

The Fusion-Fission Hybrid Revisited: Preliminary Analysis of a Fusion Driven Thorium Burner

Vincent Tang, Ronald R. Parker

MIT Plasma Science and Fusion Center, 167 Albany Street, Cambridge, MA 02139, USA

3/17/2001

Abstract

The fusion-fission hybrid is revisited with the emphasis of meeting Rubbia's "nuclear revival" requirements laid out in his sub-critical thorium burner study. We postulate that an inherently safe and simple blanket with modest power density, long operating time, high resistance to proliferation, and minimum fuel management needs can provide superior performance compared with existing light-water reactors and planned accelerator systems. One feasible engineering design is presented in detail. Key characteristics of such a Tokamak Fusion-Fission Hybrid Reactor configuration utilizing a U233-Th232 Lead-Lithium Blanket are discussed. The analysis consists of simulating a 10-year burn-up at constant power. No fuel reprocessing occurs, with the exception of tritium, which is extracted continuously. The reactor is modeled via an infinite cylinder approximation, and isotopes are tracked using three neutronics codes: MCNP4C, ORIGEN2.1, and MonteBurns1.0. Burn-up results show that even with engineering considerations, a 10+ year burn-up at 3250MWt using the parameters of the ITER-FEAT tokamak and only ~1/5 of its blanket is easily achieved, while satisfying the "inherently safe and simple" concept. The hybrid is also shown to process better actinide burning performance compared with an accelerator concept. Long-lived fission product waste levels are comparable, however. Future work required includes a detailed 2-D neutronics and hydraulics model, optimization study, and an economic analysis to confirm our postulate.

Introduction

The use of the thorium-uranium fuel cycles has been examined in many reactor analyses^{1,10,14-16,23}. Compared with the uranium-plutonium cycle, designs utilizing Th-U fuels have some advantages, such as greater fertile fuel supply, less radioactivity, and in general, none of the stigma associated with plutonium. In the last decade, there have been several proposed accelerator driven sub-critical systems utilizing the Th-U cycle. Specifically, Rubbia's thorium burner study²³ addresses many of the key issues that are important for long-term viable nuclear power. As the CERN study states, the criteria for new designs are:

- 1) Extremely high level of inherent safety
- 2) Minimal production of long lived waste and elimination of the need of the geologic repositories
- 3) High resistance to diversion, since latent proliferation is a major concern.
- 4) More efficient use of a widely available natural fuel, without the need of isotopic separation
- 5) Lower cost of the heat produced and higher operation temperature than conventional PWRs in order to permit competitive generation of substitutes to fossil fuels. Substitution fuels are necessary to allow a widespread utilization of the energy source and to permit retrofitting of existing facilities, now operating with CO₂ producing fuels.

Can a fusion-fission Th-U hybrid achieve these same goals while providing better performance? Ever since fusion's inception, numerous papers and studies have been performed concerning fusion driven systems designed to burn LWR wastes and/or breed fissile LWR fuel^{3,5-9,11-19,21,22,24-27}. Fewer papers have looked at pure fusion-fission hybrids, due to the premise that breeders and waste burners are a better way to utilize the neutron/energy imbalance duality of fusion and fission^{12,14}.

However, in light of the above revival criteria, we believe the fusion-fission power hybrid is a better use of excess fusion neutrons, since it might be possible to develop blanket power modules for fusion hybrids that burns its own wastes, while processing extremely long operating periods without fuel management (i.e. upwards of 10 years). The fusion-fission LWR fissile breeders symbiosis, on the other hand, will have large fuel management needs, coupled with the inability of LWRs to meet Rubbia's requirements. On the other hand, fusion-fission waste burners should be studied as a solution to the current weapons and LWR waste stockpile. Of course, realistically, any Th-U hybrid will probably need to use stockpile plutonium for startup, since there is no supply of U233.

Given the above, the accelerator driven sub-critical system is the fusion hybrid's main competitor. We believe that a fusion neutron source might have advantages relative to an accelerator source, since:

- 1) Compared with an accelerator, a fusion neutron source can potentially have a self-gain greater than one; an accelerator will always have a self-gain of less than one.
- 2) A fusion source can produce a sharp spectrum of 14 MeV neutrons, compared with the distributed spectrum of an accelerator source.
- 3) 14 MeV neutrons can induce various neutron-multiplying reactions easily, can fission all actinides, processes a higher actinide fission-to-capture ratio, and essentially bypasses fission products. This gives designers more neutrons to work with, and more flexibility in allocating those neutrons to specific tasks.

The fusion-fission hybrid, however, has some disadvantages compared with accelerators:

- 1) A fusion-fission hybrid might have more safety problems, as it basically combines a fusion reactor with a fission reactor in a tight system.
- 2) Using a fusion source instead of an accelerator source will require tritium, and therefore will increase overall radioactivity. Also, the blanket must be tritium self-sufficient
- 3) The blanket geometry in fusion reactors is not ideal fission reactor geometry. Specifically, a tokamak fission blanket will have very high fuel inventory, compared with an accelerator driven fission reactor.
- 4) Arguably, accelerator sources are technologically more developed than fusion neutron sources.

On the other hand, it is our belief that some of these disadvantages can be nullified; for example, high fuel loading is not a shortcoming if the reactor is only refueled once a decade or longer. We feel that an inherently safe and simple blanket with modest power density, long operating time, high resistance to proliferation, and minimum fuel management needs can provide superior performance compared with existing light-water reactors and planned accelerator systems. To that end, this paper illustrates our preliminary neutronics work on Th-U designs, which, with an admittedly slightly arbitrary design, pinpoints a workable blanket regime for future detailed analysis.

Design Basis

Because of the large number of variables in a hybrid, several characteristics and specifications we believe will satisfy our above thesis were chosen for a design basis. They consist of:

- 1) Using ITER-FEAT parameters for the fusion source and physical blanket layout. ITER is a mature tokamak design, and if constructed, its blanket modules test bed might be a good place to operate and experiment with hybrid modules.
- 2) Using Pb83-Li17 as both coolant and tritium breeder. Pb-Li has good thermodynamic properties, such as large heat capacity, low melting point, and good thermal conductivity. Its reactivity with water and air is low. Previous ARIES studies have shown it to be a good low-cost neutron multiplier and tritium breeder. However, Pb-Li has some chemical compatibility issues with structural materials.
- 3) No enrichment of Li-6. This will lower coolant costs.
- 4) No online processing except for tritium purges and no reshuffling of fuel during burn-up. In keeping with our design philosophy, we want to minimize fuel management and outages to lower costs. Also, akin to Rubbia's thorium burner, this will allow the hybrid blanket modules to be essentially sealed and operated as a nuclear battery, thus increasing proliferation resistance.
- 5) Very long operating period between refueling (i.e. upwards of 10 years). Again, this follows from our premise of keeping fuel management and outages to a minimum. Maintenance periods, however, will be dictated by structural damage.
- 6) No actinide waste stream; all actinides stay on site and are eventually burned. The waste stream, if any, can only consist of fission products and actinide leakage during reprocessing. This implies that at least part of the neutron spectrum in the reactor must be fast.
- 7) Relatively low keffs, <.97. Sub-criticality and lower keffs will increase the inherent safety of the system. However, careful accident analysis must be performed, since total fuel loading is high.
- 8) Use of denser fuels, which, according to previous sub-critical studies⁹, were found to achieve better performance compared with oxide fuels. We chose carbide fuel, since it is well developed.
- 9) Use of carbon moderator, if moderator is needed. Graphite moderators are simple and very understood.
- 10) No fuel or other actinides in the inboard blanket. Actinides in the inboard blanket will most likely complicate tokamak operation, due to increase neutron flux from fission.

- 11) The system must be tritium and uranium-233 self-sufficient; specifically, enough tritium must be produced continuously during operation, and enough U-233 must be produced for the next operating fuel cycle.
- 12) The minimum hybrid output is ~3000MWt.

In summary, we are primarily interested in fast to epithermal sub-critical systems based on a Th-U cycle, cooled by lead-lithium, which use only carbon as moderator. The above constraints leave the initial fuel/coolant/moderator ratios and starting U233 fuel fraction as the main neutronics design variables.

Analysis Path

Many configurations were analyzed; however, we discuss one of these in detail, in order to highlight fundamental issues of a Th-U fast fusion fission hybrid, and to provide a feasible engineering solution. The design is by no means optimized, but it is capable of meeting all of our requirements and more.

Blanket Model

Table 1 Beginning of Life(BOL) Summary

Section Description	Radial Thickness (cm)	Materials(vol%)	Notes
Center Post	323	Center Post	
Inner Shield	33.7	SS316 (20%), H ₂ O(80%)	Neutron sink
Inner Blanket	45.1	SS316(10%), PbLi(65%), C(25%)	T Breeding
Inner First Wall	0.2	SS316(100%)	
Plasma	448		
Outer First Wall	0.2	SS316(100%)	
Blanket Section 1-7	45.1 total, 5.65 per section	SS316(10%), Fuel(35%) ¹ , PbLi(55%)	
Blanket Section 8	5.65	SS316(10%), Fuel(45%) ² , PbLi(45%)	U Breeder
Outer Shield	50	SS316(10%), PbLi(65%), C(25%)	T Breeding
¹ Section 1-7 fuel atomic ratio: UC/ThC=10.5%			
² Section 8 fuel atomic ratio: UC/ThC=0%			
Fuel Loading Summary		Material Densities	
Total U233: 14.1 tons Total Th232: 160 tons		ThC density: 10.0 gm/cc UC density: 13.63 gm/cc PbLi density: 9.15 gm/cc(500C) SS316 density: 7.98 gm/cc	

The reactor neutronics model consists of an infinite cylinder divided into 14 concentric sections. The first 6 sections make up the center post, inner shield, inner blanket, inner first wall, plasma, and outer first wall. The remaining 9 sections are composed of the outer blanket divided into 8 parts and the outer shield. Figure 1 and Table 1 provides dimensions and loading summary. Roughly, the dimensions follow those of the proposed ITER-FEAT Tokamak, with the exception of a 50cm extended outer blanket section. Total power and inventory calculations are based on a 2m high blanket, and thus, approximately ~20% of the available blanket area in ITER-FEAT. Since the fission modules occupy only a fraction of the total blanket, it may not be necessary to breed tritium in them, as long as the rest of the blanket can meet the total tritium requirement.

Transport and burn-up calculations was performed with MCNP4C and ORIGEN v2.1, coupled by MonteBurns v1.0. A burn-up time of 11 years was chosen, with MCNP4C runs to update one-group cross sections 2 times a year. A MonteBurns importance factor of .001 was used, and 121 of the available isotopes were explicitly tracked with MCNP4C, and thus, had updated irradiation one-group cross sections every 6 months. The rest of the isotopes used the cross sections in the ORIGEN2.1 FFTFC library. Finally, 99% of the total helium and hydrogen was purged every 6 months. No other processing occurred.

The loading in each outer blanket section is assumed to be homogenous. Realistically, we envision typical fuel rod-coolant configurations. However, the smear model should be adequate for preliminary analysis. Furthermore, our engineering blanket uses SS316 steel, and is assumed to be 10%vol total for both structure and cladding.

Our model provides good estimates on power densities, fuel utilization, and fuel and tritium breeding. However, because not every isotope could be followed, and thus, not every decay chain tracked and carried through each ORIGEN-MCNP exchange, individual fission product results are not completely accurate for some nuclei. Nevertheless, based on comparative runs, the net fission product cross-section is pretty accurate and certainly better than using the lumped fission product cross sections (i.e 45117 & 46119 in MCNP). Additionally, inventories for the tracked long-lived fission products are not affected, since their parents decay quickly compared with the 182.5 days burnup intervals. All in all, these problems are caused by the lack of MCNP cross sections for many isotopes, and aggravated by the processing time required.

For a complete list of nuclei tracked and followed, see appendix A.

Finally, coolant mixing is not modeled, and therefore, the Li-6 enrichment in each section is incorrect vs. time. Each section calculates its own Li-6 burnup (i.e. tritium production). This exaggerates results per section, since sections with lower than the correct amount Li-6 will have higher keff, while sections with higher than the correct amount will have a lower keff. For the outer sections, the effect is small, since the Li-6 burnup is roughly the same in all 8 sections and outer shield. The inner blanket, however, suffers very large Li-6 burnups compared with the outer sections, and therefore, in the model, is a better reflector. This still should not be drastic, since the BOL atomic fraction of Li-6 in all sections is only ~0.5%.

Results and Discussion

Table 2 End of 11 Years (EOL) Operating Summary

Table 2 End of 11 Years (EOL) Operating Summary		
Main System Parameters		
Total Power(MWt)		3250
14 MeV Keff Range		0.900 to 0.9233
Kcode Keff Range		0.821 to 0.853
Source Required(n/s)		3.29x10 ¹⁹ to 2.62 x10 ¹⁹
Wall Loading Required(MW/m ²)		0.517 to 0.412, ~90% of ITER-FEAT max.
Neutron Spectrum ¹		Fast; >~60% are >100 keV, >~10% are >1MeV
Fuel Utilization		
Fuel Burnup(GWd/MTHM)		21.0 to 118, 77.2 avg.
Power Density (W/cc)		39.2 to 95.8, 65.6 avg.
Thorium Usage		10.11% Burned, 160 tons BOL, 144 tons EOL
U233 Breeding Ratio		104.3%, 14.1 tons BOL, 14.7 tons EOL (w/out ~0.14 tons Pa233 EOL)
U/Th Ratio		11.1% for section 1-7, 5.52% for section 8
Tritium Breeding		
Tritium Breeding Ratio		138.4% to 111.8%, 125.7% avg
Tritium Production(kg/182.5d)		2.909 avg.
Li-6 Depletion		40.8% Burned
Selected Inventory and Waste Comparisons ²		
Actinides(tons)		161
Actinides(tons) (w/out Th232, U233, Th233, Pa233)		1.8
Total Fuel and FP EOL Activity(Ci)		1.20x10 ¹⁰
Actinide Activity at EOL(Ci)		5.77x10 ⁹ , 8.10x10 ⁷ w/o Th233 and Pa233
Selected Actinides at EOL(35.8 GWyr)		CERN Thorium Burner at EOL(7.5 GWyr)
Total Pu(tons)	2.94x10 ⁻⁵	7.15x10 ⁻⁵
Np237 (tons)	2.43x10 ⁻⁴	2.889x10 ⁻⁴
Long-Lived Fission Products at EOL		CERN Thorium Burner (normalized by net thermal energy output)
Zr93(kg)	377	421
Tc99(kg)	258	267

I129(kg)	154	130
Cs135(kg)	486	552
1,2 See appendix B for the complete inventory of 121 isotopes vs. time, and a summary of the neutron spectrum for each section vs. time.		

Figure Description and Breakdown

*Figures are attached

Figure 2 plots key system parameters vs. time, and reveals important operating trends of the reactor. The chart shows that our blanket design contains the right operating trends, such as rising keff to lower tritium demand as Li-6 is burned, and self-sufficient U233 breeding. However, the blanket could use better flattening in order to avoid large operating ranges.

Figure 3 plots 14MeV keff and normal keff vs. time. Specifically, full 11-year data is plotted for burn-up with all available fission products and a Monteburns importance factor of 0.001. For comparison, the normal keff is also plotted to show that 14MeV source neutrons have a considerably higher keff.

Figure 4 charts the MCNP effective multiplication factor, and reflects the fact that the system nu remains the same throughout burnup. Also, it shows that a significant portion of the reactor consists of fusion neutrons, due to the use of lower keffs.

Figure 7 and 8 illustrates power density vs. time and blanket sections. The trends are explained by a characteristic of sub-critical systems, namely, exponential power density decay for a sub-critical system. Additionally, the charts illustrate how section 8, the breeding section, shifts more power production to the back of the blanket with burnup; this aids in keeping tritium production in the shield relatively constant even with large total reduction of Li-6.

Because of the large heat capacity and thermo-conductivity of Pb-Li, even a sharp exponential power spectrum is not a problem, much less a linear one. However, it might still be beneficial to flatten out the power spectrum, in order to even out fuel burn-up, and to minimize excessively large temperature driven coolant flows. One possible way to achieve this is by lowering the fuel loading in the front blanket sections, relative to the rear blanket sections. However, the trade-off is additional complexity in blanket design.

Figure 5 and 6 charts burnup vs. time for each blanket section. It is clear that section one to seven's burnup is a linear relationship vs. time. This implies that the relative neutronics of those sections are not changing dramatically with time, since a linear relationship entails that each source fusion neutron into the system induces the same amount of actinide burnup each time. As for the breeding section, the data shows that as more U233 is bred, the greater the effect on burnup per source fusion neutron into the system.

Figure 9 to 12 is a complete summary of all tracked actinides vs. time. Overall, many of the isotopes, including the heavy actinides, do not reach equilibrium during the 11-year period. As expected from the Rubbia study, very few higher actinides are produced, including Np and Pu.

Figure 13 and 14 charts the long-lived fission product buildup vs. time and plots actinide activity vs. time in reactor. Since all actinides are eventually burned, only fission products and actinide leakage contributes to the waste stream.

Figure 15 is a plot of the neutron spectrum at BOL. As expected, the spectrum is hard for fuel blanket sections, and moderated for the shielding sections, due to the carbon moderator.

Figure 16 depicts the effect of Li-6 enrichment on BOL keff. Li-6 acts as a burnable poison and moderator in the system, and thus, decreasing Li-6 increases keff. The blanket configurations analyzed for figure 16 are not the same as the engineering blanket; in particular, they are uncapped non-infinite cylinders. However, the qualitative trends remain the same.

Key Design Variables

Overall, our blanket studies points out several characteristics of U-Th Pb-Li cooled sub-critical systems that confirm reactor theory. These characteristics include large power density ranges for homogenous blankets, a keff trend

resulting from the BOL U/Th ratio, different keffs depending on initial source neutron energies and distribution, and slight feedback based on Li-6 depletion in the coolant. Understanding these key trends and their cross-effects is critical to designing workable non-steady state hybrid systems.

Given that the optimum fusion-fission system fitting our design requirements processes a close-to-flat upside down parabola keff curve, and operates without conflicting trends or large ranges, the key neutronics variables are the BOL U/Th ratio and total fuel loading. Obviously, these variables determine the BOL energy output per source neutron and the possible burnup. However, the BOL U/Th ratio is important in other more subtle ways. Setting this ratio below equilibrium will allow the system to compensate for fission product buildup, and depending on how much lower, raise the keff over time. A rising keff also has the effect of creating the proper tritium requirement trend, effectively compensating for Li-6 burnup (if it is not replenished online); less tritium is needed over time as more Li-6 is depleted. The BOL U/Th effect on keff will remain paramount until a significant portion of the fuel has been burned, since even with 10% fuel burnup, U233 and Th232 remain the largest absorbers in the system.

Another interesting characteristic of fusion-fission systems is the large difference between the normal and operating (14MeV) keff. For our scenario, Figure 3 effectively demonstrates this discrepancy. This effect is a plus for fusion driven systems, since it implies if the plasma is terminated, the blanket has a much lower keff.

Finally, another result concerning tritium breeding is the effect on keff caused by depletion of Li-6. As Li-6 is consumed, the neutron spectrum and flux levels harden, since Li-6 is both an absorber and moderator in the system. Conceivably, this raises keff, as shown by the BOL studies depicted in figure 16. This rise in keff will increase the average flux, and can help keep tritium production up with Li-6 burnup. The global keff effect over the blanket operating lifetime should depend on the initial fraction of Li-6. As suggested by Greenspan⁸, Li-6 depletion might be a good control system, since a harder neutron spectrum bypasses fission product poisoning easier.

Reactor Summary and Comparison

As a reactor design, our engineering blanket is capable of meeting all of our design criteria and more; in fact, the system should be able to easily operate another 10 years with only a coolant Li-6 refueling in order to keep the tritium breeding ratio above one. This can be easily done without touching any of the fuel. Lastly, the design is by no means optimized; for example, a narrower keff band will enable more efficient use of the ITER-FEAT fusion source.

Concerning waste levels, Table 2 demonstrates that the U-Th PbLi fast fusion-fission hybrid operates around the same regime as Rubbia's accelerator concept, but with better performance regarding actinide burning. Specifically, the long-lived fission products produced are approximately equal for the same energy output. As for the actinides, we expect that the EOL mass-to-energy produced ratio for the undesirable actinides should be much more favorable for hybrids since the fission-to-capture ratio for fusion neutrons is higher, and in general, the neutron spectrum is harder. A high fission-to-capture ratio is important since a transmuted actinide has effectively stolen at least two neutrons; one for transmutation, and one for fission. The results confirm our expectations, since the growth rate for the higher actinides is much lower for our hybrid compared with the CERN accelerator system. This is indicated by the fact that the total Pu inventory at EOL for the hybrid is lower than the accelerator's, even though the hybrid produces 4.7 times more energy, and has ~5 times more total actinide inventory. A similar situation is observed for the 237Np inventory. In the end, actinide radioactivity and waste contribution should remain a small concern, due to complete recycling and small leakage. Thus, compared to LWRs, the hybrid produces orders of magnitudes less waste, and has an actinide burning advantage compared with the accelerator. However, because of the hard spectrum, very little fission product transmutation occurs. A possible fission product waste reduction option is burning them in the moderated blanket modules. All in all, we believe that the waste situation is not an issue, and similar to Rubbia's study, a geological depository should not be needed.

Overall, compared with Rubbia's accelerator reactor design, our fusion-fission hybrid delivers ~2.2 times as much power using only ~1/5 of the available blanket, can operate for 10+ years partly due to the high source neutron energies available from fusion, and produces comparable fission product waste levels per burnup. Additionally, the system is inherently safer due to much lower keffs (~0.84 vs. 0.97) and much lower power densities (~70 W/cc vs. ~500W/cc). However, the fusion-fission hybrid does have a much higher fuel loading, and the ITER-FEAT reactor is inherently larger than accelerator driven systems. Also, this preliminary study is obviously not as detailed as

Rubbia's final report, and future detailed reviews might minimize some of our advantages; nevertheless, we feel these positive comparisons will not change radically.

Future Work

In order to further assess the effectiveness of fusion-fission hybrids based on Rubbia's nuclear revival guidelines will require significantly more work. Additional near-term work include retrieving more cross section files, extending the burnup to 20+ years, substituting stockpile Pu for realistic startup, and more detailed analysis of the available data. For the longer term, a detailed 2-D neutronics and hydraulics model, optimization study, and an economic analysis is needed.

Conclusion

The fusion-fission hybrid is revisited with the emphasis of meeting Rubbia's "nuclear revival" requirements laid out in his sub-critical thorium burner study. We postulate that an inherently safe and simple blanket with modest power density, long operating time, high resistance to proliferation, and minimum fuel management needs can provide superior performance compared with existing light-water reactors and even planned accelerator systems. One feasible engineering design is presented in detail. Key design variables and characteristics, such as the BOL U/Th ratio, and keff differences of a Tokamak Fusion-Fission Hybrid Reactor configuration utilizing a U233-Th232 Lead-Lithium Blanket are discussed. Burn-up results shows that even with engineering considerations, a 10+ year burn-up at 3250 MWt using the ITER-FEAT tokamak can be easily achieved, while satisfying the "inherently safe and simple" concept, and at waste levels comparable to Rubbia's accelerator concept. Therefore, additional work into this promising concept is warranted.

Acknowledgment

We take pleasure in thanking Pavel Hejzlar, Holly Trelue, and David Poston for their assistance. This work was supported by DOE.

References

1. Bowman et al, "Nuclear energy generation and waste transmutation using an accelerator-driven intense thermal neutron source", Nuclear Instruments and Methods in Physics Research, **A320**, 336, (1992).
2. Briesmeister, "MCNP-A General MonteCarlo N-Particle Transport Code- Version 4C", LA-13709-M, Los Alamos National Laboratory, (2000).
3. Cheng and Cerbone, "Prospect of Nuclear Waste Transmutation and Power Production in Fusion Reactors", TSI Research, Inc.
4. Croff, "ORGIE 2.1", ORNL/TM-7175, ORNL, (1991).
5. Feng and Huang, "Transmutation of the actinide neptunium-237 with a hybrid reactor", Fusion Engineering and Design, **29**, 64 (1995).
6. Feng and Hu, "Transmutation of nuclear wastes in a fusion breeder", Fusion Engineering and Design, **41**, 449 (1998).
7. Gohar, "Fusion Option to Dispose of Spent Nuclear Fuel and Transuranic Elements", ANL/TD/TM00-09, ANL (2000).
8. Greenspan et al., "Power Density Flattening in Fusion-Fission Hybrid Reactors", Nuclear Technology/Fusion, **3**, 485 (1983).
9. Jassby, Meyer, and Ku, "Fusion-Fission Hybrid Reactors For Burning Depleted Uranium and LWR Spent Fuel", PPPL, (1999).
10. Kimura, "Review of Cooperative Research on Thorium Fuel Cycle As A Promising Energy Source In The Next Century", Progress in Nuclear Energy, **29**, 445 (1995)
11. Lee and Moir, "Fission-Suppressed Blankets for Fissile Fuel Breeding Fusion Reactors", Journal of Fusion Energy, **1**, 299 (1981).
12. Lidsky, "End Product Economics and Fusion Research Program Priorities", Journal of Fusion Energy, **2**, 269 (1982).
13. Lidsky, "Fission-Fusion Symbiosis: General Considerations and a Specific Example", B.N.E.S. Nuclear Fusion Reactor Conference at Culham Laboratory (1969).
14. Lidsky, "Fission-Fusion Systems: Hybrid, Symbiotic and Aqueous", Review Paper.
15. Manheimer, "Back to the Future: The Historical, Scientific, Naval, and Environmental Case for Fission Fusion", Fusion Technology, **36**, 1 (1999).

16. Maniscalco et al., "The Fusion Breeder-An Early Application of Nuclear Fusion", *Fusion Technology*, **6**, 584 (1984).
17. Parish and Davidson, "Reduction in the Toxicity of Fission Product Wastes Through Transmutation with Deuterium-Tritium Fusion Neutrons", *Nuclear Technology*, **47**, 324 (1980).
18. Peng and Cheng, "Magnetic Fusion Driven Transmutation of Nuclear Waste", *Journal of Fusion Energy*, **12**, 381 (1993).
19. Perkins and Hartman, "The Application of a High-Power-Density Fusion Neutron Source To Plutonium Disposition and Driven, Sub-Critical Fission", UCRL-JC-120150, LLNL (1995).
20. Poston and Trellue, "Monteburns Version 1.0", LA-UR-99-4999, Los Alamos National Laboratory, (1999).
21. Qiu et al, "A low aspect ratio tokamak transmutation system", *Nuclear Fusion*, **40**, 629 (2000).
22. Qiu et al., "A low aspect ratio tokamak transmutation reactor", *Fusion Engineering and Design*, **41**, 437 (1998).
23. Rubbia et al., "Conceptual Design Of A Fast Neutron Operated High Power Energy Amplifier", CERN/AT/95-44(ET), CERN, (1995).
24. Stacey et al., "A Transmutation Facility for Weapons Grade Plutonium Disposition Based on a Tokamak Fusion Neutron Source", *Fusion Technology*, **27**, 327 (1995).
25. Tsutsui et al., "Transmutation of fission products by high-field tokamak reactor with force-balanced coils", *Fusion Engineering and Design*, **41**, 431 (1998).
26. Xiao and Qiu, "Neutronics study and analysis of a multifunctional blanket", *Fusion Engineering and Design*, **41**, 589 (1998).
27. Yaptic et al., "Potential of a fusion-fission hybrid reactor using uranium for various coolants to breed fissile fuel for LWRs", *Annals of Nuclear Energy*, **26**, 821 (1999).

Figure One, Infinite Cylinder ITER-FEAT Neutronics Model, Dimensions in cm

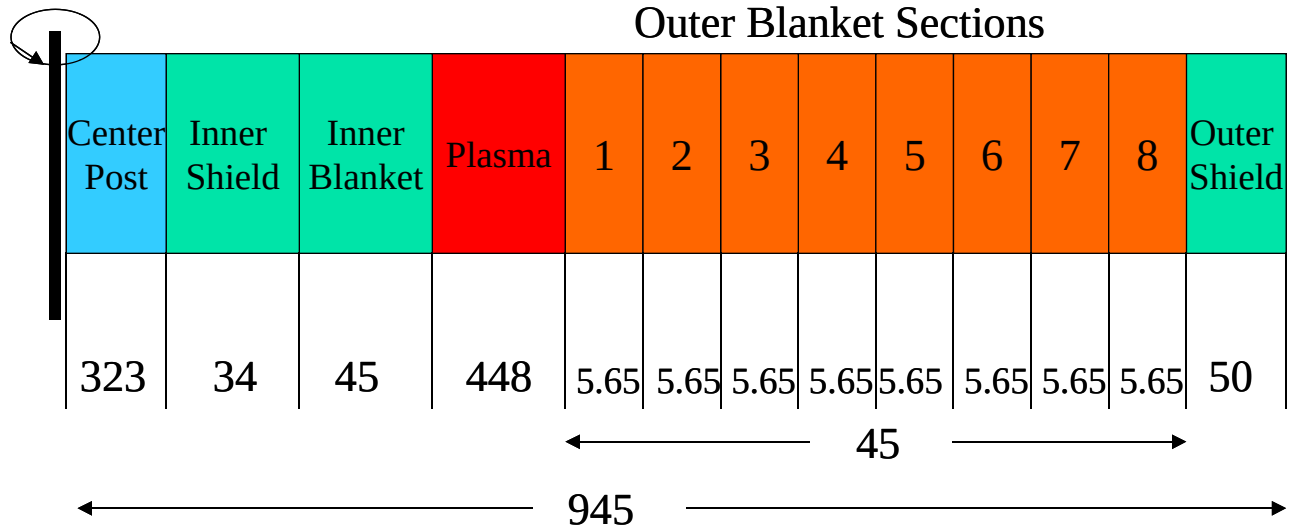
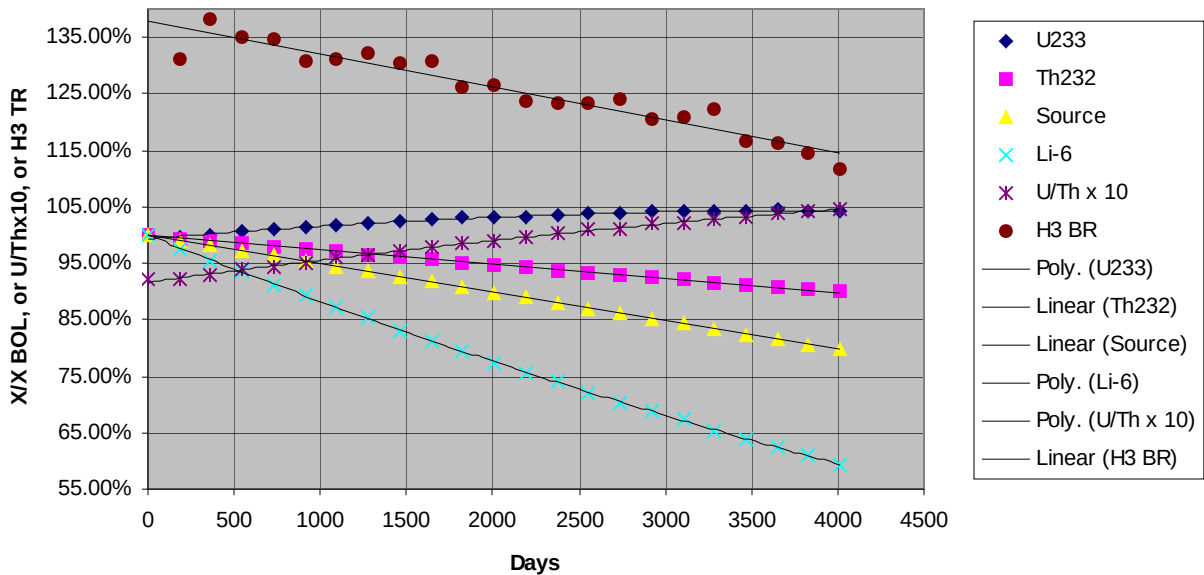


Figure 2
Key System Parameters-U233, Th232, Li-6 Source, U/Th, and H3 BR vs. Time



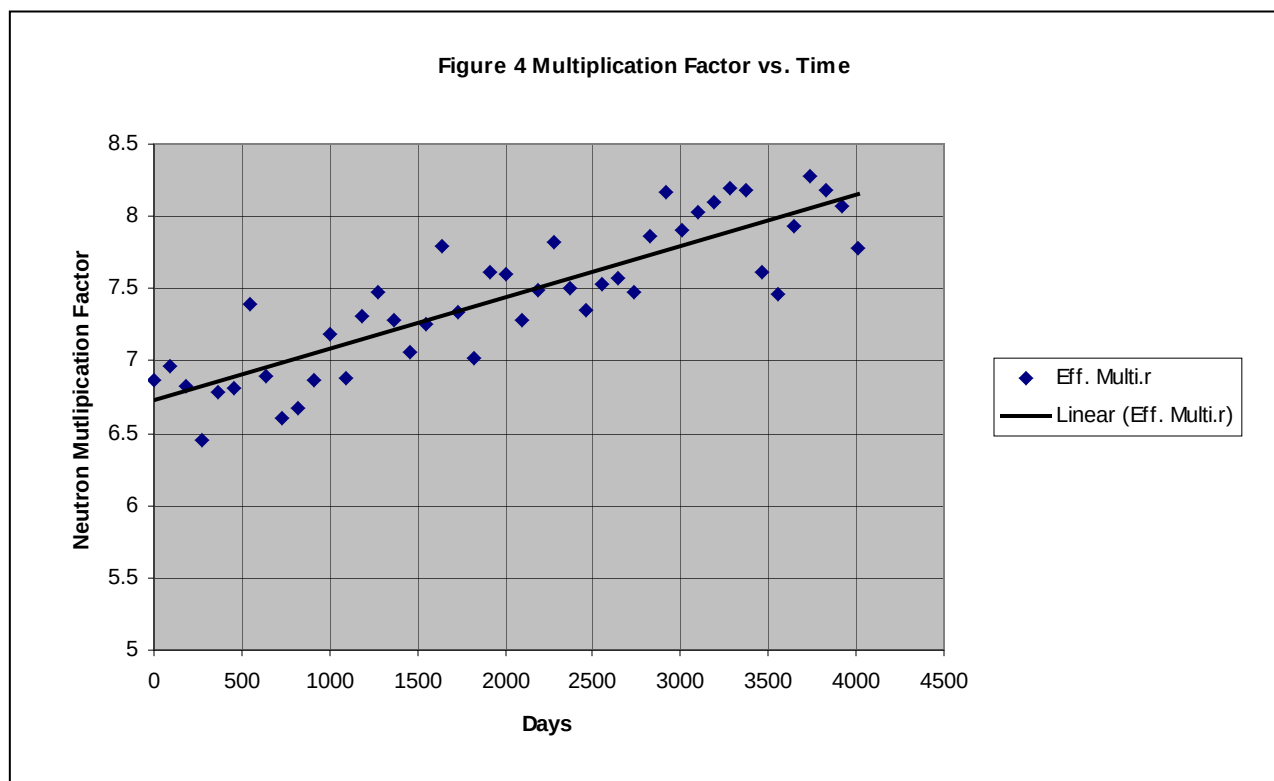
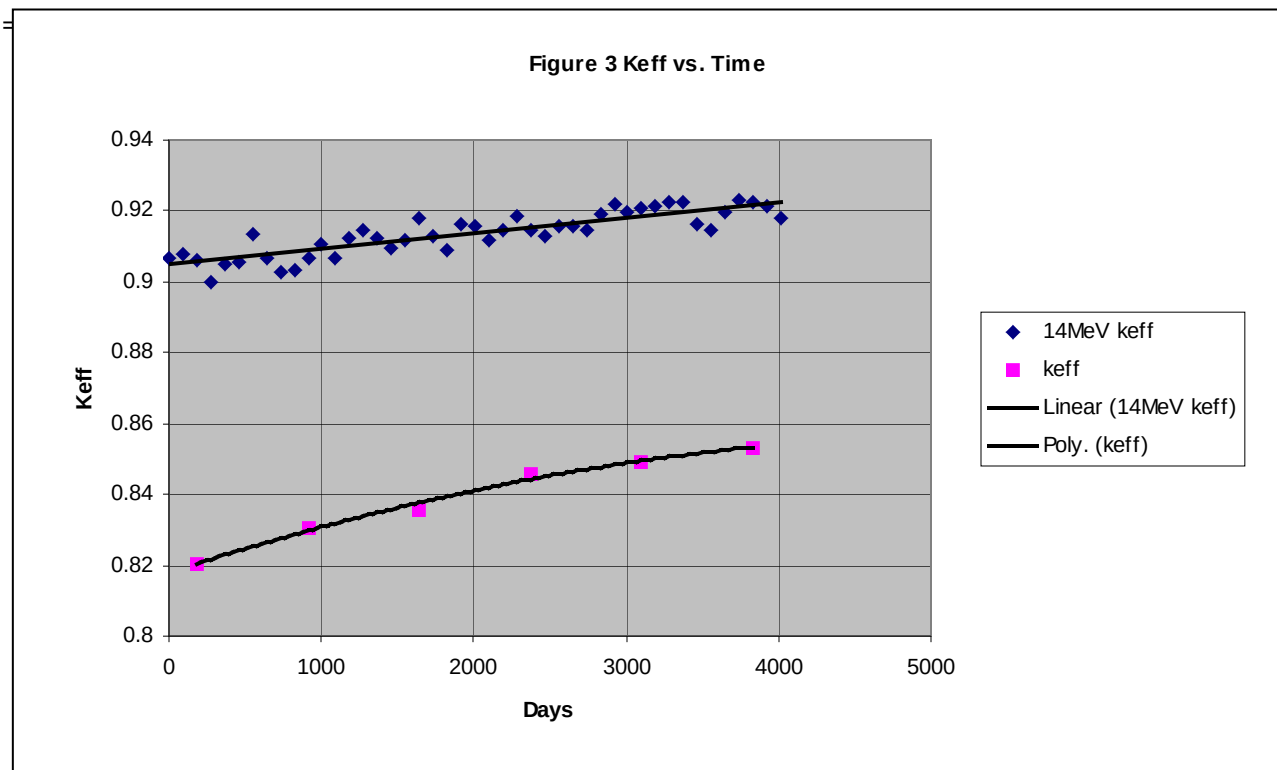


Figure 5 Burnup vs. Section

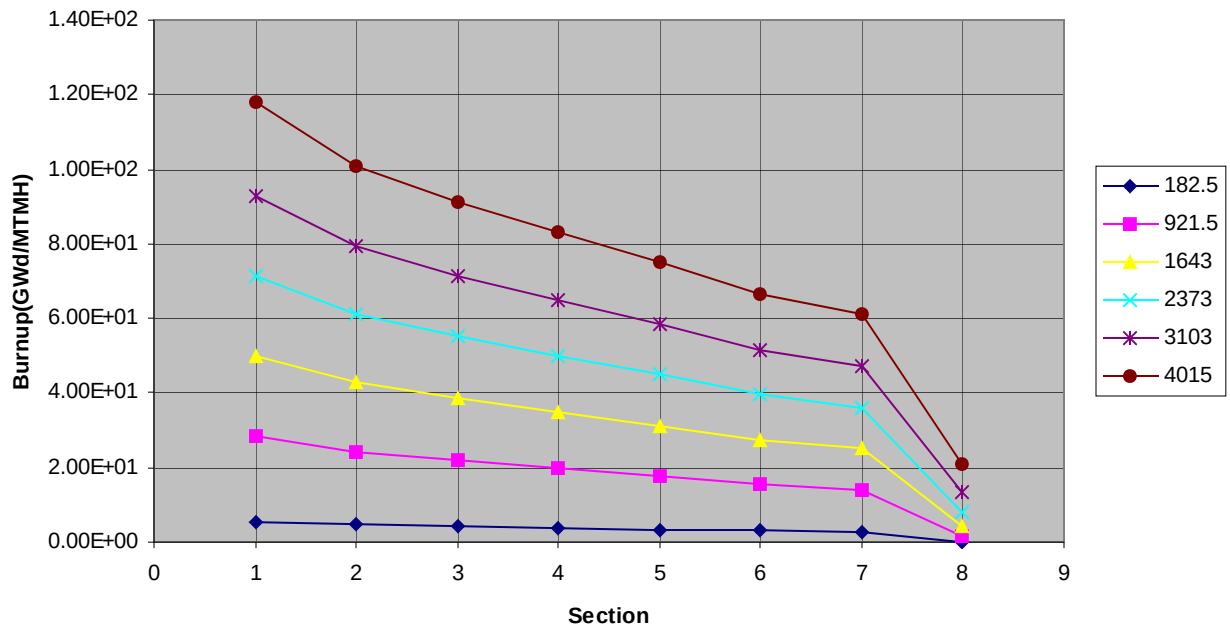


Figure 6 Burnup vs. Time

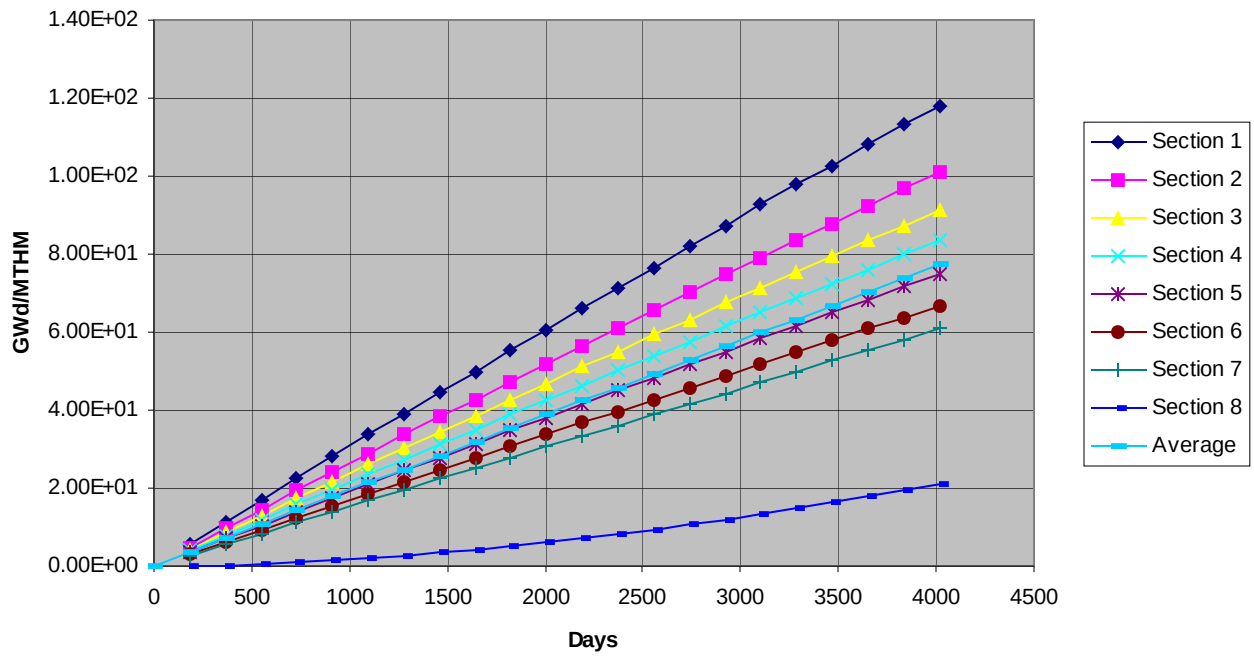


Figure 7 Power Density vs. Time for Section 1-8 and Avg.

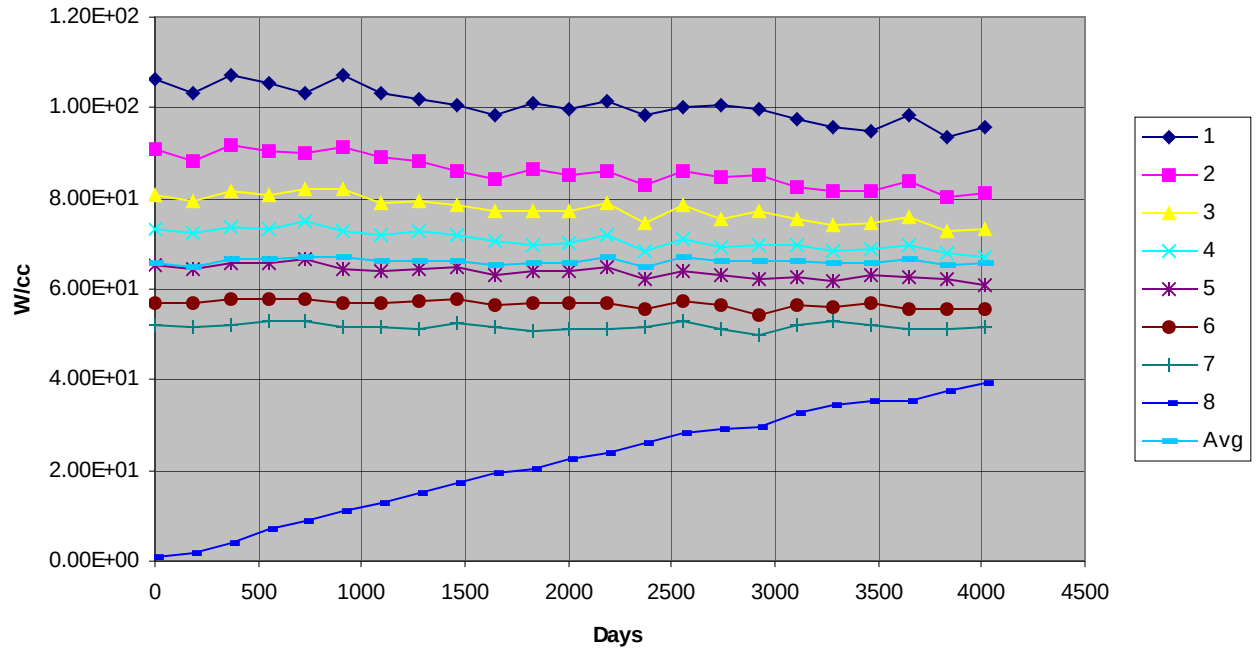


Figure 8 Power Density vs. Section vs. Time

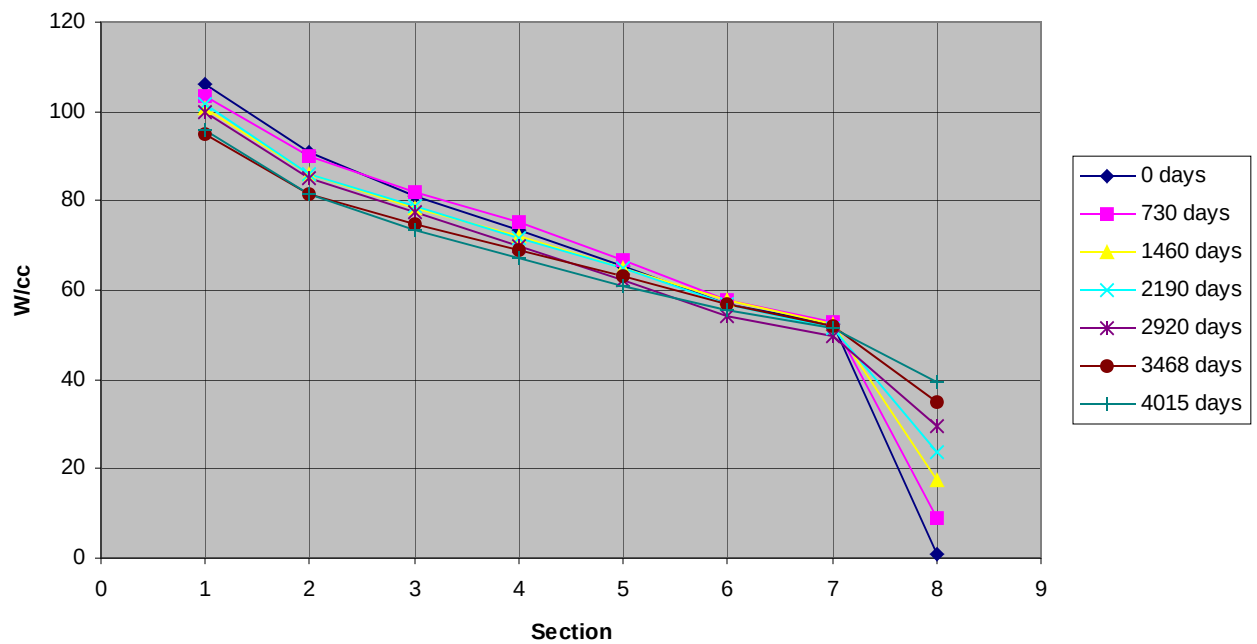


Figure 9 Actinide Inventory vs. Time, Part I

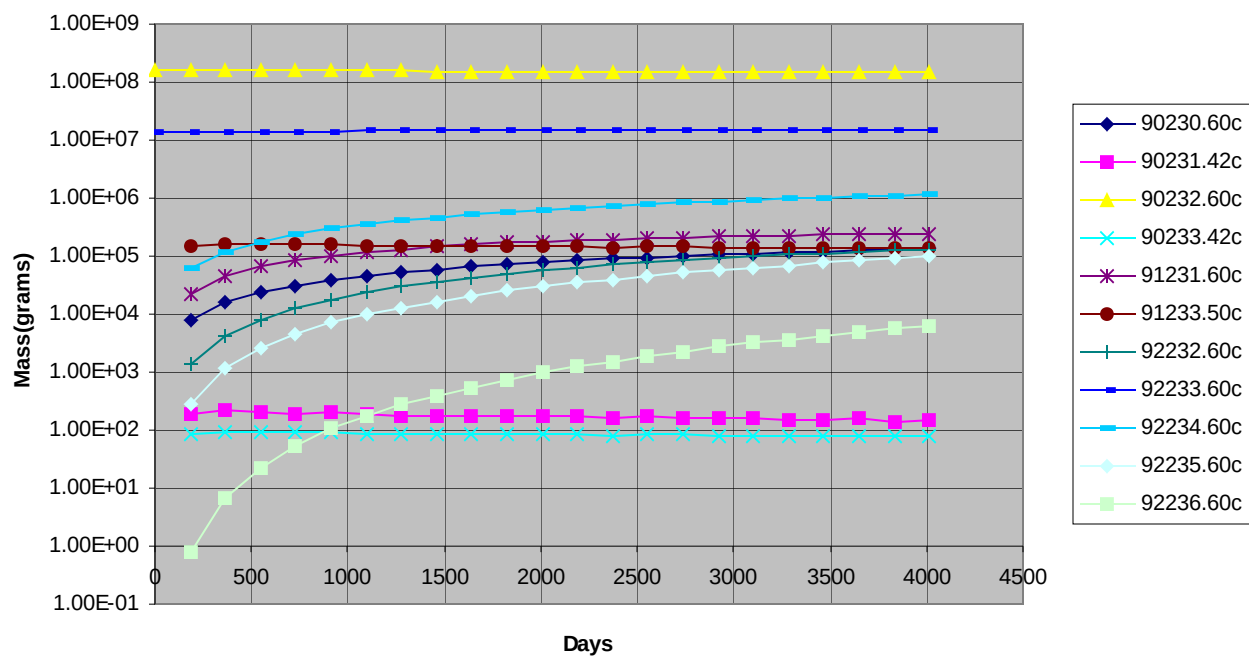


Figure 10 Actinide Inventory vs. Time, Part 2

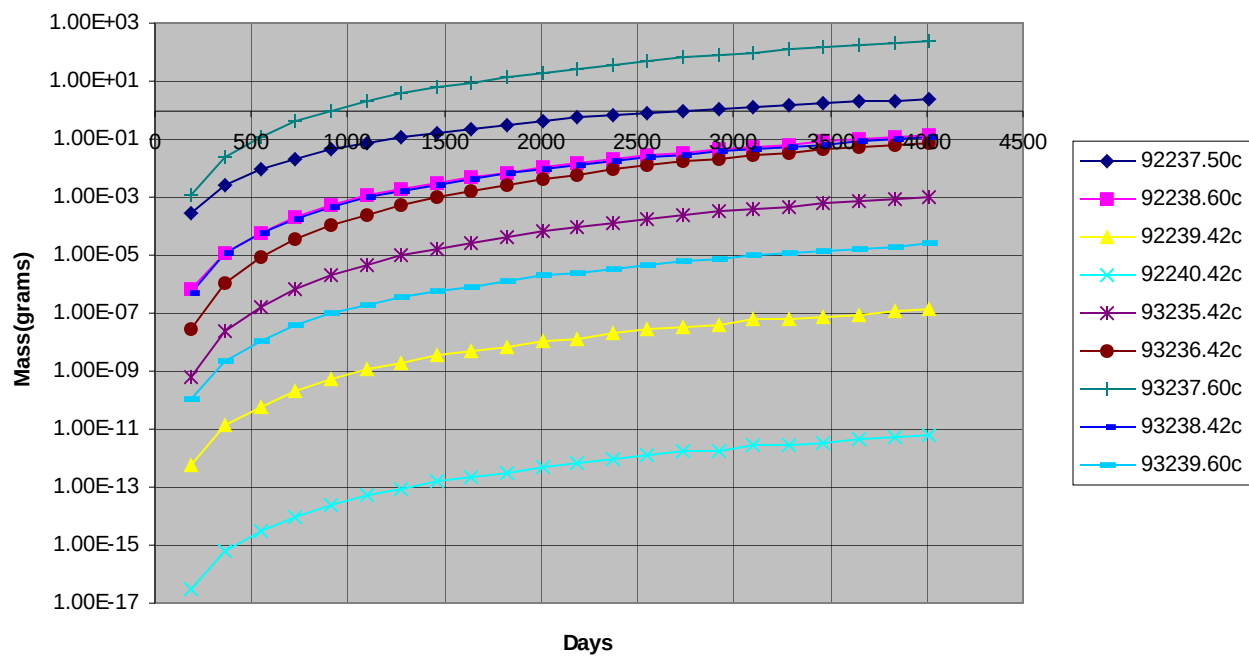


Figure 11 Actinide Inventory vs. Time, Part 3 (Pu)

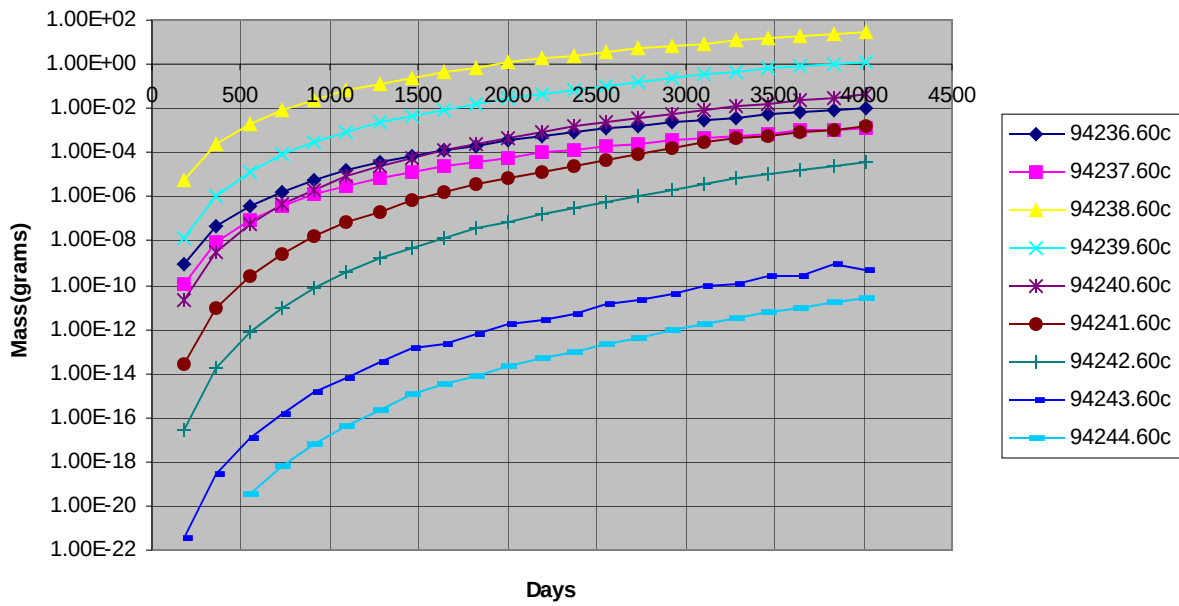


Figure 12 Actinide Inventory vs. Time, Part 4

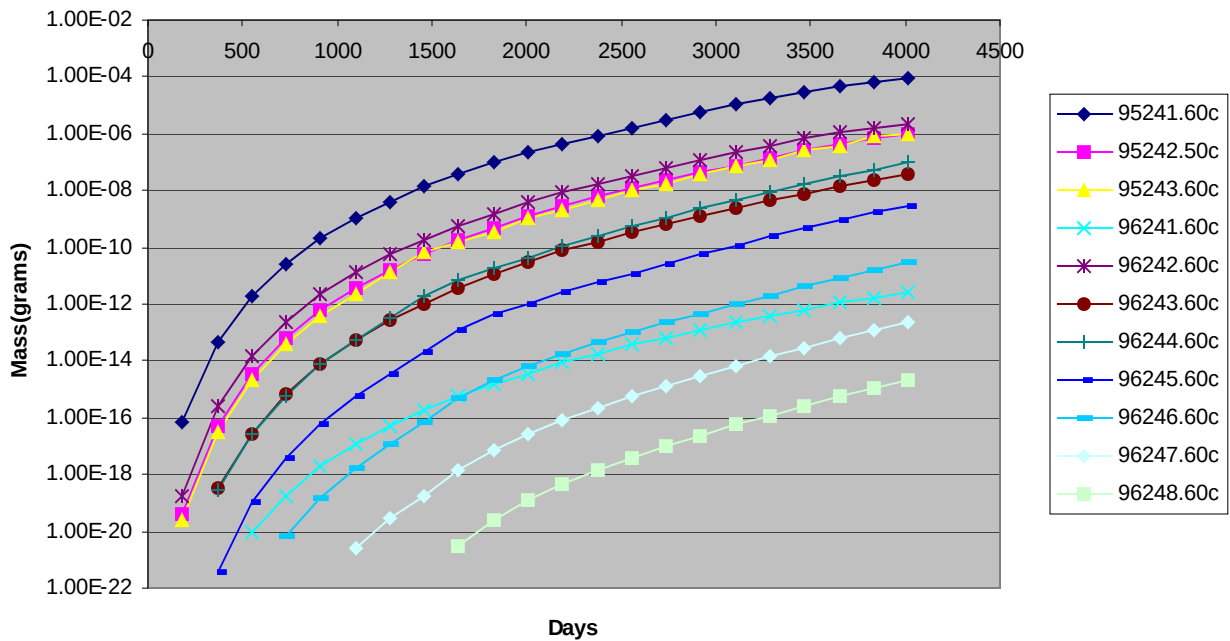


Figure 13 Long Lived Fission Products vs. Time

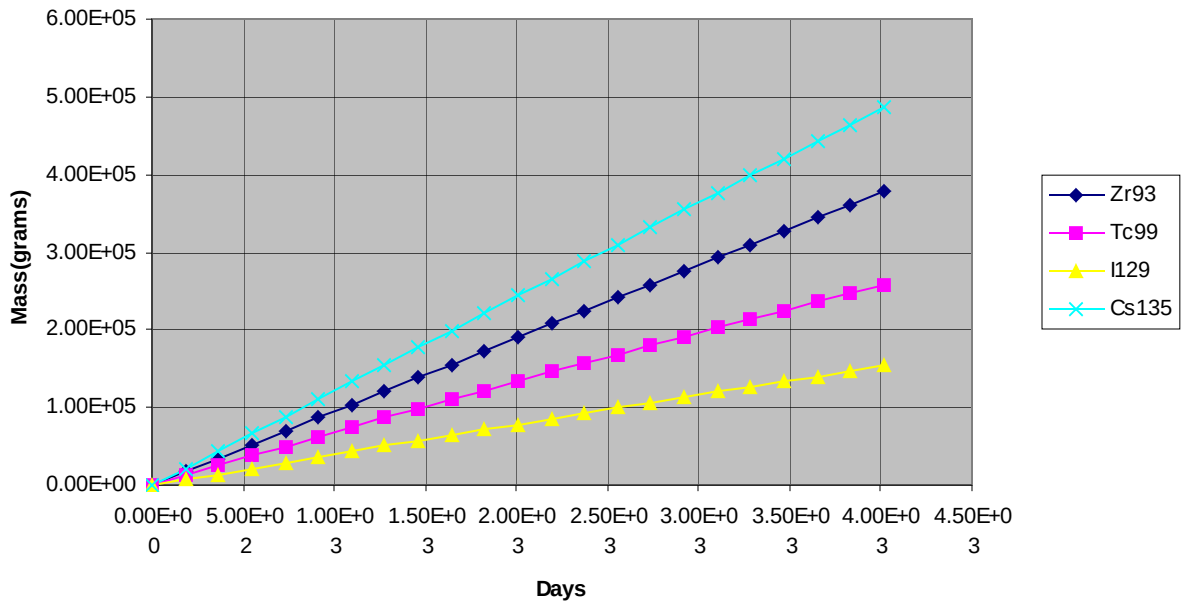


Figure 14 Actinide Activity vs. Time

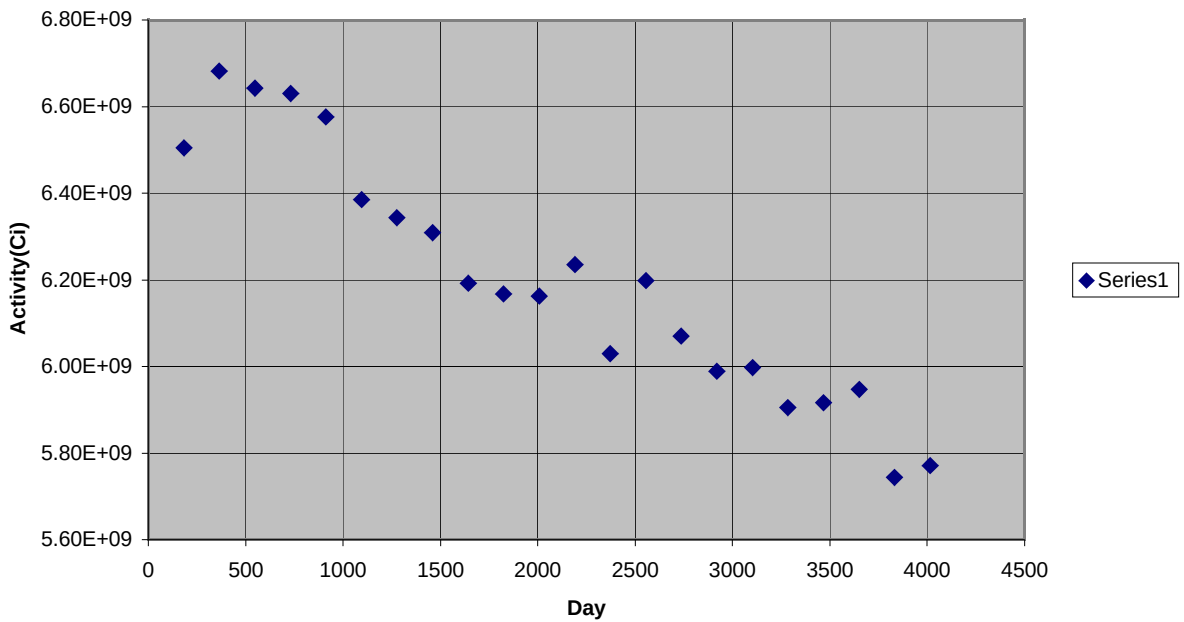


Figure 15- Relative BOL Flux vs. Energy for Section 1,4,8, and Shield (Log-Log Scale)

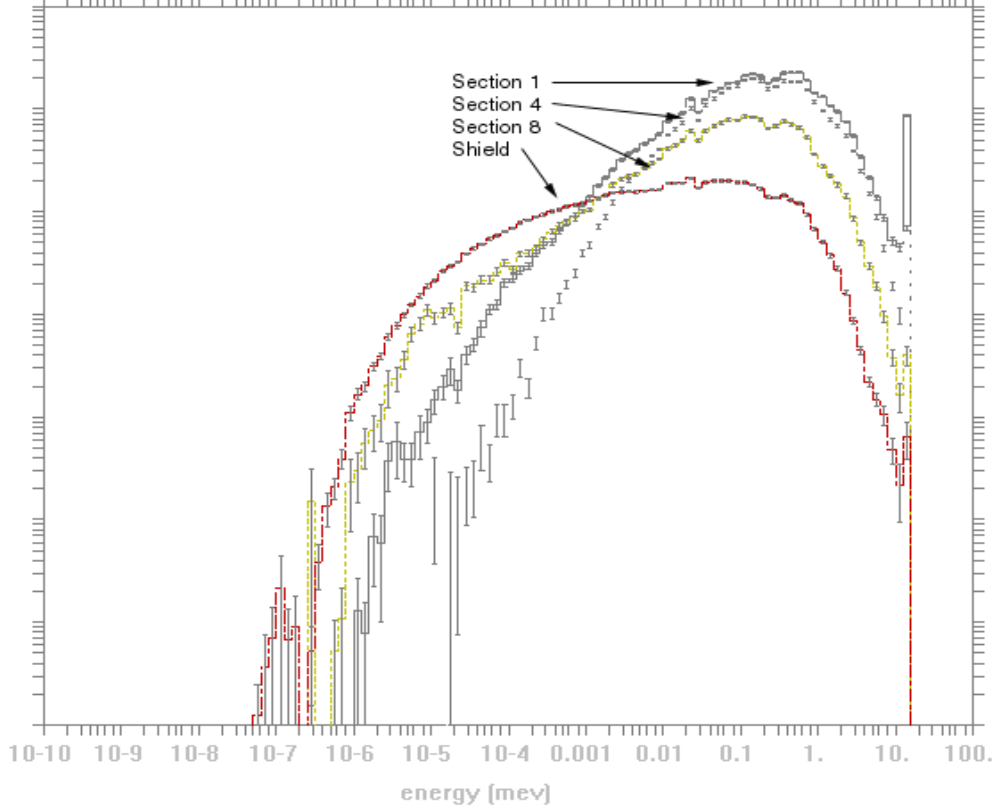
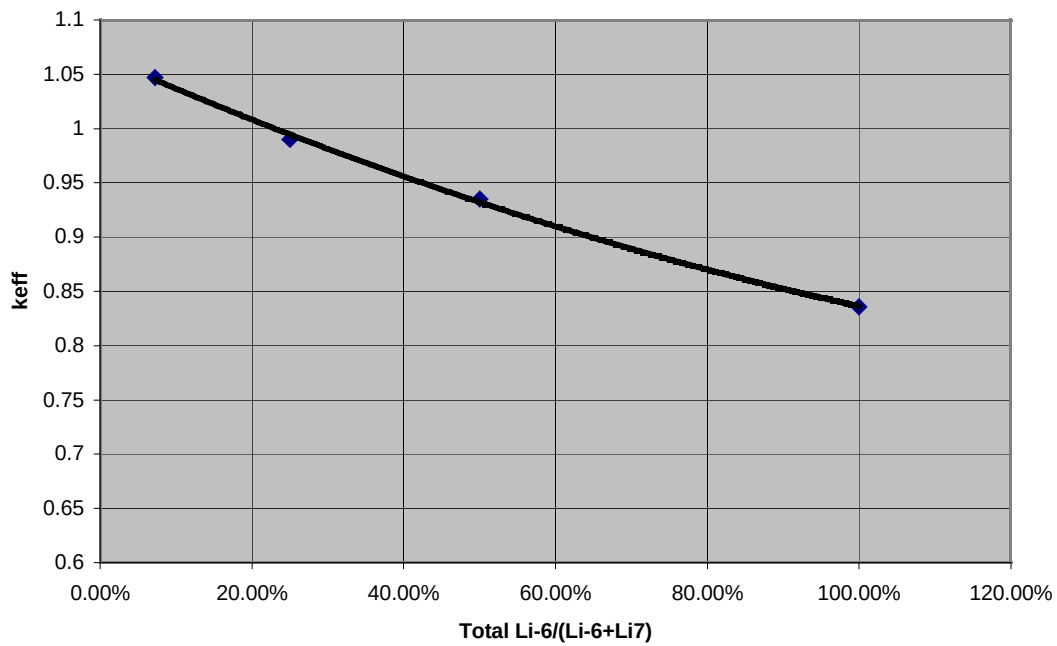


Figure 16 Li-6 Enrichment vs. keff



Appendix A—Nuclei Tracked and Followed in Blanket 1-8

1001.60c	59141.50c	94243.60c
1002.60c	60143.50c	94244.60c
1003.60c	60145.50c	95241.60c
2003.60c	60147.50c	95242.50c
2004.60c	60148.50c	95243.60c
3006.60c	61147.50c	96241.60c
3007.60c	61148.50c	96242.60c
4007.42c	61149.50c	96243.60c
4009.60c	62147.50c	96244.60c
5010.60c	62149.50c	96245.60c
5011.60c	62150.50c	96246.60c
6012.50c	62151.50c	96247.60c
6013.42c	62152.50c	96248.60c
7014.60c	63151.60c	
7015.60c	63152.50c	
8016.60c	63153.60c	
33075.42c	63154.50c	
35079.55c	63155.50c	
35081.55c	64152.60c	
36078.50c	64154.60c	
36080.50c	64155.60c	
36082.59c	64156.60c	
36083.59c	64157.60c	
36084.59c	64158.60c	
36086.59c	64160.60c	
37085.55c	67165.60c	
37087.55c	69169.55c	
39088.42c	90230.60c	
39089.60c	90231.42c	
40093.50c	90232.60c	
41093.60c	90233.42c	
42095.50c	91231.60c	
43099.60c	91233.50c	
44101.50c	92232.60c	
44103.50c	92233.60c	
45103.50c	92234.60c	
45105.50c	92235.60c	
46105.50c	92236.60c	
46108.50c	92237.50c	
47107.60c	92238.60c	
47109.60c	92239.42c	
50120.35c	92240.42c	
53127.60c	93235.42c	
53129.60c	93236.42c	
53135.50c	93237.60c	
54131.50c	93238.42c	
54134.42c	93239.60c	
54135.50c	94236.60c	
55133.60c	94237.60c	
55134.60c	94238.60c	
55135.60c	94239.60c	
55136.60c	94240.60c	
55137.60c	94241.60c	
56138.60c	94242.60c	

Appendix B- Neutron Spectrum Summary and Nuclei Summary vs. Time

Blanket Section 1

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	0	0	0.22	38.43	46.68	14.67
182.5	0	0	0.21	38.22	46.86	14.71
365	0	0	0.18	38.57	46.61	14.65
547.5	0	0	0.21	38.35	46.75	14.69
730	0	0	0.19	38.09	47	14.72
912.5	0	0	0.2	38.77	46.4	14.63
1095	0	0	0.22	38.53	47.05	14.2
1277.5	0	0	0.2	38.68	46.68	14.44
1460	0	0	0.21	38.62	46.67	14.5
1642.5	0	0	0.2	38.4	46.67	14.72
1825	0	0	0.21	38.27	46.56	14.96
2007.5	0	0	0.21	39.09	46.18	14.53
2190	0	0	0.2	39.04	46.55	14.21
2372.5	0	0	0.24	39.59	46.05	14.12
2555	0	0	0.2	39.37	46.06	14.36
2737.5	0	0	0.24	39.64	46.01	14.11
2920	0	0	0.23	39.43	46.29	14.05
3102.5	0	0	0.24	40.09	45.99	13.68
3285	0	0	0.23	39.51	46.21	14.06
3467.5	0	0	0.24	39.96	45.67	14.13
3650	0	0	0.24	39.35	46.26	14.16
3832.5	0	0	0.23	39.28	46.33	14.15
4015	0	0	0.24	39.42	46.44	13.89

Blanket Section 2

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	0	0	0.06	37.22	49.58	13.14
182.5	0	0	0.06	36.87	49.81	13.27
365	0	0	0.06	37.13	49.37	13.44
547.5	0	0	0.06	37.31	49.57	13.06
730	0	0	0.06	37.76	49.18	12.99
912.5	0	0	0.05	37.8	48.96	13.19
1095	0	0	0.08	37.29	49.5	13.14
1277.5	0	0	0.07	37.62	49.05	13.26
1460	0	0	0.05	37.5	49.5	12.95
1642.5	0	0	0.04	37.8	49.02	13.15
1825	0	0	0.06	37.25	49.52	13.18
2007.5	0	0	0.06	37.64	49.24	13.07
2190	0	0	0.04	37.67	49.34	12.95
2372.5	0	0	0.05	38.12	48.95	12.87
2555	0	0	0.06	37.86	49.17	12.91
2737.5	0	0	0.05	38.25	48.95	12.74
2920	0	0	0.06	38.14	48.88	12.91
3102.5	0	0	0.04	38.47	49.25	12.24
3285	0	0	0.05	37.94	49.32	12.69

3467.5	0	0	0.06	38.15	49.17	12.62
3650	0	0	0.08	37.79	49.41	12.72
3832.5	0	0	0.08	38.26	48.76	12.9
4015	0	0	0.06	38.2	49.09	12.66

Blanket Section 3

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	0	0	0.02	37.2	50.34	12.45
182.5	0	0	0.02	36.64	50.91	12.43
365	0	0	0.02	37.68	49.91	12.39
547.5	0	0	0.01	37.83	49.99	12.17
730	0	0	0.02	38.57	49.27	12.14
912.5	0	0	0.01	37.15	50.21	12.63
1095	0	0	0.03	37	50.59	12.37
1277.5	0	0	0.02	37.79	49.9	12.29
1460	0	0	0.02	37.28	50.45	12.25
1642.5	0	0	0.01	37.77	50.13	12.09
1825	0	0	0.02	37.74	50.19	12.05
2007.5	0	0	0.02	37.53	49.97	12.48
2190	0	0	0.01	37.69	50.19	12.11
2372.5	0	0	0.01	37.82	49.89	12.27
2555	0	0	0.02	37.99	49.93	12.06
2737.5	0	0	0.02	37.93	50.23	11.82
2920	0	0	0.02	37.8	50.15	12.04
3102.5	0	0	0.01	37.77	50.53	11.69
3285	0	0	0.01	37.7	50	12.28
3467.5	0	0	0.01	37.84	50.11	12.04
3650	0	0	0.03	37.9	50.29	11.78
3832.5	0	0	0.01	38.37	49.52	12.1
4015	0	0	0.02	37.99	49.97	12.03

Blanket Section 4

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	0	0	0	37.65	50.56	11.79
182.5	0	0	0.01	37.06	51.09	11.83
365	0	0	0.01	37.85	50.31	11.84
547.5	0	0	0.01	38.98	49.5	11.51
730	0	0	0.02	39.23	49.32	11.44
912.5	0	0	0	37.53	50.64	11.83
1095	0	0	0.01	37.57	50.59	11.83
1277.5	0	0	0.01	38.68	49.9	11.41
1460	0	0	0.01	38.05	50.4	11.55
1642.5	0	0	0.01	38.22	50.37	11.4
1825	0	0	0.01	38.34	50.38	11.27
2007.5	0	0	0.01	38.1	50.18	11.71
2190	0	0	0.01	38.15	50.34	11.5

2372.5	0	0	0	38.53	49.77	11.69
2555	0	0	0	38.47	50.27	11.26
2737.5	0	0	0.01	38.08	50.82	11.1
2920	0	0	0.01	38.94	49.86	11.2
3102.5	0	0	0.01	38.14	50.54	11.31
3285	0	0	0.01	37.77	50.6	11.62
3467.5	0	0	0.01	38.29	50.15	11.56
3650	0	0	0.01	38.52	49.97	11.5
3832.5	0	0	0.01	38.34	50.16	11.49
4015	0	0	0.01	37.92	50.44	11.64

Blanket Section 5

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	0	0	0	38.57	50.33	11.1
182.5	0	0	0.02	38.3	50.41	11.26
365	0	0	0.02	38.7	50.02	11.27
547.5	0	0	0.01	39.76	49.22	11.01
730	0	0	0.02	39.45	49.43	11.1
912.5	0	0	0.02	38.79	50.16	11.03
1095	0	0	0.01	39.06	49.62	11.32
1277.5	0	0	0.01	39.25	49.58	11.16
1460	0	0	0.02	38.72	50.33	10.93
1642.5	0	0	0.01	38.57	50.47	10.95
1825	0	0	0.01	39.53	49.64	10.82
2007.5	0	0	0.01	39.15	49.76	11.09
2190	0	0	0.01	39.22	49.75	11.02
2372.5	0	0	0.01	39.02	49.61	11.36
2555	0	0	0.01	39.57	49.14	11.28
2737.5	0	0	0.01	38.57	50.08	11.33
2920	0	0	0	38.97	49.81	11.22
3102.5	0	0	0.01	38.61	50.08	11.29
3285	0	0	0.01	38.97	49.61	11.41
3467.5	0	0	0.01	39.7	49.2	11.09
3650	0	0	0.01	39.35	49.43	11.2
3832.5	0	0	0	38.7	49.82	11.48
4015	0	0	0.01	38.41	50.33	11.25

Blanket Section 6

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	0	0	0.04	39.88	49.45	10.64
182.5	0	0	0.07	40.14	49.04	10.75
365	0	0	0.08	39.96	49.1	10.85
547.5	0	0	0.05	40.56	48.46	10.93
730	0	0	0.05	40.78	48.28	10.89
912.5	0	0	0.05	40.55	48.76	10.64
1095	0	0	0.06	40.99	48.45	10.51

1277.5	0	0	0.05	40.57	48.47	10.91
1460	0	0	0.05	40.2	49.08	10.67
1642.5	0	0	0.03	39.81	49.57	10.59
1825	0	0	0.03	40.58	48.86	10.53
2007.5	0	0	0.03	39.84	49.4	10.73
2190	0	0	0.03	40.53	48.63	10.82
2372.5	0	0	0.03	39.93	49.01	11.04
2555	0	0	0.03	40.13	48.91	10.92
2737.5	0	0	0.03	39.65	49.65	10.66
2920	0	0	0.03	39.28	49.51	11.18
3102.5	0	0	0.04	39.69	49.07	11.19
3285	0	0	0.04	39.94	49.04	10.98
3467.5	0	0	0.04	40.02	48.87	11.07
3650	0	0	0.04	40.36	49	10.61
3832.5	0	0	0.04	39.69	49.1	11.17
4015	0	0	0.04	39.53	49.38	11.05

Blanket Section 7

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	0	0	0.23	43.8	46.39	9.58
182.5	0	0	0.24	43.66	46.37	9.73
365	0	0	0.27	43.25	46.73	9.75
547.5	0	0	0.26	43.78	46.14	9.82
730	0	0	0.23	43.96	45.84	9.97
912.5	0	0	0.21	44.46	45.62	9.71
1095	0	0	0.25	44.49	45.71	9.55
1277.5	0	0	0.18	43.55	45.96	10.31
1460	0	0	0.22	43.58	46.55	9.66
1642.5	0	0	0.21	42.32	47.42	10.05
1825	0	0	0.2	42.98	46.83	9.99
2007.5	0	0	0.16	43.27	46.36	10.21
2190	0	0	0.19	42.8	46.65	10.36
2372.5	0	0	0.18	42.86	46.52	10.43
2555	0	0	0.18	42.4	46.99	10.42
2737.5	0	0	0.17	43.01	46.95	9.86
2920	0	0	0.18	42.51	46.63	10.68
3102.5	0	0	0.17	42.18	47.1	10.55
3285	0	0	0.2	42.93	46.33	10.55
3467.5	0	0	0.15	42.18	46.88	10.78
3650	0	0	0.14	42.99	46.6	10.27
3832.5	0	0	0.22	42.08	47.07	10.64
4015	0	0	0.16	41.81	47.44	10.59

Blanket Section 8

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	0	0	1.27	52.4	40.31	6.02

182.5	0	0.01	1.12	52.02	40.66	6.21
365	0	0.02	1.16	51.68	41.09	6.04
547.5	0	0.01	1.25	51.21	40.74	6.78
730	0	0.01	1	51.08	41.16	6.75
912.5	0	0.01	1.13	51.58	40.59	6.69
1095	0	0	0.92	51.58	40.88	6.62
1277.5	0	0	0.86	50.41	41.16	7.57
1460	0	0	0.94	50.67	41.3	7.08
1642.5	0	0.01	0.92	49.25	42.06	7.76
1825	0	0.01	0.96	49.78	41.71	7.54
2007.5	0	0.02	0.89	49.63	41.33	8.13
2190	0	0	0.87	49.05	42.24	7.85
2372.5	0	0	0.87	48.96	42.03	8.13
2555	0	0	0.84	48.96	42.16	8.04
2737.5	0	0	0.81	49.11	42.2	7.88
2920	0	0	0.83	48.57	42.24	8.36
3102.5	0	0.01	0.86	48.01	42.38	8.74
3285	0	0.01	0.8	48.67	41.84	8.68
3467.5	0	0.01	0.8	48.32	42.01	8.87
3650	0	0.01	0.78	48.34	42.43	8.44
3832.5	0	0	0.93	47.63	42.55	8.88
4015	0	0.01	0.9	47.43	42.69	8.97

Outer Shield

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	0	0.04	8.08	68.81	20.84	2.22
182.5	0	0.02	7.6	68.74	21.2	2.44
365	0	0.04	7.77	68.78	21.07	2.33
547.5	0	0.05	7.65	68.35	21.44	2.52
730	0	0.04	7.79	67.7	21.71	2.75
912.5	0	0.04	7.41	67.93	21.99	2.63
1095	0	0.03	7.67	68.24	21.53	2.54
1277.5	0	0.05	7.86	66.99	22.07	3.03
1460	0	0.04	8.06	67.55	21.58	2.77
1642.5	0	0.07	8.14	66.74	22.05	3.01
1825	0	0.04	7.96	66.8	22.25	2.95
2007.5	0	0.07	7.88	66.56	22.46	3.03
2190	0	0.04	8.18	66.78	22.01	3
2372.5	0	0.05	8.36	66.25	22.31	3.04
2555	0	0.06	8.42	66.49	21.91	3.11
2737.5	0	0.06	8.76	66.15	22.07	2.95
2920	0	0.06	8.28	65.9	22.55	3.22
3102.5	0	0.07	8.74	65.46	22.47	3.26
3285	0	0.07	8.74	65.54	22.51	3.14
3467.5	0	0.09	8.54	65.49	22.58	3.3
3650	0	0.07	8.64	65.57	22.38	3.34
3832.5	0	0.1	9.05	65.22	22.41	3.21

4015	0	0.09	8.69	65.19	22.83	3.19
------	---	------	------	-------	-------	------

Inner Blanket

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	0.04	0.19	6	60.98	26.87	5.92
182.5	0.04	0.17	5.89	60.98	26.93	6
365	0.05	0.19	6.36	61.31	26.43	5.67
547.5	0.05	0.2	6.3	60.97	26.8	5.67
730	0.04	0.23	6.56	60.74	26.64	5.79
912.5	0.05	0.27	6.75	60.22	26.85	5.87
1095	0.07	0.29	7.3	60.48	26.28	5.58
1277.5	0.05	0.31	7.76	60.66	25.69	5.53
1460	0.06	0.34	7.8	60.22	25.69	5.89
1642.5	0.07	0.39	8.1	59.72	25.96	5.76
1825	0.08	0.38	8.1	59.81	25.96	5.67
2007.5	0.08	0.43	8.59	59.56	25.87	5.46
2190	0.08	0.44	8.29	59.65	25.89	5.65
2372.5	0.1	0.52	8.7	59.26	25.91	5.52
2555	0.08	0.51	8.91	59.69	25.39	5.42
2737.5	0.11	0.63	9.13	59.61	24.85	5.68
2920	0.12	0.74	9.62	59.72	24.48	5.31
3102.5	0.12	0.77	9.74	59.11	24.98	5.28
3285	0.14	0.81	10.72	58.84	24.37	5.13
3467.5	0.13	0.96	10.61	59.06	23.95	5.29
3650	0.17	1.02	10.89	58.95	23.69	5.28
3832.5	0.19	1.24	10.89	58.28	24.34	5.07
4015	0.2	1.21	11.08	58.49	24.01	5

Sum of Materials in Blanket Section 1-8 vs. Time(grams)

Days	1001.60c	1002.60c	1003.60c	2003.60c	2004.60c	3006.60c	3007.60c	4007.42c
0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.08E+05	1.55E+06	0.00E+00
182.5	2.19E-01	1.72E-05	8.23E+00	1.14E-01	1.15E+01	1.06E+05	1.55E+06	0.00E+00
365	2.28E-01	1.98E-05	8.35E+00	1.18E-01	1.17E+01	1.04E+05	1.55E+06	0.00E+00
547.5	2.26E-01	1.80E-05	8.25E+00	1.17E-01	1.15E+01	1.03E+05	1.55E+06	0.00E+00
730	2.26E-01	1.72E-05	8.07E+00	1.14E-01	1.12E+01	1.01E+05	1.55E+06	0.00E+00
912.5	2.26E-01	1.81E-05	7.94E+00	1.12E-01	1.11E+01	9.95E+04	1.55E+06	0.00E+00
1095	2.22E-01	1.56E-05	7.65E+00	1.08E-01	1.07E+01	9.79E+04	1.55E+06	0.00E+00
1277.5	2.21E-01	1.49E-05	7.52E+00	1.06E-01	1.05E+01	9.64E+04	1.55E+06	0.00E+00
1460	2.21E-01	1.44E-05	7.38E+00	1.04E-01	1.04E+01	9.49E+04	1.55E+06	0.00E+00
1642.5	2.19E-01	1.39E-05	7.17E+00	1.01E-01	1.01E+01	9.35E+04	1.55E+06	0.00E+00
1825	2.19E-01	1.37E-05	7.09E+00	1.00E-01	9.99E+00	9.21E+04	1.55E+06	0.00E+00
2007.5	2.18E-01	1.28E-05	6.96E+00	9.84E-02	9.84E+00	9.07E+04	1.55E+06	0.00E+00
2190	2.22E-01	1.36E-05	6.92E+00	9.77E-02	9.83E+00	8.94E+04	1.55E+06	0.00E+00
2372.5	2.15E-01	1.18E-05	6.63E+00	9.38E-02	9.44E+00	8.78E+04	1.55E+06	0.00E+00
2555	2.22E-01	1.27E-05	6.74E+00	9.50E-02	9.62E+00	8.68E+04	1.55E+06	0.00E+00
2737.5	2.18E-01	1.20E-05	6.53E+00	9.24E-02	9.38E+00	8.52E+04	1.55E+06	0.00E+00
2920	2.17E-01	1.13E-05	6.38E+00	9.01E-02	9.19E+00	8.41E+04	1.55E+06	0.00E+00

3102.5	2.18E-01	1.11E-05	6.32E+00	8.93E-02	9.14E+00	8.28E+04	1.55E+06	0.00E+00
3285	2.15E-01	1.02E-05	6.18E+00	8.72E-02	8.97E+00	8.16E+04	1.55E+06	0.00E+00
3467.5	2.16E-01	9.95E-06	6.11E+00	8.64E-02	8.91E+00	8.04E+04	1.55E+06	0.00E+00
3650	2.18E-01	1.11E-05	6.05E+00	8.55E-02	8.88E+00	7.92E+04	1.55E+06	0.00E+00
3832.5	2.14E-01	9.27E-06	5.83E+00	8.24E-02	8.57E+00	7.80E+04	1.55E+06	0.00E+00
4015	2.14E-01	9.55E-06	5.78E+00	8.18E-02	8.55E+00	7.68E+04	1.55E+06	0.00E+00

Days	4009.60c	5010.60c	5011.60c	6012.50c	6013.42c	7014.60c	7015.60c	8016.60c	33075.42c
0	0.00E+00	0.00E+00	0.00E+00	8.92E+06	9.91E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
182.5	6.18E+01	4.66E-12	5.87E-10	8.92E+06	9.91E+04	1.37E-05	6.69E-12	4.02E-19	4.54E+01
365	1.30E+02	3.80E-11	4.85E-09	8.92E+06	9.91E+04	5.47E-05	4.57E-11	5.36E-18	9.18E+01
547.5	1.93E+02	1.29E-10	1.61E-08	8.92E+06	9.91E+04	1.23E-04	1.44E-10	2.47E-17	1.38E+02
730	2.56E+02	3.03E-10	3.84E-08	8.92E+06	9.91E+04	2.20E-04	3.31E-10	7.44E-17	1.84E+02
912.5	3.21E+02	5.85E-10	7.50E-08	8.92E+06	9.91E+04	3.44E-04	6.33E-10	1.78E-16	2.29E+02
1095	3.81E+02	9.99E-10	1.29E-07	8.92E+06	9.91E+04	4.96E-04	1.06E-09	3.57E-16	2.74E+02
1277.5	4.39E+02	1.56E-09	2.04E-07	8.92E+06	9.91E+04	6.73E-04	1.67E-09	6.46E-16	3.18E+02
1460	4.98E+02	2.29E-09	3.03E-07	8.92E+06	9.91E+04	8.80E-04	2.46E-09	1.08E-15	3.62E+02
1642.5	5.58E+02	3.21E-09	4.27E-07	8.92E+06	9.91E+04	1.11E-03	3.44E-09	1.69E-15	4.05E+02
1825	6.15E+02	4.32E-09	5.85E-07	8.91E+06	9.91E+04	1.37E-03	4.68E-09	2.55E-15	4.48E+02
2007.5	6.71E+02	5.65E-09	7.78E-07	8.91E+06	9.91E+04	1.66E-03	6.19E-09	3.68E-15	4.91E+02
2190	7.30E+02	7.18E-09	1.01E-06	8.91E+06	9.91E+04	1.97E-03	8.00E-09	5.19E-15	5.34E+02
2372.5	7.84E+02	8.98E-09	1.27E-06	8.91E+06	9.91E+04	2.31E-03	1.01E-08	7.04E-15	5.76E+02
2555	8.42E+02	1.10E-08	1.59E-06	8.91E+06	9.91E+04	2.68E-03	1.26E-08	9.44E-15	6.18E+02
2737.5	8.96E+02	1.33E-08	1.93E-06	8.91E+06	9.91E+04	3.07E-03	1.54E-08	1.24E-14	6.61E+02
2920	9.50E+02	1.59E-08	2.34E-06	8.91E+06	9.91E+04	3.49E-03	1.87E-08	1.59E-14	7.01E+02
3102.5	1.01E+03	1.88E-08	2.79E-06	8.91E+06	9.91E+04	3.94E-03	2.23E-08	2.02E-14	7.42E+02
3285	1.06E+03	2.20E-08	3.31E-06	8.91E+06	9.91E+04	4.41E-03	2.63E-08	2.52E-14	7.83E+02
3467.5	1.11E+03	2.54E-08	3.87E-06	8.91E+06	9.91E+04	4.91E-03	3.09E-08	3.10E-14	8.24E+02
3650	1.17E+03	2.91E-08	4.50E-06	8.91E+06	9.91E+04	5.44E-03	3.59E-08	3.79E-14	8.64E+02
3832.5	1.22E+03	3.33E-08	5.20E-06	8.91E+06	9.91E+04	5.99E-03	4.14E-08	4.58E-14	9.03E+02
4015	1.27E+03	3.77E-08	5.96E-06	8.91E+06	9.91E+04	6.56E-03	4.74E-08	5.49E-14	9.44E+02

Days	35079.55c	35081.55c	36078.50c	36080.50c	36082.59c	36083.59c	36084.59c	36086.59c	37085.55c
0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
182.5	1.11E-03	6.60E+02	0.00E+00	2.54E-02	5.53E+00	2.36E+03	4.00E+03	6.87E+03	3.76E+03
365	4.12E-03	1.34E+03	0.00E+00	5.15E-02	1.65E+01	4.78E+03	8.14E+03	1.39E+04	7.67E+03
547.5	9.03E-03	2.01E+03	0.00E+00	7.74E-02	3.22E+01	7.18E+03	1.23E+04	2.10E+04	1.16E+04
730	1.58E-02	2.68E+03	0.00E+00	1.04E-01	5.29E+01	9.60E+03	1.64E+04	2.81E+04	1.56E+04
912.5	2.45E-02	3.34E+03	0.00E+00	1.30E-01	7.90E+01	1.20E+04	2.06E+04	3.52E+04	1.95E+04
1095	3.50E-02	3.99E+03	0.00E+00	1.55E-01	1.10E+02	1.43E+04	2.47E+04	4.22E+04	2.34E+04
1277.5	4.73E-02	4.64E+03	0.00E+00	1.81E-01	1.44E+02	1.67E+04	2.88E+04	4.92E+04	2.74E+04
1460	6.14E-02	5.29E+03	0.00E+00	2.07E-01	1.84E+02	1.90E+04	3.30E+04	5.62E+04	3.14E+04
1642.5	7.73E-02	5.92E+03	0.00E+00	2.33E-01	2.28E+02	2.13E+04	3.70E+04	6.30E+04	3.53E+04
1825	9.50E-02	6.55E+03	0.00E+00	2.58E-01	2.75E+02	2.36E+04	4.11E+04	7.00E+04	3.93E+04
2007.5	1.14E-01	7.17E+03	0.00E+00	2.84E-01	3.27E+02	2.58E+04	4.53E+04	7.68E+04	4.33E+04
2190	1.35E-01	7.82E+03	0.00E+00	3.10E-01	3.85E+02	2.81E+04	4.95E+04	8.40E+04	4.73E+04
2372.5	1.58E-01	8.43E+03	0.00E+00	3.36E-01	4.45E+02	3.04E+04	5.35E+04	9.07E+04	5.13E+04
2555	1.83E-01	9.07E+03	0.00E+00	3.63E-01	5.12E+02	3.27E+04	5.78E+04	9.77E+04	5.54E+04

2737.5	2.09E-01	9.69E+03	0.00E+00	3.90E-01	5.81E+02	3.49E+04	6.20E+04	1.05E+05	5.95E+04
2920	2.36E-01	1.03E+04	0.00E+00	4.16E-01	6.51E+02	3.72E+04	6.60E+04	1.12E+05	6.35E+04
3102.5	2.66E-01	1.09E+04	0.00E+00	4.43E-01	7.27E+02	3.94E+04	7.02E+04	1.19E+05	6.76E+04
3285	2.97E-01	1.15E+04	0.00E+00	4.70E-01	8.08E+02	4.17E+04	7.43E+04	1.26E+05	7.16E+04
3467.5	3.29E-01	1.21E+04	0.00E+00	4.97E-01	8.89E+02	4.38E+04	7.85E+04	1.33E+05	7.57E+04
3650	3.64E-01	1.27E+04	0.00E+00	5.25E-01	9.82E+02	4.61E+04	8.26E+04	1.39E+05	7.98E+04
3832.5	4.00E-01	1.33E+04	0.00E+00	5.52E-01	1.07E+03	4.82E+04	8.69E+04	1.46E+05	8.39E+04
4015	4.37E-01	1.39E+04	0.00E+00	5.80E-01	1.17E+03	5.04E+04	9.10E+04	1.53E+05	8.79E+04

Days	37087.55c	39088.42c	39089.60c	40093.50c	41093.60c	42095.50c	43099.60c	44101.50c	44103.50c
0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E+05	0.00E+00	0.00E+00	0.00E+00
182.5	9.08E+03	0.00E+00	8.92E+03	1.70E+04	8.08E-04	1.41E+05	1.21E+04	8.97E+03	1.64E+03
365	1.84E+04	0.00E+00	2.28E+04	3.45E+04	2.07E-03	1.54E+05	2.48E+04	1.81E+04	1.76E+03
547.5	2.78E+04	0.00E+00	3.72E+04	5.20E+04	3.84E-03	1.69E+05	3.74E+04	2.72E+04	1.77E+03
730	3.71E+04	0.00E+00	5.17E+04	6.96E+04	6.24E-03	1.84E+05	4.99E+04	3.62E+04	1.79E+03
912.5	4.65E+04	0.00E+00	6.63E+04	8.70E+04	9.32E-03	1.99E+05	6.24E+04	4.52E+04	1.80E+03
1095	5.57E+04	0.00E+00	8.06E+04	1.04E+05	1.32E-02	2.14E+05	7.45E+04	5.39E+04	1.78E+03
1277.5	6.50E+04	0.00E+00	9.50E+04	1.21E+05	1.79E-02	2.29E+05	8.66E+04	6.26E+04	1.79E+03
1460	7.43E+04	0.00E+00	1.09E+05	1.39E+05	2.35E-02	2.44E+05	9.87E+04	7.13E+04	1.79E+03
1642.5	8.33E+04	0.00E+00	1.23E+05	1.56E+05	3.02E-02	2.58E+05	1.11E+05	7.96E+04	1.77E+03
1825	9.26E+04	0.00E+00	1.38E+05	1.73E+05	3.79E-02	2.73E+05	1.22E+05	8.80E+04	1.79E+03
2007.5	1.02E+05	0.00E+00	1.52E+05	1.90E+05	4.68E-02	2.87E+05	1.34E+05	9.64E+04	1.80E+03
2190	1.11E+05	0.00E+00	1.66E+05	2.07E+05	5.68E-02	3.02E+05	1.46E+05	1.05E+05	1.84E+03
2372.5	1.20E+05	0.00E+00	1.80E+05	2.24E+05	6.82E-02	3.16E+05	1.57E+05	1.13E+05	1.80E+03
2555	1.29E+05	0.00E+00	1.95E+05	2.42E+05	8.10E-02	3.31E+05	1.69E+05	1.21E+05	1.86E+03
2737.5	1.39E+05	0.00E+00	2.09E+05	2.59E+05	9.50E-02	3.45E+05	1.80E+05	1.29E+05	1.84E+03
2920	1.48E+05	0.00E+00	2.23E+05	2.76E+05	1.10E-01	3.60E+05	1.92E+05	1.37E+05	1.84E+03
3102.5	1.57E+05	0.00E+00	2.37E+05	2.93E+05	1.27E-01	3.74E+05	2.03E+05	1.45E+05	1.85E+03
3285	1.66E+05	0.00E+00	2.52E+05	3.10E+05	1.46E-01	3.88E+05	2.14E+05	1.53E+05	1.84E+03
3467.5	1.75E+05	0.00E+00	2.66E+05	3.27E+05	1.66E-01	4.02E+05	2.25E+05	1.61E+05	1.86E+03
3650	1.85E+05	0.00E+00	2.80E+05	3.44E+05	1.88E-01	4.16E+05	2.36E+05	1.69E+05	1.88E+03
3832.5	1.94E+05	0.00E+00	2.94E+05	3.60E+05	2.12E-01	4.30E+05	2.47E+05	1.77E+05	1.85E+03
4015	2.03E+05	0.00E+00	3.08E+05	3.77E+05	2.38E-01	4.44E+05	2.58E+05	1.84E+05	1.87E+03

Days	45103.50c	45105.50c	46105.50c	46108.50c	47107.60c	47109.60c	50120.35c	53127.60c	53129.60c
0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
182.5	3.85E+03	2.27E+01	1.91E+03	5.98E+02	2.89E-05	6.97E+02	3.04E+02	3.24E+03	6.80E+03
365	9.35E+03	2.35E+01	3.89E+03	1.22E+03	1.16E-04	1.41E+03	6.15E+02	6.87E+03	1.41E+04
547.5	1.49E+04	2.36E+01	5.85E+03	1.85E+03	2.61E-04	2.12E+03	9.21E+02	1.05E+04	2.14E+04
730	2.04E+04	2.38E+01	7.80E+03	2.48E+03	4.64E-04	2.83E+03	1.23E+03	1.42E+04	2.87E+04
912.5	2.59E+04	2.39E+01	9.73E+03	3.12E+03	7.23E-04	3.54E+03	1.53E+03	1.79E+04	3.60E+04
1095	3.13E+04	2.36E+01	1.16E+04	3.76E+03	1.04E-03	4.23E+03	1.82E+03	2.14E+04	4.32E+04
1277.5	3.67E+04	2.37E+01	1.35E+04	4.41E+03	1.41E-03	4.92E+03	2.12E+03	2.49E+04	5.03E+04
1460	4.20E+04	2.38E+01	1.53E+04	5.06E+03	1.84E-03	5.60E+03	2.41E+03	2.84E+04	5.74E+04
1642.5	4.72E+04	2.35E+01	1.72E+04	5.70E+03	2.31E-03	6.26E+03	2.69E+03	3.19E+04	6.44E+04
1825	5.24E+04	2.38E+01	1.90E+04	6.35E+03	2.84E-03	6.93E+03	2.97E+03	3.53E+04	7.13E+04
2007.5	5.75E+04	2.39E+01	2.08E+04	7.01E+03	3.42E-03	7.59E+03	3.26E+03	3.87E+04	7.84E+04
2190	6.26E+04	2.43E+01	2.26E+04	7.69E+03	4.05E-03	8.26E+03	3.54E+03	4.21E+04	8.55E+04

2372.5	6.77E+04	2.37E+01	2.44E+04	8.34E+03	4.74E-03	8.92E+03	3.81E+03	4.54E+04	9.23E+04
2555	7.28E+04	2.46E+01	2.62E+04	9.02E+03	5.47E-03	9.58E+03	4.09E+03	4.87E+04	9.93E+04
2737.5	7.80E+04	2.43E+01	2.79E+04	9.71E+03	6.25E-03	1.03E+04	4.36E+03	5.20E+04	1.06E+05
2920	8.28E+04	2.43E+01	2.97E+04	1.04E+04	7.09E-03	1.09E+04	4.63E+03	5.52E+04	1.13E+05
3102.5	8.77E+04	2.44E+01	3.14E+04	1.11E+04	7.98E-03	1.16E+04	4.90E+03	5.84E+04	1.20E+05
3285	9.27E+04	2.43E+01	3.32E+04	1.18E+04	8.91E-03	1.22E+04	5.16E+03	6.16E+04	1.27E+05
3467.5	9.76E+04	2.44E+01	3.48E+04	1.25E+04	9.88E-03	1.28E+04	5.42E+03	6.47E+04	1.33E+05
3650	1.03E+05	2.48E+01	3.66E+04	1.32E+04	1.09E-02	1.34E+04	5.68E+03	6.79E+04	1.40E+05
3832.5	1.07E+05	2.43E+01	3.82E+04	1.39E+04	1.20E-02	1.41E+04	5.93E+03	7.09E+04	1.47E+05
4015	1.12E+05	2.45E+01	3.99E+04	1.45E+04	1.31E-02	1.47E+04	6.19E+03	7.40E+04	1.54E+05

Days	53135.50c	54131.50c	54134.42c	54135.50c	55133.60c	55134.60c	55135.60c	55136.60c	55137.60c
0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
182.5	3.72E+01	1.19E+04	2.05E+04	6.47E+01	1.95E+04	7.48E+01	2.16E+04	4.14E+01	2.28E+04
365	3.84E+01	2.50E+04	4.16E+04	6.68E+01	4.03E+04	2.99E+02	4.39E+04	4.57E+01	4.60E+04
547.5	3.84E+01	3.80E+04	6.26E+04	6.69E+01	6.11E+04	6.55E+02	6.63E+04	4.89E+01	6.89E+04
730	3.86E+01	5.11E+04	8.38E+04	6.73E+01	8.17E+04	1.09E+03	8.88E+04	5.21E+01	9.16E+04
912.5	3.86E+01	6.42E+04	1.05E+05	6.74E+01	1.02E+05	1.62E+03	1.11E+05	5.51E+01	1.14E+05
1095	3.80E+01	7.68E+04	1.26E+05	6.64E+01	1.23E+05	2.19E+03	1.33E+05	5.79E+01	1.36E+05
1277.5	3.81E+01	8.95E+04	1.46E+05	6.66E+01	1.43E+05	2.82E+03	1.55E+05	6.02E+01	1.58E+05
1460	3.81E+01	1.02E+05	1.67E+05	6.65E+01	1.62E+05	3.48E+03	1.77E+05	6.29E+01	1.79E+05
1642.5	3.75E+01	1.14E+05	1.88E+05	6.57E+01	1.82E+05	4.15E+03	1.99E+05	6.40E+01	2.00E+05
1825	3.78E+01	1.27E+05	2.08E+05	6.63E+01	2.01E+05	4.86E+03	2.21E+05	6.83E+01	2.21E+05
2007.5	3.79E+01	1.39E+05	2.29E+05	6.64E+01	2.21E+05	5.65E+03	2.43E+05	7.11E+01	2.42E+05
2190	3.85E+01	1.52E+05	2.50E+05	6.76E+01	2.40E+05	6.44E+03	2.66E+05	7.46E+01	2.62E+05
2372.5	3.74E+01	1.64E+05	2.70E+05	6.57E+01	2.59E+05	7.19E+03	2.88E+05	7.60E+01	2.82E+05
2555	3.87E+01	1.76E+05	2.91E+05	6.80E+01	2.78E+05	8.08E+03	3.10E+05	8.15E+01	3.02E+05
2737.5	3.81E+01	1.89E+05	3.12E+05	6.71E+01	2.98E+05	8.85E+03	3.32E+05	8.39E+01	3.22E+05
2920	3.80E+01	2.01E+05	3.32E+05	6.69E+01	3.16E+05	9.63E+03	3.54E+05	8.58E+01	3.42E+05
3102.5	3.80E+01	2.13E+05	3.53E+05	6.71E+01	3.35E+05	1.04E+04	3.76E+05	8.89E+01	3.61E+05
3285	3.78E+01	2.25E+05	3.73E+05	6.67E+01	3.53E+05	1.12E+04	3.98E+05	9.12E+01	3.80E+05
3467.5	3.79E+01	2.37E+05	3.94E+05	6.69E+01	3.72E+05	1.21E+04	4.20E+05	9.42E+01	3.99E+05
3650	3.83E+01	2.49E+05	4.14E+05	6.77E+01	3.90E+05	1.29E+04	4.42E+05	9.99E+01	4.17E+05
3832.5	3.75E+01	2.61E+05	4.34E+05	6.63E+01	4.08E+05	1.37E+04	4.64E+05	1.00E+02	4.35E+05
4015	3.77E+01	2.73E+05	4.55E+05	6.68E+01	4.26E+05	1.45E+04	4.86E+05	1.04E+02	4.53E+05

Days	56138.60c	59141.50c	60143.50c	60145.50c	60147.50c	60148.50c	61147.50c	61148.50c	61149.50c
0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
182.5	2.06E+04	1.85E+04	1.85E+04	1.25E+04	6.34E+02	5.07E+03	6.11E+03	5.06E+00	5.18E+01
365	4.18E+04	4.37E+04	4.00E+04	2.53E+04	6.57E+02	1.03E+04	1.20E+04	1.03E+01	5.36E+01
547.5	6.30E+04	6.91E+04	6.15E+04	3.81E+04	6.57E+02	1.55E+04	1.70E+04	1.46E+01	5.38E+01
730	8.43E+04	9.46E+04	8.30E+04	5.08E+04	6.62E+02	2.07E+04	2.12E+04	1.87E+01	5.44E+01
912.5	1.06E+05	1.20E+05	1.04E+05	6.35E+04	6.64E+02	2.59E+04	2.47E+04	2.20E+01	5.47E+01
1095	1.27E+05	1.45E+05	1.25E+05	7.59E+04	6.56E+02	3.10E+04	2.77E+04	2.49E+01	5.40E+01
1277.5	1.48E+05	1.70E+05	1.46E+05	8.82E+04	6.59E+02	3.61E+04	3.02E+04	2.56E+01	5.44E+01
1460	1.69E+05	1.95E+05	1.67E+05	1.01E+05	6.59E+02	4.12E+04	3.23E+04	2.73E+01	5.45E+01
1642.5	1.89E+05	2.20E+05	1.87E+05	1.13E+05	6.51E+02	4.62E+04	3.40E+04	2.89E+01	5.38E+01
1825	2.10E+05	2.45E+05	2.08E+05	1.25E+05	6.59E+02	5.12E+04	3.55E+04	3.02E+01	5.46E+01

2007.5	2.31E+05	2.69E+05	2.28E+05	1.37E+05	6.60E+02	5.63E+04	3.68E+04	3.14E+01	5.48E+01
2190	2.52E+05	2.94E+05	2.49E+05	1.49E+05	6.73E+02	6.13E+04	3.80E+04	3.41E+01	5.59E+01
2372.5	2.73E+05	3.19E+05	2.69E+05	1.61E+05	6.55E+02	6.63E+04	3.89E+04	3.33E+01	5.45E+01
2555	2.94E+05	3.44E+05	2.89E+05	1.73E+05	6.80E+02	7.13E+04	3.98E+04	3.50E+01	5.66E+01
2737.5	3.15E+05	3.68E+05	3.09E+05	1.85E+05	6.71E+02	7.64E+04	4.05E+04	3.49E+01	5.60E+01
2920	3.36E+05	3.93E+05	3.30E+05	1.97E+05	6.70E+02	8.14E+04	4.11E+04	3.64E+01	5.60E+01
3102.5	3.57E+05	4.18E+05	3.50E+05	2.08E+05	6.73E+02	8.64E+04	4.17E+04	3.56E+01	5.62E+01
3285	3.78E+05	4.42E+05	3.69E+05	2.20E+05	6.70E+02	9.13E+04	4.21E+04	3.61E+01	5.60E+01
3467.5	3.99E+05	4.66E+05	3.89E+05	2.32E+05	6.73E+02	9.62E+04	4.25E+04	3.68E+01	5.64E+01
3650	4.20E+05	4.91E+05	4.09E+05	2.43E+05	6.82E+02	1.01E+05	4.29E+04	3.94E+01	5.70E+01
3832.5	4.41E+05	5.15E+05	4.29E+05	2.55E+05	6.69E+02	1.06E+05	4.32E+04	3.60E+01	5.61E+01
4015	4.62E+05	5.39E+05	4.48E+05	2.66E+05	6.75E+02	1.11E+05	4.34E+04	3.64E+01	5.67E+01

Days	62147.50c	62149.50c	62150.50c	62151.50c	62152.50c	63151.60c	63152.50c	63153.60c	63154.50c
0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
182.5	3.79E+02	2.90E+03	6.34E+01	1.25E+03	8.89E+02	2.33E+00	9.78E-02	4.90E+02	8.43E+00
365	1.57E+03	5.84E+03	2.34E+02	2.49E+03	1.84E+03	9.11E+00	5.54E-01	9.94E+02	3.31E+01
547.5	3.44E+03	8.70E+03	5.12E+02	3.69E+03	2.84E+03	1.99E+01	1.52E+00	1.49E+03	7.28E+01
730	5.86E+03	1.15E+04	8.90E+02	4.85E+03	3.87E+03	3.42E+01	3.14E+00	1.99E+03	1.26E+02
912.5	8.75E+03	1.42E+04	1.36E+03	5.98E+03	4.94E+03	5.17E+01	5.52E+00	2.47E+03	1.92E+02
1095	1.20E+04	1.68E+04	1.91E+03	7.05E+03	6.03E+03	7.20E+01	8.66E+00	2.95E+03	2.68E+02
1277.5	1.55E+04	1.93E+04	2.56E+03	8.09E+03	7.13E+03	9.47E+01	1.26E+01	3.43E+03	3.55E+02
1460	1.93E+04	2.18E+04	3.27E+03	9.09E+03	8.26E+03	1.20E+02	1.74E+01	3.92E+03	4.50E+02
1642.5	2.32E+04	2.42E+04	4.05E+03	1.01E+04	9.38E+03	1.47E+02	2.30E+01	4.41E+03	5.52E+02
1825	2.73E+04	2.65E+04	4.93E+03	1.10E+04	1.06E+04	1.75E+02	2.95E+01	4.87E+03	6.64E+02
2007.5	3.15E+04	2.87E+04	5.86E+03	1.19E+04	1.18E+04	2.05E+02	3.70E+01	5.30E+03	7.81E+02
2190	3.58E+04	3.10E+04	6.90E+03	1.28E+04	1.30E+04	2.36E+02	4.52E+01	5.77E+03	9.05E+02
2372.5	4.01E+04	3.31E+04	7.97E+03	1.37E+04	1.42E+04	2.69E+02	5.39E+01	6.30E+03	1.03E+03
2555	4.44E+04	3.53E+04	9.14E+03	1.45E+04	1.55E+04	3.01E+02	6.38E+01	6.74E+03	1.17E+03
2737.5	4.88E+04	3.74E+04	1.03E+04	1.54E+04	1.68E+04	3.35E+02	7.45E+01	7.22E+03	1.31E+03
2920	5.32E+04	3.94E+04	1.16E+04	1.62E+04	1.80E+04	3.70E+02	8.56E+01	7.70E+03	1.45E+03
3102.5	5.76E+04	4.14E+04	1.29E+04	1.70E+04	1.93E+04	4.06E+02	9.73E+01	8.19E+03	1.60E+03
3285	6.20E+04	4.33E+04	1.43E+04	1.78E+04	2.06E+04	4.42E+02	1.10E+02	8.64E+03	1.75E+03
3467.5	6.63E+04	4.52E+04	1.58E+04	1.85E+04	2.19E+04	4.78E+02	1.23E+02	9.21E+03	1.91E+03
3650	7.06E+04	4.70E+04	1.73E+04	1.93E+04	2.32E+04	5.14E+02	1.37E+02	9.66E+03	2.08E+03
3832.5	7.48E+04	4.89E+04	1.88E+04	2.00E+04	2.46E+04	5.52E+02	1.51E+02	1.01E+04	2.24E+03
4015	7.91E+04	5.06E+04	2.04E+04	2.07E+04	2.60E+04	5.89E+02	1.65E+02	1.06E+04	2.41E+03

Days	63155.50c	64152.60c	64154.60c	64155.60c	64156.60c	64157.60c	64158.60c	64160.60c	67165.60c
0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
182.5	1.34E+02	1.50E-02	1.14E-01	4.70E+00	8.12E+01	6.65E+01	2.51E+01	4.93E+00	9.40E-02
365	2.59E+02	1.19E-01	8.92E-01	1.81E+01	1.81E+02	1.35E+02	5.22E+01	1.00E+01	1.91E-01
547.5	3.73E+02	3.89E-01	2.95E+00	3.93E+01	2.84E+02	2.03E+02	8.07E+01	1.50E+01	2.89E-01
730	4.79E+02	8.98E-01	6.84E+00	6.73E+01	3.94E+02	2.70E+02	1.11E+02	2.01E+01	3.89E-01
912.5	5.78E+02	1.72E+00	1.30E+01	1.01E+02	5.06E+02	3.38E+02	1.42E+02	2.52E+01	4.89E-01
1095	6.69E+02	2.86E+00	2.20E+01	1.41E+02	6.22E+02	4.04E+02	1.74E+02	3.02E+01	5.88E-01
1277.5	7.53E+02	4.41E+00	3.40E+01	1.85E+02	7.42E+02	4.70E+02	2.07E+02	3.51E+01	6.89E-01
1460	8.34E+02	6.39E+00	4.95E+01	2.33E+02	8.65E+02	5.36E+02	2.41E+02	4.01E+01	7.89E-01

1642.5	9.10E+02	8.81E+00	6.86E+01	2.86E+02	9.89E+02	6.02E+02	2.76E+02	4.50E+01	8.89E-01
1825	9.84E+02	1.17E+01	9.15E+01	3.43E+02	1.12E+03	6.67E+02	3.13E+02	4.99E+01	9.93E-01
2007.5	1.06E+03	1.52E+01	1.19E+02	4.02E+02	1.25E+03	7.31E+02	3.50E+02	5.48E+01	1.09E+00
2190	1.13E+03	1.93E+01	1.50E+02	4.66E+02	1.39E+03	7.96E+02	3.89E+02	5.98E+01	1.20E+00
2372.5	1.20E+03	2.37E+01	1.86E+02	5.32E+02	1.53E+03	8.61E+02	4.29E+02	6.46E+01	1.30E+00
2555	1.27E+03	2.89E+01	2.26E+02	6.01E+02	1.68E+03	9.28E+02	4.71E+02	6.96E+01	1.41E+00
2737.5	1.34E+03	3.46E+01	2.71E+02	6.73E+02	1.83E+03	9.92E+02	5.13E+02	7.46E+01	1.52E+00
2920	1.40E+03	4.09E+01	3.21E+02	7.49E+02	1.98E+03	1.06E+03	5.56E+02	7.93E+01	1.62E+00
3102.5	1.47E+03	4.78E+01	3.76E+02	8.28E+02	2.14E+03	1.12E+03	6.02E+02	8.43E+01	1.73E+00
3285	1.53E+03	5.52E+01	4.36E+02	9.08E+02	2.30E+03	1.19E+03	6.48E+02	8.91E+01	1.84E+00
3467.5	1.60E+03	6.33E+01	5.01E+02	9.90E+02	2.47E+03	1.25E+03	6.94E+02	9.40E+01	1.95E+00
3650	1.67E+03	7.20E+01	5.72E+02	1.08E+03	2.64E+03	1.32E+03	7.43E+02	9.88E+01	2.06E+00
3832.5	1.74E+03	8.11E+01	6.47E+02	1.17E+03	2.81E+03	1.38E+03	7.91E+02	1.04E+02	2.17E+00
4015	1.80E+03	9.11E+01	7.29E+02	1.26E+03	2.99E+03	1.45E+03	8.41E+02	1.09E+02	2.28E+00

Days	69169.55c	90230.60c	90231.42c	90232.60c	90233.42c	91231.60c	91233.50c	92232.60c	92233.60c
0	0.00E+00	0.00E+00	0.00E+00	1.60E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.41E+07
182.5	2.09E-08	7.67E+03	1.95E+02	1.59E+08	8.82E+01	2.25E+04	1.53E+05	1.40E+03	1.40E+07
365	1.94E-07	1.61E+04	2.14E+02	1.59E+08	9.02E+01	4.59E+04	1.58E+05	4.09E+03	1.40E+07
547.5	6.82E-07	2.38E+04	1.99E+02	1.58E+08	8.97E+01	6.61E+04	1.57E+05	7.75E+03	1.41E+07
730	1.64E-06	3.12E+04	1.95E+02	1.57E+08	8.96E+01	8.46E+04	1.57E+05	1.22E+04	1.42E+07
912.5	3.26E-06	3.89E+04	2.02E+02	1.56E+08	8.88E+01	1.03E+05	1.56E+05	1.75E+04	1.42E+07
1095	5.64E-06	4.57E+04	1.83E+02	1.56E+08	8.63E+01	1.18E+05	1.51E+05	2.32E+04	1.43E+07
1277.5	8.93E-06	5.23E+04	1.81E+02	1.55E+08	8.58E+01	1.32E+05	1.50E+05	2.93E+04	1.43E+07
1460	1.33E-05	5.88E+04	1.80E+02	1.54E+08	8.52E+01	1.45E+05	1.49E+05	3.56E+04	1.44E+07
1642.5	1.89E-05	6.53E+04	1.78E+02	1.53E+08	8.36E+01	1.57E+05	1.47E+05	4.21E+04	1.44E+07
1825	2.58E-05	7.15E+04	1.74E+02	1.53E+08	8.34E+01	1.68E+05	1.46E+05	4.88E+04	1.45E+07
2007.5	3.41E-05	7.74E+04	1.70E+02	1.52E+08	8.33E+01	1.78E+05	1.46E+05	5.59E+04	1.45E+07
2190	4.44E-05	8.36E+04	1.78E+02	1.51E+08	8.42E+01	1.88E+05	1.47E+05	6.30E+04	1.45E+07
2372.5	5.60E-05	8.91E+04	1.60E+02	1.50E+08	8.15E+01	1.96E+05	1.43E+05	7.01E+04	1.46E+07
2555	7.00E-05	9.51E+04	1.71E+02	1.50E+08	8.39E+01	2.05E+05	1.47E+05	7.71E+04	1.46E+07
2737.5	8.60E-05	1.01E+05	1.62E+02	1.49E+08	8.21E+01	2.12E+05	1.44E+05	8.43E+04	1.46E+07
2920	1.04E-04	1.06E+05	1.57E+02	1.48E+08	8.09E+01	2.17E+05	1.42E+05	9.13E+04	1.46E+07
3102.5	1.25E-04	1.11E+05	1.59E+02	1.48E+08	8.12E+01	2.23E+05	1.42E+05	9.81E+04	1.46E+07
3285	1.47E-04	1.16E+05	1.51E+02	1.47E+08	8.00E+01	2.28E+05	1.40E+05	1.05E+05	1.47E+07
3467.5	1.72E-04	1.20E+05	1.51E+02	1.46E+08	8.01E+01	2.33E+05	1.40E+05	1.11E+05	1.46E+07
3650	2.01E-04	1.25E+05	1.65E+02	1.45E+08	8.04E+01	2.38E+05	1.41E+05	1.18E+05	1.47E+07
3832.5	2.32E-04	1.30E+05	1.43E+02	1.45E+08	7.77E+01	2.41E+05	1.36E+05	1.24E+05	1.47E+07
4015	2.66E-04	1.34E+05	1.46E+02	1.44E+08	7.81E+01	2.46E+05	1.37E+05	1.30E+05	1.47E+07

Days	92234.60c	92235.60c	92236.60c	92237.50c	92238.60c	92239.42c	92240.42c	93235.42c	93236.42c
0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
182.5	5.97E+04	2.82E+02	8.15E-01	2.73E-04	6.41E-07	6.09E-13	2.83E-17	5.88E-10	2.72E-08
365	1.21E+05	1.14E+03	6.73E+00	2.64E-03	1.22E-05	1.27E-11	6.21E-16	2.46E-08	1.17E-06
547.5	1.81E+05	2.56E+03	2.28E+01	8.80E-03	6.15E-05	5.95E-11	2.84E-15	1.72E-07	8.51E-06
730	2.41E+05	4.55E+03	5.37E+01	2.17E-02	2.02E-04	1.99E-10	9.43E-15	6.94E-07	3.52E-05
912.5	3.00E+05	7.03E+03	1.05E+02	4.31E-02	5.09E-04	5.25E-10	2.59E-14	2.09E-06	1.09E-04
1095	3.57E+05	9.83E+03	1.76E+02	7.49E-02	1.08E-03	1.12E-09	5.36E-14	4.75E-06	2.57E-04

1277.5	4.13E+05	1.31E+04	2.74E+02	1.08E-01	1.95E-03	1.88E-09	8.87E-14	9.42E-06	5.26E-04
1460	4.69E+05	1.65E+04	3.98E+02	1.58E-01	3.15E-03	3.31E-09	1.54E-13	1.69E-05	9.71E-04
1642.5	5.22E+05	2.09E+04	5.51E+02	2.17E-01	4.82E-03	4.54E-09	2.06E-13	2.81E-05	1.67E-03
1825	5.75E+05	2.52E+04	7.41E+02	2.95E-01	7.21E-03	6.79E-09	3.16E-13	4.38E-05	2.67E-03
2007.5	6.28E+05	2.98E+04	9.67E+02	3.99E-01	1.04E-02	1.09E-08	5.11E-13	6.45E-05	4.04E-03
2190	6.81E+05	3.46E+04	1.23E+03	5.36E-01	1.49E-02	1.34E-08	6.34E-13	9.78E-05	6.16E-03
2372.5	7.31E+05	3.97E+04	1.53E+03	6.22E-01	2.00E-02	1.94E-08	9.02E-13	1.33E-04	8.71E-03
2555	7.82E+05	4.52E+04	1.89E+03	7.71E-01	2.65E-02	2.64E-08	1.24E-12	1.87E-04	1.23E-02
2737.5	8.32E+05	5.09E+04	2.27E+03	9.37E-01	3.43E-02	3.39E-08	1.62E-12	2.46E-04	1.65E-02
2920	8.80E+05	5.69E+04	2.71E+03	1.10E+00	4.38E-02	3.98E-08	1.88E-12	3.13E-04	2.16E-02
3102.5	9.28E+05	6.31E+04	3.19E+03	1.25E+00	5.46E-02	5.97E-08	2.84E-12	3.92E-04	2.78E-02
3285	9.76E+05	6.96E+04	3.71E+03	1.50E+00	6.69E-02	6.30E-08	2.90E-12	4.80E-04	3.50E-02
3467.5	1.02E+06	7.62E+04	4.28E+03	1.68E+00	8.11E-02	7.58E-08	3.49E-12	5.81E-04	4.32E-02
3650	1.07E+06	8.27E+04	4.91E+03	2.04E+00	9.79E-02	9.15E-08	4.29E-12	7.34E-04	5.47E-02
3832.5	1.11E+06	8.94E+04	5.56E+03	2.13E+00	1.15E-01	1.10E-07	4.94E-12	8.56E-04	6.57E-02
4015	1.16E+06	9.61E+04	6.28E+03	2.49E+00	1.36E-01	1.42E-07	6.57E-12	1.01E-03	7.87E-02

Days	93237.60c	93238.42c	93239.60c	94236.60c	94237.60c	94238.60c	94239.60c	94240.60c	94241.60c
0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
182.5	1.21E-03	5.26E-07	1.04E-10	9.75E-10	1.22E-10	5.88E-06	1.39E-08	2.05E-11	2.84E-14
365	2.34E-02	1.11E-05	2.28E-09	4.55E-08	8.98E-09	2.48E-04	1.15E-06	3.40E-09	9.57E-12
547.5	1.20E-01	5.64E-05	1.10E-08	3.89E-07	8.11E-08	1.96E-03	1.36E-05	6.13E-08	2.64E-10
730	3.88E-01	1.85E-04	3.67E-08	1.79E-06	3.80E-07	8.44E-03	7.80E-05	4.60E-07	2.59E-09
912.5	9.59E-01	4.67E-04	9.67E-08	6.08E-06	1.34E-06	2.64E-02	3.04E-04	2.21E-06	1.69E-08
1095	2.01E+00	9.64E-04	2.04E-07	1.58E-05	3.19E-06	6.58E-02	9.00E-04	7.94E-06	6.63E-08
1277.5	3.57E+00	1.69E-03	3.46E-07	3.50E-05	6.94E-06	1.39E-01	2.26E-03	2.36E-05	2.24E-07
1460	5.89E+00	2.69E-03	5.94E-07	6.93E-05	1.32E-05	2.58E-01	4.81E-03	5.70E-05	6.52E-07
1642.5	9.11E+00	4.10E-03	8.31E-07	1.25E-04	2.32E-05	4.44E-01	9.15E-03	1.24E-04	1.57E-06
1825	1.35E+01	6.24E-03	1.26E-06	2.13E-04	3.78E-05	7.31E-01	1.67E-02	2.48E-04	3.70E-06
2007.5	1.95E+01	9.10E-03	1.97E-06	3.40E-04	5.78E-05	1.15E+00	2.87E-02	4.68E-04	7.35E-06
2190	2.76E+01	1.30E-02	2.53E-06	5.41E-04	9.50E-05	1.75E+00	4.71E-02	8.40E-04	1.40E-05
2372.5	3.71E+01	1.70E-02	3.54E-06	7.98E-04	1.28E-04	2.54E+00	7.35E-02	1.43E-03	2.59E-05
2555	4.86E+01	2.32E-02	4.86E-06	1.19E-03	1.97E-04	3.63E+00	1.13E-01	2.34E-03	4.55E-05
2737.5	6.27E+01	2.99E-02	6.24E-06	1.68E-03	2.65E-04	5.04E+00	1.66E-01	3.70E-03	7.78E-05
2920	7.93E+01	3.70E-02	7.42E-06	2.31E-03	3.51E-04	6.79E+00	2.38E-01	5.67E-03	1.55E-04
3102.5	9.78E+01	4.51E-02	1.06E-05	3.09E-03	4.63E-04	8.92E+00	3.33E-01	8.43E-03	2.71E-04
3285	1.20E+02	5.52E-02	1.15E-05	4.02E-03	5.72E-04	1.15E+01	4.55E-01	1.20E-02	4.73E-04
3467.5	1.45E+02	6.67E-02	1.39E-05	5.16E-03	7.17E-04	1.47E+01	6.11E-01	1.70E-02	6.04E-04
3650	1.75E+02	8.33E-02	1.70E-05	6.76E-03	1.01E-03	1.86E+01	8.07E-01	2.38E-02	8.10E-04
3832.5	2.07E+02	9.29E-02	1.99E-05	8.40E-03	1.11E-03	2.29E+01	1.04E+00	3.23E-02	1.06E-03
4015	2.43E+02	1.11E-01	2.53E-05	1.04E-02	1.39E-03	2.80E+01	1.33E+00	4.33E-02	1.46E-03

Days	94242.60c	94243.60c	94244.60c	95241.60c	95242.50c	95243.60c	96241.60c	96242.60c	96243.60c
0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
182.5	2.58E-17	3.58E-22	0.00E+00	7.34E-17	3.85E-20	2.35E-20	0.00E+00	1.80E-19	0.00E+00
365	1.77E-14	2.71E-19	0.00E+00	4.88E-14	5.47E-17	3.18E-17	0.00E+00	2.37E-16	3.28E-19
547.5	7.52E-13	1.23E-17	3.19E-20	2.05E-12	3.40E-15	2.21E-15	8.97E-21	1.43E-14	2.82E-17
730	9.83E-12	1.50E-16	5.85E-19	2.72E-11	5.98E-14	3.67E-14	1.80E-19	2.38E-13	7.05E-16

912.5	8.09E-11	1.29E-15	6.40E-18	2.14E-10	5.83E-13	3.75E-13	1.97E-18	2.26E-12	8.02E-15
1095	3.88E-10	6.20E-15	4.03E-17	1.07E-09	3.52E-12	2.30E-12	1.11E-17	1.29E-11	5.47E-14
1277.5	1.52E-09	3.07E-14	2.23E-16	4.11E-09	1.55E-11	1.24E-11	4.95E-17	5.51E-11	2.76E-13
1460	4.89E-09	1.55E-13	1.22E-15	1.36E-08	5.68E-11	6.75E-11	1.78E-16	1.92E-10	1.05E-12
1642.5	1.34E-08	2.29E-13	3.02E-15	3.78E-08	1.77E-10	1.53E-10	5.57E-16	5.71E-10	3.45E-12
1825	3.49E-08	5.57E-13	7.53E-15	9.54E-08	4.95E-10	3.64E-10	1.53E-15	1.56E-09	1.10E-11
2007.5	7.85E-08	1.56E-12	2.08E-14	2.16E-07	1.23E-09	9.99E-10	3.68E-15	3.77E-09	3.03E-11
2190	1.64E-07	2.57E-12	4.51E-14	4.51E-07	2.84E-09	2.06E-09	9.16E-15	8.45E-09	7.39E-11
2372.5	3.23E-07	5.36E-12	9.60E-14	8.88E-07	5.94E-09	4.34E-09	1.71E-14	1.70E-08	1.64E-10
2555	6.11E-07	1.25E-11	2.15E-13	1.66E-06	1.20E-08	9.77E-09	3.61E-14	3.35E-08	3.56E-10
2737.5	1.14E-06	1.93E-11	4.17E-13	3.01E-06	2.30E-08	1.81E-08	6.55E-14	6.23E-08	7.01E-10
2920	2.09E-06	3.97E-11	8.27E-13	5.55E-06	4.25E-08	3.50E-08	1.19E-13	1.14E-07	1.34E-09
3102.5	3.84E-06	9.50E-11	1.75E-12	1.02E-05	7.83E-08	7.64E-08	2.21E-13	2.12E-07	2.48E-09
3285	6.86E-06	1.03E-10	2.95E-12	1.84E-05	1.43E-07	1.20E-07	3.81E-13	3.78E-07	4.48E-09
3467.5	1.12E-05	2.83E-10	5.83E-12	3.01E-05	2.51E-07	2.51E-07	6.66E-13	6.63E-07	7.83E-09
3650	1.71E-05	2.72E-10	9.53E-12	4.52E-05	4.23E-07	3.75E-07	1.25E-12	1.07E-06	1.38E-08
3832.5	2.43E-05	8.45E-10	1.87E-11	6.50E-05	6.61E-07	7.89E-07	1.66E-12	1.56E-06	2.21E-08
4015	3.50E-05	5.26E-10	2.75E-11	9.16E-05	9.96E-07	1.02E-06	2.50E-12	2.28E-06	3.55E-08

Days	96244.60c	96245.60c	96246.60c	96247.60c	96248.60c	actinide
0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.74E+08
182.5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.74E+08
365	2.68E-19	3.78E-22	0.00E+00	0.00E+00	0.00E+00	1.73E+08
547.5	2.75E-17	1.15E-19	0.00E+00	0.00E+00	0.00E+00	1.72E+08
730	6.21E-16	3.78E-18	6.32E-21	0.00E+00	0.00E+00	1.72E+08
912.5	7.85E-15	6.02E-17	1.48E-19	0.00E+00	0.00E+00	1.71E+08
1095	5.84E-14	5.39E-16	1.62E-18	2.55E-21	0.00E+00	1.71E+08
1277.5	3.46E-13	3.33E-15	1.15E-17	2.82E-20	0.00E+00	1.70E+08
1460	1.91E-12	1.94E-14	6.95E-17	1.82E-19	0.00E+00	1.69E+08
1642.5	6.47E-12	1.26E-13	4.67E-16	1.34E-18	2.97E-21	1.69E+08
1825	1.71E-11	4.35E-13	2.11E-15	6.97E-18	2.53E-20	1.68E+08
2007.5	4.51E-11	9.26E-13	6.15E-15	2.70E-17	1.24E-19	1.68E+08
2190	1.11E-10	2.65E-12	1.69E-14	8.47E-17	4.61E-19	1.67E+08
2372.5	2.44E-10	5.83E-12	4.25E-14	2.33E-16	1.42E-18	1.66E+08
2555	5.42E-10	1.21E-11	9.68E-14	5.61E-16	3.82E-18	1.66E+08
2737.5	1.14E-09	2.68E-11	2.17E-13	1.38E-15	9.89E-18	1.65E+08
2920	2.28E-09	5.63E-11	4.72E-13	3.09E-15	2.42E-17	1.64E+08
3102.5	4.65E-09	1.15E-10	9.92E-13	6.83E-15	5.57E-17	1.64E+08
3285	8.83E-09	2.43E-10	2.07E-12	1.37E-14	1.20E-16	1.63E+08
3467.5	1.66E-08	4.98E-10	4.29E-12	2.90E-14	2.50E-16	1.62E+08
3650	2.98E-08	8.73E-10	8.52E-12	6.13E-14	5.34E-16	1.62E+08
3832.5	5.33E-08	1.60E-09	1.58E-11	1.23E-13	1.09E-15	1.61E+08
4015	9.30E-08	3.00E-09	2.96E-11	2.37E-13	2.21E-15	1.61E+08

This document was created with Win2PDF available at <http://www.daneprairie.com>.
The unregistered version of Win2PDF is for evaluation or non-commercial use only.