	2.71E-05	2.72E-05	2.72E-05	2.72E-05	2.72E-05
I138	5.11E-09	5.13E-09	5.12E-09	5.11E-09	5.11E-09
I139	1.43E-13	1.44E-13	1.43E-13	1.43E-13	1.42E-13
Xe128	9.68E+00	9.08E+00	8.68E+00	8.56E+00	8.53E+00
Xe130	1.28E+01	1.06E+01	9.15E+00	8.70E+00	8.59E+00
Xe131	6.81E+02	6.98E+02	7.17E+02	7.25E+02	7.27E+02
Xe132	1.81E+03	1.77E+03	1.74E+03	1.73E+03	1.73E+03
Xe133	9.90E+00	9.90E+00	9.90E+00	9.90E+00	9.90E+00
Xe133M	5.95E-02	5.92E-02	5.91E-02	5.91E-02	5.92E-02
Xe134	2.21E+03	2.21E+03	2.21E+03	2.21E+03	2.20E+03
Xe135	3.00E-01	3.84E-01	4.65E-01	4.96E-01	5.04E-01
Xe135M	3.49E-03	3.48E-03	3.49E-03	3.50E-03	3.50E-03
Xe136	3.19E+03	3.00E+03	2.83E+03	2.76E+03	2.74E+03
Xe137	3.96E-03	3.97E-03	3.97E-03	3.97E-03	3.97E-03
Xe138	1.51E-02	1.51E-02	1.51E-02	1.51E-02	1.51E-02
Xe139	1.32E-04	1.32E-04	1.32E-04	1.32E-04	1.32E-04
Xe140	1.95E-06	1.96E-06	1.95E-06	1.95E-06	1.94E-06
Xe141	1.72E-13	1.73E-13	1.72E-13	1.72E-13	1.71E-13
Cs133	1.63E+03	1.64E+03	1.65E+03	1.66E+03	1.66E+03
Cs134	2.13E+02	2.02E+02	1.92E+02	1.88E+02	1.87E+02
Cs134M	7.99E-03	7.35E-03	6.84E-03	6.66E-03	6.61E-03
Cs135	9.91E+02	1.16E+03	1.32E+03	1.38E+03	1.40E+03
Cs135M	2.01E-04	2.19E-04	2.39E-04	2.47E-04	2.49E-04
Cs136	1.13E+00	1.19E+00	1.24E+00	1.26E+00	1.27E+00
Cs137	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03
Cs138	4.21E-02	4.22E-02	4.22E-02	4.23E-02	4.23E-02
Cs138M	1.89E-04	1.88E-04	1.89E-04	1.89E-04	1.90E-04

Isotopic output mass vector					
Isotope	**1st Cycle**	**2nd Cycle**	**5th Cycle**	**10th Cycle**	**15th Cycle**
Cs139	1.03E-02	1.03E-02	1.03E-02	1.03E-02	1.03E-02
Cs140	4.84E-04	4.87E-04	4.87E-04	4.87E-04	4.87E-04
Cs141	3.59E-05	3.60E-05	3.59E-05	3.59E-05	3.59E-05
Cs142	3.76E-13	3.79E-13	3.79E-13	3.78E-13	3.78E-13
Cs143	2.11E-13	2.13E-13	2.12E-13	2.12E-13	2.11E-13
Ba134	1.02E+02	9.78E+01	9.33E+01	9.15E+01	9.10E+01
Ba135	9.11E-01	8.33E-01	7.62E-01	7.35E-01	7.28E-01
Ba136	5.82E+01	5.95E+01	6.13E+01	6.20E+01	6.22E+01
Ba137	8.45E+01	8.43E+01	8.43E+01	8.42E+01	8.42E+01
Ba137M	2.80E-04	2.80E-04	2.80E-04	2.80E-04	2.80E-04
Ba138	1.83E+03	1.83E+03	1.83E+03	1.83E+03	1.83E+03
Ba139	1.00E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01
Ba140	2.13E+01	2.13E+01	2.13E+01	2.13E+01	2.13E+01
Ba141	1.91E-02	1.91E-02	1.91E-02	1.91E-02	1.91E-02
Ba142	9.69E-03	9.69E-03	9.69E-03	9.69E-03	9.69E-03
Ba143	4.64E-06	4.65E-06	4.64E-06	4.63E-06	4.63E-06
Ba144	9.80E-07	9.82E-07	9.79E-07	9.77E-07	9.77E-07
Ba145	5.62E-11	5.65E-11	5.64E-11	5.63E-11	5.62E-11
Ba146	1.38E-13	1.38E-13	1.38E-13	1.37E-13	1.37E-13
La138	3.19E-02	3.20E-02	3.24E-02	3.26E-02	3.26E-02
La139	1.70E+03	1.70E+03	1.71E+03	1.71E+03	1.71E+03
La140	3.00E+00	2.99E+00	2.98E+00	2.98E+00	2.98E+00
La141	2.57E-01	2.57E-01	2.57E-01	2.57E-01	2.57E-01
La142	9.43E-02	9.44E-02	9.44E-02	9.44E-02	9.44E-02
La143	1.31E-02	1.31E-02	1.31E-02	1.31E-02	1.31E-02
La144	1.91E-04	1.91E-04	1.91E-04	1.90E-04	1.90E-04
La145	2.99E-05	2.99E-05	2.99E-05	2.99E-05	2.99E-05
La146	5.19E-09	5.22E-09	5.21E-09	5.20E-09	5.19E-09
La147	1.66E-11	1.68E-11	1.69E-11	1.68E-11	1.68E-11
La148	5.29E-14	5.39E-14	5.41E-14	5.40E-14	5.39E-14
Ce140	1.72E+03	1.72E+03	1.72E+03	1.72E+03	1.72E+03
Ce141	5.09E+01	5.09E+01	5.09E+01	5.09E+01	5.09E+01
Ce142	1.51E+03	1.50E+03	1.50E+03	1.49E+03	1.49E+03
Ce143	1.93E+00	1.93E+00	1.93E+00	1.93E+00	1.93E+00
Ce144	3.45E+02	3.45E+02	3.44E+02	3.44E+02	3.44E+02
Ce145	1.73E-03	1.73E-03	1.73E-03	1.73E-03	1.73E-03
Ce146	7.29E-03	7.31E-03	7.32E-03	7.32E-03	7.31E-03

Isotopic output mass vector					
Isotope	1st Cycle	2nd Cycle	5th Cycle	10th Cycle	15th Cycle
Ce147	1.62E-04	1.63E-04	1.64E-04	1.64E-04	1.64E-04
Ce148	1.05E-04	1.06E-04	1.06E-04	1.06E-04	1.06E-04
Ce149	5.06E-10	5.13E-10	5.15E-10	5.15E-10	5.15E-10
Ce150	7.10E-12	7.20E-12	7.23E-12	7.23E-12	7.22E-12
Pr141	1.50E+03	1.49E+03	1.49E+03	1.49E+03	1.49E+03
Pr142	5.02E-02	4.18E-02	3.63E-02	3.46E-02	3.41E-02
Pr143	1.84E+01	1.84E+01	1.83E+01	1.83E+01	1.83E+01
Pr144	1.46E-02	1.46E-02	1.46E-02	1.45E-02	1.45E-02
Pr145	2.47E-01	2.47E-01	2.47E-01	2.47E-01	2.47E-01
Pr146	1.39E-02	1.39E-02	1.39E-02	1.39E-02	1.39E-02
Pr147	6.12E-03	6.14E-03	6.15E-03	6.15E-03	6.15E-03
Pr148	6.66E-04	6.71E-04	6.74E-04	6.74E-04	6.74E-04
Pr149	4.40E-04	4.43E-04	4.45E-04	4.45E-04	4.45E-04
Pr150	5.37E-09	5.44E-09	5.46E-09	5.46E-09	5.46E-09
Pr151	2.16E-06	2.19E-06	2.20E-06	2.20E-06	2.20E-06
Pr152	1.11E-12	1.14E-12	1.15E-12	1.15E-12	1.15E-12
Pr153	4.74E-12	4.87E-12	4.92E-12	4.92E-12	4.92E-12
Nd142	2.61E+01	2.26E+01	2.02E+01	1.94E+01	1.92E+01
Nd143	1.08E+03	1.14E+03	1.18E+03	1.19E+03	1.20E+03
Nd144	1.18E+03	1.11E+03	1.07E+03	1.05E+03	1.05E+03
Nd145	8.50E+02	8.61E+02	8.69E+02	8.72E+02	8.73E+02
Nd146	9.45E+02	9.35E+02	9.26E+02	9.22E+02	9.21E+02
Nd147	7.40E+00	7.43E+00	7.45E+00	7.45E+00	7.45E+00
Nd148	5.44E+02	5.48E+02	5.50E+02	5.50E+02	5.50E+02
Nd149	3.13E-02	3.14E-02	3.15E-02	3.15E-02	3.15E-02
Nd150	3.17E+02	3.23E+02	3.25E+02	3.26E+02	3.26E+02
Nd151	2.10E-03	2.12E-03	2.13E-03	2.13E-03	2.13E-03
Nd152	1.37E-03	1.39E-03	1.40E-03	1.41E-03	1.41E-03
Nd153	7.74E-06	7.91E-06	8.00E-06	8.02E-06	8.03E-06
Nd154	2.43E-06	2.48E-06	2.51E-06	2.52E-06	2.52E-06
Nd155	5.92E-09	6.11E-09	6.20E-09	6.22E-09	6.22E-09
Pm147	2.14E+02	2.24E+02	2.33E+02	2.36E+02	2.37E+02
Pm148	1.23E+00	1.18E+00	1.13E+00	1.11E+00	1.10E+00
Pm148M	2.50E+00	3.03E+00	3.52E+00	3.71E+00	3.75E+00
Pm149	1.31E+00	1.25E+00	1.20E+00	1.18E+00	1.18E+00
Pm150	5.68E-04	4.30E-04	3.40E-04	3.12E-04	3.05E-04
Pm151	3.06E-01	3.09E-01	3.11E-01	3.12E-01	3.12E-01

Isotopic output mass vector					
Isotope	**1st Cycle**	**2nd Cycle**	**5th Cycle**	**10th Cycle**	**15th Cycle**
Pm152	5.36E-04	5.44E-04	5.49E-04	5.50E-04	5.51E-04
Pm152M	2.23E-05	2.22E-05	2.23E-05	2.24E-05	2.25E-05
Pm153	4.38E-04	4.47E-04	4.52E-04	4.54E-04	4.54E-04
Pm154	1.19E-04	1.21E-04	1.23E-04	1.23E-04	1.23E-04
Pm154M	7.93E-06	8.04E-06	8.14E-06	8.19E-06	8.21E-06
Pm155	7.76E-06	7.97E-06	8.10E-06	8.14E-06	8.14E-06
Pm156	1.36E-06	1.40E-06	1.42E-06	1.42E-06	1.43E-06
Pm157	1.11E-08	1.15E-08	1.17E-08	1.18E-08	1.18E-08
Sm147	1.10E+02	1.16E+02	1.21E+02	1.23E+02	1.23E+02
Sm148	2.33E+02	2.35E+02	2.35E+02	2.34E+02	2.34E+02
Sm149	3.99E+00	5.88E+00	8.40E+00	9.66E+00	1.00E+01
Sm150	4.49E+02	4.45E+02	4.38E+02	4.35E+02	4.34E+02
Sm151	2.41E+01	3.28E+01	4.34E+01	4.82E+01	4.96E+01
Sm152	1.69E+02	1.76E+02	1.82E+02	1.84E+02	1.85E+02
Sm153	1.31E+00	1.24E+00	1.18E+00	1.16E+00	1.15E+00
Sm154	8.79E+01	9.04E+01	9.18E+01	9.21E+01	9.22E+01
Sm155	9.81E-04	9.98E-04	1.01E-03	1.01E-03	1.01E-03
Sm156	1.67E-02	1.71E-02	1.74E-02	1.75E-02	1.75E-02
Sm157	1.40E-04	1.45E-04	1.48E-04	1.49E-04	1.49E-04
Sm158	5.01E-05	5.23E-05	5.36E-05	5.39E-05	5.40E-05
Eu151	4.26E-02	7.87E-02	1.36E-01	1.67E-01	1.77E-01
Eu152	3.83E-02	7.45E-02	1.30E-01	1.59E-01	1.67E-01
Eu153	2.26E+02	2.30E+02	2.30E+02	2.30E+02	2.30E+02
Eu154	6.58E+01	7.23E+01	7.57E+01	7.62E+01	7.62E+01
Eu155	1.78E+01	1.79E+01	1.78E+01	1.77E+01	1.77E+01
Eu156	6.56E+00	5.47E+00	4.56E+00	4.24E+00	4.16E+00
Eu157	2.45E-02	2.35E-02	2.27E-02	2.24E-02	2.23E-02
Eu158	5.55E-04	5.79E-04	5.93E-04	5.97E-04	5.97E-04
Eu159	1.07E-04	1.13E-04	1.16E-04	1.17E-04	1.17E-04
Eu160	4.83E-07	5.16E-07	5.34E-07	5.39E-07	5.40E-07
Gd152	9.36E-02	1.33E-01	1.74E-01	1.90E-01	1.95E-01
Gd154	7.39E+00	7.86E+00	8.00E+00	7.97E+00	7.95E+00
Gd155	2.53E-01	3.78E-01	5.37E-01	6.13E-01	6.35E-01
Gd156	1.84E+02	1.64E+02	1.48E+02	1.42E+02	1.40E+02
Gd157	2.99E-01	4.25E-01	5.96E-01	6.82E-01	7.07E-01
Gd158	5.13E+01	5.23E+01	5.25E+01	5.25E+01	5.24E+01
Gd159	1.01E-02	1.03E-02	1.04E-02	1.04E-02	1.04E-02

Isotopic output mass vector					
Isotope	**1st Cycle**	**2nd Cycle**	**5th Cycle**	**10th Cycle**	**15th Cycle**
Gd160	3.50E+00	3.81E+00	4.00E+00	4.06E+00	4.07E+00
Gd161	4.27E-06	4.64E-06	4.85E-06	4.91E-06	4.93E-06
Tb159	7.49E+00	8.09E+00	8.45E+00	8.56E+00	8.58E+00
Tb160	2.32E-01	2.40E-01	2.40E-01	2.38E-01	2.38E-01
Tb161	1.77E-02	1.83E-02	1.85E-02	1.85E-02	1.85E-02
Dy160	8.35E-01	9.09E-01	9.45E-01	9.53E-01	9.54E-01
Dy161	1.22E+00	1.39E+00	1.51E+00	1.55E+00	1.56E+00
Dy162	8.37E-01	8.67E-01	8.79E-01	8.83E-01	8.83E-01
Dy163	7.33E-01	7.37E-01	7.36E-01	7.36E-01	7.36E-01
Dy164	2.65E-01	3.02E-01	3.28E-01	3.37E-01	3.39E-01
Dy166	8.77E-05	1.03E-04	1.12E-04	1.15E-04	1.16E-04
Ho165	3.05E-01	2.46E-01	2.00E-01	1.85E-01	1.81E-01
Er166	1.01E-01	8.48E-02	7.40E-02	7.10E-02	7.03E-02
Er167	5.37E-03	5.40E-03	5.63E-03	5.80E-03	5.85E-03
Er168	1.59E-02	1.55E-02	1.53E-02	1.53E-02	1.53E-02

Appendix 3: Mid-cycle 1-group cross sections of most important actinides

n,fission 1-group cross-sections (BU 25.0 GWd/tHM)					
Isotope	**1st Cycle**	**2nd Cycle**	**5th Cycle**	**10th Cycle**	**15th Cycle**
IDs	***Weighted using the total neutron flux***				
U232	13.03000	12.58000	12.16000	11.99000	11.95000
U233	36.62000	32.72000	29.69000	28.60000	28.31000
U234	0.53730	0.54750	0.55640	0.55990	0.56090
U235	19.49000	16.46000	14.19000	13.41000	13.21000
U236	0.34140	0.34410	0.34560	0.34620	0.34630
U238	0.11510	0.11740	0.11950	0.12040	0.12060
Np237	0.59220	0.60380	0.61380	0.61780	0.61890
Pu238	1.99100	1.94600	1.90700	1.89200	1.88800
Pu239	37.21000	30.57000	25.24000	23.35000	22.85000
Pu240	0.63200	0.63350	0.64140	0.64480	0.64580
Pu241	44.62000	37.34000	31.66000	29.68000	29.16000
Pu242	0.47570	0.48550	0.49370	0.49700	0.49790
Pu244	0.39960	0.40710	0.41380	0.41660	0.41730
Am241	0.88110	0.84230	0.81370	0.80380	0.80120
Am242m	225.30000	178.10000	142.40000	130.10000	126.90000
Am243	0.48200	0.48670	0.49130	0.49320	0.49380
Cm242	0.46030	0.45180	0.44670	0.44540	0.44520
Cm243	54.19000	48.18000	43.39000	41.61000	41.14000
Cm244	0.85870	0.86690	0.87310	0.87550	0.87620
Cm245	56.16000	46.60000	39.38000	36.88000	36.23000
Cm246	0.63800	0.64370	0.64820	0.65000	0.65060
Cm247	31.66000	27.41000	24.71000	23.75000	23.51000
Cm248	0.79750	0.80700	0.81290	0.81490	0.81540
Cm250	0.51710	0.52760	0.53670	0.54040	0.54140
Bk249	1.23600	1.10700	1.00800	0.97290	0.96390
Cf249	99.24000	83.99000	73.21000	69.39000	68.41000
Cf250	14.16000	10.94000	9.61600	9.19400	9.08800
Cf251	281.40000	233.90000	200.10000	188.20000	185.10000
Cf252	4.89000	4.65100	4.46400	4.39500	4.37700

n,gamma 1-group cross-sections (BU 25.0 GWd/tHM)					
Isotope	**1st Cycle**	**2nd Cycle**	**5th Cycle**	**10th Cycle**	**15th Cycle**
IDs	***Weighted using the total neutron flux***				
U232	9.93600	9.47600	9.05300	8.89100	8.84800
U233	5.13200	4.70300	4.34400	4.20800	4.17200
U234	18.25000	17.52000	16.80000	16.51000	16.44000
U235	5.77700	5.23500	4.80800	4.65400	4.61400
U236	8.78900	8.62200	8.40400	8.31100	8.28600
U238	0.86360	0.85360	0.84440	0.84120	0.84040
Np237	25.32000	23.07000	21.20000	20.48000	20.29000
Pu238	13.80000	11.52000	9.67000	9.01600	8.84600
Pu239	20.28000	16.77000	13.90000	12.86000	12.59000
Pu240	96.03000	43.53000	31.49000	28.26000	27.52000
Pu241	15.51000	12.82000	10.73000	10.00000	9.81000
Pu242	35.01000	24.37000	15.76000	12.99000	12.27000
Pu244	3.17500	3.18300	3.16500	3.15200	3.14800
Am241	57.23000	48.59000	41.91000	39.47000	38.83000
Am242m	42.33000	33.36000	26.52000	24.16000	23.55000
Am243	49.34000	44.65000	40.91000	39.46000	39.08000
Cm242	3.64700	3.53400	3.42200	3.37600	3.36400
Cm243	8.22500	7.32300	6.60000	6.33400	6.26400
Cm244	16.09000	15.78000	15.27000	15.02000	14.95000
Cm245	8.34800	6.92000	5.82900	5.45300	5.35500
Cm246	3.41600	3.34000	3.25200	3.21700	3.20700
Cm247	15.69000	13.38000	11.92000	11.40000	11.26000
Cm248	6.65400	6.59000	6.45700	6.39100	6.37100
Cm250	50.64000	49.42000	47.97000	47.36000	47.19000
Bk249	157.10000	132.70000	113.80000	107.10000	105.40000
Cf249	34.82000	29.50000	25.78000	24.45000	24.11000
Cf250	342.00000	292.80000	258.80000	246.30000	243.00000
Cf251	121.70000	100.30000	84.83000	79.42000	78.02000
Cf252	2.02900	1.91500	1.81900	1.78300	1.77400