ADVANCED POLYMERIC BURNABLE POISON ROD ASSEMBLIES FOR PRESSURIZED WATER REACTORS

By

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by

Kenneth S. Allen

To my best friend and companion Stephanie and our wonderful boys Zachary and Nicholas. Your faithful support and encouragement has made this and every task easy to accomplish. Always – Ken.

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KEY TO SYMBOLS AND ACRONYMS

Acronym or Symbol	**Definition**
BOC	Beginning of cycle
BPRA	Burnable poison rod assemblies
BWR	Boiling water reactor
C	Coefficient of thermal expansion
CNP	Cold-no-power
E_T	Most probable thermal neutron energy
EFPD	Effective full power days
ENDF/B-V	Evaluated nuclear data files Brookhaven V
EOC	End of cycle
HFP	Hot-full-power
HNP	Hot-no-power
IFBA	Integral fuel burnable absorber
k	Neutron multiplication factor (a.k.a. criticality constant)
k_∞	Infinite neutron multiplication factor
k_{eff}	Effective neutron multiplication factor
LWR	Light water reactor
MCNP	Monte Carlo Neutron Photon Transport code
MWd/MTU	Mega-watt days per metric ton uranium
MWt	Mega watts (thermal)

PACS	Polyacetyleniccarboranosiloxane
$PNL_{Thermal}$	Probability of non-leakage for thermal neutrons
PWR	Pressurized water reactor
RSICC	Radiation Safety Information Computational Center
T_{Cl}	Centerline temperature
v_T	Most probable thermal neutron velocity
WABA	Wet annular burnable assembly
ξ	Average logarithmic energy decrement
σ_a	Microscopic absorption cross section
$\sum_a$	Macroscopic absorption cross section

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Engineering

ADVANCED POLYMERIC BURNABLE POISON ROD
ASSEMBLIES FOR PRESSURIZED WATER REACTORS

By

Kenneth S. Allen

May 2003

Chair: Professor James Tulenko
Department: Nuclear and Radiological Engineering

This study examines the use of a high-hydrogen, boron-enriched polymer materials in burnable poison rod assemblies (BPRAs) in pressurized water reactors (PWRs). Polyacetyleniccarboranosiloxane "carborane" is a boron-containing, high-hydrogen polymer that is representative of these polymers. It is thermally stable and can be used to eliminate the water displacement penalty created at end of cycle (EOC) by currently used boron-carbide burnable poisons. This material substitution is projected to result in higher burn ups and greater fuel use for fuels of equal enrichments.

The polymer's chemical composition can be tailored to achieve the desired amount of boron and hydrogen. This tailoring feature allows carborane to be produced with a high hydrogen content serving as a moderator at EOC, softening the reactor spectrum and eliminating the moderator displacement penalty currently associated with boron carbide BPRAs and wet annular burnable assemblies (WABAs).

Once the desired components in the polymer were derived, a series of analyses were run comparing the polymer to boron-carbide BPRAs and WABAs. Each PWR assembly was modeled in CASMO-3, a 2-D nodal transport depletion code from Studsvik of America. Additionally, each assembly was modeled in MCNP and depleted using MONTEBURNS, a PERL code script from the Radiation Safety Information Computational Center (RSICC) that depletes MCNP4C2 KCODE problems using ORIGEN2.1. The results from both codes demonstrated that the carborane material consistently had a lower k-infinity value at BOL, indicating a harder spectrum; and a higher k-infinity at EOC, indicating a lower amount of burnable absorber present and a larger thermal flux at EOC.

The materials were also modeled in a simulation of a core in accordance with the reload report for the Crystal River 3 reactor to determine the power peaking and expected core burn-ups in an actual PWR reload scenario. The core was modeled in EASCYC, a diffusion theory nodal code, and in MCNP / MONTEBURNS. Each of the core modeling codes closely matched the predicted values in the reload report for the core parameters with the boron-carbide BPRAs. The carborane cores were found to have longer core lives and slightly higher power peaking indices at EOC .

CHAPTER 1
INTRODUCTION

Background

The focus of this study is the development of a polymeric burnable poison material that burns out more completely (reducing the negative reactivity at end of cycle (EOC)) and eliminates the water displacement penalty caused by burnable poison rod assemblies (BPRAs) occupying moderator space in the control rod guide tubes.

Utilities and fuel vendors have made extensive use of burnable poisons in the past decade, resulting in dramatic improvements in fuel utilization and depletion, or "burnup," improved overall conversion of uranium-238 into fissile plutonium, and reduction of leakage of thermal neutrons from the core. Extended lifetimes of fuel batches and higher burnups have made nuclear power extremely cost-competitive with other forms of energy production. In fact, based on fuel cycle costs, nuclear energy is the least expensive alternative in terms of dollars per kilowatt-hour of electricity produced. Further improvements in burnable poisons could result in even greater fuel use and cost-reduction.

This study examines the use of high-hydrogen and boron-enriched polymer materials for use in burnable poison rod assemblies (BPRAs) in pressurized water reactors (PWRs). The reason for using boron-containing organic polymers is to provide moderating hydrogen atoms in the polymer to replace the currently used B_4C/Al_2O_3 inorganic system. A new material named polyacetyleniccarboranosiloxane (PACS), developed by Dr. Keller of the Naval Research Laboratory is typical of the material we

are seeking [1]. Keller's PACS is a boron-containing, high-hydrogen polymer which has been shown to be stable up to 1000 °C. It can be used in BPRAs to eliminate the water displacement penalty created at EOC by currently used boron-carbide burnable poisons. Previous research predicts that this material substitution results in higher burnups and greater fuel utilization for fuels of equal enrichments [2].

The chemical formula for PACS or "carborane" is $(B_{10}H_{10}C_2)_{\mathbf{a}}((CH_3)_2SiO)_{\mathbf{b}}(C_2)_{\mathbf{c}}$. Its composition can be tailored for the amount of boron and hydrogen present by adjusting the quantities of the components represented by the subscripts a, b, and c in the formula. This tailoring feature allows carborane to be produced with a high hydrogen content which will serve as a moderator at EOC softening the reactor spectrum and eliminating the moderator displacement penalty. The softer spectrum also increases the worth of the boron in the polymeric BPRA at BOC and enhances the consumption of plutonium in the core by providing more thermal neutrons for conversion and fission at EOC.

Rational for Use of Burnable Poisons

The probability for any type of nuclear reaction, such as neutron absorption or scatter, within a particular material is referred to as the microscopic cross section (σ) of the material and is represented in units of area. The common unit of area used in nuclear engineering is the barn which equals 1×10^{-24} cm^2. The product of the microscopic cross section and the material's number density (atoms / volume) is called the macroscopic cross section ($\sum$) of the material and is given in units of inverse length (cm^{-1}). The macroscopic cross section is a more effective measure of the element or compound's actual probability of reaction because it accounts for the nuclear probability of interaction and the physical probability of the target atoms being present in a particular region.

A reactor must have excess reactivity in the core in order to compensate for fuel depletion, fission product absorption, and temperature effects [3]. High-absorption fission products (xenon and samarium) reach equilibrium within a few days after the reactor going critical and achieving full power. The temperature effects caused by changes in power can be compensated for with control rods and changes in chemical shim. Therefore, the primary purpose of a burnable poison is to offset the excess reactivity required to sustain the reactor over time, or fuel depletion and fission product build-up. A burnable poison performs this function by absorbing large amounts of thermal neutrons at BOC and progressively absorbing fewer neutrons as the absorber material changes to a daughter product or "burns" until EOC when it is removed from the core. Some properties of an ideal burnable poison are shown in Table 1-1.

Table 1-1. Ideal properties of a burnable poison

Desired Effect	Property
Max	Cross section for thermal neutrons at beginning of cycle (BOC) of the fuel
Max	Burn-out at EOC resulting in maximum reactivity when desired
Min	Daughter product cross section (to allow the poison to deplete or "burn")
Min	Excess unwanted products (such as gases) produced during depletion
Min	Corrosive or other harmful interactions with reactor components
Min	Impact on amount of fuel or moderator displaced in core (esp. at EOC)
Min	Impact on heat transfer between fuel and coolant and melting point of fuel
Min	Impact on power peaking over the cycle

A burnable poison allows a higher amount of excess reactivity to be present at the beginning of cycle (BOC) in the reactor. This higher reactivity increases the amount of time the fuel can be used which is referred to as the burnup for the cycle. A longer time between cycle reloads and a higher burnup reduces reactor downtime for reloads, reduces the amount of waste products (spent fuel assemblies), and reduces the frequency of purchasing new fuel.

Burnable poisons also allow fresh fuel to be placed in the center of a reactor core in an "Ultra Low Leakage" design. The burnable poisons quench the high reactivity of the new fuel and help maintain a constant power and flux within the reactor core that is below the maximum value allowed for the reactor. This low-leakage core converts more fertile material to fissile material allowing a greater proportion of the fuel to be burned by the end of life. The low leakage design also helps eliminate damage to the pressure vessel due to neutrons escaping from the core [4].

Types of Burnable Poison Isotopes

Some of the burnable poison isotopes commonly used today are boron-10, gadolinium-157 and erbium-167. Boron is used both in ZrB_2 coatings on fuel pellets and in B_4C / Al_2O_3 fixed BPRAs. Gadolinium and erbium are used in mixed oxides (Gd_2O_3 and Er_2O_3) within the fuel pellet [3]. These materials meet to some extent the eight optimum criteria in Table 1-1. Other isotopes with significant cross sections for thermal neutron absorption are europium, dysprosium, and palladium. Figure 1-1 shows microscopic absorption cross sections and natural abundance for several isotopes of burnable poison materials generated using a NITAWL 238 group library that used source data from the Evaluated Nuclear Data Files from Brookhaven National Laboratories version five (ENDF/B-V) [5]. The primary region of interest for a burnable poison is the absorption of thermal neutrons. Thermal neutrons are those whose energies are located within a Maxwellian distribution function and are normally assumed to have a most probable energy (E_T) and speed based on the temperature of the system. A temperature of 293°K corresponds to $E_T = 0.025$ eV and $v_T = 2200$ m/s while a reactor operating temperature of 590 °K results in $E_T = 0.051$ eV and $v_T = 3100$ m/s [6]. A high natural abundance for a material is normally associated with a lower manufacturing cost. Not all

of the natural isotopes are shown in Figure 1-1. For instance, gadolinium has seven naturally occurring isotopes but only the most commonly used parent (GD-157) is shown to make the data easier to interpret.

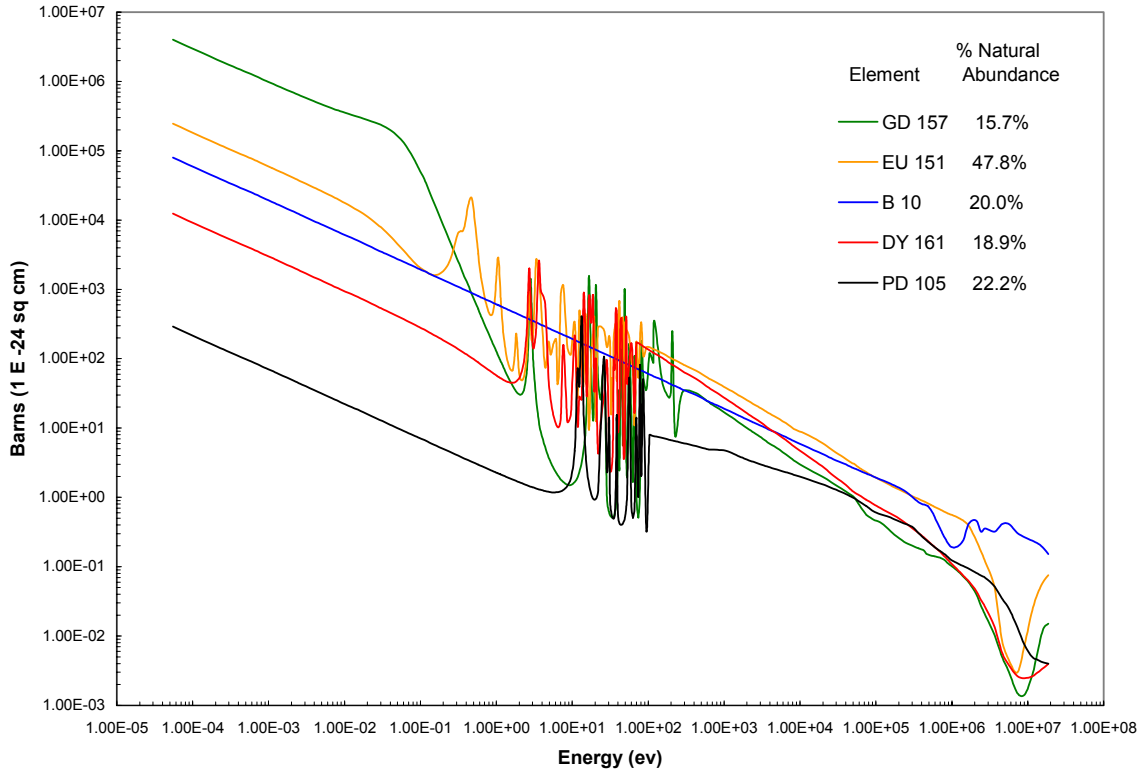


Figure 1-1. Microscopic cross sections of various isotopes of burnable poison materials.

Carriers and Locations for Burnable Poisons

The primary difference with respect to control between a boiling water reactor (BWR) and a PWR is that a PWR uses boron in the water (chemical shim) to assist in the control of reactivity within the core while the BWR uses coolant flow control. Chemical shim is usually boric acid added in parts per million (ppm) to the reactor's coolant water to offset excess reactivity. A PWR can use chemical shim because the water does not boil in the core. A light water reactor (LWR) has a negative void coefficient meaning that when the water is heated and decreases in density the moderation effect is reduced

and the reactivity in the core is also reduced. However, with the use of chemical shim, the amount of control poison is also reduced with the increase in temperature resulting in a positive reactivity effect. This change in the void coefficient often limits the amount of chemical shim that can be added to a core [6]. In a BWR the boiling water in the core is not suitable for the use of chemical shim to offset reactivity but the amount of water flowing through the core can be changed (flow control) to change the amount of voids within the core.

Table 1-2. Example reactivity worths of control elements in LWRs

Reactivity (Δk/k)	PWR	BWR
Excess reactivity		0.25
• at 20° C	0.293	
• at op. temp	0.248	
• at eq. Xe and Sm	0.181	
Total control rod worth†	0.07	0.17
	~ 60 clusters	140-185 cruciforms
Fixed burnable poisons		0.12
Chemical shim worth		—
Shutdown margin	0.14	0.04
• Cold and clean		
• Hot and eq. Xe and Sm		

†Approximately half of the total control rod worth is dedicated for shutdown rods and is not used for power maneuvering or depletion compensation. Adapted from J. DUDERSTADT, L. HAMILTON, *Nuclear Reactor Analysis,* John Wiley and Sons Inc., New York 1976.pg. 539.

Because of the chemical shim, the control requirements for the mechanical control rods are different between BWRs and PWRs. A PWR's control rods must have enough negative reactivity to take the reactor from hot-full-power (HFP) to hot-no-power (HNP). A BWR's control rods must be able to take the reactor from hot-full-power to cold-no-power (CNP). The PWR achieves CNP by using chemical shim. Chemical shim is not part of this study with the assumption that it will continue to be used in the same manner as it is currently employed.

Reactivity (ρ) represents a ratio in the fractional change in a system from critical (Δk/k). The unit of reactivity worth in a light water reactor (LWR) is the percent mill (pcm) where 1pcm = ρ x 10^{-5} [7]. Another unit of reactivity is the dollar which is the amount of reactivity required to make a reactor critical on the prompt neutrons alone, prompt critical, and varies as a function of the type of fuel used. Prompt neutrons are those generated immediately from the fission process. Delayed neutrons are generated up to a couple of minutes following fission and are the product of fission fragment radioactive decay. Table 1-2 shows various worths of different control elements in typical BWR and PWR reactors [6].

As shown in Table 1-2, a PWR has approximately 60 clusters of control rods fixed within the reactor's geometry. Every fuel assembly must be designed to accept a control rod cluster because the assemblies are moved throughout the core during each reload. This "shuffle" allows for the fuel assemblies to be arranged in such a manner to produce the optimum lifetime for the core. Also it optimizes the power peaking and control requirements during the cycle. The reload design also attempts to place fresh fuel assemblies in locations without control rod clusters to allow the BPRA assemblies to fill the empty control rod guide tubes in the new assembly.

Figure 1-2 shows plan views of Framatome Mark IVB 15 x 15 assemblies with various configurations of BPRAs. This particular assembly was designed to accept up to 16 control rods in a cluster and can accept up to 16 BPRAs. Some reactor designs have as many as 20 control rod guide tubes. The center hole in the assembly is for in-core instrumentation and the triangle region illustrates the area of symmetry used by some computer codes to simplify calculations. The assembly shown in Figure 1-2 is the same

assembly used in the Crystal River Three reactor for the cycle 12 core reload. The reload report for the Crystal River Three reactor is the primary benchmark comparison for all of the calculations and models within this study.

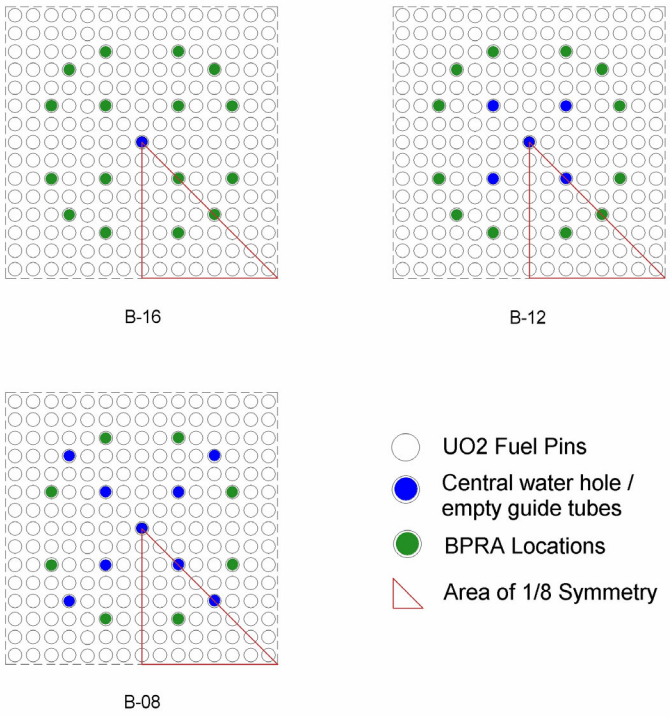


Figure 1-2. The BPRA locations in a 15 x 15 Framatome Mark IVB assembly

Some of the various fixed burnable poison materials and carriers used today include the BPRA, the Integral Fuel Burnable Absorber (IFBA), gadolinia-urania burnable poison fuel rod, the erbia-urania burnable poison fuel rod, and the Wet Annular Burnable Absorber (WABA). The BPRA, illustrated in Figure 1-3, is a boron carbide aluminum oxide mixture used by Westinghouse and Framatome in PWRs. The IFBA is a fuel pellet that is coated with a layer of zirconium diboride used by Westinghouse. Gadolinia-urania fuel rods are used by Framatome in PWRs and General Electric in BWRs. The erbia-urania fuel rods are used by Combustion Engineering in PWRs. The WABA, in Figure 1-4, is a Westinghouse modification to the typical BPRA that includes

a hole, or annulus, in the middle of the BPRA to allow for less of a moderator penalty at EOC. However, this design is expensive to fabricate.

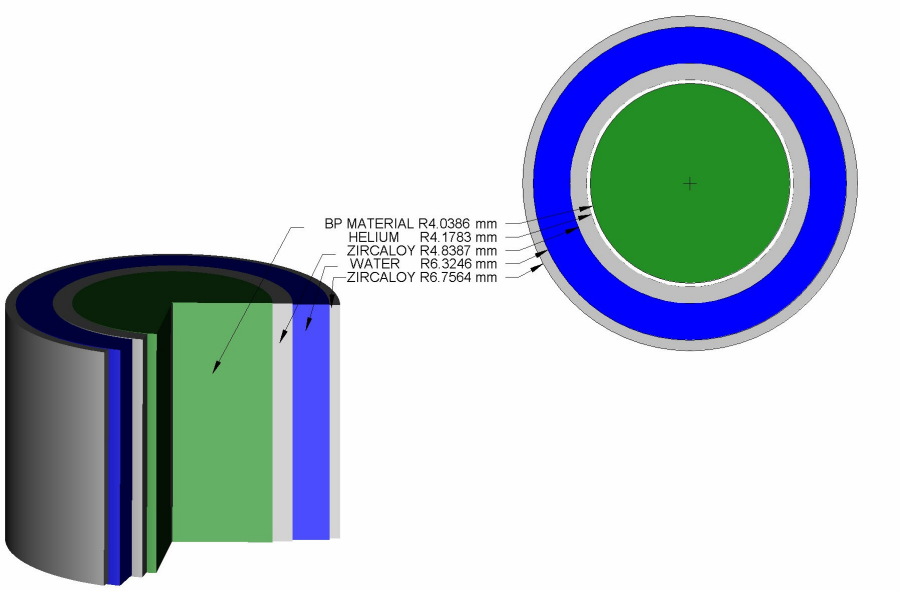


Figure 1-3. The BPRA plan view and cross section

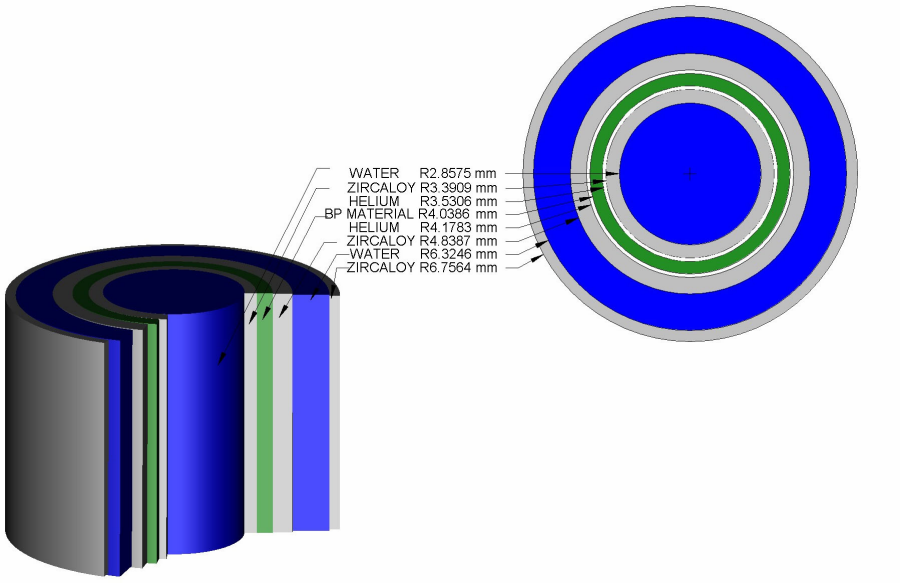


Figure 1-4. The WABA plan view and cross section

The moderator displacement penalty is just one of many design concerns that are considered when attempting to generate an improved burnable poison design. Just as

there are numerous desirable properties of the burnable poison material, shown in Table 1-1, each of the current designs for burnable absorbing systems have distinct advantages and disadvantages. Advantages and disadvantages for each of these burnable poison systems are listed in Table 1-3. The central issue with this study is to take the desirable characteristics of a material and combine it with the most cost effective manufacturing process and generate an improved burnable poison assembly. The improved assembly must not only be able to demonstrate better performance but it must be able to withstand the harsh conditions within the reactor both in normal operations and in the event of an emergency as well as or better than the current BPRAs.

Table 1-3. Properties of burnable poison systems.

Type	Advantages	Disadvantages
BPRA (B_4C-Al_2O_3)	• Inexpensive and easy to manufacture • Uniform boron distribution • Low swelling	• Some residual reactivity at EOC • Moderator displacement • Separate assembly creates an additional waste product
IFBA	• No moderator displacement penalty	• Helium gas produced by the burnup of boron adds to the fission gases inside the fuel rod and is a limiting criteria
Gd_2O_3-UO_2	• Gadolinium has a very high thermal neutron cross section • No moderator displacement penalty	• Reduces the melting point of uranium and thermal conductivity of the fuel • Daughter products have moderate cross sections for absorption
WABA	• Less excess reactivity because the annular design allows moderator to flow through the center of the rod enhancing boron burnup • A 21% smaller moderator displacement penalty than a BPRA	• Cost of manufacture for the annular design • Still results in some moderator displacement • Separate assembly creates an additional waste product

The overall differences between two burnable poison systems may only result in a change of one percent of burnup over the cycle of a core. However, because of the enormous costs to a utility during a shutdown, one percent of a 2-year cycle could result in a savings of $6 million per reload to the utility. It is therefore feasible to research a new material that could overcome some of the disadvantages listed in Table 1-3 even if the differences are subtle.

CHAPTER 2
MATERIAL SELECTION

Chapter 1 showed some of the different types of burnable poisons used today and displayed their overall advantages and disadvantages in Table 1-3. This chapter examines the required nuclear reaction properties, specifically the moderation effect at EOC, of an advanced burnable poison material. It also establishes the benchmark criteria for an improved polymeric burnable absorber versus the standard boron carbide BPRA and WABA. The IFBA and Gd_2O_3/UO_2 burnable absorbers are not discussed in this chapter because they do not directly relate to the study of an improved BPRA. Additionally, the benchmark requirements of the thermal mechanical properties, to include radiation effects, are discussed in Chapter 4.

The first step in the development of a burnable poison polymer that has the moderation ability equal to or better than light water at EOC was to determine the amount of moderation materials required in the PACS, or "carborane," polymer. As stated in Chapter 1, carborane ($(B_{10}H_{10}C_2)_a((CH_3)_2SiO)_b(C_2)_c$) can be modified by adjusting the values of a, b, and c in the subscript of the formula. By determining a measure of the moderation effectiveness of light water, a benchmark standard could be established and an estimate can be made of the minimum weight percent of moderation materials that will be required for the burnable poison to offset the water displacement penalty at EOC. Although PACS is not the only advanced polymeric burnable absorber considered within this study, it is characteristic of these polymers. The method of determining the optimum

material concentration in PACS could be directly related to any advanced polymer by substitution of the appropriate elements and concentrations in the methodology.

Moderation Effectiveness and Benchmark Calculations

Neutrons produced in fission are "born" at energies between 1 to 2 MeV. In a thermal nuclear reactor, neutrons are slowed down, or moderated, to thermal energies (approximately 0.625 eV) by elastic and inelastic scattering with nuclei within the core in order to generate further fissions. Inelastic scatters occur primarily at energy ranges above 10 keV because there must be a threshold energy in which the neutron excites the target nucleus [6]. The primary moderation mechanism is elastic scatter with the moderator in the lower part of the slowing-down region of the neutron energy spectrum [3]. For the purpose of this research this section of the slowing-down region is referred to as the epithermal region of the neutron energy spectrum.

A measure of a potential moderator's effectiveness at slowing down neutrons is its average logarithmic energy decrement represented by ξ. Because this value uses the isotropic nature of the scatter and integrates over all possible angles it provides a meaningful value of an element or compound's ability to moderate neutrons without respect to angle or energy. The average logarithmic energy decrement [7] is given in Eq. 2-1.

$$\xi \equiv \overline{\ln \frac{E_1}{E_2}} = \frac{\int_{-1}^{1} \ln \frac{E_1}{E_2} d(\cos\theta)}{\int_{-1}^{1} d(\cos\theta)} = 1 + \frac{(A-1)^2}{2A} \ln \frac{A-1}{A+1} \tag{2-1}$$

Using the relationship for the reduced mass $\alpha = ((A\text{-}1/A\text{+}1)^2)$ it is more commonly seen as Eq. 2-2.

$$\xi = 1 + \frac{\alpha}{1-\alpha}\ln\alpha \tag{2-2}$$

For a neutron born at E_b slowed down to E_t the average number of collisions required to reach E_t can be derived from the relationship given by Eq. 2-3.

$$\text{Average number of collisions} = \frac{\ln\left(\frac{E_b}{E_t}\right)}{\xi} \tag{2-3}$$

Using E_b = 2 MeV and E_t = 0.625 eV, Eq. 2-3 = $\frac{14.98}{\xi}$. Table 2-1 shows common values for various nuclei scattering neutrons from 2 MeV to 0.625 eV.

Table 2-1. Scattering properties of various nuclei

Element	Atomic Mass #	α	ξ	# Colls. to 0.625 eV
Hydrogen	1	0.000	1.000	15
Deuterium	2	0.111	0.726	20
Beryllium	9	0.640	0.207	70
Carbon	12	0.716	0.158	92
Oxygen	16	0.779	0.120	121
Uranium	238	0.983	0.0083	1700

Adapted from Glasstone S, Sesonske A. Nuclear Reactor Engineering. New York: Chapman & Hall, Inc; 1994. pg 169.

A more relevant measure of a moderator's ability to slow down neutrons is a combination of its average logarithmic energy decrement and its cross section. A microscopic cross section (σ) is a measure of an element or compound's probability of having a particular reaction with a given particle. Different elements and compound's are more likely to scatter, absorb, or fission and this relative probability is measured in area (typically in barns or 1 x 10^{-24} cm^2). A macroscopic cross section (∑) is the combination of the microscopic cross section and the number density (atoms/cc) of the material. The macroscopic cross section is given in units of cm^{-1} and is a measure of the true

probability of the interaction of the material based on the physical conditions at the time of the interaction. For instance, at a given energy, water always has the same microscopic cross section but the macroscopic cross section varies as the density of water changes under pressure and temperature differentials. For the case of a pressurized light water reactor, at a pressure of 13,790 kilopascals and temperature of 583 °C, the specific volume of saturated liquid water is 0.02565 ft^3/lb or 1.6011 cm^3/gm which yields a density of 0.715 gm/cm^3 [8]. Table 2-2 compares various moderating media to include the macroscopic elastic scattering cross section ($\sum_s$) and the product of $\sum_s$ and the average logarithmic energy decrement. It also includes the ratio of the macroscopic elastic scattering cross section to the macroscopic absorption cross section multiplied by the average logarithmic energy decrement.

Table 2-2. Scattering properties of various moderators

Mod.	Atomic Mass #	ξ	Density (gm/cc)	Epith. σ_s (barns)	# Dens (atm/cm^3 x 10^{22})	$\sum_s$ (cm^{-1})	$\sum_s \xi$ (cm^{-1})	$\sum_s \xi$ / $\sum_a$
H_2O	18	0.93	0.715	42.0	2.389	1.003	0.936	45
H_2O	18	0.93	1.0	42.0	3.340	1.403	1.310	63
D_2O	20	0.51	1.10	10.5	3.320	0.35	0.179	20,883
Be	9	0.207	1.85	6.1	12.400	0.75	0.155	122
C	12	0.158	1.70	4.7	8.550	0.41	0.065	216

The best moderator of the compounds listed in Table 2-2 based on the product of the average logarithmic energy decrement (amount the neutron slows down in a collision) and the macroscopic cross section (probability that the neutron will have a collision) is light water at room temperature. However, because of water's relatively high neutron absorption cross section, it absorbs thermal neutrons much greater than the other materials as indicated by the product of the ratio of the scatting to absorption cross sections and the logarithmic energy decrement. For this study, the concern is for the

improvement of a burnable poison in a light water reactor so the benchmark to use is that of light water. Of course, the reactor cannot produce power at room temperature so the benchmark standard for $\sum_s \xi$ for the advanced burnable poison assemblies should be 0.936 cm^{-1}. Any burnable poison compound that has a higher $\sum_s \xi$ than 0.936 cm^{-1} at the end of cycle would be considered an increase in moderator (above the standard for the coolant) and would be highly desirable. Additionally, the benchmark for $\sum_s \xi / \sum_a$ should be 45 and a burnable poison with a higher value than 45 would also be desirable.

Optimization of PACS Structure for Moderation

The next step in determining the optimum burnable poison composition was to vary the compositions within carborane and determine its moderator effectiveness at EOC. This calculation for the moderator effectiveness represents only one possible combination of elements. It accounts for varying percentages of boron and hydrogen but does not consider the possible physical effects of changing the constituent materials such as possibly reducing the thermal stability of the polymer. Again, this methodology could be used for any polymeric structure or compound. Appendix A contains a spreadsheet of permutations of these calculations.

Calculation of the Weight Percent of Each Element

First, the subscript coefficients for the PACS molecular structure are selected to get the number of atoms in the molecule. Using the first line of the spreadsheet in Appendix A as an example, the carborane molecule is:

$$(B_{10}H_{10}C_2)\ ((CH_3)_2SiO)_{12}(C_2)_9.$$

The number of atoms per molecule and the calculation of the total atomic masses for the element and the carborane compound are given in Table 2-3. The calculation of the total weight percents of each element are shown in Table 2-4.

Table 2-3. Total atomic masses for each element and compound

Element	Number of atoms		Atomic weight		Total
C	44	x	12.01	=	528.44
Si	12	x	28.09	=	337.08
O	5	x	15.99	=	79.95
B	10	x	10.81	=	108.10
H	82	x	1.01	=	82.82
				Total	1136.39

Table 2-4. Weight percents of each element

Element	Atomic mass in material		Total mass		Weight Percent
C	528.44	/	1136.39	=	46.50%
Si	337.08	/	1136.39	=	29.66%
O	79.95	/	1136.39	=	7.04%
B	108.10	/	1136.39	=	9.51%
H	82.82	/	1136.39	=	7.29%

Average Epithermal Microscopic Cross Sections

From the previous definition of epithermal (the lower end of the slowing down region of the spectrum) the region of interest is from 2.0 eV to 100 eV. The average epithermal microscopic cross section for each of the materials was determined by taking the ENDF/B-V cross section values for elastic scattering from a 238-group NITAWL model and averaging the values from 2.0 eV to 100 eV (75 groups total shown in Figure 2-1) [5]. The value for B was taken as a weighted average between the values of B_{10} and B_{11} to represent natural boron (20% B_{10} to 80% B_{11}). The assumption is also made that the creation of lithium-7 and other isotopes during the absorption or "burn" process will not significantly change the epithermal scatting cross sections for the compound as a whole. The average thermal absorption cross section (Figure 2-2) was calculated in the same manner as the epithermal scattering cross section. Although depicted on the figure, the boron is assumed to be completely burned out at EOC and will not significantly add to the total absorption cross section of the material.

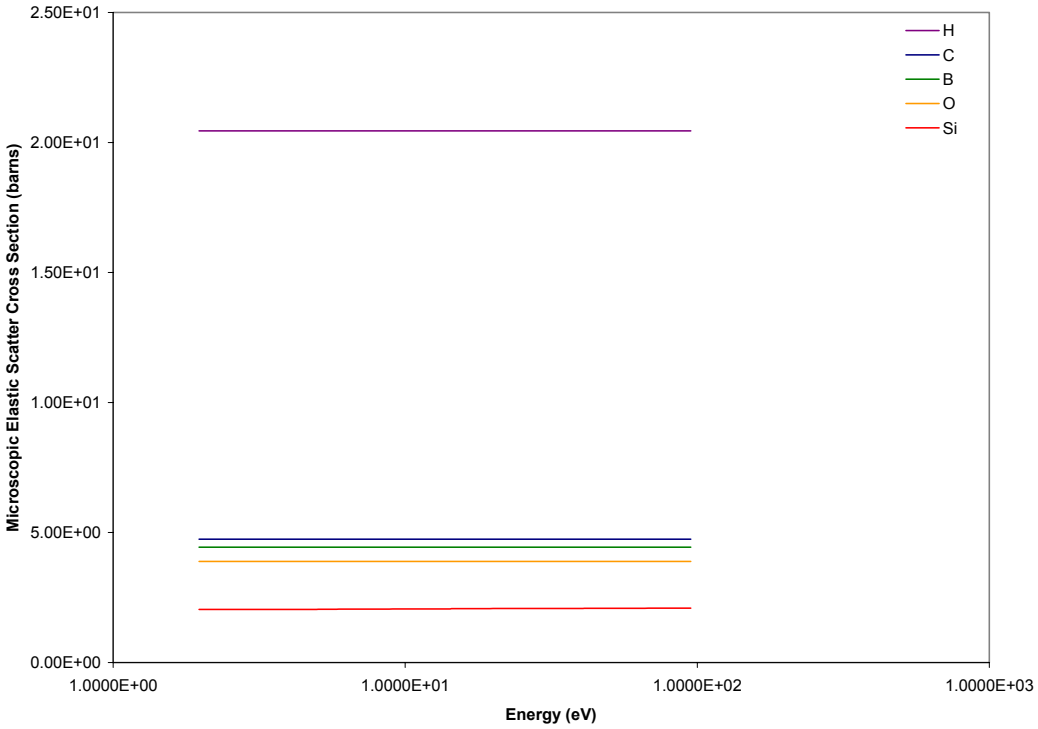


Figure 2-1. Epithermal microscopic elastic scattering cross sections for PACS elements. Cross section remains nearly constant as a function of energy.

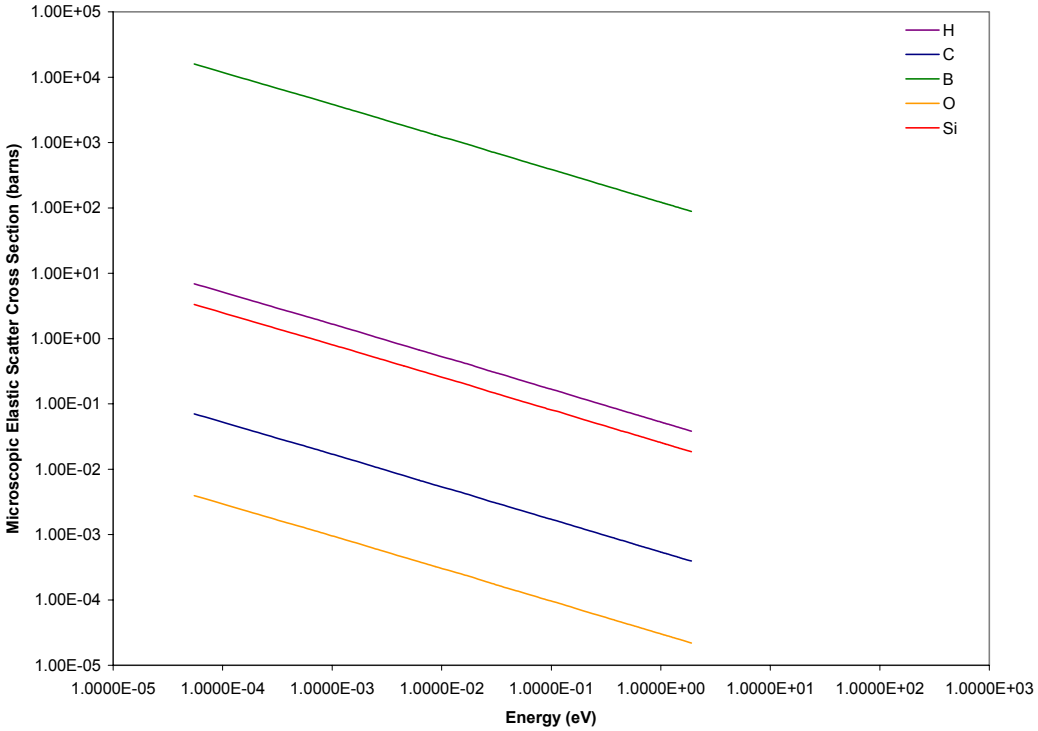


Figure 2-2. Thermal microscopic absorption cross sections for PACS elements. Cross sections are linear in this region.

The results of the averaging gives average epithermal microscopic elastic scattering cross sections shown in Table 2-5. Note that the value of carbon closely matches the tabulated value from Appendix A in Glasstone and Sesonske [7]. The values for the microscopic absorption cross section cannot be reasonably averaged for boron because of the extensive changes of cross section with energy. Additionally, the benchmark of $\xi \sum_s / \sum_a$ has little meaning at BOC because the concentrations of boron are high and the concern for this study is the moderation effectiveness at EOC. For this purpose, the value of $\sum_a$ for the benchmark does not include boron assuming that all of the boron has been depleted at EOC. This benchmark can be used when comparing various compounds knowing that all of the boron will never actually be depleted. The results for the remaining elements give average microscopic absorption cross section shown in Table 2-5.

Table 2-5. Average microscopic cross sections for carborane elements

	Element microscopic cross section (barns)				
	C	Si	O	B	H
Epithermal Scatter (σ_s)	4.78	2.08	3.92	4.47	20.7
Absorption (σ_a)	3.40×10^{-3}	1.60×10^{-1}	9.43×10^{-6}	—	3.32×10^{-1}

Calculation of the Number Density of Each Element

The number densities for the elements can be determined using the same elemental composition for PACS that was used for the weight percent calculation and using an assumed mass density from previous research on the material [2]. The number density of an element in a compound is given by Eq. 2-4.

$$N = \left(\rho \frac{N_A}{M} \right) \nu_i \tag{2-4}$$

N = molecular atom density (atoms / cc)
ρ = mass density of the compound (0.9 gms/cm^3)

M = molecular weight of the coumpound (1136.39)
NA = Avagadro's number (6.022 x 1023 atoms/mole)
vi = Number of atoms of i type in the material

Therefore $$N = \left(0.9\frac{6.022\times10^{23}}{1136.39}\right)\nu_i = 4.7693\times10^{20}\nu_i \quad (2\text{-}5)$$

The corresponding number densities (atoms/cm^3) for each of the elements are shown in Table 2-6.

Table 2-6. Number densities for each element in carborane

Number density by element (atoms/cm^3)				
C	Si	O	B	H
2.099 x 10^{22}	5.723 x 10^{21}	2.385 x 10^{21}	4.769 x 10^{21}	3.912 x 10^{22}

Macroscopic Cross Sections of Each Element

The epithermal macroscopic elastic scattering cross sections ($\sum_s$ (cm^{-1})) and the macroscopic absorption cross sections ($\sum_a$ (cm^{-1})) are determined by multiplying the results of the microscopic cross sections (in cm^2) from Table 2-5 and the number densities of the materials from Table 2-6. The results are shown in Table 2-7.

Table 2-7. Macroscopic cross sections for each element of carborane

	Element macroscopic cross section (cm^{-1})					
	C	Si	O	B	H	Total
$\sum_s$	1.00 x 10^{-1}	1.19 x 10^{-2}	9.35 x 10^{-3}	2.13 x 10^{-2}	8.10 x 10^{-1}	9.35 x 10^{-1}
$\sum_a$	7.13 x 10^{-5}	9.16 x 10^{-4}	2.25 x 10^{-8}	—	1.30 x 10^{-2}	1.40 x 10^{-2}

Average Logarithmic Energy Decrement for the Elements

A common quantity related to the scatting nucleus mass is α [7] which is given by Eq. 2-6.

$$\alpha \equiv \left(\frac{A-1}{A+1}\right)^2 \quad (2\text{-}6)$$

Using the relationship given by α and Eq. 2-2 the average logarithmic energy decrement for the elements in the compound are given in Table 2-8. Note that again the value of

carbon, hydrogen and oxygen match the tabulated values from Table 3.3 in Glasstone and Sesonske [7] (Table 2-1).

Table 2-8. Calculated average logarithmic energy decrement for PACS elements.

Element	α	ξ
C	0.716	0.158
Si	0.751	0.136
O	0.779	0.120
B	0.444	0.351
H	0.0	1.0

Average Logarithmic Energy Decrement for the Material

For a molecule the average logarithmic energy decrement [7] is found by Eq. 2-7.

$$\bar{\xi} = \frac{\nu_i \sigma_{s(i)} \xi_{(i)} + \nu_j \sigma_{s(j)} \xi_{(j)} + \ldots}{\nu_i \sigma_{s(i)} + \nu_j \sigma_{s(j)} + \ldots} \tag{2-7}$$

Where ν_i = Number of atoms of i or j type in the material.

For our case this equation becomes Eq. 2-8.

$$\bar{\xi} = \frac{\nu_C \sigma_{s(C)} \xi_{(C)} + \nu_{Si} \sigma_{s(Si)} \xi_{(Si)} + \nu_O \sigma_{s(O)} \xi_{(O)} + \nu_B \sigma_{s(B)} \xi_{(B)} + \nu_H \sigma_{s(H)} \xi_{(H)}}{\nu_C \sigma_{s(C)} + \nu_{Si} \sigma_{s(Si)} + \nu_O \sigma_{s(O)} + \nu_B \sigma_{s(B)} + \nu_H \sigma_{s(H)}} \tag{2-8}$$

With substitution

$$\bar{\xi} = \frac{(44)(4.78)(0.158) + (12)(2.08)(0.136) + (5)(3.92)(0.230) + (10)(4.47)(0.351) + (82)(20.7)(1.0)}{(44)(4.78) + (12)(2.08) + (5)(3.92) + (10)(4.47) + (82)(20.7)}$$

$$\bar{\xi} = 0.878426$$

The final product of the macroscopic elastic scattering cross section of the material and the average logarithmic energy decrement is simply $PRODUCT = \bar{\xi} \cdot \Sigma_S = 0.837$. The ratio of the macroscopic elastic scatting cross section to the macroscopic absorption cross section and the logarithmic energy decrement is $PRODUCT = \frac{\bar{\xi} \cdot \Sigma_S}{\Sigma_A} = 59.9$. This result is higher than the value of 45 given as a benchmark for light water at operating temperatures. However, it will be significantly reduced by any amount of

residual boron in the system at EOC. This value is most useful as a comparison between different polymeric materials.

Results of Permutations of PACS Formula

Numerous permutations of the above calculations on various combinations of the PACS polymer were conducted (Appendix A). It became evident that the overwhelming factor in the product of the logarithmic energy decrement and the macroscopic cross section, or the moderator effectiveness, was the weight percent of hydrogen within the molecule.

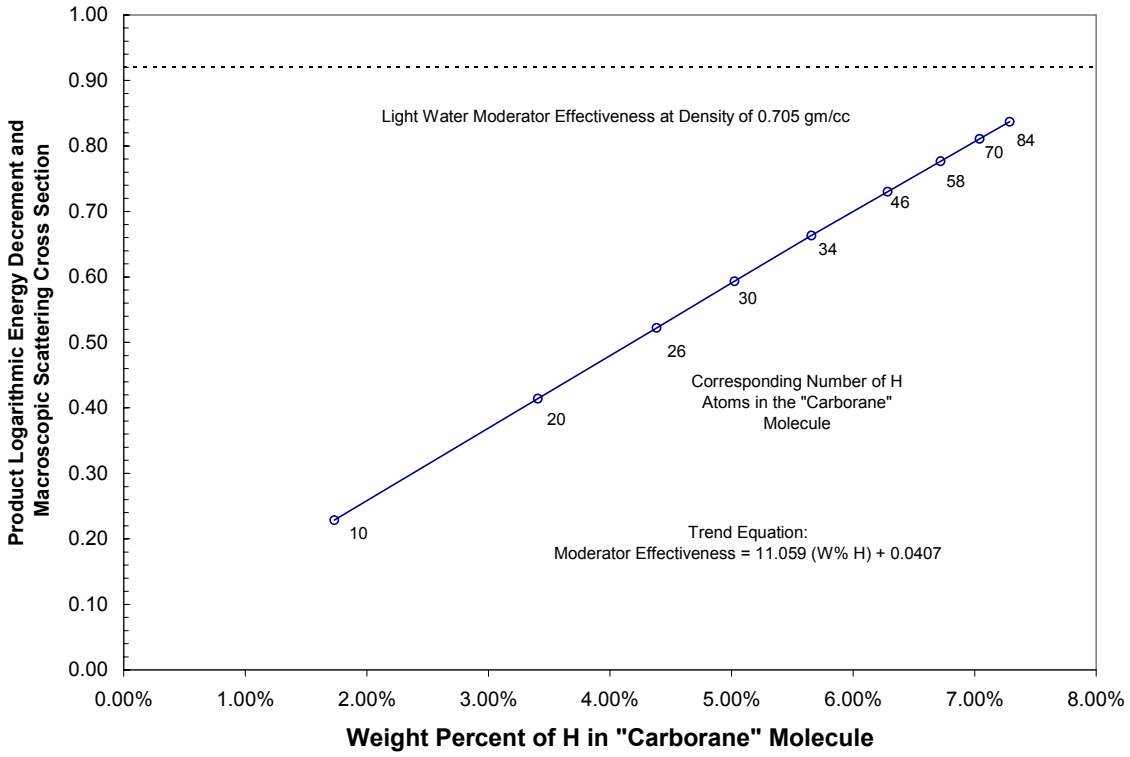


Figure 2-3. Moderator effectiveness vs. weight percent of H in carborane.

Adjusting the concentrations of hydrogen within carborane, the moderation effectiveness of the polymer at EOC can approach that of the light water in the moderator (Figure 2-3). The empirical linear formula on the figure serves as a guide for the desired weight percent of hydrogen needed when designing the polymer. The empirical formula

also works on other hydrogen compounds such as water. Because of the overall dominance of hydrogen in the moderation process, it is possible to conduct various simulations of the model using different weight percents of hydrogen and determine the point at which the polymer would perform better than the BPRA or WABA in moderation at EOC. These simulations are explained in detail in Chapter 3 and the results of the simulations are shown in Chapter 5.

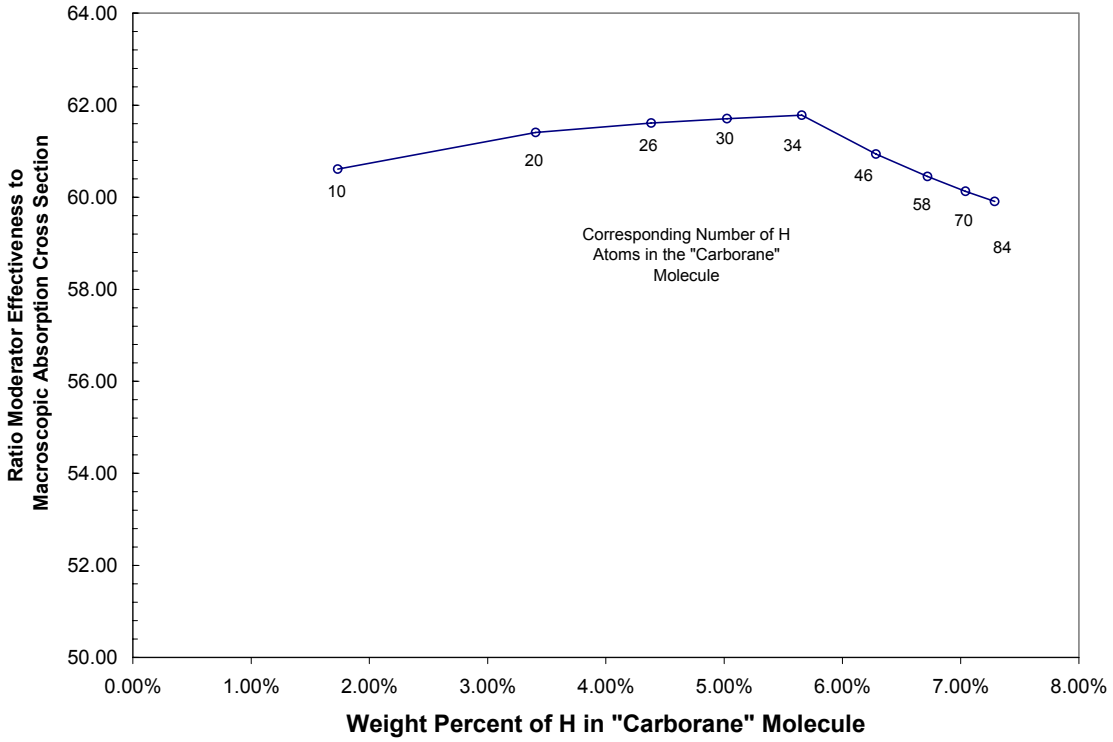


Figure 2-4. Effectiveness to macroscopic cross section vs. weight percent H in carborane

The ratio of the moderator effectiveness to the macroscopic absorption cross section also varied as a function of weight percent hydrogen in the PACS material. Figure 2-4 shows that as the weight percent of hydrogen is increased, that between five and six weight percent the absorption effects of hydrogen begin to dominate the moderator effectiveness and start to pull the trend line down. All of the PACS values exceed that of light water but do not include the effects of residual boron in the BPRA.

Optimization of PACS for Absorption

The primary focus of this study is an improved replacement for boron carbide aluminum oxide (Figure 2-5) in BPRAs. In addition to the moderation ability of the improved burnable poison, it must also perform as well or better than current BPRAs in absorbing neutrons and depleting as a function of time. The advantage of using a PACS model is that it is a boron based polymer that can be directly compared to boron carbide alumina without converting between absorption cross sections of different burnable poison isotopes.

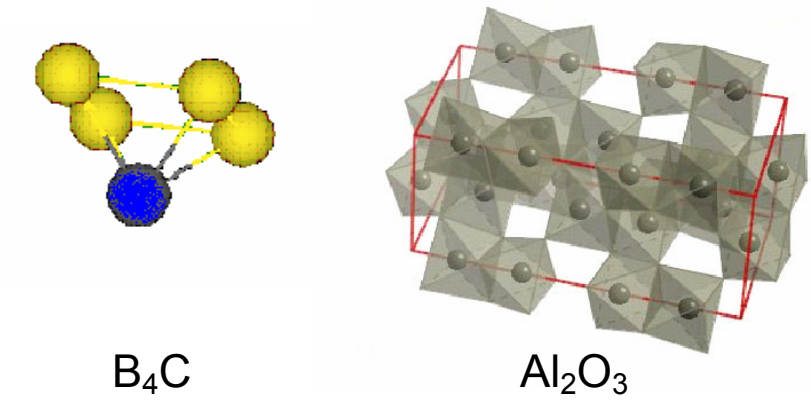
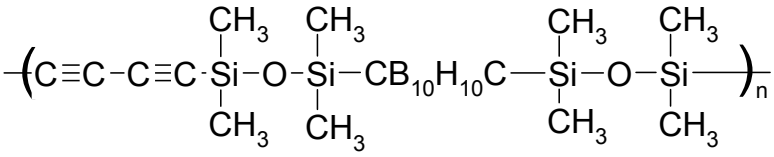


Figure 2-5. Boron carbide alumina chemical structures

Polyacetyleniccarboranosiloxane (Figure 2-6) consists of a chain of acetylene and siloxane segments added to the $B_{10}H_{10}C_2$ root structure. Previous research on carborane used a notional combination of the PACS structure that fixed the amount of boron within the carborane to match that of B_4C/Al_2O_3 BPRAs used in the Crystal River Three reactor [2]. The PACS structure was modified by adding numerous siloxane strings in the chain to dilute the amount of boron present in the polymer. It is believed that the additional siloxane strings will make the molecule weak and unable to sustain the hydro-thermal

stresses of the reactor environment. However, because this material does represent a direct relationship between the current BPRA and in the interest of continuity of research, this material was used in several modeling experiments in this study. The notional legacy polymer will be referred to as "L-Carborane" throughout this study.



$$[(B_{10}H_{10}C_2)_a((CH_3)_2SiO)_b(C_2)_c]_n$$

Figure 2-6. The PACS chemical structure

The Materials Sciences and Engineering department of the University of Florida has synthesized a polymer following the guidelines of the original polymer created by Dr. Keller. This material (Figure 2-6) is not diluted so it has a much higher boron concentration that the current BPRA materials. This material also is used in several of the simulations within this study and it is referred to as "J-Carborane" throughout this report. The important molecular comparisons between the three compounds are given in Table 2-9.

Table 2-9. Molecular properties of burnable poison materials.

Material	Density	Number of atoms / molecule						Weight Percent					
	g /cm^3	C	H	B	O	Si	Al	C	H	B	O	Si	Al
B_4C/AL_2O_3	3.1	1	0	4	3	0	2	1	0	3	45	0	51
L-Carborane	0.9†	44	84	10	5	12	0	46	7	9	7	30	0
J-Carborane	1.0†	14	34	10	2	4	0	37	8	24	7	25	0

†Density of carborane compounds are estimated based on chemical composition.

The weight percents in Table 2-9 can be used with the density of the material to estimate the number of atoms/cm^3 or, number density, of the boron in the materials. The J-Carborane has over twice the amount of natural boron as either the L-Carborane or boron carbide alumina. Two primary concerns arise from the use of a burnable poison

with a higher amount of boron than the current standard. First, it is uncertain whether or not the boron will deplete completely by EOC and therefore, allow the maximum excess reactivity to be present when necessary. Second, the additional concentration of poison within the core could cause power peaking problems in areas away from the burnable absorber. Chapters 5 and 6 discuss the results and effects of an increased amount of boron within the burnable absorber.

The materials used for all of the modeling and throughout the remainder of this study are the B_4C/Al_2O_3 as formulated in the Crystal River Unit Three reactor, L-Carborane, and J-Carborane. Any deviations to the material structure or densities will be clearly annotated. The procedures for modeling and calculations can be applied to any elemental polymeric composition and this study does not assume that all possible combinations of PACS or similar polymers have been investigated. The benchmark methodology does provide an important process in the elimination of undesirable properties of a polymer such as a material's moderator effectiveness less than that of a WABA or a concentration of burnable absorber that is significantly less than the BPRA.

CHAPTER 3
MODELING AND METHODOLOGY

Overview of Modeling

The modeling for this problem began with a single PWR assembly analysis between fresh fuel assemblies with boron carbide BPRAs, boron carbide WABAs, and PACS BPRAs. Once the single assembly analysis was complete, the various BPRA assemblies were incorporated in a two by two array, called a colorset, which allowed for analysis of the different burnable poison materials within a group of four different assemblies. The last modeling phase took an actual PWR reactor model and recreated all of the assemblies and absorbers and exchanged the boron carbide burnable poisons used in the reactor for the PACS BPRAs.

General Problem Description and Geometry

The Crystal River Unit Three reactor is a PWR operated by Florida Power Corporation. The cycle 12 reload report submitted to the Nuclear Regulatory Commission in August 1999 is the basis of all assembly and reactor fuel and geometry information. Cycle 12 was scheduled to begin in November 1999 and operate for 670 ± 10 Effective Full Power Days (EFPD) at a rated power level of 2544 mega watts thermal (MWt). The general dimensions and characteristics of the Crystal River assemblies and core are outlined in Table 3-1 [9]. The pitch of the assemblies refers to the centerline distance between one fuel rod to the next adjacent one. The water gap is a water filled separation between two adjacent assemblies. These dimensions were held constant in all

of the models except in cases where a WABA rod is inserted and the geometry includes the center annulus as shown in Figure 1-4.

Table 3-1. Reactor and assembly characteristics for the Crystal River 3 Reactor

Reactor Information		
Core Lifetime	670 ± 10	EFPDs
Rated Power	2544	MWt
Water Pressure	15.67	MPa
Number of Assemblies	177	
Number of Control Rods	68	
Assembly Information		
Number of Fuel Rods	208	
Number of Guide Tubes	1 center 16 control	
Water Gap Thickness	0.33	cm
Pitch	1.443	cm
Height	358	cm
Height of Primary Fuel (non-Gd rod)	326	cm
Axial Blanket Height (top and bottom non-Gd rod)	16	cm
Height of Primary Fuel (Gd rod)	308	cm
Axial Blanket Height (top and bottom Gd rod)	25	cm
Radius Fuel / BPRA Pellet	0.4699	cm
Radius Fuel / BPRA Gap	0.4788	cm
Radius Fuel / BPRA Clad	0.5461	cm
Radius Guide Tube Moderator	0.632	cm
Radius Guide Tube Clad	0.6731	cm

The materials in the fuel assemblies for each of the models also represented the Crystal River Three cycle 12 reload. The most notable exception would be the exchange of boron carbide for PACS material in the BPRAs. Table 3-2 gives composition information for the reload cycle [9]. Figure 3-1 shows the locations for each of the fuel assemblies, the previous burn-up for used assemblies, the number of BPRAs and the location of BPRAs or control rod assemblies for $1/8^{th}$ of the core. The BPRAs in the assembly are located as shown in Figure 1-2. The core has $1/8^{th}$ symmetry and the information is repeated for the remaining octants that comprise the core.

Table 3-2. Fuel composition information for Crystal River Cycle 12

Fuel Batch Number	Number of Fuel Assemblies	Wt% ^{235}U	Wt% Gd_2O_3	Number of Gd Fuel Rods
10A3	12	3.94	0.00	0
12A2	21	4.19/3.89†	0.00	0
13A	36	4.79/3.35‡	6.00	8
13B	8	4.79/4.07‡	3.00	4
13C	8	4.96	0.00	0
13D	12	4.96/3.35‡	6.00	8
13E	8	4.96/4.07‡	3.00	8
14A	24	4.52/3.16‡	6.00	8
14B	8	4.66	0.00	0
14C	8	4.66/3.96‡	3.00	4
14D	8	4.66/3.96‡	3.00	8
14E	24	4.66/3.16‡	6.00	8

† These assemblies are radially zone loaded, with 16 rods having the lower enrichment.
‡ These assemblies have Gd rods with the Gd_2O_3 concentration indicated and the lower ^{235}U enrichment.

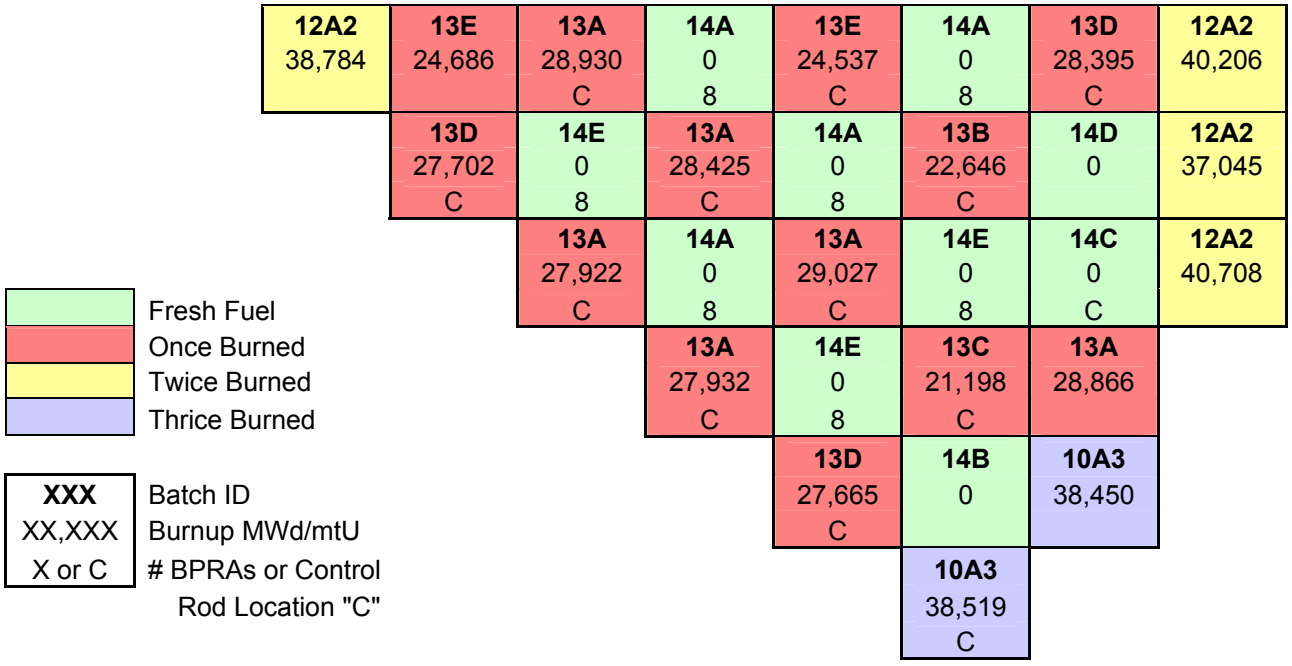


Figure 3-1. Map of 1/8th Crystal River Three Cycle 12 core

From Figure 3-1 it is noted that in the actual reactor design only the 14A and 14E assemblies received BPRAs and that they only have eight BPRA rods located in the B-08 arrangement in Figure 1-2. The control rod locations are important in that a BPRA cannot go in those locations because the control rods must occupy the guide rod space.

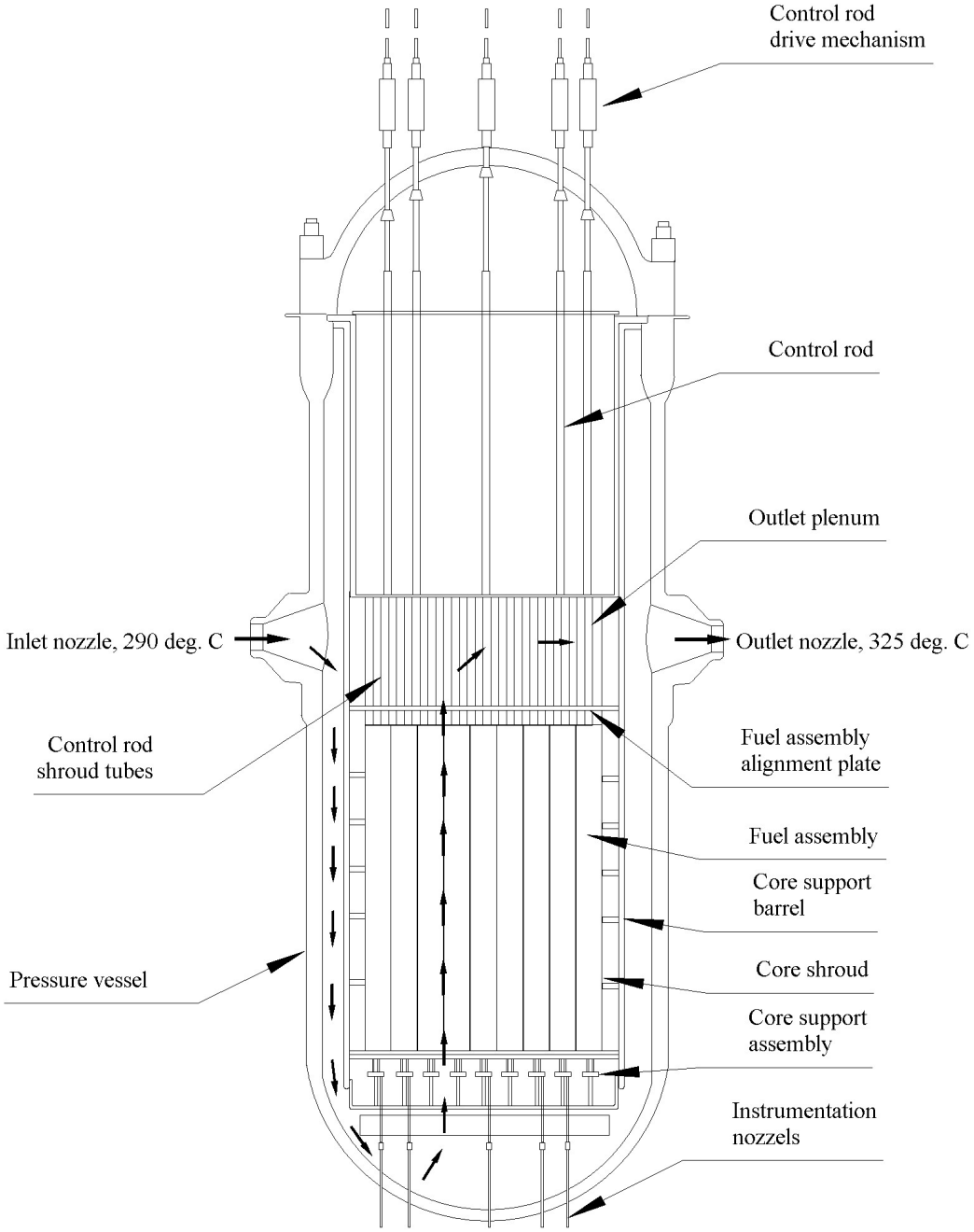


Figure 3-2. Example of a PWR core cross section

General Assumptions in Models

Figure 3-2 is a PWR cross sectional view. Based on the fuel compositions and the characteristics of the reactor the assemblies and reactor, core can be modeled. The entire PWR shown in Figure 3-2 cannot be modeled and general assumptions are made to simplify the problem because of certain limitations in the computer codes.

The following assumptions apply to the modeling simulations for the assemblies and core mock ups:

- Except for cases where chemical shim is expressly specified, there is no absorber in the moderator and it is assumed that excess reactivity in the core or assembly can be controlled by a combination of chemical shim and control rods.
- For cases where chemical shim is specified, all of the excess reactivity is controlled with chemical shim and the control rods are not modeled.
- It is assumed that $1/8^{th}$ assembly symmetry and $1/8^{th}$ core symmetry are always true.
- The probability of non-leakage for thermal neutrons ($PNL_{Thermal}$) is approximately 1.0 for a large reactor core. The reactor vessel is thereby not modeled and a reflected surface is the boundary of the axial and radial reactor reflectors. The comparisons in this study are relative so errors caused by simplification of the model are assumed to affect each BPRA system equally and will not affect the overall outcome of the study.
- The probability of non-leakage for thermal neutrons ($PNL_{Thermal}$) is constant. Therefore, the ratio of reactivity between the different cases is the same for k_{∞} as it would be for k_{eff}.
- For codes not including a Zircalloy composite material, zirconium is assumed to neutronically model the cladding.
- Except where provided by a code, the spacer grids and fuel assembly top and bottom plates are not modeled and the difference in reactivity is assumed to be negligible.

Codes Used for Modeling

The various calculations and scenarios were completed using five principle computer codes. Where possible, similar problems were completed using two different codes to ensure accurate results. Additionally, the results for the $1/8^{th}$ core simulations were compared to the results from the Crystal River Three reload report to ensure consistency with the codes used by Framatome to model the core.

The CASMO-3 Code

The fuel assembly burnup program CASMO-3 is a commercial nuclear fuel analysis code from Studsvik of America Inc.

> CASMO is a multigroup, two-dimensional transport theory code for burnup calculations on BWR and PWR assemblies or simple pin cells. The code handles a geometry consisting of cylindrical fuel rods of varying composition in a square pitch array with allowance for fuel rods loaded with gadolinium, burnable absorber rods, cluster control rods, in-core instrument channels, water gaps, boron steel curtains and cruciform control rods in the regions separating fuel assemblies [10].

The CASMO code is used in depletion comparisons for single assembly calculations and two by two assembly models. The CASMO code is also used to generate depletion libraries for assemblies in other codes such as SIMULATE and EASCYC. Additionally, CASMO was used to derive the compositions of depleted fuel assemblies at the BOC for the MONTEBURNS simulations that used depleted assemblies.

The EASCYC Code

The EASCYC code is a two-dimensional diffusion theory code for reactor fuel cycle analysis developed by Harvey W. Graves for Energy Analysis Software Services.

> EASCYC is a computational system for evaluation of fuel cycle loading requirements for pressurized water reactors that has been specifically developed to take advantage of the characteristics of desktop computers. It consists of a set of computational subroutines for neutronic analysis coupled to a set of engineering rules for the manipulation and utilization of these subroutines. The computational subroutines are based on Nodal/Modal analysis, an extremely efficient and accurate technique for evaluation the neutron multiplication and power distribution for an array of fuel assemblies [11,12]. The engineering rules are based on extensive experience in fuel cycles and reactor performance evaluation, as well as logic algorithms based on fuel symmetry, core geometry, and fuel assembly design constraints [13].

The EASCYC code is used primarily to analyze the power distribution of the core models and compare the core distribution over time. Each of the various assemblies in the core is first modeled in CASMO and depleted to the required burnup and then EASY, a FORTRAN-77 routine, is run to extract the necessary cross section library information from the CASMO output for EASCYC. Additionally, another FORTRAN-77 routine, EASYLIB is run to combine the geometry and burnable poison information for the

particular PWR with the library in a binary file that is executable in EASCYC. The EASCYC code has several limitations particularly concerning burnable poisons and is only used as a reference comparison for power peaking with other codes and the reload report.

The MCNP Code

Monte Carlo Neutron Photon Transport Code (MCNP) is a particle transport code for neutrons and photons created by Los Alamos National Laboratory and distributed by the Radiation Safety Information Computational Center (RSICC) in Oak Ridge, Tennessee.

> MCNP is a neutral particle transport code that uses the Monte Carlo technique. The Monte Carlo technique is a statistical method in which estimates for system characteristics are obtained through multiple computer simulation of the behavior of individual particles in a system. A Monte Carlo code generates a statistical history for a particle based on random samples from probability distributions. Distributions are used in calculations to determine the type of interaction the particle undergoes at each point in its life, the resulting energy of the particle if it scatters, the number of particles that "leak" from the system because of geometry constraints, and the number of neutrons produced if the neutron causes a fission [14].

The MCNP code is used in this study as a stand alone code for single step modeling of a single pin, assembly or, $1/8^{th}$ core model to get a point in time analysis of flux, energy deposition, or criticality. The MCNP code is also used in conjunction with ORIGEN2 inside MONTEBURNS in depletion calculations of single assembly and $1/8^{th}$ core models.

The ORIGEN2 Code

The ORIGEN2 code is another RSICC code package that computes decay and isotope depletion information for materials under irradiation. It is not used in this study as a stand alone program but rather part of the MONTEBURNS depletion package.

ORIGEN2 inputs can be complicated to generate and the output difficult to interpret, but MONTEBURNS completes all of the reading and writing of ORIGEN2 files.

> ORIGEN2 performs burnup calculations for MONTEBURNS using the matrix exponential method [15] ORIGEN2 considers time-dependent formulation, destruction, and decay concurrently [16]. These calculations require (1) the initial compositions and amounts of material, (2) one-group microscopic cross-sections for each isotope, (3) material feed and removal rates (if desired), (4) the length of the irradiation period(s), and (5) the flux or power of the irradiation [17].

The MONTEBURNS Code

The MONTEBURNS code is a RSICC code that couples MCNP and ORIGEN2 to generate depletion and burnup calculations.

> MONTEBURNS consists of a PERL script file that frequently interacts with a FORTRAN77 program, *monteb.f*. It is designed to link the Monte Carlo transport code MCNP with the radioactive decay and burnup code ORIGEN2. MONTEBURNS produces a large number of criticality and burnup results based on various material feed/removal specifications, power(s), and time intervals. The program processes input from the user that specifies the system geometry, initial material compositions, feed/removal specifications, and other code-specific parameters. Various results from MCNP, ORIGEN2, and other calculations are then output successively as the code runs [14].

Figure 3-3 illustrates how MONTEBURNS interacts with the codes it controls. The MONTEBURNS code is used in this study for single assembly and $1/8^{th}$ core depletion calculations to include criticality comparisons, power peaking, and chemical shim models. The predictor-corrector step is the same methodology used in CASMO for depletion and burnup calculations. The user of MONTEBURNS has to generate three files to complete the depletion model, an MCNP input file, a MONTEBURNS input file, and a feed rate input file. Models in MONTEBURNS are compared to CASMO and EASCYC and the reactor reload report when possible to ensure consistency and accuracy in the models.

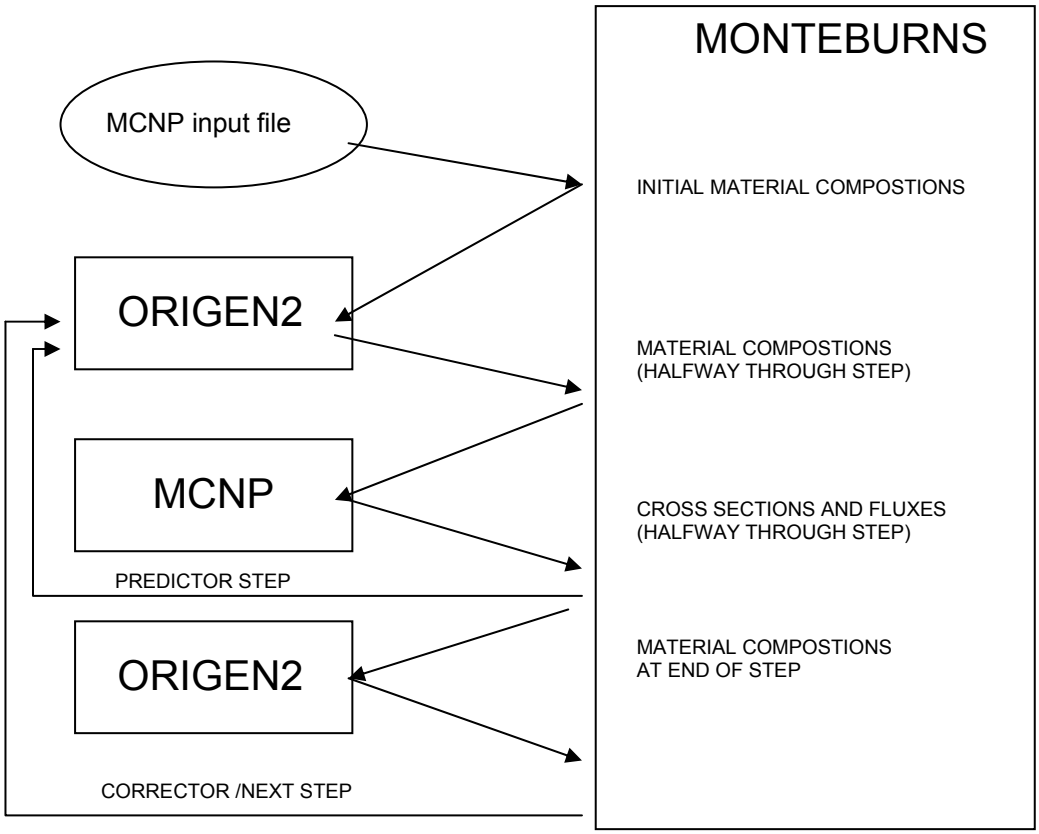


Figure 3-3. Interaction of MONTEBURNS with MCNP and ORIGEN2. Adapted from Figure 1. Poston DI, Trellue HR. User's Manual, Version 2.0 for MONTEBURNS, Ver 1.0. Washington, DC: Oak Ridge National Laboratory, Office of Nuclear Material Safety and Safeguards. US Nuclear Regulatory Commission; 2001. 4.

Single Assembly Calculations

Single assembly calculations were the core of the original research conducted on this topic [2]. In order to maintain consistency with previous research, the fresh fuel single assembly analysis used the Framatome Mark IVB fuel assembly (Figure 1-2) with 16 burnable poison rods and a fuel enrichment of 4.66 weight percent enriched uranium. Each of the different types of burnable poison assemblies, boron carbide BPRA, boron carbide WABA and L-Carborane BPRA was compared with a single assembly with only water in the guide tubes. Analysis was completed using CASMO and MONTEBURNS. Figure 3-4 shows a SABRINA plot of the upper portion of the MCNP model used in

MONTEBURNS for the single assembly. The MCNP model of the assembly does not contain spacer grids or end plates (see problem assumptions). The single assembly model also does not include gadolinium oxide rods or axial blanket material.

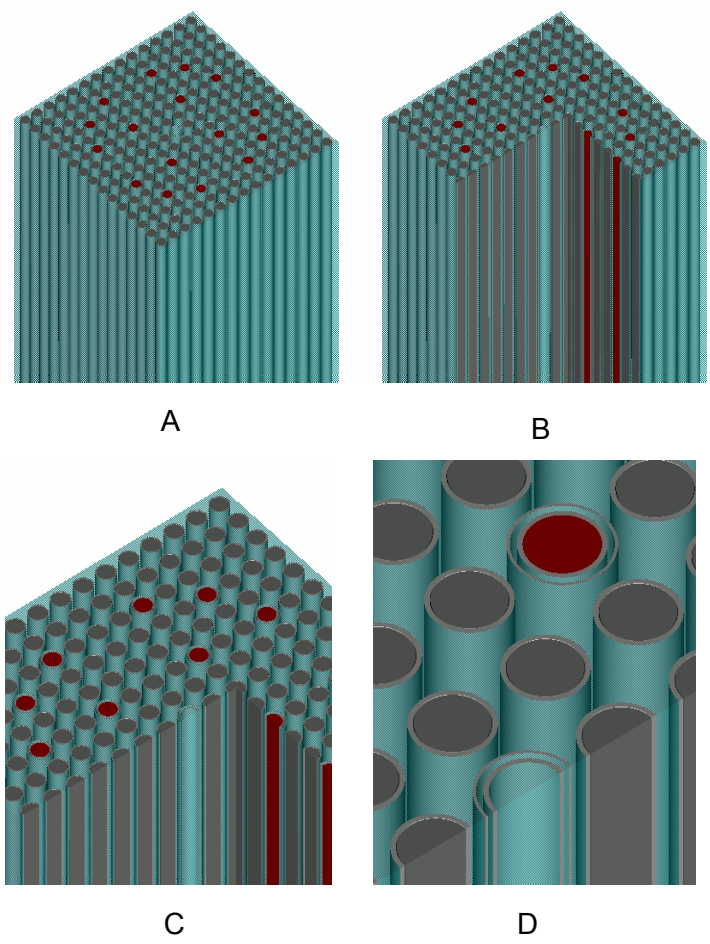


Figure 3-4. A SABRINA plot of top portion of Mark IV assembly model in MCNP. Red rods are BPRAs, grey are fuel rods, and the central instrument guide tube has no fuel or BPRA rod. Segments C and D are close-ups of the cut-away in Segment B.

In order to model the assembly in CASMO, a single input deck file was written specifying the geometry, power, operating temperature and material compositions for the reactor. Figure 3-5 is an example of the CASMO input deck for an assembly with B_4C/Al_2O_3 BPRAs. Explanatory information concerning each of the lines of input within the deck can be found in the comments (denoted by an asterisk) behind each input line.

Also note that the geometry and material compositions match those required by Table 3-1 in the original problem mock-up. All subsequent CASMO input and output files for the single assembly case are included in Appendix B.

```
TIT  TFU=990  TMO=583  BOR=0  *4.66% B4 W 15 X 15
*Crystal River-3 15x15 Assembly with B4C-AL2O2 in guide tubes
*Fuel temp 990 deg K moderator temp 583 deg K no chem shim
FUE  1 10.4/4.66  *FUEL COMP. #, DENSITY/ENRICHMENT
PDE  33  *POWER DENSITY (W/Gm Uranium)
MI2  3.1/5010=0.55 5011=2.22 6000=0.76 13000=51.04 8000=45.43
Mixture 2: B10, C, Al, O (BP Material)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  2 .4699 .4788 .5461 .632 .6731/ 'MI2' 'AIR' 'CAN' 'COO'
'CAN'/1,3,5
*  BPRA pin homogenized 'AIR+CAN' and 'COO+CAN'
PIN  3 .632 .6731/ 'COO' 'CAN'  *Center water hole
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI   *Pin Layout in 1/8th of the assembly
3
1 1
1 1 2
1 1 1 1
1 1 1 1 2
1 1 2 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
DEP  0.5 2.5 5 10 15 20 25 30 35 40 *Depletion steps
STA   *Start
END   *End
```

Figure 3-5. Example of CASMO input file for a single assembly.

Modeling the same problem in MONTEBURNS requires two separate input files, an MCNP criticality deck for the assembly (KCODE) and a MONTEBURNS input file. A feed file is not required for a continuous burn case. Figures 3-6 and 3-7 contain sample inputs for MCNP and MONTEBURNS for the same assembly. The explanatory comments for MCNP are denoted by a “C” or a “$” and by an “!” in MONTEBURNS. As shown in the figures, it takes significantly more work to model an assembly in MCNP / MONTEBURNS than in CASMO. However, MONTEBURNS is not constrained to the set configurations of a PWR or BWR. All of the MCNP/MONTEBURNS input and output files for the single assembly cases are in Appendix B.

```
RESEARCH 15 X 15 ASSEMBLY WITH B4CAL2O3 BPRA'S 4.66% ENRICH NO BORON
1       0 20 -21 22 -23 90 -91 FILL=1 VOL=1.712434E+05
2       1 -0.660 30 -31 32 -33 LAT=1 U=1 FILL=-7:7 -7:7 0:0  $ BOUNDRY OF ASSEMBLY
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 2 2 2 3 2 2 2 3 2 2 2 2 2
        2 2 2 3 2 2 2 2 2 2 2 3 2 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 3 2 2 3 2 2 2 3 2 2 3 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2    $PIN LAYOUT REPEATED LATTICE
        2 2 2 2 2 2 2 4 2 2 2 2 2 2 2    $EACH UNIVERSE "U" NUMBER IS
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2    $DIFFERENT TYPE OF UNIT CELL
        2 2 3 2 2 3 2 2 2 3 2 2 3 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 2 3 2 2 2 2 2 2 2 3 2 2 2
        2 2 2 2 2 3 2 2 2 3 2 2 2 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
3       1    -0.660     -4 U=4 $WATER HOLE
                        VOL=257.8345
4       3    -6.503 4 -5 U=4 $INTERIOR CLAD
                        VOL=77.57637
5       1    -0.660   5 -6 U=4 $GUIDE TUBE WATER RADIUS
                        VOL=113.8173
6       3    -6.503 6 -7 U=4 $GUIDE TUBE CLAD RADIUS
                        VOL=60.32794
7       1    -0.660   #3 #4 #5 #6 U=4 $UNIT CELL WATER
                        VOL=235.8889
8       4    -3.1     -4 U=3 $BPRA MATERIAL
                        VOL=257.8345
9       3    -6.503 4 -5 U=3 $INTERIOR CLAD
                        VOL=77.57637
10      1    -0.660   5 -6 U=3 $GUIDE TUBE WATER RADIUS
                        VOL=113.8173
11      3    -6.503 6 -7 U=3 $GUIDE TUBE CLAD RADIUS
                        VOL=60.32794
12      1    -0.660   #8 #9 #10 #11 U=3 $UNIT CELL WATER
                        VOL=235.8889
13      2    -10.201    -8 U=2 $UO2 FUEL PELLET
                        VOL=248.3383
14      0               8 -4 U=2 $GAP RADIUS
                        VOL=9.496242
15      3    -6.503 4 -5 U=2 $FUEL PIN CLAD
                        VOL=77.57637
16      1    -0.660   #13 #14 #15 U=2 $UNIT CELL WATER
                        VOL=410.0342
17      1    -0.660   (-20:21:-22:23:-90:91) -9 $OUTSIDE OF ASSMBLY
                        VOL=3518.23905
99              0      9    $VOID REGION OUTSIDE ASSEMBLY

20              PX    -10.8225
21              PX     10.8225
22              PY    -10.8225
23              PY     10.8225
C   OUTSIDE OF ASSEMBLY LATICE
30              PX    -0.7215
31              PX     0.7215
32              PY    -0.7215
33              PY     0.7215
C  OUTSIDE OF UNIT CELL (1.443 PITCH)
4               CZ     0.4788
C  CYLINDER BPRA / WATER HOLE / GAP RADIUS
5               CZ     0.5461
C  CYLINDER INTERIOR CLAD RADIUS
6               CZ     0.6320
C  CYLINDER WATER RADIUS GUIDE TUBE
7               CZ     0.6731
C  CYLINDER CLAD RADIUS GUIDE TUBE
8               CZ     0.4699
C  CYLINDER RADIUS OF FUEL PELLET
*9              RPP    -10.905 10.905 -10.905 10.905 -180 180
C  RECT PARALLEL PIPED OUTSIDE OF ASSEMBLY
90              PZ     -179
91              PZ      179

MODE    N
IMP:N   1.0 16R 0.0
KCODE   2000    1.3     5       55      500
KSRC    1.443     0.0     0.0
M1      8016.60C        -8.88100E+01        1001.60C     -1.11900E+01
MT1     LWTR.04T $H20 AT 600 K
M2      92235.54C       -4.10779E+00       92238.54C     -8.40421623E+01
        8016.54C      -1.18500E+01
        $UO2 4.66% at 881K EN
M3      40000.60C 1.0 $ZIRCONIUM (APPROX. FOR ZIRCALLOY)
M4      5010.50C   -0.55   5011.56C -2.22 6000.60C   -0.76   13027.60C
        -51.04   8016.54C   -45.43  $B4CAL2O3 BP MATERIAL
PRINT
```

Figure 3-6. Example of MCNP input file for single assembly.

```
RESEARCH 15 X 15 ASSEMBLY WITH B4CAL2O3 BPRA'S 4.66% ENRICH NO BORON
PC          ! Type of Operating System
2           ! Two MCNP Materials to burn (fuel cells/BPRAs)
2           ! MCNP material number #2 (will burn all cells with this mat)
4           ! MCNP material number #4 (will burn all cells with this mat)
51654.376   ! Material #2 volume (cc)
4125.353    ! Material #4 volume (cc)
17.75       ! Power in MWt (for the entire system in MCNP)
-180.88     ! Recov. energy/fis (MeV); if negative use for U235, ratio other isos
657.36      ! Total number of days burned (used if no feed)
10          ! Number of outer burn steps
100         ! Number of internal burn steps (multiple of 10)
1           ! Number of predictor steps (+1 on first step), 1 usually sufficient
0           ! Step number to restart after (0=beginning)
PWRU50      ! number of default origen2 lib - next line is origen2 lib location
c:\Origen2\Libs
.005        ! fractional importance (track isos with abs,fis,atom,mass fraction)
1           ! Intermediate keff calc. 0) No 1) Yes
2           ! Number of automatic tally isotopes, followed by list.
92235.54c
92238.54c
1
5010.50C
```

Figure 3-7. Example of MONTEBURNS input file for single assembly.

Multiple 2-D Assembly Calculations

The CASMO computer model allows for 2 x 2 arrays of assemblies called a colorset. The colorset allows for up to three different types of fuels to be used. There are once-burned, twice-burned, and thrice-burned fuel assemblies in the array (Figure 3-8).

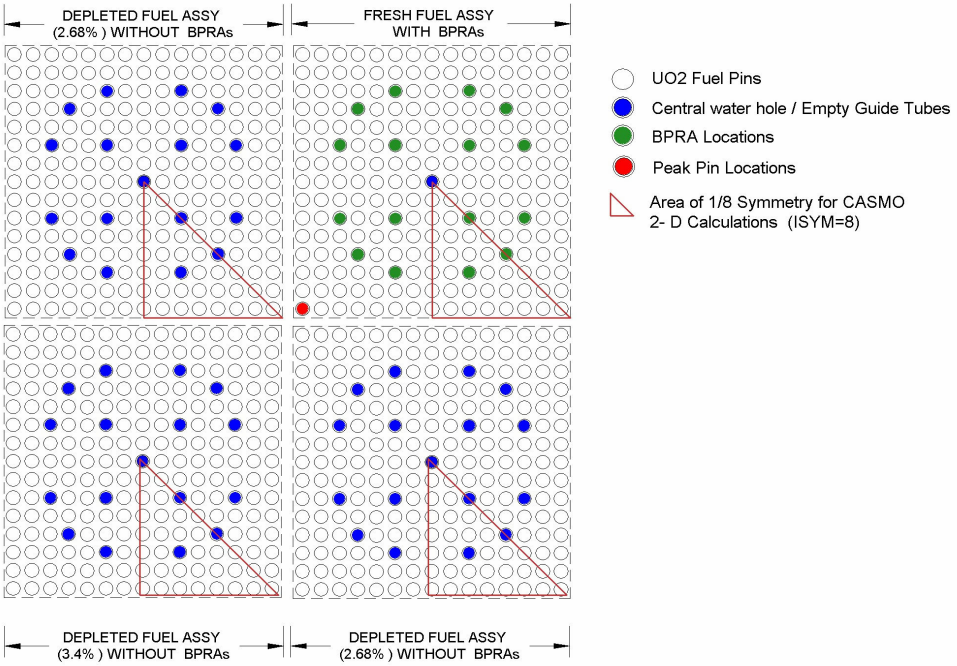


Figure 3-8. A CASMO 2 x 2 colorset array model

```
TFU=990  TMO=583  BOR=0
FUE  1 10.4/4.66  *FUEL COMP. #, DENSITY/ENRICHMENT fresh fuel
MI2  3.1/5010=0.55 6000=0.76 13000=51.04 8000=45.43
*  Mixture 2: B10, C, Al, O (BP Material)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  2 .4699 .4788 .5461 .632 .6731/ 'MI2' 'AIR' 'CAN' 'COO'
'CAN'/1,3,5
*  BPRA pin homogenized 'AIR+CAN' and 'COO+CAN'
PIN  3 .632 .6731/ 'COO' 'CAN'  *Center water hole / empty shroud
tube
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI
3
1 1                                *Common segment information
1 1 2                              *Fresh fuel
1 1 1 1                            *B4C-AL2O2 BPRAs
1 1 1 1 2
1 1 2 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
PDE  33  *POWER DENSITY (W/Gu)
DEP  0.5 2.5 5 10 15 20 25 30 35 40 *Depletion steps
*
*  SEGMENT SPECIFIC INPUT
*
SEG 1  *+DEPLETED FUEL 2.268% NO BPRAs
FUE 1 10.4/2.268
LPI
3
1 1                                *Segment information
1 1 3                              *Low Enrich depleted fuel
1 1 1 1                            *No BPRAs
1 1 1 1 3
1 1 3 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
*
SEG 2 *+LOW ENRICHED DEPELTED FUEL NO BPRAs
*
SEG 3 *+MEDIUM ENRICHED DEPLETED FUEL NO BPRAs
FUE 1 10.4/3.4
LPI
3
1 1                                *Segment information
1 1 3                              *Medium fuel
1 1 1 1
1 1 1 1 3
1 1 3 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
*
STA
END
```

Figure 3-9. Example of CASMO input file for a 2 x 2 colorset

The colorset input is similar to the input for a single assembly except segments are required to describe the different fuel assemblies (Figure 3-9). The colorset output describes each of the individual fuel assemblies by type and includes the combined effect of the different fuels. The colorset represents an infinite repeated structure meaning that the 2 x 2 structure has a boundary that causes the model to act as though the structure is repeated laterally over an over again. The colorset is not a good substitution for a core analysis but it does give more realistic results that take into account the fact that the entire core is not comprised of identical assemblies of fuel at one enrichment. Figure 3-9 is an example colorset input deck. All of the multiple assembly CASMO input and output files are in Appendix C.

Core Modeling

The EASCYC models

The EASCYC modeling process begins by modeling each of the individual assemblies throughout their lives in CASMO and extracting their properties into a data library using EASY. Once created, the EASY cross section library file is combined with a geometry file using EASLIB to generate a binary input file for EASCYC. The last step is running the EASCYC program. Because EASCYC allows limited numbers of different assemblies, the assemblies from Table 3-2 were given combined weighted average ^{235}U enrichment and Gd_2O_3 concentrations for batches 13A–13E and 14A–14E. The result was four types of fuel (10A3, 12A2, 13AE, and 14AE). Appendix D contains all of the CASMO input files for the various fuel assemblies used in the modeling of this problem and the EASY generated cross section library for the problem.

Figure 3-10 is an example of the geometry file required for EASLIB and Table 3-3 contains general explanatory comments about the input lines (detailed information for the

input into EASLIB can be found in the EASLIB input manual [17]). Within the burnable poison input line (Line 10) there are three self shielding factors (g_0, a_0 and a_1). These three factors are fixes to the thermal flux depression created within the middle of the burnable absorber rod. Based on a homogenous burnable poison rod the relationship between the three self shielding factors can be approximated by Eq. 3-1.

$$g(t) \cong \frac{1}{a_o + a_1[\overline{N}(t)/N_0]} \tag{3-1}$$

In Eq. 3-1 N_0 = the original number density for the burnable poison and $\overline{N}(t)$ is the volume average of the number density of the burnable absorber as a function of time [18]. The remainder of the burnable poison input line refers to the amount of burnable absorber and cross section and the amount of moderator displaced by the insertion of the BPRA.

```
1.  CRYSTAL RIVER RELOAD #12 CORE WITH CASMO LIB (B4CAL2)
2.  crystal3.asc
3.  crystal1.out
4.     3    1    0    0    1    1    0    1    3
5.   177   29    3    6    4   -4   -12   3    4
6.     8    7    6    4    3    1
7.     1    2    3    4
8.     2    3    3    4    3    4    3    2
       3    4    3    4    3    4    2
       3    4    3    4    4    2
       3    4    3    3
       3    4    1
       1
9.  2568.0,360.17,21.81,800.0,0.7232,1.2,1.0,1.0,0.0
10.     1 B-20 16.190E-6  4.500E+1  2.050E+3 0.9480E-0  1.170E-0  0.616E-0 -9.29E-04
        1       0.375E-3 -0.094E-6   0.00E-0   1.00E-0  1.000E+2  0.000E+0 4.394E-02
        2 B-16 36.351E-6  4.500E+1  2.050E+3 0.9643E-0  0.959E-0  0.701E-0 -7.43E-04
        2       0.300E-3 -0.075E-6   0.00E-0   1.00E-0  1.000E+2  0.000E+0 3.515E-02
        3 B-12  9.710E-6  4.500E+1  2.050E+3 0.9480E-0  1.170E-0  0.616E-0 -5.57E-04
        3       0.225E-3 -0.056E-6   0.00E-0   1.00E-0  1.000E+2  0.000E+0 2.636E-02
        4 B-08 13.336E-6  4.500E+1  2.050E+3 0.9810E-0  0.979E-0  0.748E-0 -3.72E-04
        4       0.150E-3 -0.375E-7   0.00E-0   1.00E-0  1.000E+2  0.000E+0 1.758E-02
11.  3,2,0.0 5,7,0.0 7,6,0.0 9,2,0.0 11,4,0.0 13,5,0.0 16,6,0.0 18,8,0.0 20,1,0.0
     22,5,0.0 24,3,0.0 26,7,0.0
     *BRN
12.  38.784  24.686  28.930   0.000  24.537   0.000  28.395  40.206
           27.702   0.000  28.425   0.000  22.646   0.000  37.045
                  27.922   0.000  29.027   0.000   0.000  40.708
                           27.932   0.000  21.198  28.866
                                   27.655   0.000  38.450
                                            38.519
13.  3,0.0 2,10.0 1,20.0
```

Figure 3-10. Example of EASLIB input file.

Table 3-3. Input description for EASLIB.

Line Number	Description
1	72 Character alphanumeric title
2	File name for ASCII Library input file
3	File name for printfile output
4	10 element problem option vector
5	10 element integer reactor description vector
6	No. of assemblies in row I
7	Fuel type index assigned to each batch
8	Batch index of fuel in Ith assembly one line for each assembly row in the problem corresponds to line 6 and 7
9	8 element reactor operating condition vector
10	Burnable poison name and information (two lines per burnable poison type)
11	Group identification, and percent insertion for each control rod
12	Average burnup at BOC for each fuel assembly
13	Type/ burnup pair for each spare assembly

Adapted from Table 2. Graves HW Jr. EASLIB-C Binary Input File Generation for the EASCYC Fuel Cycle Analysis Program. Chevy Chase (MD): Energy Analysis Software Service; 1995.

Because there is no way to change the volume fraction of moderator displaced over the core burnup as a function of time within EASCYC it is impossible to show a significant reactivity gain between different burnable absorbers having similar amounts of boron. Therefore, the only core model for this research made using EASCYC is the B_4C/Al_2O_3 BPRA system. The model is useful in determining relative power peaking factors and general core behavior over a cycle and it gives comparative information for other models (MONTEBURNS). The EASCYC output file for the boron carbide BPRAs is located in Appendix D.

The MCNP/MONTEBURNS models

The concept for modeling the core in MCNP/MONTEBURNS is identical to the single assembly model expanded to the $1/8^{th}$ core. In the $1/8^{th}$ core model detail is added to the assemblies to more closely model the characteristics of the core in Table 3-1. These details include an axial blanket of two-percent enriched uranium on the top and

bottom, the modeling of Gd_2O_3/UO_2 fuel rods where required, and the use of only eight BPRAs in the locations specified in Figure 3-1.

The first step in modeling the core is to determine an approximation for the fuel in depleted fuel assemblies going into the current cycle. The fuel approximation is made using CASMO for each of the assemblies much like the process used in generating the EASCYC cross section libraries. As with EASCYC, similar assemblies with similar depletion burnups and starting enrichments are combined to limit the number of fuels.

However, additional simplifications to the problem are required because MONTEBURNS is limited to a maximum of 100 materials. Also, MONTEBURNS specifies a tally for each material depleted. These tallies can cause the dynamic storage allocation required for modeling all possible fuel elements (primary, blanket, and Gd_2O_3/UO_2) for every fuel assembly for every burnup step to become unreasonably large an effectively prevent MCNP from getting a result. Therefore, CASMO is used to deplete the fuel assembly to the appropriate burnup. Then a fresh fuel assembly is created with a lower enrichment derived from the remaining weight percent of fissile fuel (mostly ^{235}U, ^{239}Pu and ^{241}Pu) and the percent of fission products (mostly Xe and Sm) at the EOC from the depleted assembly. The original assembly is then burned an additional 10 mega-watt days per metric ton uranium (MWd/MTU) to simulate the first 10 MWd in the new cycle. The lower enrichment fuel assembly is then checked in CASMO by depleting it from zero burnup to 10 MWd/MTU to see if it has the same reactivity at BOC and BOC + 10 as the original assembly. If it does, then it is assumed that it closely simulates the original depleted assembly for the next cycle. All of the assemblies are modeled in batches according to their enrichment and average burnup.

Once the materials are specified, the reactor geometry is created using a repeated lattice within a cylinder and two planes to generate the 1/8th core. Figure 3-11 shows a full core model with a ¼ cut-out. Figure 3-12 shows the same model as a 1/8th core. Notice that in accordance with the stated assumptions, the models do not have a reactor vessel or control mechanisms but do have axial and radial water reflectors.

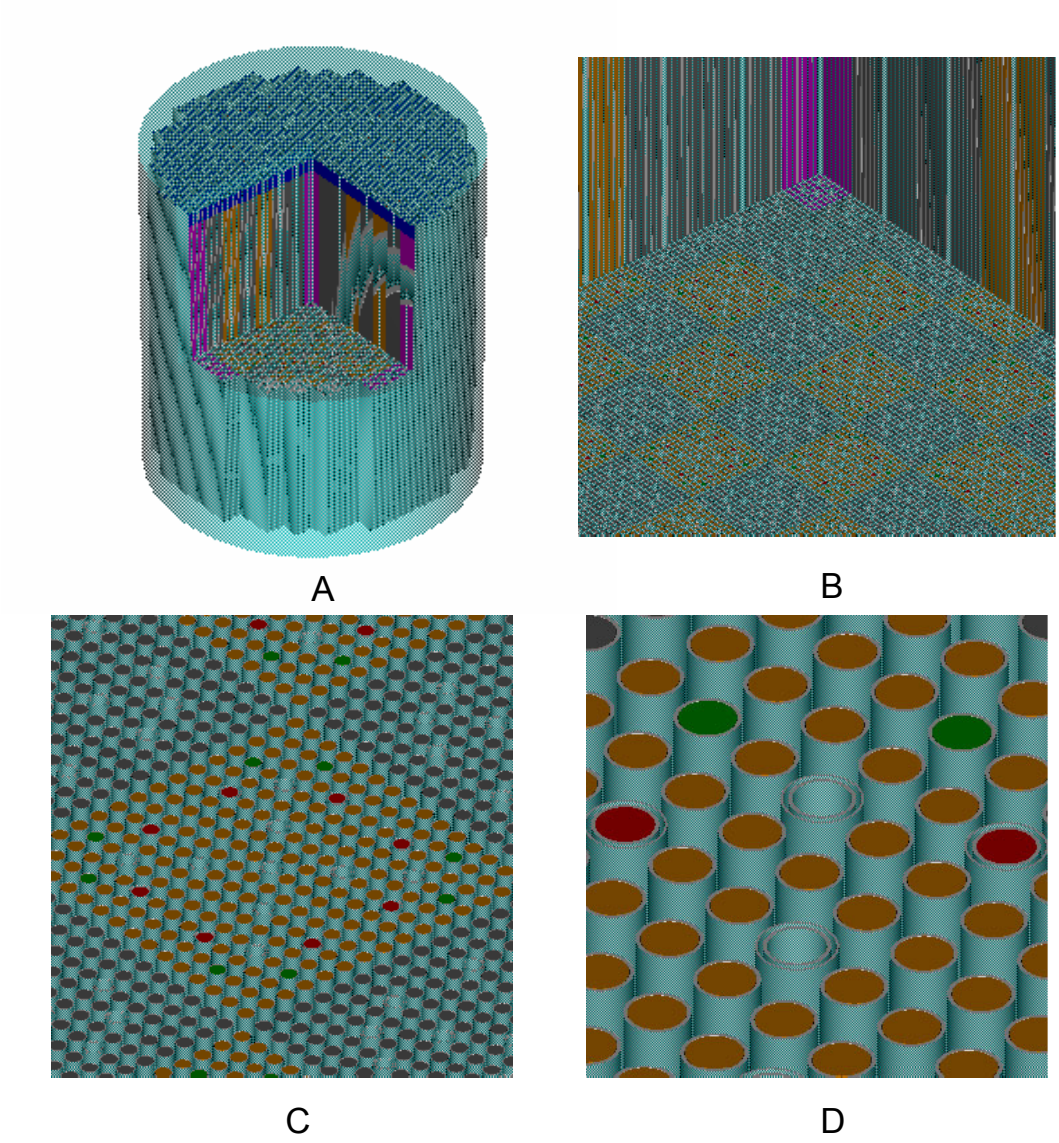


Figure 3-11. Multiple SABRINA plots of full core reactor MCNP model. Segments B-D are close-ups of the cut-away and illustrate the different types of rods. Grey and orange fuel rods, green Gd rods, red BPRAs, and empty control rod and instrument guide tubes.

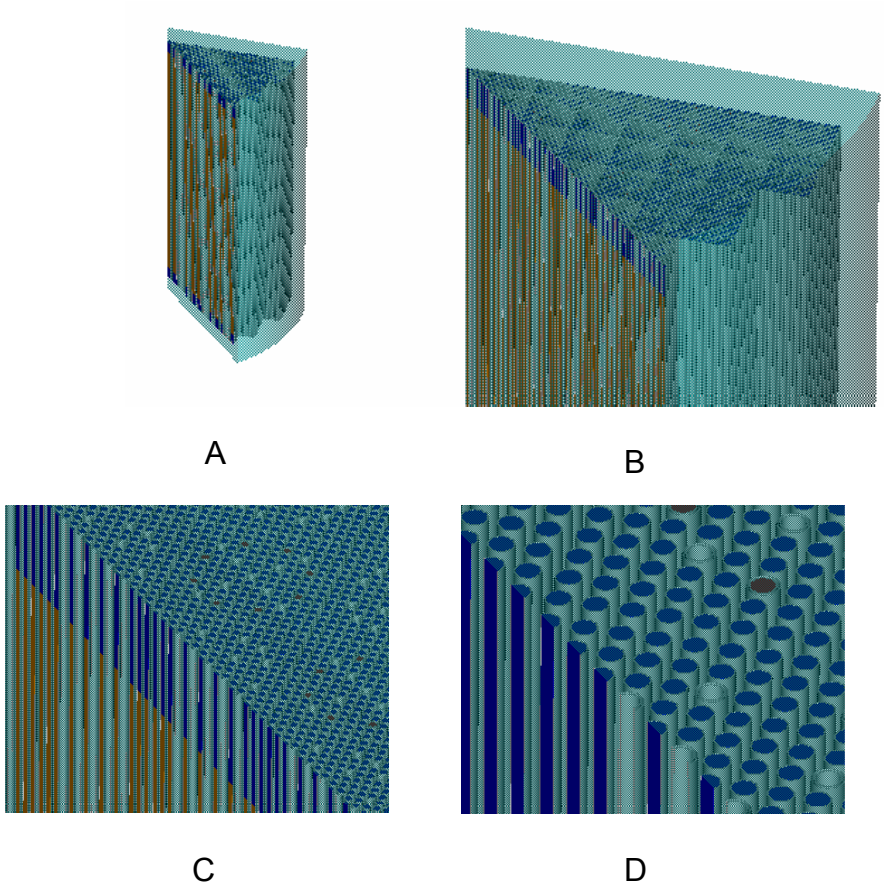


Figure 3-12. Multiple SABRINA plots of 1/8th core reactor MCNP model. Segments B-D are close-ups of the top of the reactor and illustrate the different types of rods. Orange primary fuel, dark blue blanket fuel, red BPRAs, and empty control rod and instrument guide tubes.

The core input files for MCNP and MONTEBURNS are similar to those in Figures 3-6 and 3-7 except that they repeat for multiple assemblies and multiple materials. The standard input file would have all of the similar assemblies having the same material number and the same universe number in the MCNP input. To get a single assembly's information, (e.g. power distribution), an additional universe and material must be added for that assembly. These models are referred to as power peak models in the remainder of this thesis and in the appendices. Because of the multiple materials, (up to 13 are depleted in MONTEBURNS for the 1/8th core power peak model versus the two for the

single assembly calculation), the process takes considerably more time to calculate. The complete input and output files for all of the 1/8th core MCNP/MONTEBURNS models are included in Appendix E.

Chemical Shim Models

All of the models up to this point have used water as the moderator with no chemical shim with the exception of EASCYC which calculates a critical boron concentration automatically. For the particular purpose of determining the power peak within the core for an assembly or to determine the power peak for a pin within a single assembly in the presence of chemical shim an additional model is required. This model is identical to the single assembly or 1/8th core MCNP/MONTEBURNS model discussed earlier except that the chemical shim (boron) is added to the water at BOC and smaller and smaller amounts of boron are removed during the lifetime of the cycle.

```
Time    Days    Power MBMat Feed Begin&EndRates Remov. Fraction
F.P.Removed
 Step Burned  Fract.   #    #      grams/day    Group#
   1  13.086  1.000    1    1   0.697   0.691    0    0.000
   2  52.342  1.000    1    1    -1.0   0.670    0    0.000
   3  65.428  1.000    1    1    -1.0   0.643    0    0.000
   4  130.856 1.000    1    1    -1.0   0.590    0    0.000
   5  130.856 1.000    1    1    -1.0   0.537    0    0.000
   6  130.856 1.000    1    1    -1.0   0.483    0    0.000
   7  130.856 1.000    1    1    -1.0   0.430    0    0.000
   8  130.856 1.000    1    1    -1.0   0.377    0    0.000
   9  130.856 1.000    1    1    -1.0   0.323    0    0.000
  10  130.856 1.000    1    1    -1.0   0.270    0    0.000
   1                             ! # of feed specs
   1                             ! # of isos in Feed #1
5010  1.0
   0                             ! # of removal groups
```

Figure 3-13. Example of single assembly MONTEBURNS feed file.

This process of adding or removing materials to the model during the depletion is achieved using a feed file in MONTEBURNS. The MONTEBURNS input file for the

continuous depletion case (Figure 3-10) had the total number of days burned and no feed file was used. For the chemical shim model, that parameter is set to zero and a feed file (Figure 3-13) details the type and amount of material added or taken away and at what time step during the depletion process. The feed file can also be used for a continuous burnup model where uneven time steps are requested (i.e. 10, 20, 50, 100, 1000 days). All of the chemical shim model inputs and outputs are in Appendix F.

CHAPTER 4
THERMAL AND RADIATION PROPERTY CALCULATIONS

Part of the material selection process not addressed in Chapter 2 involves the material's ability to withstand the extreme heat and radiation environment for a cycle within a PWR. The maximum centerline temperature within the BPRA is especially important for selection of a polymeric BPRA. Many polymers have ceiling temperatures above which they completely and rapidly revert back to their constituent species. As seen in Figure 2-2, the key component to moderation within the polymer is the weight percent of hydrogen present. Radiation environments tend to drive hydrogen off of the polymer and create cross-linking within the structure. The amount of radiation exposure the BPRA receives is important to predict the amount of hydrogen that will remain in the polymer at EOC. Also, hydrogen can hydride with the zirconium alloy cladding and cause the clad to become brittle and more susceptible to failure.

The actual selection of the polymer material based on radiation and thermal properties is not part of this thesis but is part of a joint research effort with the University of Florida's Materials Sciences and Engineering Department for the development and testing of advanced polymeric burnable poisons. The maximum expected centerline temperature, maximum acceptable coefficient of thermal expansion, and the maximum dose exposure are outlined in this research to present model-based calculations as benchmarks for selection of materials yet to be fully developed. Many of the values for the physical properties of the polymers are based on example polymers similar to the ones we are investigating.

Maximum Expected Centerline Temperature in BPRA

The calculation of the maximum expected centerline temperature (T_{Cl}) is based on several key assumptions. First, that the heat transfer in the axial direction is insignificant due to the length-to-radius ratio of the rod. Second, the specifications of the reactor are the same as those outlined in Chapter 3 (power, geometry etc.). And third, that the heat generated within the BPRA can be modeled using an MCNP energy deposition tally.

The heat deposition tally for neutrons (F6:N) in MCNP uses Eq. 4-1 to determine the heating response H(E) as a measure of energy deposition averaged over a cell [19].

$$H_{avg}(E) = E - \sum_i p_i(E)\left[\overline{E}_{out_i}(E) - Q_i + \overline{E}_{\gamma_i}(E)\right] \tag{4-1}$$

E = incident neutron energy
$p_i(E)$ = probability of reaction i
$\overline{E}_{out_i}$ = average exiting neutron energy for reaction i
Q_i = Q-value of reaction i
$\overline{E}_{\gamma_i}$ = average energy of exiting gammas for reaction i.

The heat deposition tally for photons (F6:P) in MCNP uses Eq. 4-2 to determine the heating response H(E) as a measure of energy deposition averaged over a cell [19].

$$H_{avg}(E) = \sum_{i=1}^{3} p_i(E) * (E - \overline{E}_{out}) \tag{4-2}$$

i = 1 incoherent (Compton) scattering with form factors
i = 2 pair production $\overline{E}_{out}$ = 1.022016 = $2m_oc^2$
i = 3 photoelectric

Energy transferred to electrons from gamma heating is assumed to be locally deposited.

The combination of the heat deposition tallies for neutrons and photons (F6:N,P) in MCNP for the BPRA cells gives the total expected heat generated within the BPRA. The heat transfer problem from the BPRA to the outside surface of the cladding is similar to the heat transfer model used for the thermal design of fuel rods. A common model for

the two-dimensional heat transfer in fuel is given in Duderstadt and Hamilton [6] (Eq. 4-3).

$$T_{Cl} - T_{fl} = \frac{q'}{2\pi r_F}\left[\frac{r_F}{2\bar{k}_F} + \frac{1}{h_G} + \frac{t_C}{k_C} + \frac{r_F}{h_s(r_F + t_C)}\right] \tag{4-3}$$

T_{Cl} = centerline temperature of the fuel element
T_{fl} = temperature of the moderator
q' = linear power density of the fuel element (W/cm)
r_F = radius of the fuel pellet (cm)
$\bar{k}_F$ = average thermal conductivity of the fuel (W/cm °K)
h_g = gap heat transfer coefficient (0.5 – 1.1 W/cm^2 °K)
k_C = thermal conductivity of the clad (W/cm °K)
h_s = coefficient of convective heat transfer (2.8 – 4.5 W/cm^2 °K)
t_C = thickness of the clad (cm).

Using the above relationship and substituting values for the burnable poison instead of the fuel, the maximum centerline temperature of a burnable poison rod can be determined. All of the values for the equation are known properties of the system except the linear power density within the burnable poison rod. For h_s and h_g the smallest value in the range was used to get the maximum temperature. The linear power density can be determined from MCNP using the energy deposition tally.

From MCNP:

Q for neutron and gamma heating = 1.6273E-26 jerks / gm /source particle
1 jerk = 10^9 joules, therefore,
Q = 1.6273E-17 joules/gm/source particle

For a total of 1.6273E-17 joules/gm/source particle.

All MCNP tallies are based on the number of sources particles. MONTEBURNS translates the per source particle tally to an actual value for the system based on the power level specified by the user. The relationships MONTEBURNS uses for normalization of the flux to system power are derived in Eqs. 4-4 and 4-5 [14].

$$\varphi = \varphi_n \cdot C \tag{4-4}$$

φ = true value of the flux (normalized to system power)
φ_n = the MCNP flux (normalized to the number of source particles)

$$C = \frac{\upsilon \cdot P \cdot 10^6 W/MW}{(1.602 \times 10^{-13} J/MeV) \cdot k_{eff} \cdot Q_{ave}} \tag{4-5}$$

υ = average number of neutrons produced per fission
P = power defined by the user for the material in (MW)
Q_{ave} = average energy produced per fission (MeV)
k_{eff} = effective multiplication factor obtained by MCNP.

MONTEBURNS calculated the actual average total (fast and thermal) flux for neutrons at full power in the BPRA as 3.15E+14 neutrons/cm^2-s. MCNP calculated the average total flux for neutrons in the BPRA as 2.439E-04 neutrons/cm^2/source particle. By dividing the MONTEBURNS flux by the MCNP flux we get a nominal value for the number of source particles per second for one assembly at full power of 1.291E+18 which translates to 2.286E+20 n/s being produced from fission within the reactor at 2544 MWt.

The total volumetric heat rate for the BPRA can be determined by using the number of source particles in the assembly and the results from the heating tally for the assembly. The total volumetric heating (q’’’) in the BPRA is given as:

q’’’ = 1.6273E-17 joules/gm/source particle x 1.291E+18 source particles/s

q’’’ = 21.01 W/gm.

The linear heat rate can be determined using the radius of the BPRA pellet and the density of the BPRA material. For boron carbide, ρ = 3.1 gm/cc and q’ = 44.29 W/cm which converts to 1.35 kw/ft heating rate and is comparable to a quoted example from

Framatome Fuels for a larger system of 1.679 kw/ft. For carborane, $\rho = 1.0$ gm/cc and q' = 14.3 W/cm.

The maximum centerline temperature is calculated by substituting known quantities for the other variables into Equation 4-3 and using values for polyethylene and high density polyethylene as example polymers (Table 4-1). In Table 4-1, the thermal conductivity values for the polymers were taken at room temperature. Thermal conductivity tends to decrease with time, so the resulting estimate is slightly lower than what would be expected. Also shown in the table is the value where the linear heat rate was changed in the calculation to match a quoted value from Framatome fuels for their BPRA estimates which are based on a different reactor system and are 5 – 10% higher.

Table 4-1. Evaluated data for centerline temperature in various BPRA materials.

	Thermal Conductivity[†]	Max Difference between T_{MOD} and T_{CL} for BP rod	Linear q' value from MCNP	Linear q' value from Framatome
	W/cm °K	°C	T_{Cl} °C	T_{Cl} °C
High Density PE	0.0046	261.44	571.44	633.83
Polyethyline	0.0033	358.83	668.83	754.45
B_4C/Al_2O_3	0.0200	295.87	605.87	676.48
Alumina	0.1180	73.99	383.99	401.65

[†] Callister WD Jr. Material Science and Engineering Introduction 5th ed. New York: John Wiley and Sons Inc; 2000.

The obvious implication from Table 4-1 is that the centerline temperature is strongly dependant on the thermal conductivity of the burnable poison material. This relationship corresponds to the relative importance of thermal conductivity in Eq. 4-3. A critical benchmark for the BPRA material depends on the thermal conductivity of the material. Materials with low thermal conductivity and low thermal stability would be unsuitable for this application. Unfortunately, many polymers have thermal conductivities and order of magnitude lower than those of ceramics.

Maximum Coefficient of Thermal Expansion

The calculation of the maximum coefficient of thermal expansion is important because the integrity of the BPRA assembly depends on the burnable absorber remaining within the cladding. If the absorber expands too much it could rupture the cladding and be lost from the system causing unacceptable power shifts within the core. This calculation assumes that the expansion in the axial direction can be neglected because of the overall length-to-diameter ratio of the BPRA. Additionally, it assumes that all of the dimensions and geometry are the same as the Crystal River Reactor modeled in Chapter 3. Figure 4-1 shows an example cross section of the BPRA with the correct dimensions.

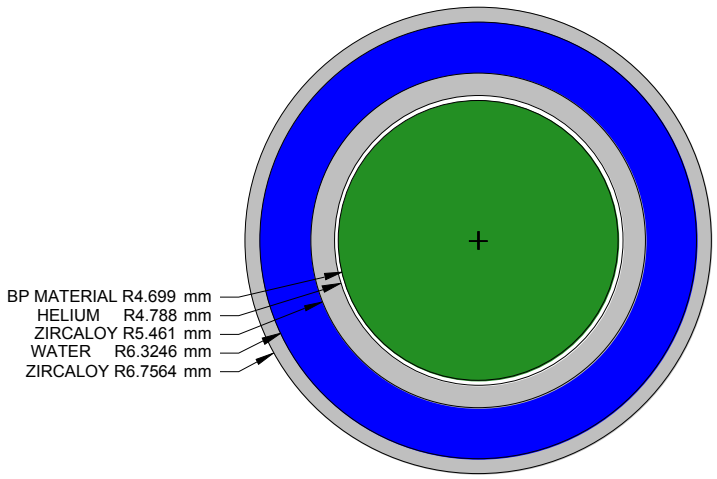


Figure 4-1. Cross section diagram of a BPRA

Using Figure 4-1 as a standard for the dimensions of a BPRA the maximum coefficient of thermal expansion for a BP material can be calculated by first determining the maximum amount the zircalloy cladding will expand under normal temperature changes. The coefficient of thermal expansion for zircalloy is $C = 7.0 \times 10^{-6}\ °K^{-1}$ [10].

Thermal expansion for a homogenous object can be thought of as a magnification, or photographic enlargement, of the object when it is heated. Ignoring the axial

expansion, the cladding acts like the washer in Figure 4-2 and all dimensions increase, including the radius of the hole [20]. The inner radius is the primary concern for this problem because the maximum expansion of the inner radius of the cladding is needed to determine the maximum allowable expansion of the BPRA before it interacts with the clad.

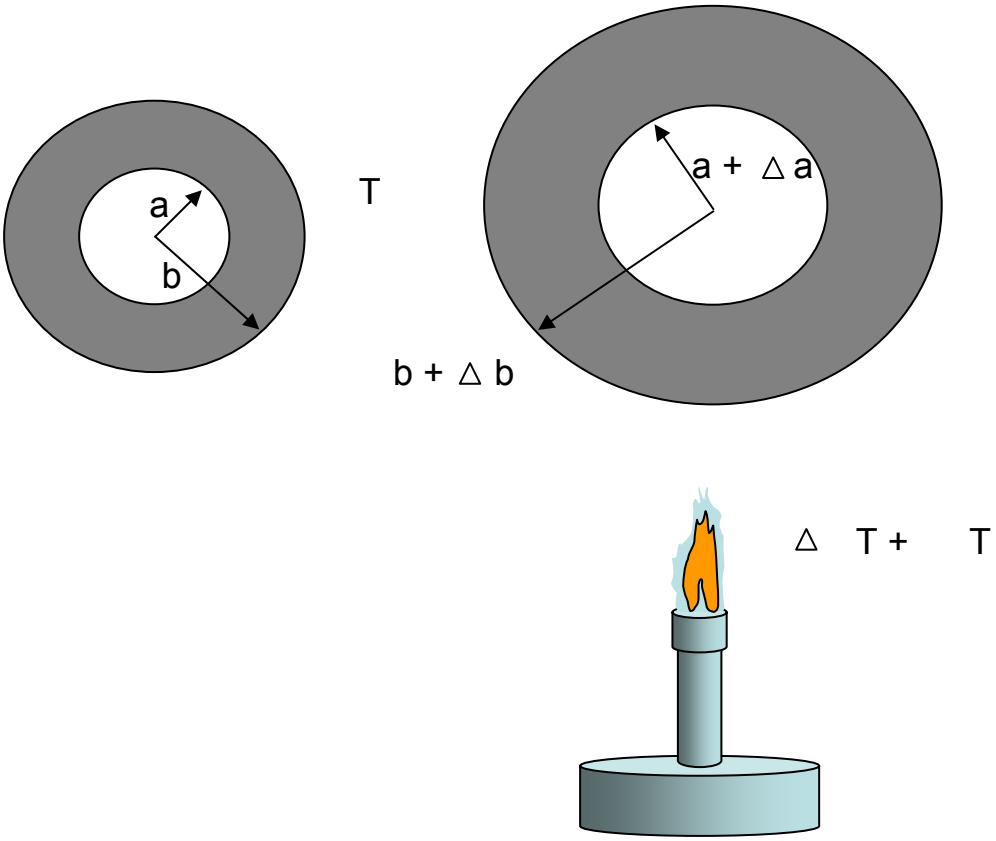


Figure 4-2. Thermal expansion of a metal washer. All dimensions increase when it is heated. Adapted from Figure 19.9. Serway RA. Physics for Scientists and Engineers with Modern Physics, Third Ed. Philadelphia: Saunders College Publishing; 1990. Pg 514.

Using the inner radius for the BPRA zircalloy cladding (from Figure 4-1), C, and ΔT = difference between room temperature and the temperature of the moderator (583°K – 293°K) the relationship for the maximum inner radius of the cladding after expansion is derived (Eq. 4-5).

$$r_{Max} = r + r \cdot C \cdot \Delta T \tag{4-5}$$

$$r_{Max} = 4.788 + 4.788 \cdot (7 \times 10^{-6}) \cdot 290 = 4.798mm$$

The maximum coefficient of thermal expansion for the burnable poison material can be determined by working backwards and using the inner radius of the clad at full temperature as the maximum radius for the BP material. This calculation assumes the BP material replaces all of the gap area during expansion and assumes that the change in temperature across the BPRA is on the order of 380 °K (2/3 of the maximum centerline temperature of 571 °C minus room temperature 20 °C converted to kelvin). The relationship for the maximum C for the BP material is given in Eqs. 4-6 and 4-7.

$$r_{BP} + r_{BP} \cdot C_{BPMAX} \cdot \Delta T \leq 4.798mm \tag{4-6}$$

$$C_{BPMAX} \leq \frac{4.798 - r_{BP}}{r_{BP} \cdot \Delta T} = \frac{4.798 - 4.699}{4.699 \cdot 380} = 5.544 \times 10^{-5}\, mm/mm^{o}K \tag{4-7}$$

The coefficient of thermal expansion for various materials is listed in Table 4-2. Based on these values, the polymers have a higher coefficient of thermal expansion than the ceramics and are above the maximum allowable of 5.544 x 10^{-5} °K^{-1} and may interfere with the cladding unless more gap is provided between the outer radius of the BPRA and the inner radius of the clad. However, the materials listed in Table 4-2 have not undergone radiation cross-linking and are not entirely equivalent to the polymers that are being sought for this study. The proposed burnable poison polymers will undergo cross-linking before entering the reactor and will be partially ceramic in nature and should have a much lower value of thermal expansion. The actual measured values for the coefficient of thermal expansion and the centerline temperature should be applied before any practical application of this material is made.

Table 4-2. Coefficients of thermal expansion of various materials

Material	Coefficient of Thermal Expansion[†] (x 10^{-6}) °K^{-1}
High Density Polyethylene	106 – 198
Polyethylene	145 – 180
Pyrex Glass	3.3
Alumna Oxide Al_2O_3	7.6

[†] Callister WD Jr. Material Science and Engineering Introduction 5th ed. New York: John Wiley and Sons Inc; 2000.

Dose Delivered to BPRA during Cycle

Once the calculation of the amount of energy deposited within the BPRA is complete, the calculation of the total dose to the BPRA over one cycle is straightforward. Dose equals energy deposited per unit mass and is expressed in the unit Gray where 1 Gray = 1 joule/kg. Taking the volumetric heat rate of q''' = 21.01 W/gm = 21.01 joules/sec/gm the dose is calculated by multiplying it by a time in seconds and converting gm to kg. Assuming the BPRA is in core for 18 months (4.7304E+7 seconds) the total dose is 9.939E+11 gray = 9.939E+13 rad = 90.39 Trad.

The above value is an enormous dose to any object and a key concern for the use of polymers within the reactor. The primary advantage to the PACS, or carborane, polymers in this aspect is that they have been used as adhesives in high radiation environment and have been shown to be thermally stable up to 1000 °C [2]. What is unknown about PACS, or any other polymer, is how much hydrogen will be produced (i.e. released from the polymer) during the irradiation process at these high doses. Estimates of the remaining hydrogen at EOC need to be established in order to determine the true moderation benefit and predict the amount of hydrating to the zircalloy clad.

CHAPTER 5
RESULTS AND DISCUSSION

The purpose of the research is to demonstrate that the increased hydrogen content at EOC in an advanced polymeric burnable poison rod provides sufficient additional moderation to increase the cycle life of the core. Ideally, the polymeric burnable poison rod would outperform not only the current boron carbide alumina BPRA but also the WABA. To prove this, several models of the PWR assemblies and cores were made in accordance with the procedures outlined in Chapter 3. The process begins with a single assembly analysis and continues with a multi-assembly two-dimensional comparison and ends with a 1/8th core three-dimensional model of the core. At each step comparisons were made, where possible, between different codes and against the actual cycle reload report provided for the core being modeled.

Single Assembly Analysis

Single assembly analysis was conducted using MCNP/MONTEBURNS and CASMO. The assemblies were depleted out to 40 MWd/kg in CASMO and the k-infinity vs. time values for the various burnable poison cases were compared to a standard of no burnable absorber in the assembly. The results, shown in Figure 5-1, illustrate the effect of increased moderation at EOC. Each of these materials has the same amount of burnable absorber, but because of the wet annulus in the WABA, it has an increased reactivity over the B_4C/Al_2O_3 BPRA throughout the cycle. Most importantly to this study, relative to the B_4C/Al_2O_3 BPRA and the WABA, the L-Carborane polymer has a lower k-infinity value at BOC, meaning the burnable absorber is performing better. Also,

as shown in the inset of Figure 5-1, L-Carborane has a higher k-infinity than the B_4C/Al_2O_3 BPRA (approximately 1%) at 40 MWd/kg illustrating that the increased hydrogen in the polymer offsets the water displacement penalty of the BPRA.

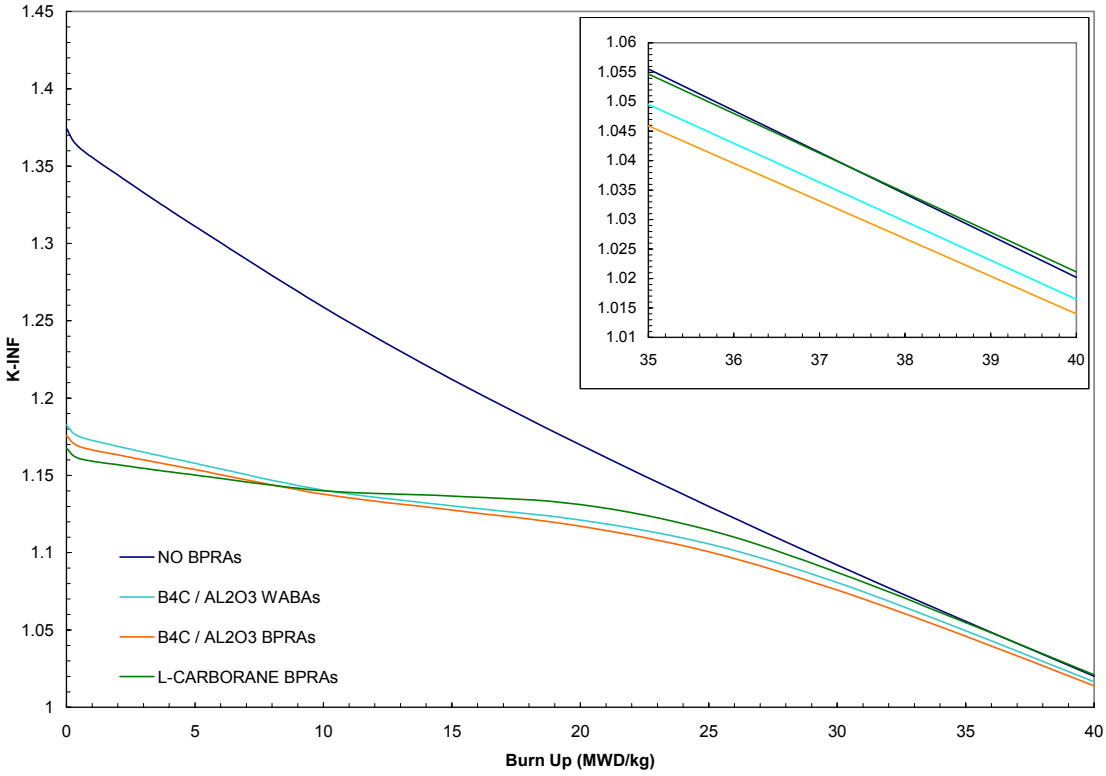


Figure 5-1. Single assembly k-infinity vs. time for various BPRAs using CASMO. The inset of the graph represents an enlargement of the last five MWDs of the cycle.

Whenever the reactivity shifts within a reactor or assembly there is a subsequent shift of power. Of primary concern is the ratio of the power in one portion of the assembly or reactor to the average across the structure. This peak-to-average, or pin-peaking, factor is a major limiting factor in fuel design and core management because of structural safety limits to the materials within the core. The CASMO output of the single assembly analysis shown in Figure 5-1 also produced the pin power peaking results illustrated in Figure 5-2. From the pin power peaking results it can be seen that the L-Carborane BPRA has a lower peak-to-average pin power ratio at BOC than the

B_4C/Al_2O_3 BPRA and a higher pin power peaking at EOC. This is to be expected because of the increase in reactivity at EOC causes the power peaking to increase. However, an important fact is that the overall highest peak-to-average power ratio is lower in L-Carborane than for the boron carbide BPRA. The importance of the peak-to average power ratio also depends on where it occurs within the cycle. In a real reactor situation the power peaking may occur later in the cycle and would have a much greater safety concern than at BOC.

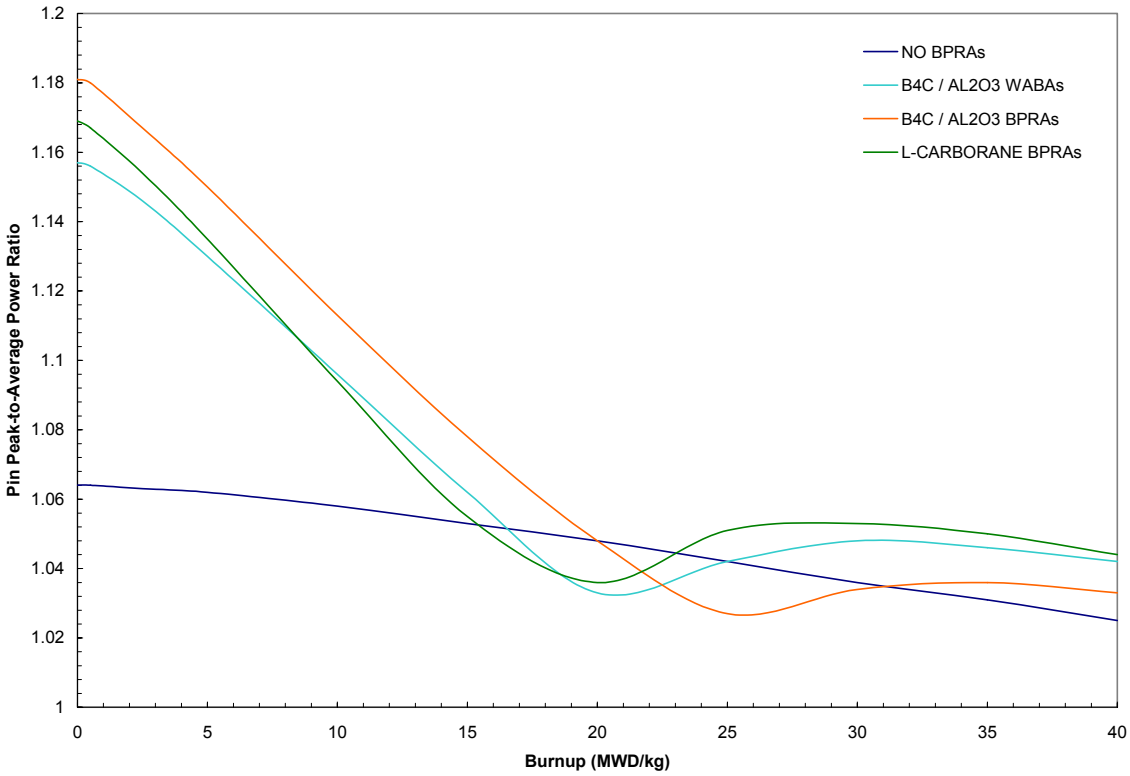


Figure 5-2. Single assembly pin power peaking for various burnable absorbers. Results are from single assembly CASMO runs.

One of the criteria for an optimum burnable absorber described in Chapter 1 is the property of the absorber to deplete, or burn, over time. Another useful comparison between the various burnable absorbers is the number of boron-10 atoms present over time. Ideally, at EOC no boron-10 would remain so that the maximum reactivity would

be present when the fuel is most depleted. Figure 5-3 shows that the L-Carborane has a lower amount of residual boron at EOC than either the B_4C/Al_2O_3 BPRA or WABA. This adds to the desirability of the polymeric burnable absorber and lowers its negative reactivity worth at EOC.

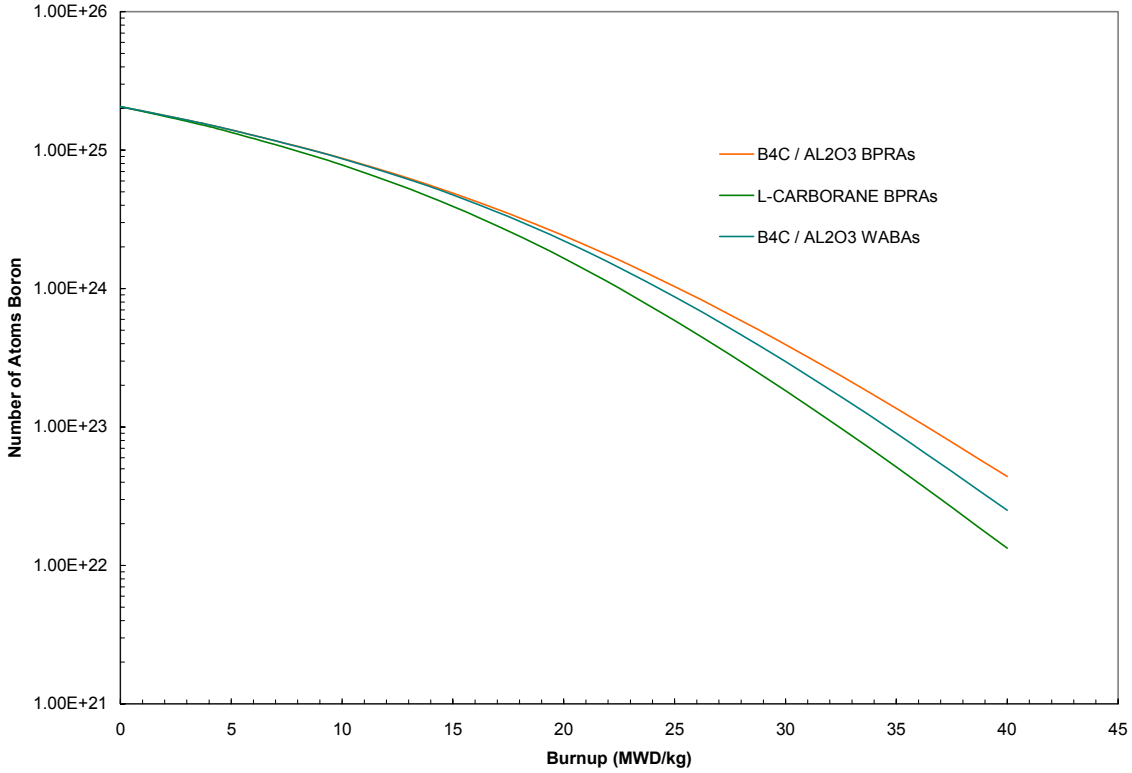


Figure 5-3. Number of B-10 atoms present vs. burnup for various burnable absorbers. Results are from multiple single assembly CASMO runs.

As mentioned in Chapter 2 of this study, L-Carborane is a fictional material made by modifying the subscripts within the PACS formula to obtain a boron content equivalent to that of B_4C/Al_2O_3. The L-Carborane structure has approximately seven weight percent of hydrogen. Because this study incorporates the use of various polymers, the actual weight percent of hydrogen will vary from the hypothetical L-Carborane. In order to ensure the material will perform better than the B_4C/Al_2O_3 WABA the weight percent of hydrogen in L-Carborane was adjusted to determine at what point the benefit

of the polymer over the current technology is lost. Figure 5-4 shows that at approximately 4.5 weight percent hydrogen the L-Carborane material outperforms the B_4C/Al_2O_3 WABA.

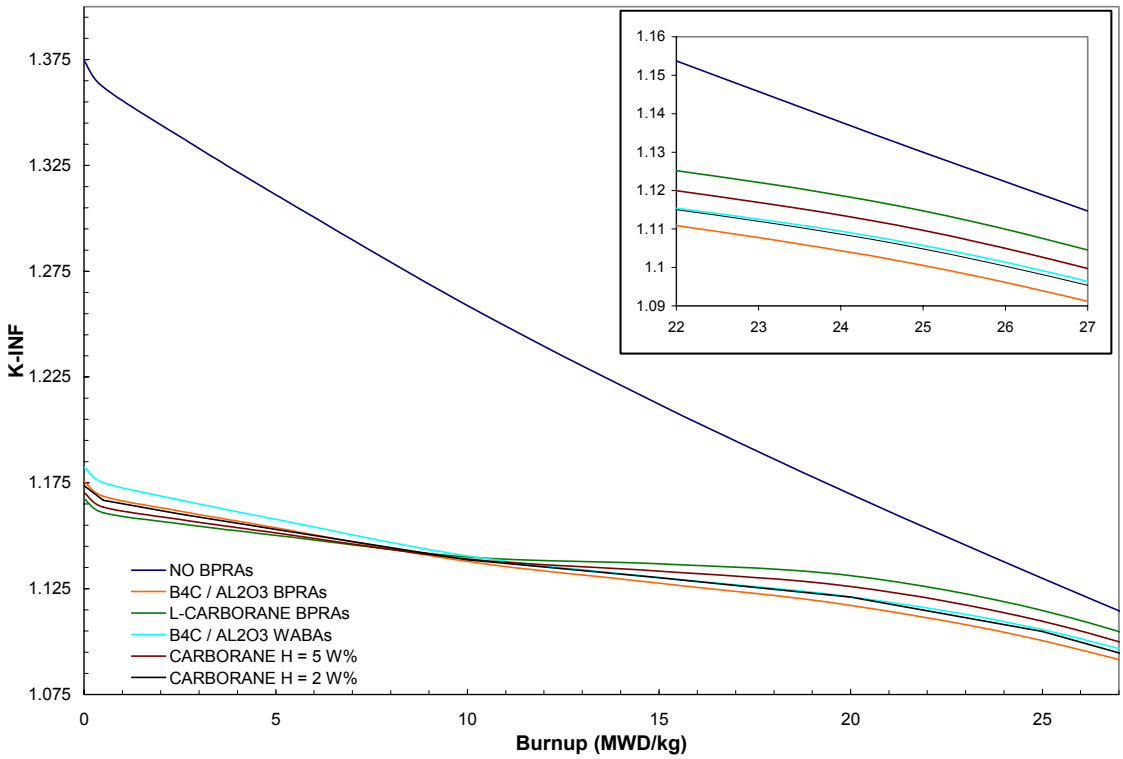


Figure 5-4. K-infinity for different carborane compounds with varying amounts of H. Also includes results for B4C / AL2O3 BPRAs and WABAs. The inset of the graph represents the last five days of the cycle. All results are from multiple single assembly CASMO runs.

The MCNP/MONTEBURNS code has the unique ability to capture virtually any data anywhere within a given structure with regards to flux, power, material generated and destroyed, or materials activated. To get additional information about the single assembly performance of the polymeric burnable absorber vs. the standard BPRAs and WABAs, the assemblies were modeled in MCNP/MONTEBURNS. In order to ensure that the results from MCNP/MONTEBURNS were comparable to CASMO, care was taken to ensure that the same material compositions, geometry and power distributions

were used in both codes. The results of the k-infinity vs. time calculation for both codes are shown in Figure 5-5.

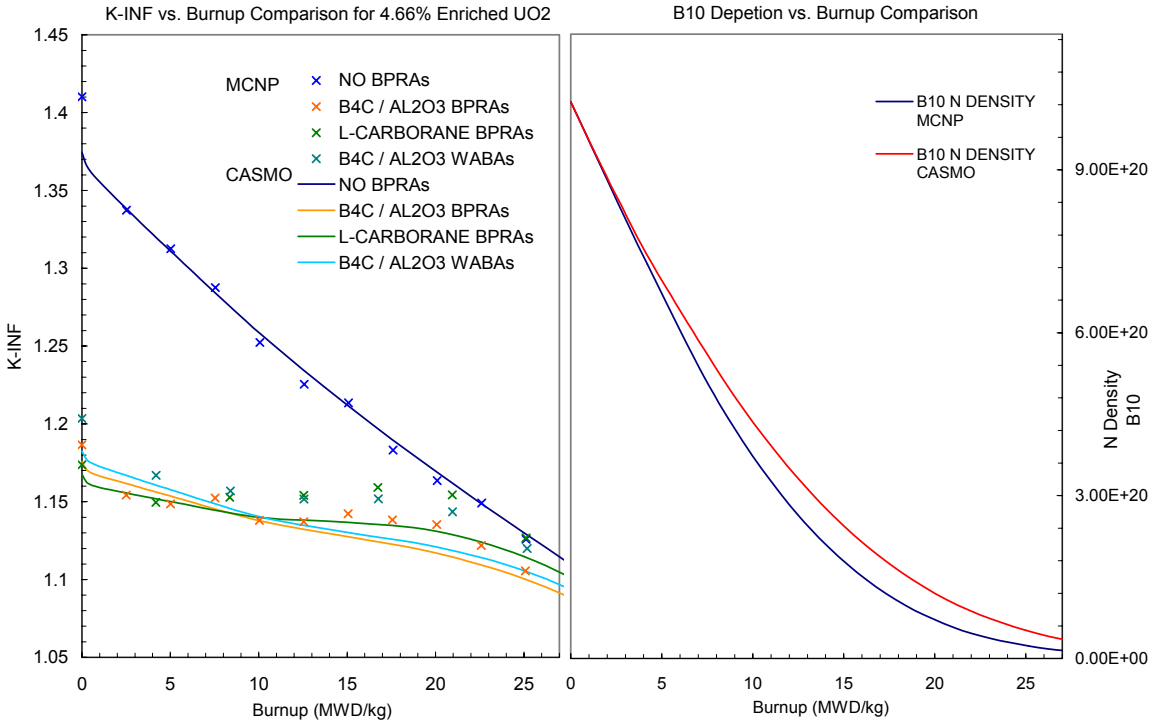


Figure 5-5. K-infinity vs. burnup comparison of CASMO and MCNP/MONTEBURNS. Left side of the figure shows the single assembly burnup results from both codes. Right side of figure shows the relative boron depletion for the two codes.

The proportional differences between the various burnable poisons are the same for either code. This means that the relative difference between L-Carborane and B_4C/Al_2O_3 BPRA at BOC is the same in MONTEBURNS as it is to CASMO. However, the difference between the MONTEBURNS and CASMO results gradually increases over time. The right side of Figure 5-5 shows that the k value decreases less rapidly in MONTEBURNS for cases other than the one without BPRAs because the boron content depletes faster in the code. The differences in values between the codes is not important here because this study is a relative comparison between two materials and, therefore, the MONTEBURNS model can be used for further analysis. Additionally, the fact that the

L-Carborane continued to perform better than the other burnable poisons for the different codes adds to the validity of the argument for an advanced polymeric burnable absorber.

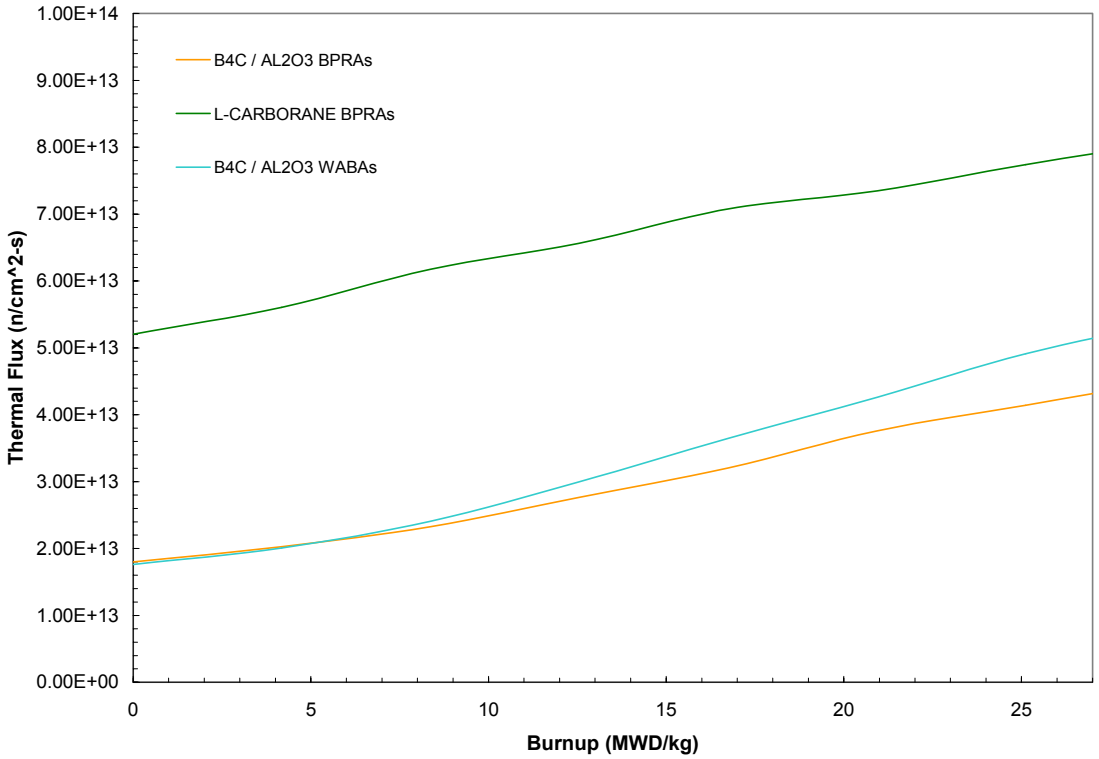


Figure 5-6. Thermal flux vs. burnup inside BPRA for various burnable poison materials.

One of the unique tallies that can be obtained from MONTEBURNS is the flux in a particular region or material. The thermal neutron flux within the BPRA shows a combination of the absorption effects of the BPRA and the moderation effects (if any) of the BPRA material. Figure 5-6 shows thermal flux (< 1 eV) vs. burnup inside BPRAs and WABAs. This increase in moderation eliminates the water displacement penalty caused by BPRAs at EOC.

Multiple Assembly Results

The multiple assembly "colorset" models were run in accordance with Chapter 3 of this study. As with the single assembly models, no chemical shim was added to the moderator and the boron concentration within all of the BPRAs was held constant. The

major impact of having one fresh fuel assembly with 16 BPRAs and three other assemblies of lower enrichments and with no BPRAs to simulate depleted fuels was a general reduction of the effect of the BPRAs on the reactivity of the model. These results are predictable because the overall effect of the BPRAs is spread out over four assemblies, although the majority of the positive reactivity effect is located within the fresh assembly. This is important because this model more closely represents the actual conditions within the reactor where not all fuel elements are fresh with BPRAs.

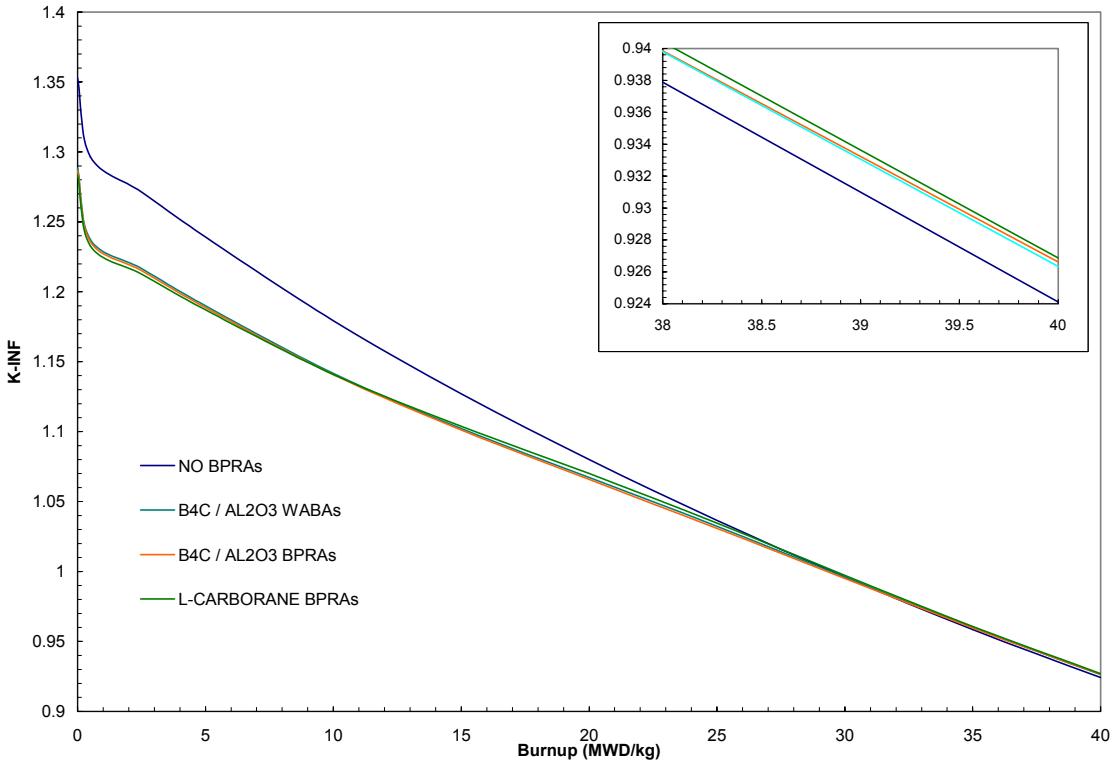


Figure 5-7. CASMO 2 X 2 colorset comparison k-infinity vs. burnup. Graph inset shows last two days of the cycle.

The results of the colorset comparison are shown in Figure 5-7. When compared with the single assembly results of Figure 5-1, it becomes evident that the overall difference between the various BPRAs is significantly less at 40 MWd/kg. However, it is possible to observe differences (approximately 1% increase in reactivity) at around 20-25

MWd/kg. This corresponds to the normal single cycle burnup point for a fresh fuel assembly. A one percent increase in the length of a cycle is a considerable increase in reactivity when one considers the amount of money associated with a reactor's down-time. Estimates of up to a million dollars a day for reactor down time in reload means that a one percent increase in a cycle could result in a six million dollar savings for an 24 month cycle.

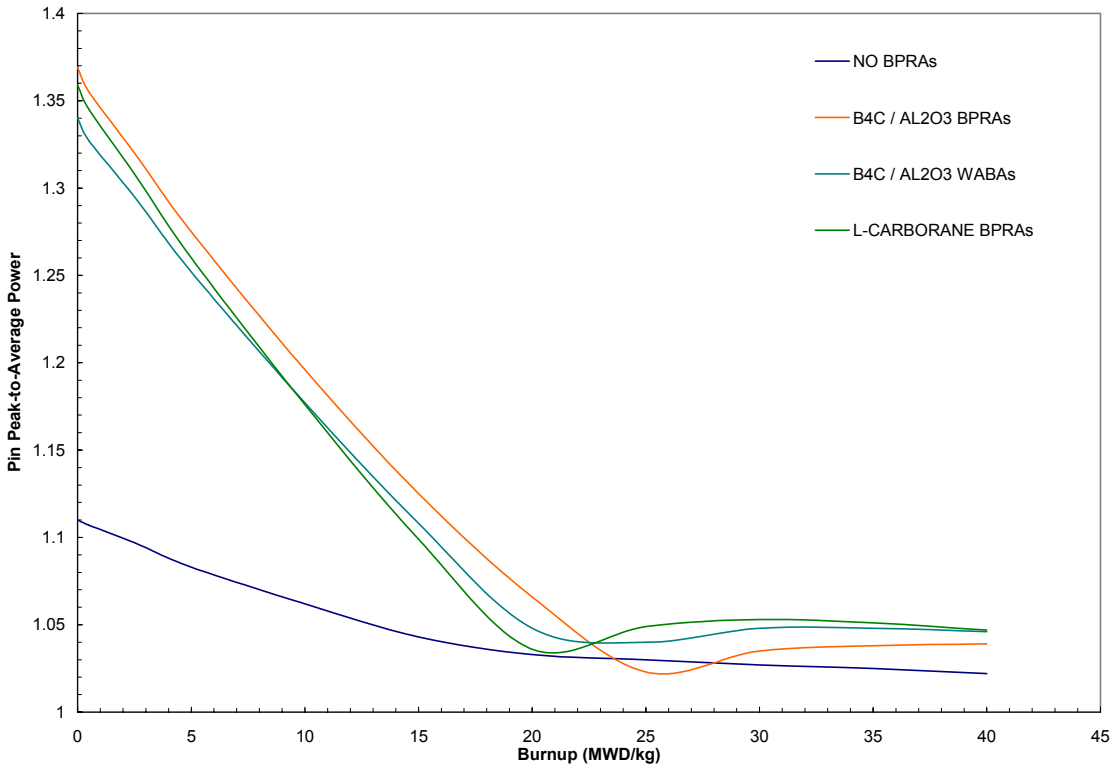


Figure 5-8. CASMO 2 X 2 colorset comparison pin power peaking vs. burnup.

As with the single assembly calculation, the pin power peaking response is equally important in the multi-assembly model. Figure 5-8 shows that the relative pin power peaking results were the same for the colorset as observed in the single assembly (Figure 5-2). As with the single assembly, compared to the boron carbide BPRA, the polymer BPRA created a greater pin peaking at EOC indicating greater reactivity and generated a lower pin peaking at BOC indicating better performance at holding down excess

reactivity when needed. A significantly lower reactivity at BOC could be taken advantage of by increasing the enrichment of the fresh fuel. Increasing the enrichment would allow an even longer fuel cycle life and higher burnup in addition to the longer core life given by the reduction in the moderator displacement penalty. However, the increase in enrichment would also affect the power peaking of the assembly and the stress induced to the materials.

One-Eighth Core Results

The single and multiple assembly results were all based on an infinite array of similar assemblies. This means that a reflected boundary on the assembly or colorset made the system act like it was in an infinite field of like assemblies. The actual reactor geometry is symmetric about a 1/8th core model described in Chapter 3. The consequence of dissimilar assemblies on the overall reactivity of the core is seen in the colorset and it is predicted that the same effect will be observed in the core model.

Criticality vs. Time Results

The accuracy of the model is important in order to determine the effectiveness of the various BPRAs. The PWR model used, outlined in Table 3-1, burned to 670 ± 10 EFPDs in the Framatame NERO modeling code.12 Any model that would closely resemble the Framatome model would have to burn to a similar duration and have similar power characteristics. This core was modeled with boron carbide BPRAs as in the Framatome model in both EASCYC and MCNP/MOTEBURNS. The EASCYC model was only used for power peaking comparisons because it could not model the decrease in moderator displacement generated by the polymeric BPRA. EASCYC depletes the core to 22.8 MWD/kg at an operating power of 85.9% of 2990 MWt (approximately 2544 MWt). With 89,679 kg of uranium in the core this equates to 684 EFPDs. From

MONTEBURNS, using no chemical shim at the rated power of 2544 MWt the excess reactivity in the core is depleted at 670 EFPDs with k = 0.99753. This leads to the assumption that the models both provide similar reactivity results to those of the NERO code.

The k-infinity vs. time for the one-eighth core model in MONTEBURNS is shown in Figure 5-9. As expected from the colorset results, the L-Carborane shows little to no improvement over the standard B_4C/Al_2O_3 BPRAs. This result is the combination of both the effect of the other depleted fuel assemblies and the fact that the core model depended on Gd_2O_3/UO_2 burnable absorber fuels along with BPRAs and this reduced the number and the effect of the BPRAs on the core's reactivity.

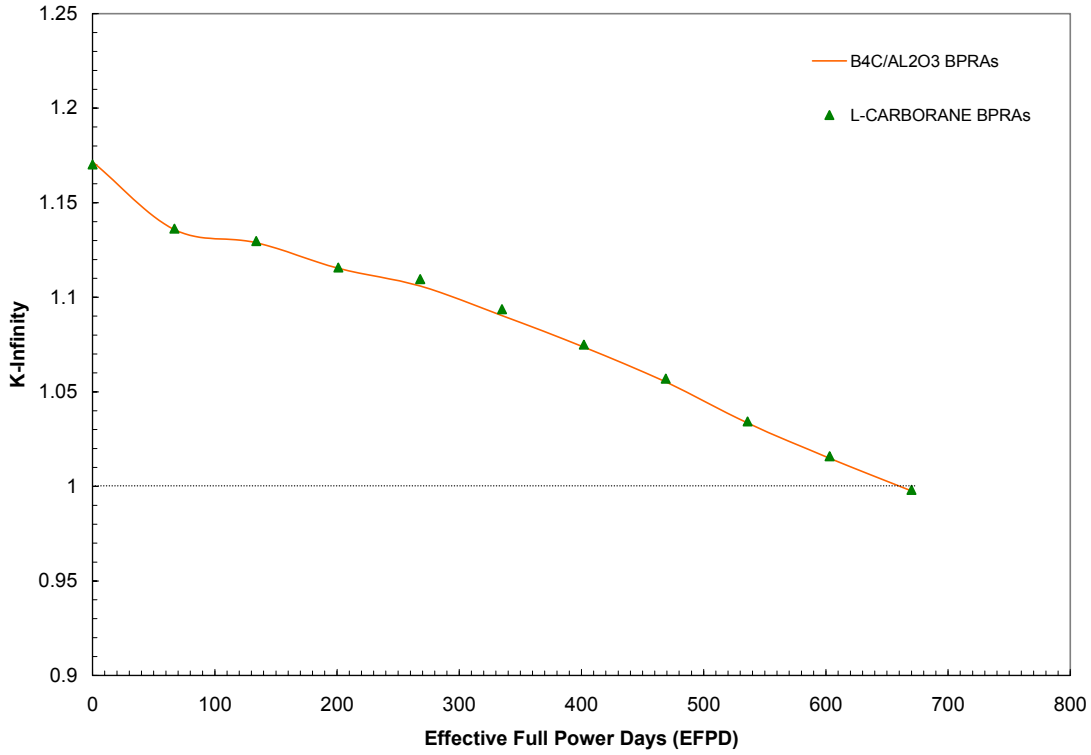


Figure 5-9. K-infinity vs. time for various BPRA materials ($1/8^{th}$ core MONTEBURNS). The cycle length ends at approximately 670 EFPDs for both materials.

As stated in Chapter 2, the L-Carborane material is a hypothetical molecule developed to have the same boron content as B_4C/Al_2O_3 BPRAs. The actual composition of a PACS polymer synthesized was described in Chapter 2 as J-Carborane. Up to this point, no models contained the J-Carborane BPRAs because the emphasis has been on showing an increase in reactivity over time with a polymer of equal boron content. Now with a more realistic model of the core, the actual polymer content can be introduced to see how its effectiveness compares to the standards.

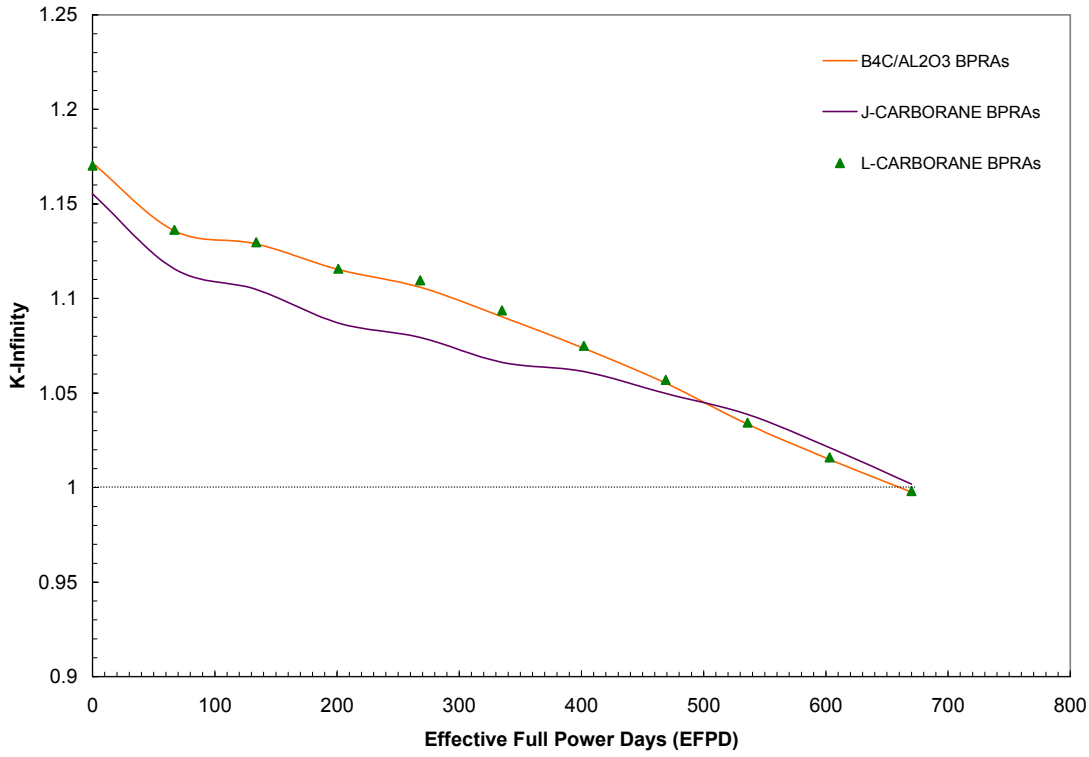


Figure 5-10. K-infinity vs. time for 1/8th core for BPRA materials including J-Carborane. The J-Carborane extends the cycle length by approximately 6-10 EFPDs.

The k-infinity vs. time for boron carbide and both L and J Carboranes is shown in Figure 5-10. As seen in the figure the J-Carborane composition adds approximately one percent reactivity at EOC and holds down an extra one and one-half percent reactivity at BOC when compared to either the boron carbide alumina or the L-Carborane BPRAs.

The combined effects at BOC and EOC make J-Carborane appear to be superior to either the standard boron carbide alumina or L-Carborane BPRAs. The primary concern for the use of J-Carborane is that its higher absorption cross section may cause power peaking problems within the core. Further analysis of the power peaking for the core would determine if in fact the J-Carborane material would be a viable alternative to B_4C/Al_2O_3.

Power Peaking Results

The 1/8th core model can be mapped out so that each assembly is given a reference number as in Figure 5-11. When conducting power peaking calculations, the benchmark for the core was set as the BOC power map from the Crystal River Three Cycle 12 Reload Report. The power peaking was taken as the value of one assembly's power to the average power across the core.

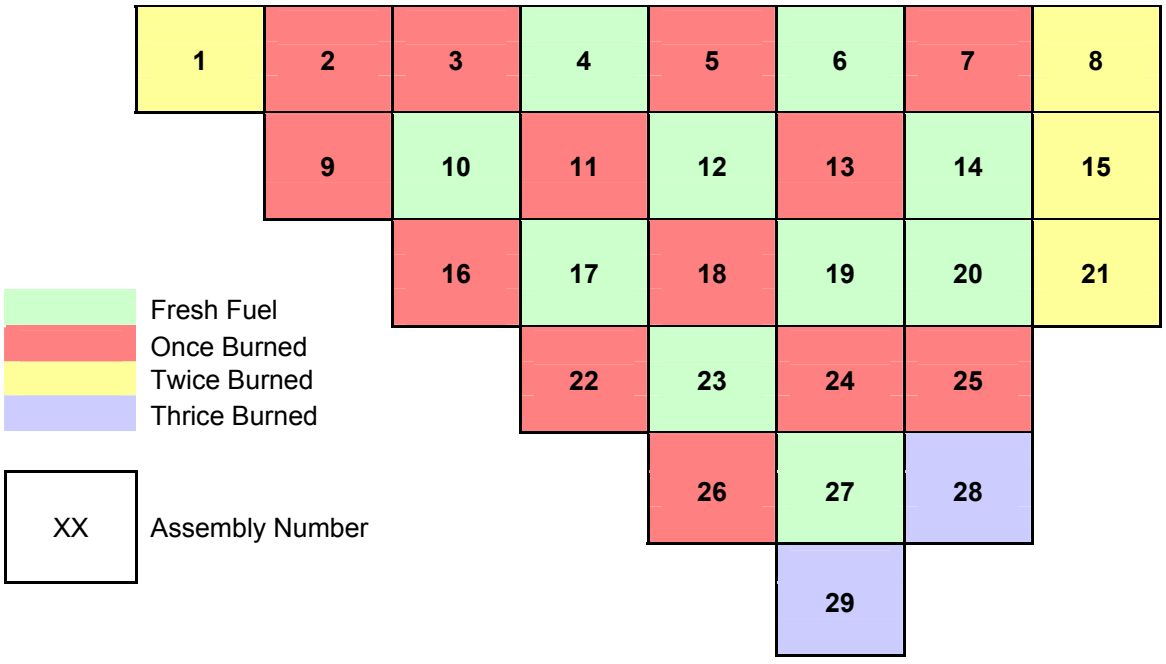


Figure 5-11. Assembly number identification for 1/8th core model.

The EASCYC code performed power peaking calculations for all the depletion steps for the lifetime of the cycle. Both EASCYC and the reload report indicated that

Assemblies 4 and 12 consistently had the highest peak-to-average values for the core cycle. From these results it is assumed that they are the likely candidates for more complex modeling in MONTEBURNS which requires a specific assembly to be modeled independent of the rest of the batch.

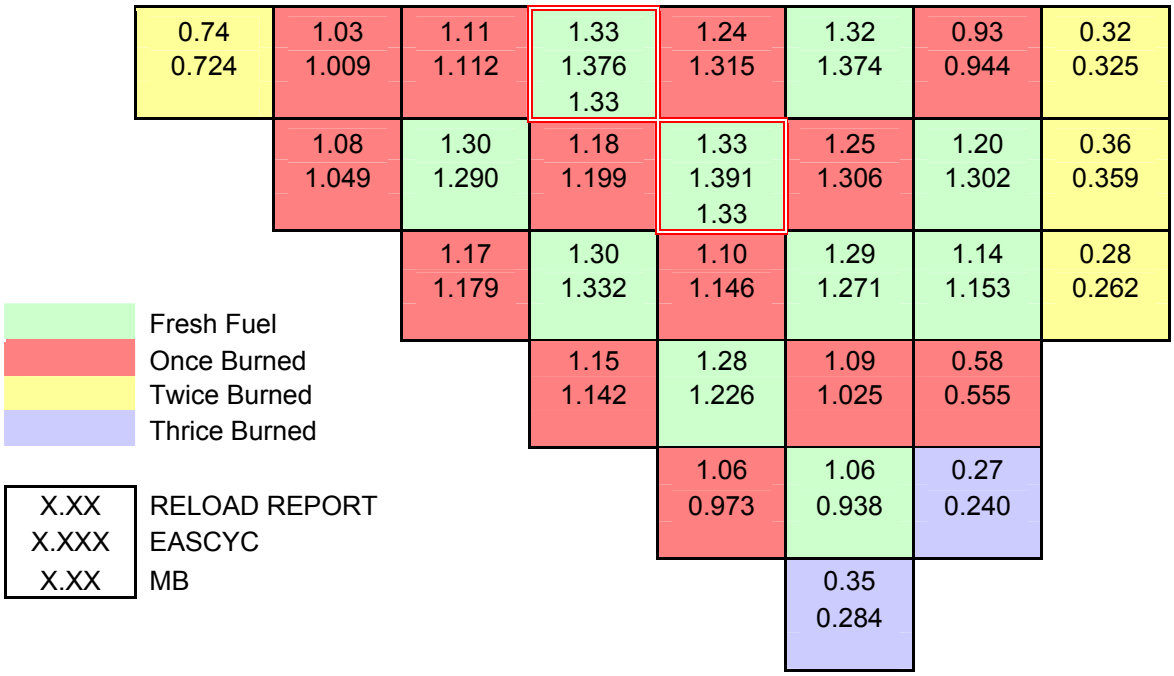


Figure 5-12. Power distribution for 1/8th core with B_4C/Al_2O_3 BPRAs at BOC.

The results of the three cases for the peak-to-average power in the core at BOC for B_4C/Al_2O_3 BPRAs are shown in Figure 5-12. Although the results from MONTEBURNS appear to have no deviation from the reload report model for Assemblies 4 and 12, it should not be assumed that the MONTEBURNS model is precise, especially because no chemical shim was used in this power distribution model. The important function of the power map is to ensure that the codes are providing a reasonable distribution of power throughout the core, allowing a relative shift in power peaking to be observed between the different BPRA materials. For this study, the absolute accuracy of the core model is less important than noting the relative differences

between BPRA materials, so that potential candidates can be pursued or eliminated without extensive testing.

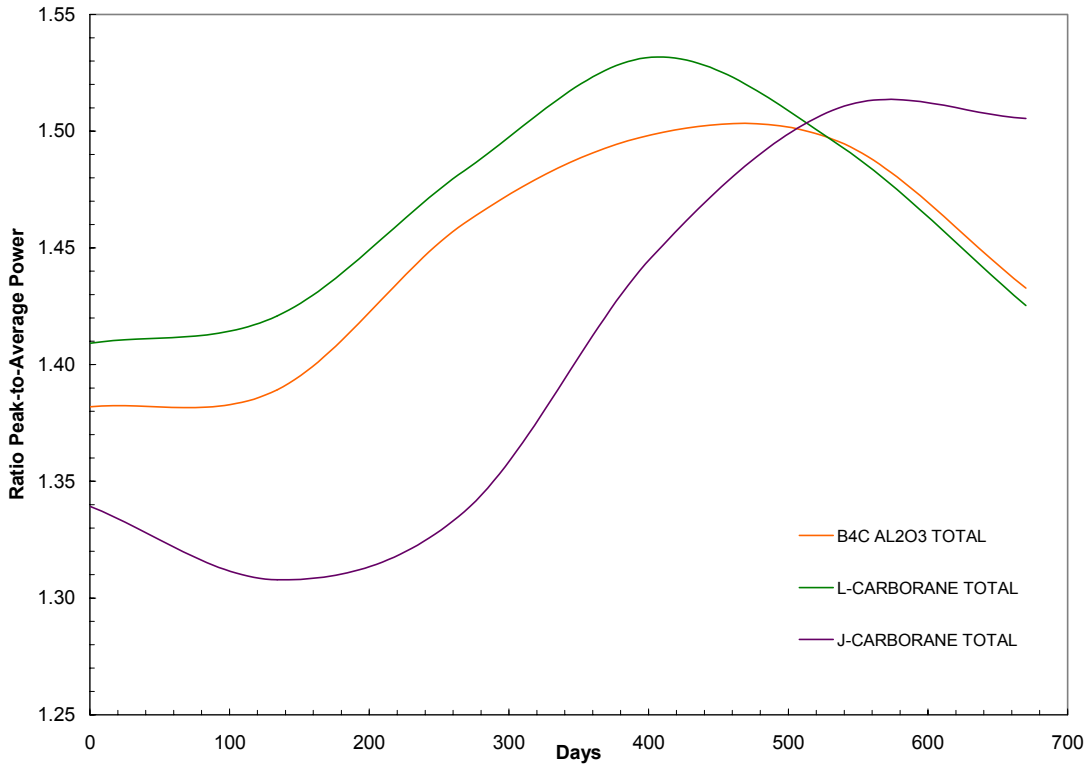


Figure 5-13. Power peaking vs. depletion time (average of assemblies by type). Multiple MONTEBURNS models for 1/8th core without the presence of chemical shim.

Once the models for power peaking were established and the suspect high power assemblies were identified, the detailed comparison of the power peaking throughout the cycle could be performed for the three BPRA materials. The first modeling case used a continuous burnup calculation in MONTEBURNS without chemical shim. The peak-to-average power was calculated by taking a weighted average of the batches for the various types of burnable absorbers (Figure 5-13). This model is a rough estimate because it assigns an average for each batch and takes a ratio between the batch averages to the core average. The results show an advantage for the J-Carborane at BOC on out until a

burnup of about 500 days. Thereafter, the J-Carborane yields a higher power peaking factor than the B_4C/Al_2O_3 BPRA.

The more detailed models of the individual results for Assemblies 4 and 12 are shown in Figures 5-14 and 5-15. These results are more precise. From BOC out until about 420 days, the power peaking advantage goes to the J-Carborane (Figure 5-14). Thereafter, the J-Carborane has the highest power peaking factor. The J-Carborane has the lowest power peaking factor throughout the cycle for Assembly 12 (Figure 5-15). These results, however, do not include the effects of chemical shim within the core and the overall power peaking response may be different in the presence of borated water.

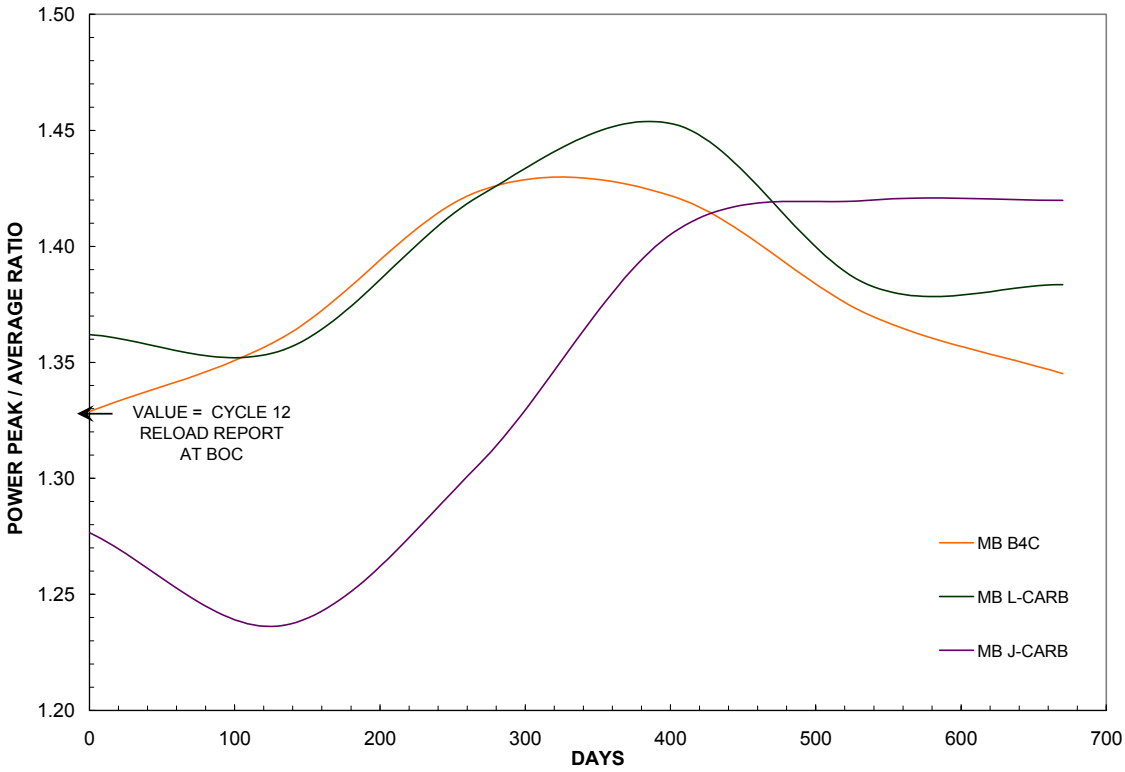


Figure 5-14. Power peaking for various BPRAs in Assembly 4 with no chemical shim. Multiple 1/8th core MONTEBURNS results indicate that the J-Carborane has a lower peak-to-average power ratio up to approximately 420 days. The MONTEBURNS result for the boron carbide matched the result from the reload report.

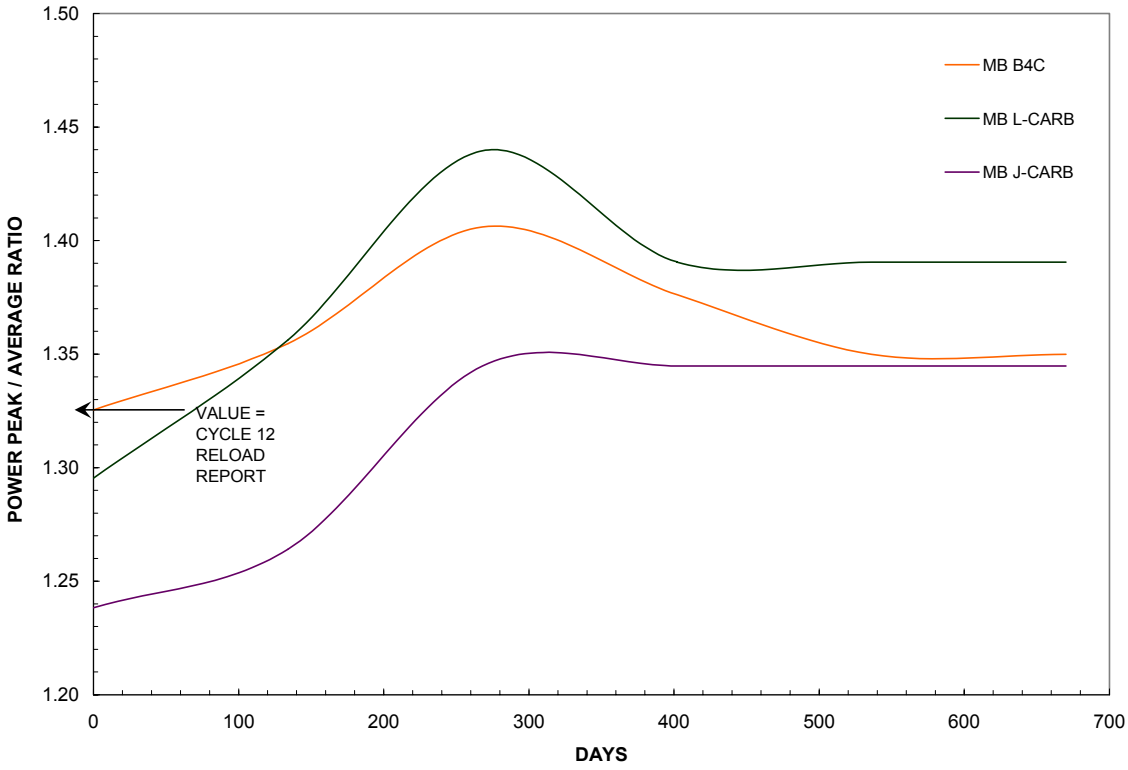


Figure 5-15. Power peaking for various BPRAs in Assembly 12 with no chemical shim.

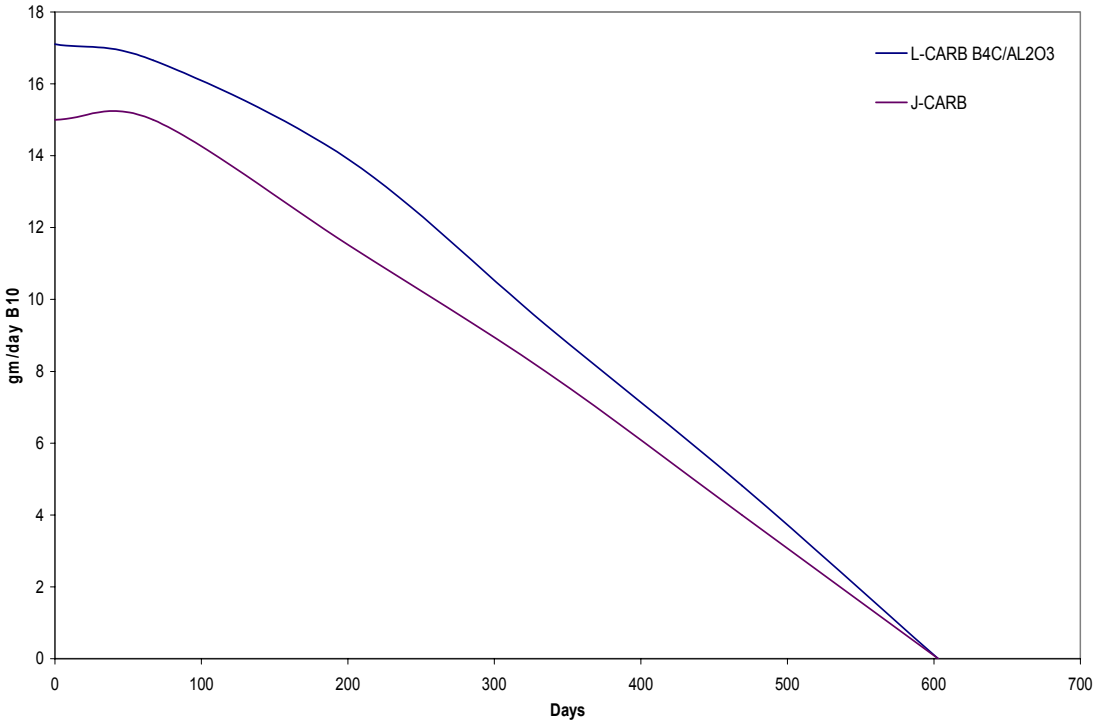


Figure 5-16. Chemical shim vs. time for core models.

The final core peaking evaluation in this study continued the refinement process by evaluating the power peaking results for the core with chemical shim. For this case the chemical shim model as described in Chapter 3 was applied to keep the reactor at k = 1 throughout the life of the cycle. The chemical shim was added using the feed file described in Chapter 3. The boron carbide and L-carborane had nearly identical reactivity vs. time responses and used the same chemical shim let-down. The J-Carborane shim was adjusted for the differences in reactivity over time (Figure 5-16). The model used an initial loading of boron in the water so the let-down is not linear as it approaches zero time.

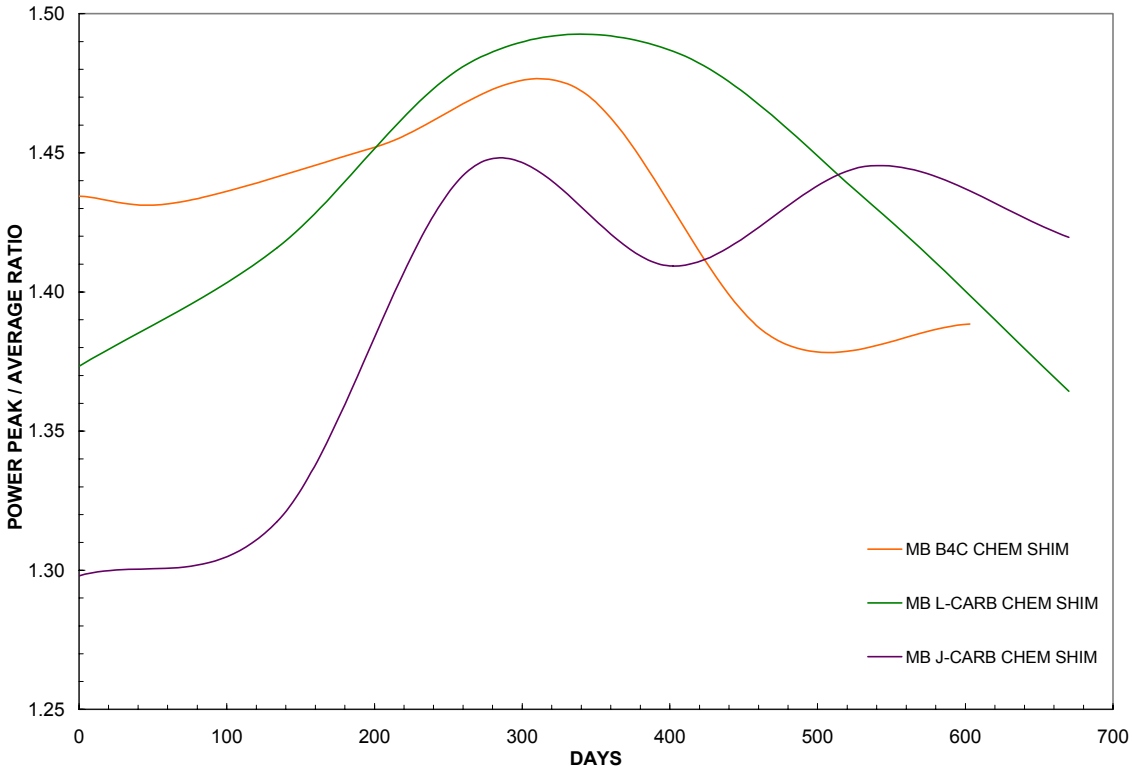


Figure 5-17. Power peaking for various BPRAs in Assembly 4 with chemical shim.

The results for this model are shown in Figures 5-17 and 5-18. Again, the J-Carborane had superior power peaking results for Assemblies 4 and 12 out to about 420 days and a higher power peaking than the B_4C/Al_2O_3 BPRAs thereafter. The J-Carborane

advantage in the power peaking factor extends out to about 480 days for assembly 12 and thereafter is higher than the B_4C/Al_2O_3 BPRAs (Figure 5-18). It is evident that the overall power peaking results vary from the case with no chemical shim in the water. The most significant difference is an increase in the power peaking factor for the J-Carborane case in Assembly 12 above the boron carbide BPRA case in the chemical shim model after about 420 days that is not seen in the model without chemical shim. Additionally, there is a sinusoidal decrease and subsequent increase in the power peaking factors for the J-Carborane case at about 400 days in the chemical shim model.

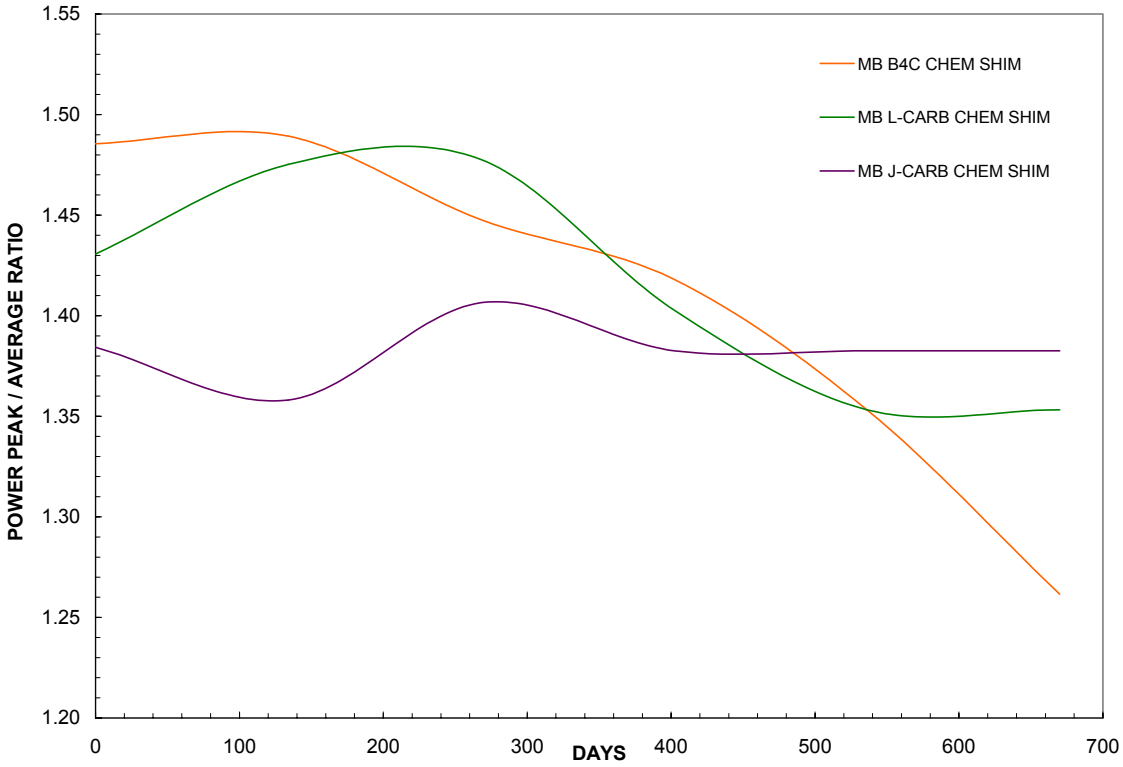


Figure 5-18. Power peaking for various BPRAs in Assembly 12 with chemical shim.

Other Polymer Materials

It should be noted that the relative comparison for the different materials within the model parameters should allow for easy investigation of other polymer materials to eventually develop the advanced burnable poison absorber desired. Because of the

benchmarks set in Chapter 2 and 4 for hydrogen composition and thermal and radioactive stability requirements, numerous materials can either be eliminated or sent forward for simulation calculations.

One such proposal is a combination of high density polyethylene and boron carbide (B_4C/CH_2). The initial single assembly results with equal amounts of boron for this material are shown in Figure 5-19. From these results it can be predicted that the overall 1/8th core distribution would be slightly better than the L-Carborane model. From the carborane comparisons, it would be likely that the 1/8th core distribution would benefit from a higher boron concentration to more closely match that of J-Carborane.

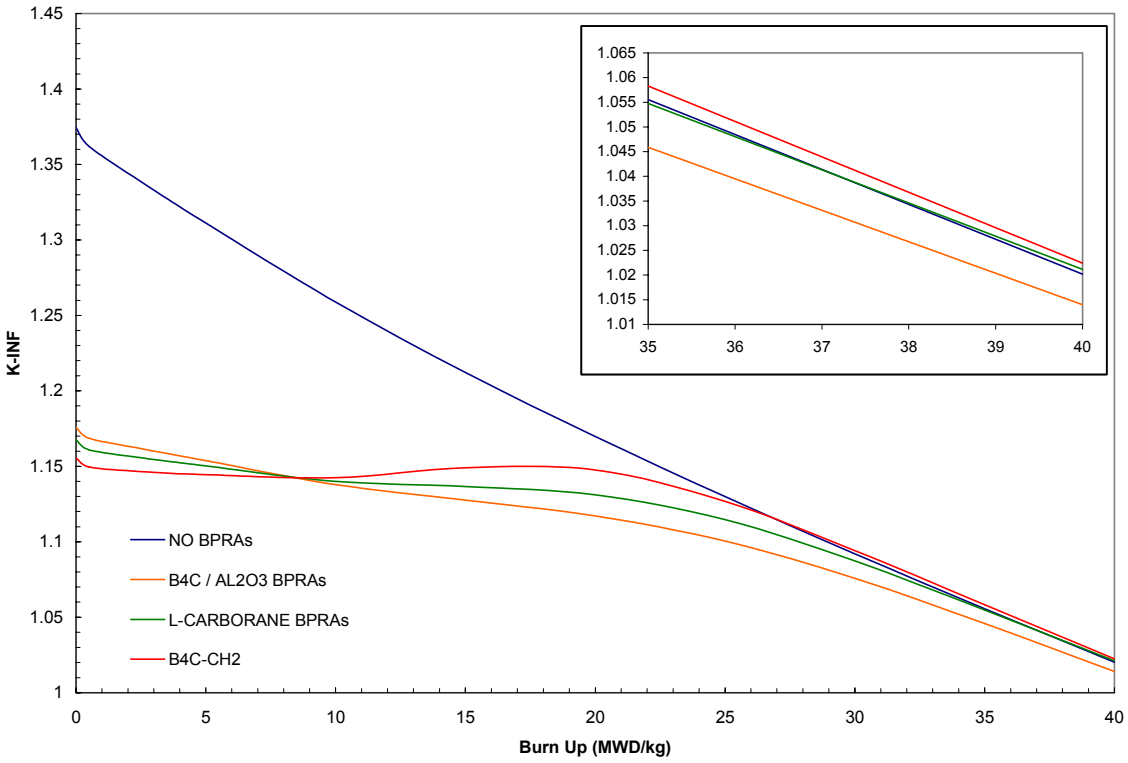


Figure 5-19. Single assembly comparison of various absorbers to include polyethylene. The polyethylene is doped with boron carbide to act as an absorber.

Because of the benchmarking, the process of material selection and combinations thereof can become systematic. The material is first selected based on its nuclear

properties and modeled within the simulations and then physically tested to determine if it can withstand the radiation and thermal environment and then the core model is modified and the core is analyzed again.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

Conclusions

The purpose of this research was to examine the use of high hydrogen content boron carrying polymers for use as burnable poison rods in pressurized water reactors. The premise of the use of a hydrogen based polymer is that it would eliminate the water displacement penalty at end of cycle created by the current boron carbide alumina BPRAs and extend the lifetime of the reactor core. One characteristic polymer, Polyacetyleniccarboranosiloxane (PACS), was described as thermally stable up to 1000 °C and able to be tailored to optimize the boron and hydrogen content within the polymer. The effects of variations in the PACS structure on core performance were determined using various two-dimensional and three-dimensional transport nodal and Monte Carlo codes and compared to results obtained when using boron carbide alumina burnable poison rods and wet annular burnable poison rods. Performance criteria for each material was based on its ability to control reactivity at beginning of cycle and the combination of its burnup, its reduction in moderator displacement at end of cycle, and its power peaking response throughout the cycle.

The study made specific calculations for the minimum required hydrogen content within the PACS polymer structure and developed an empirical equation that related the moderator effectiveness of a substance to its weight percent hydrogen. This formula works well for the PACS structure and appears to work for other hydrogen based materials. The benchmark from the PACS study places a minimum requirement of 4.5

weight percent of hydrogen within the polymer in order to get a moderator displacement penalty that is less than the WABA and a higher reactivity at EOC. This 4.5 weight percent must be present at end of cycle to be effective. This means that if the polymer losses a significant amount of hydrogen due to radiation cross-linking during the fuel cycle it will have to start the cycle with a significantly higher amount of hydrogen present.

In addition to the hydrogen content calculations, benchmarks were set for the maximum centerline temperature and the maximum coefficient of thermal expansion for the polymer. The centerline temperature was shown to depend almost entirely on the thermal conductivity of the material. Using an estimate of volumetric heat rate from an MCNP simulation and a thermal conductivity from a similar polymer, the maximum centerline temperature was calculated to be between 571 - 633 °C. Using 2/3 of 571 °C and the known thermal expansion for the cladding, the maximum coefficient for thermal expansion was calculated to be 5.544 x 10-5. Because most polymers have thermal expansion coefficients higher than this and that the actual coefficient will depend on the cross-linking of the polymer, it was concluded that expansion of the PACS polymer should be measured to determine if it is a concern for this research. The centerline temperature may prove to be a problem or material performance because the ceiling temperatures for many polymers are around 500 °C and the polymer must remain intact throughout the core cycle.

The radiation dose delivered to the BPRA throughout the life of the core was also calculated from the estimate of the volumetric heat rate. The value of 90.39 Trad is a tremendous amount of radiation and it is not known how a polymer will react over time

to this amount of dose. The primary concern with respect to radiation is the cross-linking and loss of hydrogen both from a loss of moderation perspective but also for the hydrating of the zircalloy cladding which could lead to failures within the BPRA elements.

Notwithstanding the materials concerns, the simulations of the single assembly and multiple assembly models of various polymeric BPRAs showed promise that the core cycles could be extended. The single assembly calculations suggested that a 1 – 1.5% increase in reactivity over time could be obtained with the use of a polymeric BPRA with boron equivalent to the boron carbide alumina BPRA. The multi-assembly models continued to show an advantage to the polymeric BPRA but the amount of the advantage was reduced due to the lower reactivity effects of the other depleted fuel elements.

The 1/8th core models used a slightly different approach by taking an actual PWR reload report and simulating the exchange of a standard BPRA for a polymeric BPRA with no other adjustments to the core. The results for the polymer with an equivalent boron content as the B_4C/Al_2O_3 BPRA were uninspiring. The differences between the two over the life of the core were negligible at best. However, because the polymer depletes boron faster than boron carbide and because the boron content can be tailored in the polymer, another simulation was run with a polymer with more boron. This simulation not only extended the life of the core by about one percent but also resulted in a lower reactivity at BOC, which leads to the proposal of a higher enrichment at BOC for an even longer cycle length.

The primary concern with the higher boron based polymer was its effect on power peaking within the core. The critical assemblies in the core model were determined using

a diffusion theory code and the reload report for the reactor. The critical assemblies were then analyzed in detail to determine their peak-to-average power distributions with the various burnable absorber BPRAs. This is important for reactor control and safety and adds validity to the premise that a polymeric burnable poison rod is a viable option for a PWR.

The final set of simulations used a feed of boron-10 to the water to model the presence of chemical shim. The addition of the chemical shim caused the power peaking models to vary from the models without chemical shim. However, as this study is focused on the relative differences between the materials, this rise was unilateral and did not change the conclusion that the advanced BPRA did not negatively effect power peaking.

The advanced polymeric burnable absorber concept is a method of increasing core burnups without having to increase enrichments beyond the five weight percent enrichment maximum currently allowed. Increased burnups will save money and reduce waste production because of longer fuel cycles. The increase in burnup will have to be analyzed as an effect on the reactor system as a whole. In particular, longer cycle burnups will lead to longer overall burnups for assemblies in a core. The extra days per cycle could result in extra weeks on a single assembly. The material sustainability for longer burnups is an important part of this research. The keys to the development of a viable polymer will be its ability to transfer heat, withstand radiation, and not create structural damage to the cladding. In general, the materials of the reactor constitute the biggest challenge for higher burnups for all currently designed light water reactors. This research has established a basis from which any material could be quickly checked for the

proper moderation, absorption, and thermal mechanical properties. If the material passes the initial scrutiny, this research creates a framework by which any material can be analyzed in detail to determine if it will be the next generation of burnable poison assembly material.

Recommendations for Future Work

The future of this research lies in the testing and analysis of many more materials. The example of polyethylene given in the end of Chapter 5 is just one of hundreds of possible candidates that can be examined. Once a selection of a few polymers is decided, then the measured values of density, material composition, thermal conductivity, thermal and radiation stability and ceiling temperature should be used to determine if the material can be expected to survive the environment of the reactor. These values will have to be introduced into the model to ensure that the results will not significantly change under realistic conditions. In addition to material design, alternative mechanical designs may have to be employed. For instance, other methods of heat transfer may have to be investigated (such as lateral plates or pipes within the polymer) in order to ensure that the polymer does not surpass its ceiling temperature. These methods of heat transfer will increase manufacturing costs and may ultimately make the design unfeasible.

The radiation environment within the reactor poses its own problems with the hydrogen generation process. All of the research in this study assumes no loss of hydrogen within the polymer during the cycle. A detailed prediction of hydrogen loss for any polymer used in a reactor will have to be calculated and backed by measurement. The loss of hydrogen will cause adjustments to be made to the reactor models and most likely will eliminate many polymers as unsuitable alternatives. There may also be coupled effects of a change in thermal conductivity or thermal expansion coefficient

associated with additional cross-linking. These changes in material properties may be significant in the final determination of an advanced polymeric material.

Once a good candidate for a polymeric burnable poison is determined, the core should be modeled in a three-dimensional nodal code such as SIMULATE. This modeling would confirm the MONTEBURNS predictions of the cycle lifetime and also provide detailed power peaking results that would be more reliable. The SIMULATE model could give a time dependent power peaking map for all of the assemblies and ensure that the safety limits were not exceeded. Finally, the SIMULATE model could be optimized to use only advanced polymeric BPRAs and eliminate the Gd_2O_3/UO_2 fuel elements and compare the results with various combinations of 8, 12, and 16 BPRA assemblies. Ideally, an advanced polymeric burnable poison rod could eliminate the need for the Gd_2O_3/UO_2 fuel while still providing enough negative reactivity at BOC and no water displacement penalty at EOC.

After successful modeling within a core analysis code, such as SIMULATE, the advanced burnable poison material should be tested within a reactor that will produce power and heat similar to a commercial PWR. The material will have to be tested to ensure that the code predictions for burnup and absorption are correct. Additionally, a final measurement of the hydrogen displaced during the irradiation period will have to be made in order to accurately predict the moderation effectiveness of the material at EOC.

The final analysis for the advanced burnable poison material will involve cost. The PACS carborane material could be cost prohibitive to produce because of its processing steps and number of constituent elements. Any polymeric material that would increase the core burnups would have to cost less to produce than the money saved by increasing

the cycle length. It is not clear whether market demands will lower production costs for complex materials such as PACS. The best alternative material may be a simple readily produced polymer that has high hydrogen content and can be easily adapted to carry boron or some other burnable absorbing material.

APPENDIX A
CALCULATIONS OF MODERATION EFFECTIVENESS OF PACS

The formula for PACS is $(B_{10}H_{10}C_2)_a((CH_3)_2SiO)_b(C_2)_c$. The following Table shows 15 different combinations of the subscripts a, b, and c in the formula and the calculation of ξ, $\sum_{s(epithermal)}$ and the product. Twelve additional molecules were added that had lower hydrogen values than the molecular structure would normally allow.

Table A-1. Calculations of moderator effectiveness for PACS molecule.

Table A-1. Calculations of moderator effectiveness for PACS molecule.

MOLECULE I			Atoms per molecule				
a	b	c	C	Si	O	B	H
1	12	9	44	12	5	10	82
1	10	9	40	10	4	10	70
1	8	9	36	8	3	10	58
1	6	9	32	6	2	10	46
1	4	9	28	4	1	10	34
			28	4	1	10	30
			28	4	1	10	26
			28	4	1	10	20
MOLECULE II			28	4	1	10	10
a	b	c					
1	12	8	42	12	5	10	82
1	10	8	38	10	4	10	70
1	8	8	34	8	3	10	58
1	6	8	30	6	2	10	46
1	4	8	26	4	1	10	34
			26	4	1	10	30
			26	4	1	10	26
			26	4	1	10	20
MOLECULE III			26	4	1	10	10
a	b	c					
1	12	7	40	12	5	10	82
1	10	7	36	10	4	10	70
1	8	7	32	8	3	10	58
1	6	7	28	6	2	10	46
1	4	7	24	4	1	10	34
			24	4	1	10	30
			24	4	1	10	26
			24	4	1	10	20
			24	4	1	10	10

Table A-1. Continued

Atomic mass in molecule					Weight %				
C	Si	O	B	H	C	Si	O	B	H
528.44	337.08	79.95	108.1	82.82	46.50%	29.66%	7.04%	9.51%	7.29%
480.4	280.9	63.96	108.1	70.7	47.85%	27.98%	6.37%	10.77%	7.04%
432.36	224.72	47.97	108.1	58.58	49.60%	25.78%	5.50%	12.40%	6.72%
384.32	168.54	31.98	108.1	46.46	51.98%	22.79%	4.33%	14.62%	6.28%
336.28	112.36	15.99	108.1	34.34	55.39%	18.51%	2.63%	17.81%	5.66%
336.28	112.36	15.99	108.1	30.3	55.77%	18.63%	2.65%	17.93%	5.02%
336.28	112.36	15.99	108.1	26.26	56.14%	18.76%	2.67%	18.05%	4.38%
336.28	112.36	15.99	108.1	20.2	56.71%	18.95%	2.70%	18.23%	3.41%
336.28	112.36	15.99	108.1	10.1	57.70%	19.28%	2.74%	18.55%	1.73%
504.42	337.08	79.95	108.1	82.82	45.35%	30.30%	7.19%	9.72%	7.45%
456.38	280.9	63.96	108.1	70.7	46.57%	28.66%	6.53%	11.03%	7.21%
408.34	224.72	47.97	108.1	58.58	48.17%	26.51%	5.66%	12.75%	6.91%
360.3	168.54	31.98	108.1	46.46	50.36%	23.56%	4.47%	15.11%	6.49%
312.26	112.36	15.99	108.1	34.34	53.56%	19.27%	2.74%	18.54%	5.89%
312.26	112.36	15.99	108.1	30.3	53.93%	19.41%	2.76%	18.67%	5.23%
312.26	112.36	15.99	108.1	26.26	54.31%	19.54%	2.78%	18.80%	4.57%
312.26	112.36	15.99	108.1	20.2	54.89%	19.75%	2.81%	19.00%	3.55%
312.26	112.36	15.99	108.1	10.1	55.88%	20.11%	2.86%	19.34%	1.81%
480.4	337.08	79.95	108.1	82.82	44.14%	30.97%	7.35%	9.93%	7.61%
432.36	280.9	63.96	108.1	70.7	45.22%	29.38%	6.69%	11.31%	7.40%
384.32	224.72	47.97	108.1	58.58	46.66%	27.28%	5.82%	13.12%	7.11%
336.28	168.54	31.98	108.1	46.46	48.64%	24.38%	4.63%	15.64%	6.72%
288.24	112.36	15.99	108.1	34.34	51.56%	20.10%	2.86%	19.34%	6.14%
288.24	112.36	15.99	108.1	30.3	51.94%	20.25%	2.88%	19.48%	5.46%
288.24	112.36	15.99	108.1	26.26	52.32%	20.39%	2.90%	19.62%	4.77%
288.24	112.36	15.99	108.1	20.2	52.90%	20.62%	2.93%	19.84%	3.71%
288.24	112.36	15.99	108.1	10.1	53.90%	21.01%	2.99%	20.21%	1.89%

Table A-1. Continued

Average epithermal σ_s					Average thermal σ_a			
C	Si	O	B	H	C	Si	O	H
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01
4.78E+00	2.08E+00	3.92E+00	4.47E+00	2.07E+01	3.40E-03	1.60E-01	9.43E-06	3.32E-01

Table A-1. Continued

N Density (atoms/cc)					$\sum_s$				
C	Si	O	B	H	C	Si	O	B	H
2.10E+22	5.72E+21	2.38E+21	4.77E+21	3.91E+22	1.00E-01	1.19E-02	9.35E-03	2.13E-02	8.10E-01
2.16E+22	5.40E+21	2.16E+21	5.40E+21	3.78E+22	1.03E-01	1.12E-02	8.46E-03	2.41E-02	7.82E-01
2.24E+22	4.97E+21	1.87E+21	6.22E+21	3.61E+22	1.07E-01	1.04E-02	7.31E-03	2.78E-02	7.47E-01
2.35E+22	4.40E+21	1.47E+21	7.33E+21	3.37E+22	1.12E-01	9.15E-03	5.75E-03	3.28E-02	6.98E-01
2.50E+22	3.57E+21	8.93E+20	8.93E+21	3.04E+22	1.19E-01	7.43E-03	3.50E-03	3.99E-02	6.29E-01
2.52E+22	3.60E+21	8.99E+20	8.99E+21	2.70E+22	1.20E-01	7.48E-03	3.52E-03	4.02E-02	5.58E-01
2.53E+22	3.62E+21	9.05E+20	9.05E+21	2.35E+22	1.21E-01	7.53E-03	3.55E-03	4.05E-02	4.87E-01
2.56E+22	3.66E+21	9.14E+20	9.14E+21	1.83E+22	1.22E-01	7.61E-03	3.58E-03	4.09E-02	3.79E-01
2.60E+22	3.72E+21	9.30E+20	9.30E+21	9.30E+21	1.24E-01	7.74E-03	3.65E-03	4.16E-02	1.93E-01
2.05E+22	5.85E+21	2.44E+21	4.87E+21	4.00E+22	9.78E-02	1.22E-02	9.55E-03	2.18E-02	8.27E-01
2.10E+22	5.53E+21	2.21E+21	5.53E+21	3.87E+22	1.00E-01	1.15E-02	8.67E-03	2.47E-02	8.02E-01
2.17E+22	5.11E+21	1.92E+21	6.39E+21	3.71E+22	1.04E-01	1.06E-02	7.52E-03	2.86E-02	7.68E-01
2.27E+22	4.55E+21	1.52E+21	7.58E+21	3.49E+22	1.09E-01	9.46E-03	5.94E-03	3.39E-02	7.22E-01
2.42E+22	3.72E+21	9.30E+20	9.30E+21	3.16E+22	1.15E-01	7.74E-03	3.64E-03	4.16E-02	6.55E-01
2.43E+22	3.74E+21	9.36E+20	9.36E+21	2.81E+22	1.16E-01	7.79E-03	3.67E-03	4.19E-02	5.82E-01
2.45E+22	3.77E+21	9.43E+20	9.43E+21	2.45E+22	1.17E-01	7.85E-03	3.70E-03	4.22E-02	5.08E-01
2.48E+22	3.81E+21	9.53E+20	9.53E+21	1.91E+22	1.18E-01	7.93E-03	3.73E-03	4.26E-02	3.95E-01
2.52E+22	3.88E+21	9.70E+20	9.70E+21	9.70E+21	1.20E-01	8.08E-03	3.80E-03	4.34E-02	2.01E-01
1.99E+22	5.98E+21	2.49E+21	4.98E+21	4.08E+22	9.52E-02	1.24E-02	9.76E-03	2.23E-02	8.46E-01
2.04E+22	5.67E+21	2.27E+21	5.67E+21	3.97E+22	9.75E-02	1.18E-02	8.89E-03	2.54E-02	8.22E-01
2.11E+22	5.26E+21	1.97E+21	6.58E+21	3.82E+22	1.01E-01	1.10E-02	7.74E-03	2.94E-02	7.90E-01
2.20E+22	4.70E+21	1.57E+21	7.84E+21	3.61E+22	1.05E-01	9.79E-03	6.15E-03	3.51E-02	7.47E-01
2.33E+22	3.88E+21	9.70E+20	9.70E+21	3.30E+22	1.11E-01	8.07E-03	3.80E-03	4.34E-02	6.83E-01
2.34E+22	3.91E+21	9.77E+20	9.77E+21	2.93E+22	1.12E-01	8.13E-03	3.83E-03	4.37E-02	6.07E-01
2.36E+22	3.93E+21	9.84E+20	9.84E+21	2.56E+22	1.13E-01	8.19E-03	3.86E-03	4.40E-02	5.30E-01
2.39E+22	3.98E+21	9.95E+20	9.95E+21	1.99E+22	1.14E-01	8.28E-03	3.90E-03	4.45E-02	4.12E-01
2.43E+22	4.05E+21	1.01E+21	1.01E+22	1.01E+22	1.16E-01	8.44E-03	3.97E-03	4.53E-02	2.10E-01

Table A-1. Continued

$\sum_a$				Total	ξ				
C	Si	O	H	$\sum_a$	C	Si	O	B	H
7.13E-05	9.16E-04	2.25E-08	1.30E-02	1.40E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
7.34E-05	8.64E-04	2.04E-08	1.25E-02	1.35E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
7.61E-05	7.96E-04	1.76E-08	1.20E-02	1.28E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
7.98E-05	7.04E-04	1.38E-08	1.12E-02	1.20E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
8.50E-05	5.71E-04	8.42E-09	1.01E-02	1.07E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
8.56E-05	5.75E-04	8.48E-09	8.95E-03	9.61E-03	0.15776899	0.136284194	0.119946651	0.351255827	1
8.61E-05	5.79E-04	8.53E-09	7.81E-03	8.48E-03	0.15776899	0.136284194	0.119946651	0.351255827	1
8.70E-05	5.85E-04	8.62E-09	6.07E-03	6.74E-03	0.15776899	0.136284194	0.119946651	0.351255827	1
8.85E-05	5.95E-04	8.77E-09	3.09E-03	3.77E-03	0.15776899	0.136284194	0.119946651	0.351255827	1
6.96E-05	9.35E-04	2.30E-08	1.33E-02	1.43E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
7.14E-05	8.85E-04	2.09E-08	1.29E-02	1.38E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
7.39E-05	8.18E-04	1.81E-08	1.23E-02	1.32E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
7.73E-05	7.27E-04	1.43E-08	1.16E-02	1.24E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
8.22E-05	5.95E-04	8.77E-09	1.05E-02	1.12E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
8.27E-05	5.99E-04	8.83E-09	9.32E-03	1.00E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
8.33E-05	6.03E-04	8.89E-09	8.14E-03	8.82E-03	0.15776899	0.136284194	0.119946651	0.351255827	1
8.42E-05	6.10E-04	8.98E-09	6.33E-03	7.02E-03	0.15776899	0.136284194	0.119946651	0.351255827	1
8.57E-05	6.21E-04	9.15E-09	3.22E-03	3.93E-03	0.15776899	0.136284194	0.119946651	0.351255827	1
6.77E-05	9.56E-04	2.35E-08	1.36E-02	1.46E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
6.94E-05	9.07E-04	2.14E-08	1.32E-02	1.42E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
7.16E-05	8.42E-04	1.86E-08	1.27E-02	1.36E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
7.46E-05	7.53E-04	1.48E-08	1.20E-02	1.28E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
7.91E-05	6.20E-04	9.14E-09	1.09E-02	1.16E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
7.97E-05	6.25E-04	9.21E-09	9.73E-03	1.04E-02	0.15776899	0.136284194	0.119946651	0.351255827	1
8.03E-05	6.30E-04	9.28E-09	8.49E-03	9.20E-03	0.15776899	0.136284194	0.119946651	0.351255827	1
8.12E-05	6.37E-04	9.38E-09	6.60E-03	7.32E-03	0.15776899	0.136284194	0.119946651	0.351255827	1
8.27E-05	6.49E-04	9.56E-09	3.36E-03	4.10E-03	0.15776899	0.136284194	0.119946651	0.351255827	1

Table A-1. Continued

Average ξ	$\xi \sum_s$	$\xi \sum_s / \sum_a$
8.77E-01	8.36E-01	5.98E+01
8.71E-01	8.10E-01	6.01E+01
8.63E-01	7.76E-01	6.04E+01
8.50E-01	7.29E-01	6.09E+01
8.30E-01	6.63E-01	6.18E+01
8.12E-01	5.93E-01	6.17E+01
7.91E-01	5.22E-01	6.16E+01
7.48E-01	4.14E-01	6.14E+01
6.17E-01	2.28E-01	6.05E+01
8.81E-01	8.53E-01	5.98E+01
8.75E-01	8.29E-01	6.00E+01
8.67E-01	7.97E-01	6.03E+01
8.56E-01	7.53E-01	6.08E+01
8.37E-01	6.89E-01	6.17E+01
8.20E-01	6.16E-01	6.16E+01
7.99E-01	5.42E-01	6.15E+01
7.58E-01	4.30E-01	6.12E+01
6.28E-01	2.37E-01	6.03E+01
8.84E-01	8.71E-01	5.98E+01
8.79E-01	8.49E-01	6.00E+01
8.72E-01	8.19E-01	6.03E+01
8.62E-01	7.78E-01	6.08E+01
8.44E-01	7.17E-01	6.16E+01
8.28E-01	6.41E-01	6.15E+01
8.08E-01	5.64E-01	6.13E+01
7.67E-01	4.47E-01	6.11E+01
6.40E-01	2.46E-01	6.00E+01

APPENDIX B
SINGLE ASSEMBLY CASMO AND MONTEBURNS FILES

This appendix contains all of the input and output files for the single assembly depletion calculations for CASMO and MCNP/MONTEBURNS. The output files for CASMO have been abbreviated to the final state point and final k_{eff} vs. burnup summary in order to save space.

The CAMSO Input File B_4C/Al_2O_3 BPRAs

```
TIT  TFU=881  TMO=600  BOR=0  *4.66% B4 W 15 X 15
*Crystal River-3 15x15 Assembly with WATER in guide tubes
FUE  1 10.4/4.66  *FUEL COMP. #, DENSITY/ENRICHMENT
PDE  32  *POWER DENSITY (W/Gu)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  3 .632 .6731/ 'COO' 'CAN'  *Center water hole
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI
3
1 1
1 1 3
1 1 1 1
1 1 1 1 3
1 1 3 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
DEP  0.5 2.5 5 10 15 20 25 30 35 40 *Depletion steps
STA
END
```

The CASMO Output File Water in Guide Tubes

```
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/10/17   15:20:56   JOB=SUN        STATE POINT NO = 11 PAGE =   50
 * 4.66% B4 W 15 X 15
 *  BURNUP =    40.001 V= 0.0  TF= 881.0  TM= 600.0  BOR=   0.0
0AVERAGED NUMBER DENSITIES OF BURNABLE NUCLIDES AT  40.001 MWD/KGU (PREDICTOR VALUES)
   92235-  3.30459E+20  92236-  1.29998E+20  93237-  1.33643E+19  94238-  4.65240E+18  92238-  2.10928E+22  94239-  1.38552E+20
   94240-  5.28830E+19  94241-  3.24917E+19  94242-  9.72446E+18  95241-  1.16014E+18  95242-  1.79362E+16  95243-  2.02872E+18
   96242-  4.04591E+17  96244-  5.44768E+17  92234-  4.99822E+18  92239-  1.12573E+16  93239-  1.60002E+18  36083-  3.31589E+18
   45103-  2.41995E+19  45105-  5.01086E+16  47109-  3.03150E+18  54131-  2.03627E+19  55133-  5.37796E+19  55134-  5.93952E+18
   54135-  9.42077E+15  55135-  2.37123E+19  60143-  3.94993E+19  60145-  2.98650E+19  61147-  7.16701E+18  62147-  3.73346E+18
   61148-  3.54250E+16  61248-  6.88233E+16  62149-  1.19266E+17  62150-  1.25681E+19  62151-  6.53882E+17  62152-  4.40811E+18
   63153-  4.80631E+18  63154-  1.36880E+18  63155-  7.80258E+17    401-  1.25402E+21    402-  2.69848E+20  53135-  1.93342E+16
   61149-  4.49538E+16  64155-  7.26774E+15
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/10/17   15:20:56   JOB=SUN        STATE POINT NO = 12 PAGE =   51
 * 4.66% B4 W 15 X 15
 *  BURNUP =    40.001 V= 0.0  TF= 881.0  TM= 600.0  BOR=   0.0
 END                                                                  INPUT CARD
0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  40.0010 TYPE OF FILE = 470 STATEP =  12
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/10/17   15:20:56   JOB=SUN             PAGE =   52
0       ** C A S M O -3   SUMMARY  **
0         4.66% B4 W 15 X 15
0       HVOI=  0.0 HTFU=  881.0 HTMO=  600.0 HBOR=    0.0
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                           MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

         1  0.0  881.0  600.0    0.0        0.000 1.36768 1.36381  66.88   1.061   4.660   0.000   0.000
         2                                  0.500 1.35525 1.35186  66.71   1.061   4.600   0.019   0.019
         3                                  2.500 1.33121 1.32817  66.38   1.060   4.368   0.106   0.110
         4                                  5.000 1.30315 1.30073  66.03   1.059   4.094   0.200   0.214
         5                                 10.000 1.25016 1.24876  65.44   1.055   3.590   0.352   0.395
         6                                 15.000 1.20327 1.20262  64.98   1.051   3.134   0.470   0.549
         7                                 20.000 1.16089 1.16076  64.62   1.046   2.721   0.562   0.682
         8                                 25.000 1.12148 1.12171  64.31   1.041   2.347   0.634   0.797
         9                                 30.000 1.08416 1.08463  64.04   1.036   2.010   0.688   0.895
        10                                 35.000 1.04846 1.04908  63.81   1.031   1.706   0.728   0.981
        11                                 40.000 1.01414 1.01483  63.59   1.026   1.434   0.756   1.055
0NORMAL TERMINATION
0RUN STARTED     (DATE,TIME):  **/10/17     15:20:56
0RUN COMPLETED   (DATE,TIME):  **/10/17     15:21:04
Thu Oct 17 15:21:04 EDT 2002
Using executable --> /home/CMSCODES/C3/vUNIV/Solaris_2/c3.exe
-rwxr-xr-x   1 122      1000     2891864 Sep 17  2001 /home/CMSCODES/C3/vUNIV/Solaris_2/c3.exe
```

The CASMO Input File B_4C/Al_2O_3 BPRAs in Guide Tubes

```
TIT  TFU=990  TMO=583  BOR=0  *4.66%  W 15 X 15
*Crystal River-3 15x15 Assembly with B4C-AL2O3 in guide
tubes
FUE  1 10.4/4.66  *FUEL COMP. #, DENSITY/ENRICHMENT
PDE  33  *POWER DENSITY (W/Gu)
MI2  3.1/5010=0.55 5011=2.22 6000=0.76 13000=51.04
8000=45.43
*  Mixture 2: B4C, AL2O3 (BP Material)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  2 .4699 .4788 .5461 .632 .6731/ 'MI2' 'AIR' 'CAN'
'COO' 'CAN'/1,3,5
*  BPRA pin homogenized 'AIR+CAN' and 'COO+CAN'
PIN  3 .632 .6731/ 'COO' 'CAN'  *Center water hole
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI
3
1 1
1 1 2
1 1 1 1
1 1 1 1 2
1 1 2 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
DEP  0.5 2.5 5 10 15 20 25 30 35 40 *Depletion steps
STA
END
```

The CASMO Output File B_4C/Al_2O_3 BPRAs in Guide Tubes

```
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/10/17   15:21:12   JOB=SUN        STATE POINT NO = 11 PAGE =   50
 * 4.66%  W 15 X 15
 *  BURNUP =    40.001 V= 0.0  TF= 990.0  TM= 583.0  BOR=   0.0
0AVERAGED NUMBER DENSITIES OF BURNABLE NUCLIDES AT  40.001 MWD/KGU (PREDICTOR VALUES)
   92235-  3.38395E+20  92236-  1.29529E+20  93237-  1.36062E+19  94238-  4.78221E+18  92238-  2.09984E+22  94239-  1.44856E+20
   94240-  5.38837E+19  94241-  3.39434E+19  94242-  9.94680E+18  95241-  1.20943E+18  95242-  1.88044E+16  95243-  2.08752E+18
   96242-  4.18442E+17  96244-  5.63997E+17  92234-  4.94141E+18  92239-  1.15569E+16  93239-  1.64438E+18  36083-  3.30172E+18
   45103-  2.43528E+19  45105-  5.17293E+16  47109-  3.09587E+18  54131-  2.03295E+19  55133-  5.35389E+19  55134-  5.95668E+18
   54135-  9.73151E+15  55135-  2.38914E+19  60143-  3.95859E+19  60145-  2.96775E+19  61147-  7.20507E+18  62147-  3.60429E+18
   61148-  3.60476E+16  61248-  7.00352E+16  62149-  1.23624E+17  62150-  1.26078E+19  62151-  6.67084E+17  62152-  4.41444E+18
   63153-  4.81895E+18  63154-  1.38750E+18  63155-  7.90027E+17    401-  1.25090E+21    402-  2.68875E+20  53135-  1.98645E+16
   61149-  4.61385E+16  64155-  7.34971E+15
0NUMBER DENSITIES AND WEIGHT PER CENTS OF BURNABLE ABSORBERS

 REGION =  18     5010   2.16377E+18 1.16047E-03
 REGION =  26     5010   2.17615E+18 1.16711E-03
 REGION =  33     5010   2.16933E+18 1.16345E-03
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/10/17   15:21:12   JOB=SUN        STATE POINT NO = 12 PAGE =   51
 * 4.66%  W 15 X 15
 *  BURNUP =    40.001 V= 0.0  TF= 990.0  TM= 583.0  BOR=   0.0
 END                                                                 INPUT CARD
0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  40.0010 TYPE OF FILE = 470 STATEP =  12
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/10/17   15:21:12   JOB=SUN             PAGE =   52
0       ** C A S M O -3   SUMMARY  **
0         4.66%  W 15 X 15
0       HVOI=  0.0 HTFU=  990.0 HTMO=  583.0 HBOR=    0.0
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                           MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

         1  0.0  990.0  583.0    0.0        0.000 1.17578 1.17434  60.43   1.181   4.660   0.000   0.000
         2                                  0.500 1.16864 1.16792  60.35   1.180   4.600   0.021   0.021
         3                                  2.500 1.16169 1.16094  60.28   1.167   4.369   0.117   0.121
         4                                  5.000 1.15374 1.15318  60.25   1.150   4.097   0.220   0.235
         5                                 10.000 1.13789 1.13767  60.25   1.113   3.598   0.386   0.432
         6                                 15.000 1.12763 1.12771  60.39   1.077   3.150   0.512   0.595
         7                                 20.000 1.11715 1.11745  60.54   1.047   2.745   0.608   0.732
         8                                 25.000 1.10053 1.10099  60.61   1.026   2.378   0.679   0.847
         9                                 30.000 1.07586 1.07644  60.56   1.034   2.045   0.731   0.945
        10                                 35.000 1.04589 1.04654  60.42   1.036   1.744   0.768   1.028
        11                                 40.000 1.01400 1.01471  60.25   1.034   1.474   0.793   1.099
0NORMAL TERMINATION
0RUN STARTED     (DATE,TIME):  **/10/17     15:21:12
0RUN COMPLETED   (DATE,TIME):  **/10/17     15:21:22
Thu Oct 17 15:21:22 EDT 2002
```

The CASMO Input File B_4C/Al_2O_3 WABAs in Guide Tubes

```
TIT  TFU=881  TMO=600  BOR=0  *4.66% B4 W 15 X 15
*Crystal River-3 15x15 Assembly with B4C-AL2O2 WABA
FUE  1 10.4/4.66  *FUEL COMP. #, DENSITY/ENRICHMENT
PDE  33  *POWER DENSITY (W/Gu)
MI2  17.8/5010=0.55 5011=2.22 6000=0.76 13000=51.04
8000=45.43
*  Mixture 2: B10, C, Al, O (BP Material)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  2 .28575 .33909 .35306 .40386 .41783 .48387 .632
.6731/
'COO' 'CAN' 'AIR' 'MI2' 'AIR' 'CAN' 'COO' 'CAN'/3,4,8
*  WABA BPRA pin
PIN  3 .632 .6731/ 'COO' 'CAN'  *Center water hole
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI
3
1 1
1 1 2
1 1 1 1
1 1 1 1 2
1 1 2 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
DEP  0.5 2.5 5 10 15 20 25 30 35 40 *Depletion steps
STA
END
```

The CASMO Output File B_4C/Al_2O_3 WABAs in Guide Tubes

```
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/05/26   10:24:32   JOB=SUN        STATE POINT NO = 11 PAGE =   50
 * 4.66% B4 W 15 X 15
 *  BURNUP =    40.001 V= 0.0  TF= 881.0  TM= 600.0  BOR=   0.0
0AVERAGED NUMBER DENSITIES OF BURNABLE NUCLIDES AT  40.001 MWD/KGU (PREDICTOR VALUES)
   92235-  3.42592E+20  92236-  1.30368E+20  93237-  1.38516E+19  94238-  4.96404E+18  92238-  2.10674E+22  94239-  1.46625E+20
   94240-  5.47323E+19  94241-  3.45468E+19  94242-  1.00040E+19  95241-  1.22844E+18  95242-  1.95653E+16  95243-  2.15477E+18
   96242-  4.27586E+17  96244-  5.94988E+17  92234-  4.90979E+18  92239-  1.16686E+16  93239-  1.66056E+18  36083-  3.30907E+18
   45103-  2.43628E+19  45105-  5.20782E+16  47109-  3.10410E+18  54131-  2.02594E+19  55133-  5.35358E+19  55134-  6.09734E+18
   54135-  1.00056E+16  55135-  2.43948E+19  60143-  3.98479E+19  60145-  2.96776E+19  61147-  7.15349E+18  62147-  3.56900E+18
   61148-  3.63167E+16  61248-  7.09619E+16  62149-  1.28383E+17  62150-  1.27013E+19  62151-  6.94417E+17  62152-  4.38252E+18
   63153-  4.85879E+18  63154-  1.42312E+18  63155-  8.12991E+17    401-  1.25570E+21    402-  2.69616E+20  53135-  1.99389E+16
   61149-  4.65411E+16  64155-  7.89657E+15
0NUMBER DENSITIES AND WEIGHT PER CENTS OF BURNABLE ABSORBERS

 REGION =  54     5010   8.79955E+18 8.21914E-04
 REGION =  62     5010   8.52727E+18 7.96482E-04
 REGION =  69     5010   8.71919E+18 8.14408E-04
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/05/26   10:24:32   JOB=SUN        STATE POINT NO = 12 PAGE =   51
 * 4.66% B4 W 15 X 15
 *  BURNUP =    40.001 V= 0.0  TF= 881.0  TM= 600.0  BOR=   0.0
 END                                                                  INPUT CARD
0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  40.0010 TYPE OF FILE = 470 STATEP =  12
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/05/26   10:24:32   JOB=SUN             PAGE =   52
0       ** C A S M O -3   SUMMARY  **
0         4.66% B4 W 15 X 15
0       HVOI=  0.0 HTFU=  881.0 HTMO=  600.0 HBOR=    0.0
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                           MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

         1  0.0  881.0  600.0    0.0        0.000 1.17404 1.17279  63.14   1.154   4.660   0.000   0.000
         2                                  0.500 1.16686 1.16617  63.05   1.153   4.600   0.021   0.021
         3                                  2.500 1.15893 1.15820  62.95   1.142   4.369   0.118   0.122
         4                                  5.000 1.14995 1.14942  62.88   1.126   4.097   0.222   0.237
         5                                 10.000 1.13309 1.13289  62.84   1.094   3.600   0.389   0.435
         6                                 15.000 1.12299 1.12310  62.95   1.061   3.154   0.516   0.601
         7                                 20.000 1.11357 1.11389  63.11   1.032   2.751   0.613   0.739
         8                                 25.000 1.09792 1.09840  63.19   1.041   2.386   0.685   0.855
         9                                 30.000 1.07344 1.07402  63.12   1.046   2.055   0.737   0.954
        10                                 35.000 1.04337 1.04401  62.96   1.045   1.756   0.775   1.038
        11                                 40.000 1.01159 1.01226  62.78   1.041   1.487   0.801   1.110
0NORMAL TERMINATION
0RUN STARTED     (DATE,TIME):  **/05/26     10:24:32
0RUN COMPLETED   (DATE,TIME):  **/05/26     10:24:41
Sun May 26 10:24:41 EDT 2002
```

The CASMO Input File L-Carborane BPRAs in Guide Tubes

```
TIT  TFU=881  TMO=600  BOR=0  *4.66% B4 W 15 X 15
*Crystal River-3 15x15 Assembly with L-CARBORANE in guide
tubes
FUE  1 10.4/4.66  *FUEL COMP. #, DENSITY/ENRICHMENT
PDE  33  *POWER DENSITY (W/Gu)
MI2  0.9/6000=46.40 14000=29.60 8000=7.03 5010=1.90
1001=7.44 5011=7.63
*  Mixture 2: C, Si, O, B10, H (L-CARBORANE BP Material)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  2 .4699 .4788 .5461 .632 .6731/ 'MI2' 'AIR' 'CAN'
'COO' 'CAN'/1,3,5
*  BPRA pin homogenized 'AIR+CAN' and 'COO+CAN'
PIN  3 .632 .6731/ 'COO' 'CAN'  *Center water hole
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI
3
1 1
1 1 2
1 1 1 1
1 1 1 1 2
1 1 2 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
DEP  0.5 2.5 5 10 15 20 25 30 35 40 *Depletion steps
STA
END
```

The CASMO Output File L-Carborane BPRAs in Guide Tubes

```
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/10/17   15:21:32   JOB=SUN        STATE POINT NO = 11 PAGE =   50
 * 4.66% B4 W 15 X 15
 *  BURNUP =    40.001 V= 0.0  TF= 881.0  TM= 600.0  BOR=   0.0
0AVERAGED NUMBER DENSITIES OF BURNABLE NUCLIDES AT  40.001 MWD/KGU (PREDICTOR VALUES)
   92235-  3.41740E+20  92236-  1.30383E+20  93237-  1.37804E+19  94238-  4.91878E+18  92238-  2.10706E+22  94239-  1.44871E+20
   94240-  5.46151E+19  94241-  3.41970E+19  94242-  9.99274E+18  95241-  1.21665E+18  95242-  1.92596E+16  95243-  2.13857E+18
   96242-  4.24837E+17  96244-  5.86808E+17  92234-  4.92222E+18  92239-  1.16018E+16  93239-  1.65054E+18  36083-  3.31093E+18
   45103-  2.43809E+19  45105-  5.19297E+16  47109-  3.10162E+18  54131-  2.03077E+19  55133-  5.35975E+19  55134-  6.05440E+18
   54135-  9.91692E+15  55135-  2.43043E+19  60143-  3.98045E+19  60145-  2.97151E+19  61147-  7.18344E+18  62147-  3.58593E+18
   61148-  3.63080E+16  61248-  7.07361E+16  62149-  1.26699E+17  62150-  1.26881E+19  62151-  6.86910E+17  62152-  4.40037E+18
   63153-  4.85200E+18  63154-  1.41126E+18  63155-  8.06217E+17    401-  1.25565E+21    402-  2.69675E+20  53135-  1.99391E+16
   61149-  4.64922E+16  64155-  7.73598E+15
0NUMBER DENSITIES AND WEIGHT PER CENTS OF BURNABLE ABSORBERS

 REGION =  18     5010   7.89642E+17 1.45873E-03
 REGION =  26     5010   7.54460E+17 1.39373E-03
 REGION =  33     5010   7.79906E+17 1.44074E-03
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/10/17   15:21:32   JOB=SUN        STATE POINT NO = 12 PAGE =   51
 * 4.66% B4 W 15 X 15
 *  BURNUP =    40.001 V= 0.0  TF= 881.0  TM= 600.0  BOR=   0.0
 END                                                                  INPUT CARD
0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  40.0010 TYPE OF FILE = 470 STATEP =  12
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/10/17   15:21:32   JOB=SUN             PAGE =   52
0       ** C A S M O -3   SUMMARY  **
0         4.66% B4 W 15 X 15
0       HVOI=  0.0 HTFU=  881.0 HTMO=  600.0 HBOR=    0.0
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                            MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

         1  0.0  881.0  600.0    0.0        0.000 1.15867 1.15758  63.95   1.164   4.660   0.000   0.000
         2                                  0.500 1.15226 1.15177  63.87   1.163   4.600   0.021   0.021
         3                                  2.500 1.14731 1.14676  63.83   1.149   4.369   0.118   0.123
         4                                  5.000 1.14216 1.14178  63.83   1.130   4.098   0.223   0.238
         5                                 10.000 1.13254 1.13245  63.92   1.089   3.601   0.389   0.435
         6                                 15.000 1.12936 1.12955  64.17   1.052   3.155   0.515   0.599
         7                                 20.000 1.12330 1.12367  64.39   1.037   2.751   0.609   0.735
         8                                 25.000 1.10629 1.10678  64.45   1.051   2.385   0.679   0.849
         9                                 30.000 1.07901 1.07958  64.35   1.053   2.053   0.729   0.946
        10                                 35.000 1.04715 1.04780  64.16   1.049   1.753   0.766   1.029
        11                                 40.000 1.01448 1.01517  63.96   1.044   1.483   0.792   1.100
0NORMAL TERMINATION
0RUN STARTED     (DATE,TIME):  **/10/17     15:21:32
0RUN COMPLETED   (DATE,TIME):  **/10/17     15:21:42
Thu Oct 17 15:21:42 EDT 2002
```

The MCNP Input File Water in Guide Tubes

```
RESEARCH 15 X 15 ASSEMBLY WITH NO BPRA'S 4.66% ENRICH NO BORON
1      0 20 -21 22 -23 90 -91 FILL=1 VOL=1.712434E+05
2      1 -0.660 30 -31 32 -33 LAT=1 U=1 FILL=-7:7 -7:7 0:0  $ BOUNDRY OF
ASSEMBLY
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 2 2 2 3 2 2 2 3 2 2 2 2 2
       2 2 2 3 2 2 2 2 2 2 2 3 2 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 3 2 2 3 2 2 2 3 2 2 3 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 2 2 2 2 2 4 2 2 2 2 2 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 3 2 2 3 2 2 2 3 2 2 3 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 2 3 2 2 2 2 2 2 2 3 2 2 2
       2 2 2 2 2 3 2 2 2 3 2 2 2 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
3      1    -0.660     -4 U=4 $WATER HOLE
                       VOL=257.8345
4      3    -6.503 4 -5 U=4 $INTERIOR CLAD
                       VOL=77.57637
5      1    -0.660   5 -6 U=4 $GUIDE TUBE WATER RADIUS
                       VOL=113.8173
6      3    -6.503 6 -7 U=4 $GUIDE TUBE CLAD RADIUS
                       VOL=60.32794
7      1    -0.660   #3 #4 #5 #6 U=4 $UNIT CELL WATER
                       VOL=235.8889
8      4    -0.660     -4 U=3 $BPRA MATERIAL
                       VOL=257.8345
9      3    -6.503 4 -5 U=3 $INTERIOR CLAD
                       VOL=77.57637
10     1    -0.660   5 -6 U=3 $GUIDE TUBE WATER RADIUS
                       VOL=113.8173
11     3    -6.503 6 -7 U=3 $GUIDE TUBE CLAD RADIUS
                       VOL=60.32794
12     1    -0.660   #8 #9 #10 #11 U=3 $UNIT CELL WATER
                       VOL=235.8889
13     2    -10.201    -8 U=2 $UO2 FUEL PELLET
                       VOL=248.3383
14     0             8 -4 U=2 $GAP RADIUS
                       VOL=9.496242
15     3    -6.503 4 -5 U=2 $FUEL PIN CLAD
                       VOL=77.57637
16     1    -0.660   #13 #14 #15 U=2 $UNIT CELL WATER
                       VOL=410.0342
17     1    -0.660   (-20:21:-22:23:-90:91) -9 $OUTSIDE OF ASSMBLY
                       VOL=3518.23905
99             0      9    $VOID REGION OUTSIDE ASSEMBLY

20             PX    -10.8225
21             PX     10.8225
22             PY    -10.8225
23             PY     10.8225
C   OUTSIDE OF ASSEMBLY LATICE
30             PX    -0.7215
31             PX     0.7215
32             PY    -0.7215
33             PY     0.7215
C  OUTSIDE OF UNIT CELL (1.443 PITCH)
```

```
4              CZ     0.4788
C  CYLINDER BPRA / WATER HOLE / GAP RADIUS
5              CZ     0.5461
C  CYLINDER INTERIOR CLAD RADIUS
6              CZ     0.6320
C  CYLINDER WATER RADIUS GUIDE TUBE
7              CZ     0.6731
C  CYLINDER CLAD RADIUS GUIDE TUBE
8              CZ     0.4699
C  CYLINDER RADIUS OF FUEL PELLET
*9             RPP    -10.905 10.905 -10.905 10.905 -180 180
C  RECT PARALLEL PIPED OUTSIDE OF ASSEMBLY
90             PZ     -179
91             PZ      179

MODE    N
IMP:N   1.0 16R 0.0
KCODE   2000    1.3     5       55      500
KSRC    1.443     0.0     0.0
M1      8016.60C        -8.88100E+01        1001.60C     -1.11900E+01
MT1     LWTR.04T $H20 AT 600 K
M2      92235.54C       -4.10779E+00       92238.54C     -8.40421623E+01
        8016.54C      -1.18500E+01
        $UO2 4.66% at 881K EN
M3      40000.60C 1.0 $ZIRCONIUM (APPROX. FOR ZIRCALLOY)
M4      8016.60C        -8.88100E+01        1001.60C     -1.11900E+01
MT4     LWTR.04T $H20 AT 600 K
PRINT
```

The MONTEBURNS Input File Water in Guide Tubes

```
RESEARCH 15 X 15 ASSEMBLY WITH NO BPRA'S 4.66% ENRICH NO BORON
PC          ! Type of Operating System
2           ! Two MCNP Materials to burn (fuel cells / BPRAs)
2           ! MCNP material number #2 (will burn all cells with this mat)
4           ! MCNP material number #4 (will burn all cells with this mat)
51654.38    ! Material #2 volume (cc)
4125.353    ! Material #4 volume (cc)
17.75       ! Power in MWt (for the entire system in MCNP)
-180.88     ! Recov. energy/fis (MeV); if negative use for U235, ratio isos
657.36      ! Total number of days burned (used if no feed)
6           ! Number of outer burn steps
60          ! Number of internal burn steps (multiple of 10)
1           ! Number of predictor steps (+1 on first step), 1 usually sufficient
0           ! Step number to restart after (0=beginning)
PWRU50      ! number of default origen2 lib - next line is origen2 lib location
c:\Origen2\Libs
.005        ! fractional importance (track isos with abs,fis,atom,mass fraction)
1           ! Intermediate keff calc. 0) No 1) Yes
2           ! Number of automatic tally isotopes, followed by list.
92235.54c
92238.54c
2
8016.60C
1001.60C
```

The MONTEBURNS Output File Water in Guide Tubes

RESEARCH 15 X 15 ASSEMBLY WITH NO BPRA'S 4.66% ENRICH NO BORON

Total Power (MW) = 1.78E+01 Days = 6.57E+02
outer steps = 6, # inner steps = 60, # predictor steps = 1
Importance Fraction = 0.0050

Monteburns MCNP k-eff Versus Time

	days	k-eff	rel err	nu	avQfis	eta
0m	0.00	1.41023	0.00186	2.456	181.052	1.443
1m	54.78	1.34293	0.00172	2.482	181.479	1.357
1e	109.56	1.31922	0.00208	2.500		
2m	164.34	1.29418	0.00160	2.525	182.160	1.304
2e	219.12	1.26789	0.00191	2.543		
3m	273.90	1.24603	0.00204	2.557	182.749	1.251
3e	328.68	1.22871	0.00154	2.576		
4m	383.46	1.21029	0.00232	2.586	183.251	1.207
4e	438.24	1.19009	0.00158	2.602		
5m	493.02	1.17565	0.00191	2.613	183.726	1.170
5e	547.80	1.16014	0.00201	2.629		
6m	602.58	1.14384	0.00188	2.639	184.160	1.139
6e	657.36	1.12101	0.00235	2.647		

Monteburns Transport History

Monteburns Transport History for material 1

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.052	2.92E+14	4.05E-02	1.77E+01	3.428E+02	0.000E+00	3.98E-01	5.94E-01	1.49E+00	1.50E-03	1.473	1.19E+00	1.78E+00	1.50E+00	4.51E-03	1.476
1	181.479	3.07E+14	3.85E-02	1.77E+01	3.430E+02	4.178E+00	4.38E-01	5.64E-01	1.29E+00	1.47E-03	1.400	1.22E+00	1.70E+00	1.39E+00	4.43E-03	1.448
2	182.160	3.21E+14	3.69E-02	1.79E+01	3.458E+02	8.392E+00	4.73E-01	5.40E-01	1.14E+00	1.58E-03	1.349	1.31E+00	1.63E+00	1.25E+00	4.76E-03	1.404
3	182.749	3.35E+14	3.48E-02	1.77E+01	3.422E+02	1.256E+01	4.99E-01	5.12E-01	1.03E+00	1.63E-03	1.298	1.35E+00	1.55E+00	1.14E+00	4.92E-03	1.368
4	183.251	3.48E+14	3.34E-02	1.77E+01	3.419E+02	1.673E+01	5.22E-01	4.92E-01	9.41E-01	1.59E-03	1.257	1.40E+00	1.49E+00	1.06E+00	4.83E-03	1.337
5	183.726	3.61E+14	3.23E-02	1.77E+01	3.435E+02	2.092E+01	5.43E-01	4.76E-01	8.75E-01	1.65E-03	1.223	1.44E+00	1.45E+00	1.00E+00	5.01E-03	1.313
6	184.160	3.75E+14	3.12E-02	1.79E+01	3.456E+02	2.513E+01	5.59E-01	4.60E-01	8.23E-01	1.70E-03	1.195	1.48E+00	1.41E+00	9.52E-01	5.18E-03	1.291

Monteburns Transport History for material 2

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	2.96E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.18E-02	0.00E+00	0.00E+00	0.00E+00	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	3.11E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.10E-02	0.00E+00	0.00E+00	0.00E+00	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	3.26E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.04E-02	0.00E+00	0.00E+00	0.00E+00	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	3.42E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.00E-02	0.00E+00	0.00E+00	0.00E+00	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	3.54E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.99E-02	0.00E+00	0.00E+00	0.00E+00	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	3.66E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.96E-02	0.00E+00	0.00E+00	0.00E+00	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
6	0.000	3.81E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.00E-02	0.00E+00	0.00E+00	0.00E+00	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

Monteburns Flux Spectrum

Monteburns Flux Spectrum for material 1

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	4.02	8.29	11.39	26.36	25.79	24.15
1	3.72	7.93	11.50	26.53	25.96	24.36
2	3.66	7.51	11.55	26.70	26.03	24.55
3	3.55	7.20	11.48	26.93	26.07	24.76
4	3.57	7.06	11.49	26.89	26.17	24.82
5	3.61	6.97	11.53	26.96	26.13	24.80
6	3.71	6.95	11.43	26.96	26.12	24.84

Monteburns Flux Spectrum for material 2

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	6.54	10.18	12.83	26.35	22.93	21.16
1	6.21	9.87	12.63	26.68	23.24	21.36
2	5.99	9.63	12.79	26.92	23.29	21.37
3	5.87	9.29	12.83	27.21	23.16	21.64
4	5.90	9.18	12.80	26.81	23.65	21.64
5	5.75	9.03	13.01	27.06	23.38	21.77
6	5.99	8.93	12.90	27.17	23.20	21.81

Monteburns 1-group n,gamma Cross Sections

Monteburns 1-group n,gamma Cross Sections for material 1

	92235.54c	92238.54c
0	8.38E+00	8.33E-01
1	8.09E+00	8.41E-01
2	7.96E+00	8.42E-01
3	7.79E+00	8.40E-01
4	7.78E+00	8.41E-01
5	7.86E+00	8.42E-01
6	7.92E+00	8.40E-01

Monteburns 1-group n,gamma Cross Sections for material 2

	8016.60C	1001.60C
0	1.79E-05	3.11E-02
1	1.71E-05	2.98E-02
2	1.66E-05	2.89E-02
3	1.62E-05	2.83E-02
4	1.61E-05	2.81E-02
5	1.59E-05	2.76E-02
6	1.62E-05	2.82E-02

Monteburns 1-group Fission Cross Sections

Monteburns 1-group Fission Cross Sections for material 1

	92235.54c	92238.54c
0	3.57E+01	1.01E-01
1	3.39E+01	1.02E-01
2	3.31E+01	1.03E-01
3	3.21E+01	1.04E-01
4	3.19E+01	1.04E-01
5	3.21E+01	1.05E-01
6	3.26E+01	1.05E-01

Monteburns 1-group Fission Cross Sections for material 2

	8016.60C	1001.60C
0	2.74E-06	0.00E+00
1	1.84E-06	0.00E+00
2	3.32E-06	0.00E+00
3	6.31E-06	0.00E+00
4	6.48E-06	0.00E+00
5	7.84E-06	0.00E+00
6	6.62E-06	0.00E+00

Monteburns Fission-to-Capture Ratio

Monteburns Fission-to-Capture Ratio for material 1

	92235.54c	92238.54c
0	4.2583	0.1216
1	4.1879	0.1216
2	4.1515	0.1226
3	4.1193	0.1243
4	4.1034	0.1240
5	4.0886	0.1243
6	4.1113	0.1251

Monteburns Fission-to-Capture Ratio for material 2

	8016.60C	1001.60C
0	0.0000	0.0000
1	0.0000	0.0000
2	0.0000	0.0000
3	0.0000	0.0000
4	0.0000	0.0000
5	0.0000	0.0000
6	0.0000	0.0000

Monteburns Grams of Material at Beginning of Steps

Monteburns Grams of Material at Begin. of Steps for material 1

	92235.54c	92238.54c	actinide
0	2.16E+04	4.43E+05	4.64E+05
1	2.16E+04	4.43E+05	4.64E+05
2	1.92E+04	4.42E+05	4.62E+05
3	1.69E+04	4.40E+05	4.60E+05
4	1.49E+04	4.39E+05	4.58E+05
5	1.31E+04	4.38E+05	4.55E+05
6	1.14E+04	4.36E+05	4.53E+05

Monteburns Grams of Material at Begin. of Steps for material 2

	8016.60C	1001.60C	actinide
0	2.42E+03	3.05E+02	0.00E+00
1	2.42E+03	3.05E+02	0.00E+00
2	2.42E+03	3.05E+02	0.00E+00
3	2.42E+03	3.05E+02	0.00E+00

```
  4  2.42E+03  3.05E+02  0.00E+00
  5  2.42E+03  3.05E+02  0.00E+00
  6  2.42E+03  3.05E+02  0.00E+00

Monteburns Grams of Material at End of Steps

Monteburns Grams of Material at End of Steps for material  1
   92235.54c 92238.54c  actinide
  0  2.16E+04  4.43E+05  4.64E+05
  1  1.92E+04  4.42E+05  4.62E+05
  2  1.69E+04  4.40E+05  4.60E+05
  3  1.49E+04  4.39E+05  4.58E+05
  4  1.31E+04  4.38E+05  4.55E+05
  5  1.14E+04  4.36E+05  4.53E+05
  6  9.87E+03  4.35E+05  4.51E+05

Monteburns Grams of Material at End of Steps for material  2
   8016.60C  1001.60C   actinide
  0  2.42E+03  3.05E+02  0.00E+00
  1  2.42E+03  3.05E+02  0.00E+00
  2  2.42E+03  3.05E+02  0.00E+00
  3  2.42E+03  3.05E+02  0.00E+00
  4  2.42E+03  3.05E+02  0.00E+00
  5  2.42E+03  3.05E+02  0.00E+00
  6  2.42E+03  3.04E+02  0.00E+00

Monteburns Activity (Ci) of Material at End of Steps

Monteburns Activities (Ci) for material  1
   92235.54c 92238.54c  actinide
  0  4.68E-02  1.49E-01  1.96E-01
  1  4.14E-02  1.48E-01  1.90E-01
  2  3.66E-02  1.48E-01  1.85E-01
  3  3.22E-02  1.48E-01  1.80E-01
  4  2.83E-02  1.47E-01  1.75E-01
  5  2.46E-02  1.47E-01  1.71E-01
  6  2.13E-02  1.46E-01  1.67E-01

Monteburns Activities (Ci) for material  2
   8016.60C  1001.60C   actinide
  0  0.00E+00  0.00E+00  1.96E-01
  1  0.00E+00  0.00E+00  1.90E-01
  2  0.00E+00  0.00E+00  1.85E-01
  3  0.00E+00  0.00E+00  1.80E-01
  4  0.00E+00  0.00E+00  1.75E-01
  5  0.00E+00  0.00E+00  1.71E-01
  6  0.00E+00  0.00E+00  1.67E-01

Monteburns Heatload (W) of Material at End of Steps

Monteburns Heatloads (W) for material  1
   92235.54c 92238.54c  actinide
  0  1.23E-03  3.78E-03  5.00E-03
  1  1.08E-03  3.77E-03  4.85E-03
  2  9.58E-04  3.76E-03  4.71E-03
  3  8.44E-04  3.74E-03  4.59E-03
  4  7.40E-04  3.73E-03  4.47E-03
  5  6.45E-04  3.72E-03  4.37E-03
  6  5.59E-04  3.71E-03  4.27E-03

Monteburns Heatloads (W) for material  2
   8016.60C  1001.60C   actinide
  0  0.00E+00  0.00E+00  5.00E-03
  1  0.00E+00  0.00E+00  4.85E-03
  2  0.00E+00  0.00E+00  4.71E-03
  3  0.00E+00  0.00E+00  4.59E-03
  4  0.00E+00  0.00E+00  4.47E-03
  5  0.00E+00  0.00E+00  4.37E-03
  6  0.00E+00  0.00E+00  4.27E-03

Monteburns Inhalation Toxicity (m^3 air) of Material at End of Steps

Monteburns Inhalation Toxicities (m^3 air) for material  1
   92235.54c 92238.54c  actinide
  0  2.34E+09  4.96E+10  5.20E+10
  1  2.07E+09  4.95E+10  5.16E+10
  2  1.83E+09  4.93E+10  5.12E+10
  3  1.61E+09  4.92E+10  5.08E+10
  4  1.41E+09  4.90E+10  5.05E+10
  5  1.23E+09  4.89E+10  5.01E+10
  6  1.07E+09  4.87E+10  4.98E+10

Monteburns Inhalation Toxicities (m^3 air) for material  2
   8016.60C  1001.60C   actinide
  0  0.00E+00  0.00E+00  5.20E+10
  1  0.00E+00  0.00E+00  5.16E+10
  2  0.00E+00  0.00E+00  5.12E+10
  3  0.00E+00  0.00E+00  5.08E+10
  4  0.00E+00  0.00E+00  5.05E+10
  5  0.00E+00  0.00E+00  5.01E+10
  6  0.00E+00  0.00E+00  4.98E+10

 Monteburns Ingestion Toxicity (m^3 water) of Material at End of Steps

 Monteburns Ingestion Toxicities (m^3 water) for material  1
```

```
   92235.54c 92238.54c  actinide
  0  1.56E+03  3.72E+03  5.28E+03
  1  1.38E+03  3.71E+03  5.09E+03
  2  1.22E+03  3.70E+03  4.92E+03
  3  1.07E+03  3.69E+03  4.76E+03
  4  9.42E+02  3.68E+03  4.62E+03
  5  8.21E+02  3.67E+03  4.49E+03
  6  7.11E+02  3.65E+03  4.37E+03

 Monteburns Ingestion Toxicities (m^3 water) for material  2
   8016.60C  1001.60C   actinide
  0  0.00E+00  0.00E+00  5.28E+03
  1  0.00E+00  0.00E+00  5.09E+03
  2  0.00E+00  0.00E+00  4.92E+03
  3  0.00E+00  0.00E+00  4.76E+03
  4  0.00E+00  0.00E+00  4.62E+03
  5  0.00E+00  0.00E+00  4.49E+03
  6  0.00E+00  0.00E+00  4.37E+03

Monteburns Inventory

Monteburns Grams of Feed per Step for material  1
mat #  days     92235.54c 92238.54c  actinide
  1   109.56    0.00E+00  0.00E+00  0.00E+00
  2   109.56    0.00E+00  0.00E+00  0.00E+00
  3   109.56    0.00E+00  0.00E+00  0.00E+00
  4   109.56    0.00E+00  0.00E+00  0.00E+00
  5   109.56    0.00E+00  0.00E+00  0.00E+00
  6   109.56    0.00E+00  0.00E+00  0.00E+00
tot  657.36    0.00E+00  0.00E+00  0.00E+00

Monteburns Grams Produced (or Destroyed)  for material  1
   92235.54c 92238.54c  actinide
  1 -2.48E+03 -1.21E+03 -2.24E+03
  2 -2.25E+03 -1.29E+03 -2.28E+03
  3 -2.01E+03 -1.33E+03 -2.24E+03
  4 -1.83E+03 -1.38E+03 -2.23E+03
  5 -1.67E+03 -1.43E+03 -2.23E+03
  6 -1.53E+03 -1.48E+03 -2.24E+03
tot-1.53E+03 -1.48E+03 -2.24E+03

Summary of Inventory/Feed/Production for material  1 (MCNP Material Number  2)
   92235.54c 92238.54c  actinide
ini 2.16E+04  4.43E+05  4.64E+05
fin 9.87E+03  4.35E+05  4.51E+05
fed 0.00E+00  0.00E+00  0.00E+00
net-1.53E+03 -1.48E+03 -2.24E+03

Monteburns Grams of Feed per Step for material  2
mat #  days     8016.60C  1001.60C   actinide
  1   109.56    0.00E+00  0.00E+00  0.00E+00
  2   109.56    0.00E+00  0.00E+00  0.00E+00
  3   109.56    0.00E+00  0.00E+00  0.00E+00
  4   109.56    0.00E+00  0.00E+00  0.00E+00
  5   109.56    0.00E+00  0.00E+00  0.00E+00
  6   109.56    0.00E+00  0.00E+00  0.00E+00
tot  657.36    0.00E+00  0.00E+00  0.00E+00

Monteburns Grams Produced (or Destroyed)  for material  2
   8016.60C  1001.60C   actinide
  1  0.00E+00 -3.00E-02  0.00E+00
  2  0.00E+00 -3.00E-02  0.00E+00
  3  0.00E+00 -3.00E-02  0.00E+00
  4  0.00E+00 -3.00E-02  0.00E+00
  5  0.00E+00 -3.00E-02  0.00E+00
  6  0.00E+00 -3.00E-02  0.00E+00
tot 0.00E+00 -3.00E-02  0.00E+00

Summary of Inventory/Feed/Production for material  2 (MCNP Material Number  4)
   8016.60C  1001.60C   actinide
ini 2.42E+03  3.05E+02  0.00E+00
fin 2.42E+03  3.04E+02  0.00E+00
fed 0.00E+00  0.00E+00  0.00E+00
net 0.00E+00 -3.00E-02  0.00E+00

Monteburns Inventory (cont.)

Feed Rate (g/day) for material  1 (MCNP Material Number  2)
   92235.54c 92238.54c  actinide
  1  0.00E+00  0.00E+00  0.00E+00
  2  0.00E+00  0.00E+00  0.00E+00
  3  0.00E+00  0.00E+00  0.00E+00
  4  0.00E+00  0.00E+00  0.00E+00
  5  0.00E+00  0.00E+00  0.00E+00
  6  0.00E+00  0.00E+00  0.00E+00

Production/Destruction Rate (g/day) for material  1 (MCNP Material Number  2)
   92235.54c 92238.54c  actinide
  1 -2.26E+01 -1.10E+01 -2.04E+01
  2 -2.05E+01 -1.18E+01 -2.08E+01
  3 -1.83E+01 -1.21E+01 -2.04E+01
  4 -1.67E+01 -1.26E+01 -2.04E+01
  5 -1.52E+01 -1.31E+01 -2.04E+01
  6 -1.39E+01 -1.35E+01 -2.05E+01
```

```
Feed Rate (g/day) for material  2 (MCNP Material Number  4)
   8016.60C  1001.60C   actinide
  1  0.00E+00  0.00E+00  0.00E+00
  2  0.00E+00  0.00E+00  0.00E+00
  3  0.00E+00  0.00E+00  0.00E+00
  4  0.00E+00  0.00E+00  0.00E+00
  5  0.00E+00  0.00E+00  0.00E+00
  6  0.00E+00  0.00E+00  0.00E+00

Production/Destruction Rate (g/day) for material  2 (MCNP Material Number  4)
   8016.60C  1001.60C   actinide
  1  0.00E+00 -2.74E-04  0.00E+00
  2  0.00E+00 -2.74E-04  0.00E+00
  3  0.00E+00 -2.74E-04  0.00E+00
  4  0.00E+00 -2.74E-04  0.00E+00
  5  0.00E+00 -2.74E-04  0.00E+00
  6  0.00E+00 -2.74E-04  0.00E+00
```

The MCNP Input File B_4C/Al_2O_3 BPRAs in Guide Tubes

```
RESEARCH 15 X 15 ASSEMBLY WITH B4CAL2O3 BPRA'S 4.66% ENRICH NO BORON
1       0 20 -21 22 -23 90 -91 FILL=1 VOL=1.712434E+05
2       1 -0.660 30 -31 32 -33 LAT=1 U=1 FILL=-7:7 -7:7 0:0  $ BOUNDRY OF
ASSEMBLY
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 2 2 2 3 2 2 2 3 2 2 2 2 2
        2 2 2 3 2 2 2 2 2 2 2 3 2 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 3 2 2 3 2 2 2 3 2 2 3 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2    $PIN LAYOUT REPEATED LATTICE
        2 2 2 2 2 2 2 4 2 2 2 2 2 2 2    $EACH UNIVERSE "U" NUMBER IS
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2    $DIFFERENT TYPE OF UNIT CELL
        2 2 3 2 2 3 2 2 2 3 2 2 3 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 2 3 2 2 2 2 2 2 2 3 2 2 2
        2 2 2 2 2 3 2 2 2 3 2 2 2 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
3       1    -0.660     -4 U=4 $WATER HOLE
                        VOL=257.8345
4       3    -6.503 4 -5 U=4 $INTERIOR CLAD
                        VOL=77.57637
5       1    -0.660   5 -6 U=4 $GUIDE TUBE WATER RADIUS
                        VOL=113.8173
6       3    -6.503 6 -7 U=4 $GUIDE TUBE CLAD RADIUS
                        VOL=60.32794
7       1    -0.660   #3 #4 #5 #6 U=4 $UNIT CELL WATER
                        VOL=235.8889
8       4    -3.1     -4 U=3 $BPRA MATERIAL
                        VOL=257.8345
9       3    -6.503 4 -5 U=3 $INTERIOR CLAD
                        VOL=77.57637
10      1    -0.660   5 -6 U=3 $GUIDE TUBE WATER RADIUS
                        VOL=113.8173
11      3    -6.503 6 -7 U=3 $GUIDE TUBE CLAD RADIUS
                        VOL=60.32794
12      1    -0.660   #8 #9 #10 #11 U=3 $UNIT CELL WATER
                        VOL=235.8889
13      2    -10.201    -8 U=2 $UO2 FUEL PELLET
                        VOL=248.3383
14      0               8 -4 U=2 $GAP RADIUS
                        VOL=9.496242
15      3    -6.503 4 -5 U=2 $FUEL PIN CLAD
                        VOL=77.57637
16      1    -0.660   #13 #14 #15 U=2 $UNIT CELL WATER
                        VOL=410.0342
```

```
17     1    -0.660   (-20:21:-22:23:-90:91) -9 $OUTSIDE OF ASSMBLY
                     VOL=3518.23905
99             0      9    $VOID REGION OUTSIDE ASSEMBLY

20             PX    -10.8225
21             PX     10.8225
22             PY    -10.8225
23             PY     10.8225
C   OUTSIDE OF ASSEMBLY LATICE
30             PX    -0.7215
31             PX     0.7215
32             PY    -0.7215
33             PY     0.7215
C  OUTSIDE OF UNIT CELL (1.443 PITCH)
4              CZ     0.4788
C  CYLINDER BPRA / WATER HOLE / GAP RADIUS
5              CZ     0.5461
C  CYLINDER INTERIOR CLAD RADIUS
6              CZ     0.6320
C  CYLINDER WATER RADIUS GUIDE TUBE
7              CZ     0.6731
C  CYLINDER CLAD RADIUS GUIDE TUBE
8              CZ     0.4699
C  CYLINDER RADIUS OF FUEL PELLET
*9             RPP    -10.905 10.905 -10.905 10.905 -180 180
C  RECT PARALLEL PIPED OUTSIDE OF ASSEMBLY
90             PZ     -179
91             PZ      179

MODE    N
IMP:N   1.0 16R 0.0
KCODE   2000    1.3     5       55      500
KSRC    1.443     0.0     0.0
M1      8016.60C        -8.88100E+01        1001.60C     -1.11900E+01
MT1     LWTR.04T $H20 AT 600 K
M2      92235.54C       -4.10779E+00       92238.54C     -8.40421623E+01
        8016.54C      -1.18500E+01
        $UO2 4.66% at 881K EN
M3      40000.60C 1.0 $ZIRCONIUM (APPROX. FOR ZIRCALLOY)
M4      5010.50C   -0.55   5011.56C -2.22 6000.60C   -0.76   13027.60C
        -51.04   8016.54C   -45.43  $B4CAL2O3 BP MATERIAL
PRINT
```

The MONTEBURNS Input File B_4C/Al_2O_3 BPRAs in Guide Tubes

```
RESEARCH 15 X 15 ASSEMBLY WITH B4CAL2O3 BPRA'S 4.66% ENRICH NO BORON
PC          ! Type of Operating System
2           ! Two MCNP Materials to burn (fuel cells/BPRAs)
2           ! MCNP material number #2 (will burn all cells with this mat)
4           ! MCNP material number #4 (will burn all cells with this mat)
51654.376   ! Material #2 volume (cc)
4125.353    ! Material #4 volume (cc)
17.75       ! Power in MWt (for the entire system in MCNP)
-180.88     ! Recov. energy/fis (MeV); if negative use for U235, ratio isos
657.36      ! Total number of days burned (used if no feed)
6           ! Number of outer burn steps
60          ! Number of internal burn steps (multiple of 10)
1           ! Number of predictor steps (+1 on first step), 1 usually sufficient
0           ! Step number to restart after (0=beginning)
PWRU50      ! number of default origen2 lib - next line is origen2 lib location
c:\Origen2\Libs
.005        ! fractional importance (track isos with abs,fis,atom,mass fraction)
1           ! Intermediate keff calc. 0) No 1) Yes
```

```
2          ! Number of automatic tally isotopes, followed by list.
92235.54c
92238.54c
1
5010.50C
```

The MONTEBURNS Output File B_4C/Al_2O_3 BPRAs in Guide Tubes

RESEARCH 15 X 15 ASSEMBLY WITH B4CAL2O3 BPRA'S 4.66% ENRICH NO BORON

Total Power (MW) = 1.78E+01 Days = 6.57E+02
outer steps = 6, # inner steps = 60, # predictor steps = 1
Importance Fraction = 0.0050

Monteburns MCNP k-eff Versus Time

	days	k-eff	rel err	nu	avQfis	eta
0m	0.00	1.18653	0.00220	2.463	181.087	1.397
1m	54.78	1.15113	0.00196	2.495	181.564	1.324
1e	109.56	1.15168	0.00228	2.511		
2m	164.34	1.14744	0.00223	2.529	182.319	1.269
2e	219.12	1.14184	0.00219	2.554		
3m	273.90	1.13869	0.00224	2.565	182.921	1.226
3e	328.68	1.14499	0.00206	2.588		
4m	383.46	1.13572	0.00215	2.597	183.432	1.192
4e	438.24	1.13869	0.00217	2.610		
5m	493.02	1.13326	0.00193	2.619	183.881	1.161
5e	547.80	1.12608	0.00228	2.639		
6m	602.58	1.12037	0.00194	2.643	184.294	1.129
6e	657.36	1.10847	0.00225	2.655		

Monteburns Transport History

Monteburns Transport History for material 1

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.087	3.47E+14	3.41E-02	1.77E+01	3.436E+02	0.000E+00	3.78E-01	5.00E-01	1.32E+00	1.63E-03	1.405	1.13E+00	1.50E+00	1.33E+00	4.90E-03	1.408
1	181.564	3.59E+14	3.30E-02	1.78E+01	3.449E+02	4.202E+00	4.15E-01	4.83E-01	1.17E+00	1.55E-03	1.346	1.16E+00	1.45E+00	1.25E+00	4.66E-03	1.390
2	182.319	3.64E+14	3.22E-02	1.77E+01	3.428E+02	8.379E+00	4.50E-01	4.73E-01	1.05E+00	1.64E-03	1.300	1.25E+00	1.43E+00	1.14E+00	4.95E-03	1.351
3	182.921	3.72E+14	3.15E-02	1.77E+01	3.435E+02	1.256E+01	4.84E-01	4.63E-01	9.58E-01	1.51E-03	1.258	1.32E+00	1.40E+00	1.06E+00	4.56E-03	1.325
4	183.432	3.76E+14	3.10E-02	1.77E+01	3.430E+02	1.674E+01	5.09E-01	4.56E-01	8.96E-01	1.55E-03	1.230	1.37E+00	1.39E+00	1.01E+00	4.69E-03	1.307
5	183.881	3.81E+14	3.06E-02	1.77E+01	3.436E+02	2.093E+01	5.33E-01	4.51E-01	8.45E-01	1.60E-03	1.203	1.42E+00	1.38E+00	9.66E-01	4.88E-03	1.290
6	184.294	3.89E+14	2.98E-02	1.77E+01	3.423E+02	2.510E+01	5.51E-01	4.39E-01	7.97E-01	1.61E-03	1.175	1.47E+00	1.34E+00	9.17E-01	4.92E-03	1.268

Monteburns Transport History for material 2

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	3.15E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.26E+00	0.00E+00	0.00E+00	8.84E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	3.31E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.12E+00	0.00E+00	0.00E+00	4.76E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	3.41E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	8.75E-01	0.00E+00	0.00E+00	1.03E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	3.56E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	6.12E-01	0.00E+00	0.00E+00	1.51E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	3.68E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	3.95E-01	0.00E+00	0.00E+00	1.22E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	3.77E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.25E-01	0.00E+00	0.00E+00	1.03E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
6	0.000	3.89E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.08E-01	0.00E+00	0.00E+00	1.53E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

Monteburns Flux Spectrum

Monteburns Flux Spectrum for material 1

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	3.06	7.06	11.41	27.36	26.62	24.50
1	2.87	6.79	11.58	27.45	26.75	24.57
2	2.84	6.55	11.56	27.47	26.76	24.82
3	2.85	6.40	11.53	27.58	26.68	24.96
4	2.96	6.33	11.58	27.53	26.68	24.93
5	3.11	6.35	11.55	27.44	26.58	24.96
6	3.19	6.38	11.54	27.52	26.66	24.71

Monteburns Flux Spectrum for material 2

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	1.23	4.56	11.84	30.36	27.69	24.32
1	1.33	4.86	12.20	30.09	27.51	24.01
2	1.72	5.38	12.50	29.48	27.05	23.89
3	2.18	6.02	12.66	28.92	26.48	23.73
4	2.87	6.57	12.59	28.72	26.13	23.12
5	3.57	7.08	12.81	28.13	25.57	22.83
6	4.18	7.23	12.58	28.18	25.42	22.39

Monteburns 1-group n,gamma Cross Sections

Monteburns 1-group n,gamma Cross Sections for material 1

	92235.54c	92238.54c
0	7.35E+00	8.21E-01
1	7.15E+00	8.22E-01
2	7.08E+00	8.24E-01
3	7.06E+00	8.30E-01
4	7.14E+00	8.29E-01
5	7.27E+00	8.32E-01
6	7.37E+00	8.34E-01

Monteburns 1-group n,gamma Cross Sections for material 2

	5010.50C
0	1.50E-02
1	1.61E-02
2	1.85E-02
3	2.14E-02
4	2.50E-02
5	2.91E-02
6	3.18E-02

Monteburns 1-group Fission Cross Sections

Monteburns 1-group Fission Cross Sections for material 1

	92235.54c	92238.54c
0	2.97E+01	1.03E-01
1	2.85E+01	1.03E-01
2	2.80E+01	1.04E-01
3	2.78E+01	1.05E-01
4	2.82E+01	1.05E-01
5	2.89E+01	1.05E-01
6	2.94E+01	1.04E-01

Monteburns 1-group Fission Cross Sections for material 2

	5010.50C
0	2.74E-03
1	2.72E-03
2	2.71E-03
3	2.68E-03
4	2.64E-03
5	2.61E-03
6	2.57E-03

Monteburns Fission-to-Capture Ratio

Monteburns Fission-to-Capture Ratio for material 1

	92235.54c	92238.54c
0	4.0380	0.1254
1	3.9795	0.1254
2	3.9508	0.1265
3	3.9428	0.1264
4	3.9494	0.1264
5	3.9758	0.1264
6	3.9837	0.1246

Monteburns Fission-to-Capture Ratio for material 2

	5010.50C
0	0.0000
1	0.0000
2	0.0000
3	0.0000
4	0.0000
5	0.0000
6	0.0000

Monteburns Grams of Material at Beginning of Steps

Monteburns Grams of Material at Begin. of Steps for material 1

	92235.54c	92238.54c	actinide
0	2.16E+04	4.43E+05	4.64E+05
1	2.16E+04	4.43E+05	4.64E+05
2	1.92E+04	4.41E+05	4.62E+05
3	1.70E+04	4.40E+05	4.60E+05
4	1.50E+04	4.39E+05	4.58E+05
5	1.33E+04	4.37E+05	4.55E+05
6	1.16E+04	4.36E+05	4.53E+05

Monteburns Grams of Material at Begin. of Steps for material 2

	5010.50C	actinide
0	7.03E+01	0.00E+00
1	7.03E+01	0.00E+00
2	4.77E+01	0.00E+00
3	3.02E+01	0.00E+00

```
  4  1.73E+01  0.00E+00
  5  8.86E+00  0.00E+00
  6  3.98E+00  0.00E+00

Monteburns Grams of Material at End of Steps

Monteburns Grams of Material at End of Steps for material  1
   92235.54c 92238.54c  actinide
  0  2.16E+04  4.43E+05  4.64E+05
  1  1.92E+04  4.41E+05  4.62E+05
  2  1.70E+04  4.40E+05  4.60E+05
  3  1.50E+04  4.39E+05  4.58E+05
  4  1.33E+04  4.37E+05  4.55E+05
  5  1.16E+04  4.36E+05  4.53E+05
  6  1.02E+04  4.34E+05  4.51E+05

Monteburns Grams of Material at End of Steps for material  2
   5010.50C   actinide
  0  7.03E+01  0.00E+00
  1  4.77E+01  0.00E+00
  2  3.02E+01  0.00E+00
  3  1.73E+01  0.00E+00
  4  8.86E+00  0.00E+00
  5  3.98E+00  0.00E+00
  6  1.62E+00  0.00E+00

Monteburns Activity (Ci) of Material at End of Steps

Monteburns Activities (Ci) for material  1
   92235.54c 92238.54c  actinide
  0  4.68E-02  1.49E-01  1.96E-01
  1  4.14E-02  1.48E-01  1.90E-01
  2  3.67E-02  1.48E-01  1.85E-01
  3  3.25E-02  1.47E-01  1.80E-01
  4  2.86E-02  1.47E-01  1.76E-01
  5  2.51E-02  1.46E-01  1.72E-01
  6  2.20E-02  1.46E-01  1.68E-01

Monteburns Activities (Ci) for material  2
   5010.50C   actinide
  0  0.00E+00  1.49E-01
  1  0.00E+00  1.48E-01
  2  0.00E+00  1.48E-01
  3  0.00E+00  1.47E-01
  4  0.00E+00  1.47E-01
  5  0.00E+00  1.46E-01
  6  0.00E+00  1.46E-01

Monteburns Heatload (W) of Material at End of Steps

Monteburns Heatloads (W) for material  1
   92235.54c 92238.54c  actinide
  0  1.23E-03  3.78E-03  5.00E-03
  1  1.09E-03  3.76E-03  4.85E-03
  2  9.62E-04  3.75E-03  4.71E-03
  3  8.51E-04  3.74E-03  4.59E-03
  4  7.50E-04  3.73E-03  4.48E-03
  5  6.59E-04  3.71E-03  4.37E-03
  6  5.75E-04  3.70E-03  4.28E-03

Monteburns Heatloads (W) for material  2
   5010.50C   actinide
  0  0.00E+00  3.78E-03
  1  0.00E+00  3.76E-03
  2  0.00E+00  3.75E-03
  3  0.00E+00  3.74E-03
  4  0.00E+00  3.73E-03
  5  0.00E+00  3.71E-03
  6  0.00E+00  3.70E-03

Monteburns Inhalation Toxicity (m^3 air) of Material at End of Steps

Monteburns Inhalation Toxicities (m^3 air) for material  1
   92235.54c 92238.54c  actinide
  0  2.34E+09  4.96E+10  5.20E+10
  1  2.07E+09  4.95E+10  5.15E+10
  2  1.84E+09  4.93E+10  5.11E+10
  3  1.62E+09  4.91E+10  5.08E+10
  4  1.43E+09  4.90E+10  5.04E+10
  5  1.26E+09  4.88E+10  5.01E+10
  6  1.10E+09  4.86E+10  4.97E+10

Monteburns Inhalation Toxicities (m^3 air) for material  2
   5010.50C   actinide
  0  0.00E+00  4.96E+10
  1  0.00E+00  4.95E+10
  2  0.00E+00  4.93E+10
  3  0.00E+00  4.91E+10
  4  0.00E+00  4.90E+10
  5  0.00E+00  4.88E+10
  6  0.00E+00  4.86E+10

 Monteburns Ingestion Toxicity (m^3 water) of Material at End of Steps

 Monteburns Ingestion Toxicities (m^3 water) for material  1
```

```
   92235.54c 92238.54c  actinide
  0  1.56E+03  3.72E+03  5.28E+03
  1  1.38E+03  3.71E+03  5.09E+03
  2  1.22E+03  3.70E+03  4.92E+03
  3  1.08E+03  3.69E+03  4.77E+03
  4  9.55E+02  3.67E+03  4.63E+03
  5  8.38E+02  3.66E+03  4.50E+03
  6  7.32E+02  3.65E+03  4.38E+03

 Monteburns Ingestion Toxicities (m^3 water) for material  2
   5010.50C   actinide
  0  0.00E+00  3.72E+03
  1  0.00E+00  3.71E+03
  2  0.00E+00  3.70E+03
  3  0.00E+00  3.69E+03
  4  0.00E+00  3.67E+03
  5  0.00E+00  3.66E+03
  6  0.00E+00  3.65E+03

Monteburns Inventory

Monteburns Grams of Feed per Step for material  1
mat #  days     92235.54c 92238.54c  actinide
  1   109.56    0.00E+00  0.00E+00  0.00E+00
  2   109.56    0.00E+00  0.00E+00  0.00E+00
  3   109.56    0.00E+00  0.00E+00  0.00E+00
  4   109.56    0.00E+00  0.00E+00  0.00E+00
  5   109.56    0.00E+00  0.00E+00  0.00E+00
  6   109.56    0.00E+00  0.00E+00  0.00E+00
tot  657.36    0.00E+00  0.00E+00  0.00E+00

Monteburns Grams Produced (or Destroyed)  for material  1
   92235.54c 92238.54c  actinide
  1 -2.47E+03 -1.40E+03 -2.26E+03
  2 -2.18E+03 -1.43E+03 -2.25E+03
  3 -1.96E+03 -1.45E+03 -2.24E+03
  4 -1.78E+03 -1.48E+03 -2.24E+03
  5 -1.62E+03 -1.48E+03 -2.22E+03
  6 -1.47E+03 -1.50E+03 -2.20E+03
tot-1.47E+03 -1.50E+03 -2.20E+03

Summary of Inventory/Feed/Production for material  1 (MCNP Material Number  2)
   92235.54c 92238.54c  actinide
ini 2.16E+04  4.43E+05  4.64E+05
fin 1.02E+04  4.34E+05  4.51E+05
fed 0.00E+00  0.00E+00  0.00E+00
net-1.47E+03 -1.50E+03 -2.20E+03

Monteburns Grams of Feed per Step for material  2
mat #  days     5010.50C   actinide
  1   109.56    0.00E+00  0.00E+00
  2   109.56    0.00E+00  0.00E+00
  3   109.56    0.00E+00  0.00E+00
  4   109.56    0.00E+00  0.00E+00
  5   109.56    0.00E+00  0.00E+00
  6   109.56    0.00E+00  0.00E+00
tot  657.36    0.00E+00  0.00E+00

Monteburns Grams Produced (or Destroyed)  for material  2
   5010.50C   actinide
  1 -2.26E+01  0.00E+00
  2 -1.76E+01  0.00E+00
  3 -1.28E+01  0.00E+00
  4 -8.48E+00  0.00E+00
  5 -4.88E+00  0.00E+00
  6 -2.36E+00  0.00E+00
tot-2.36E+00  0.00E+00

Summary of Inventory/Feed/Production for material  2 (MCNP Material Number  4)
   5010.50C   actinide
ini 7.03E+01  0.00E+00
fin 1.62E+00  0.00E+00
fed 0.00E+00  0.00E+00
net-2.36E+00  0.00E+00

Monteburns Inventory (cont.)

Feed Rate (g/day) for material  1 (MCNP Material Number  2)
   92235.54c 92238.54c  actinide
  1  0.00E+00  0.00E+00  0.00E+00
  2  0.00E+00  0.00E+00  0.00E+00
  3  0.00E+00  0.00E+00  0.00E+00
  4  0.00E+00  0.00E+00  0.00E+00
  5  0.00E+00  0.00E+00  0.00E+00
  6  0.00E+00  0.00E+00  0.00E+00

Production/Destruction Rate (g/day) for material  1 (MCNP Material Number  2)
   92235.54c 92238.54c  actinide
  1 -2.25E+01 -1.28E+01 -2.06E+01
  2 -1.99E+01 -1.31E+01 -2.05E+01
  3 -1.79E+01 -1.32E+01 -2.04E+01
  4 -1.62E+01 -1.35E+01 -2.04E+01
  5 -1.48E+01 -1.35E+01 -2.03E+01
  6 -1.34E+01 -1.37E+01 -2.01E+01
```

```
Feed Rate (g/day) for material  2 (MCNP Material Number  4)
   5010.50C   actinide
  1  0.00E+00  0.00E+00
  2  0.00E+00  0.00E+00
  3  0.00E+00  0.00E+00
  4  0.00E+00  0.00E+00
  5  0.00E+00  0.00E+00
  6  0.00E+00  0.00E+00

Production/Destruction Rate (g/day) for material  2 (MCNP Material Number  4)
   5010.50C   actinide
  1 -2.06E-01  0.00E+00
  2 -1.61E-01  0.00E+00
  3 -1.17E-01  0.00E+00
  4 -7.74E-02  0.00E+00
  5 -4.45E-02  0.00E+00
  6 -2.16E-02  0.00E+00

Time   Days   Power MBMat Feed Begin&EndRates Remov. Fraction F.P.Removed
 Step Burned  Fract.  #   #      grams/day    Group#
   1  13.086  1.000   1   1   0.697   0.691    0    0.000
   2  52.342  1.000   1   1    -1.0   0.670    0    0.000
   3  65.428  1.000   1   1    -1.0   0.643    0    0.000
   4  130.856 1.000   1   1    -1.0   0.590    0    0.000
   5  130.856 1.000   1   1    -1.0   0.537    0    0.000
   6  130.856 1.000   1   1    -1.0   0.483    0    0.000
   7  130.856 1.000   1   1    -1.0   0.430    0    0.000
   8  130.856 1.000   1   1    -1.0   0.377    0    0.000
   9  130.856 1.000   1   1    -1.0   0.323    0    0.000
  10  130.856 1.000   1   1    -1.0   0.270    0    0.000
   1                             ! # of feed specs
   1                             ! # of isos in Feed #1
5010  1.0
   0                             ! # of removal groups
```

The MCNP Input File B_4C/Al_2O_3 WABAs in Guide Tubes

```
RESEARCH 15 X 15 ASSEMBLY WITH B4CAL2O3 WABA'S 4.66% ENRICH NO BORON
1      0 20 -21 22 -23 90 -91 FILL=1 VOL=1.712434E+05
2      1 -0.660 30 -31 32 -33 LAT=1 U=1 FILL=-7:7 -7:7 0:0  $ BOUNDRY OF
ASSEMBLY
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 2 2 2 3 2 2 2 3 2 2 2 2 2
       2 2 2 3 2 2 2 2 2 2 2 3 2 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 3 2 2 3 2 2 2 3 2 2 3 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 2 2 2 2 2 4 2 2 2 2 2 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 3 2 2 3 2 2 2 3 2 2 3 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 2 3 2 2 2 2 2 2 2 3 2 2 2
       2 2 2 2 2 3 2 2 2 3 2 2 2 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
       2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
3      1    -0.660     -4 U=4 $WATER HOLE
                       VOL=257.835
4      3    -6.503 4 -5 U=4 $INTERIOR CLAD
                       VOL=77.57637
5      1    -0.660   5 -6 U=4 $GUIDE TUBE WATER RADIUS
                       VOL=113.8172
6      3    -6.503 6 -7 U=4 $GUIDE TUBE CLAD RADIUS
                       VOL=60.32794
7      1    -0.660   #3 #4 #5 #6 U=4 $UNIT CELL WATER
                       VOL=235.889
81     1    -0.660   -10 U=3 $WABA ANNULUS
                       VOL=91.83439674
82     3    -6.503   10 -11 U=3 $ANNULUS CLAD
                       VOL=37.48475999
83     0             11 -12 U=3 $ANNULUS GAP
                       VOL=10.87500659
8      4    -17.8    12 -13 U=3 $BPRA MATERIAL
                       VOL=43.24606456
84     0             13 -14 U=3 $WABA GAP
                       VOL=12.91032892
9      3    -6.503 14 -15 U=3 $INTERIOR CLAD
                       VOL=66.97335166
10     1    -0.660   15 -6 U=3 $GUIDE TUBE WATER RADIUS
                       VOL=185.904338
11     3    -6.503 6 -7 U=3 $GUIDE TUBE CLAD RADIUS
                       VOL=60.32794209
12     1    -0.660   #81 #82 #83 #84 #8 #9 #10 #11 U=3 $UNIT CELL WATER
                       VOL=235.8889535
13     2    -10.201    -8 U=2 $UO2 FUEL PELLET
                       VOL=248.3383489
14     0             8 -4 U=2 $GAP RADIUS
                       VOL=9.496242722
15     3    -6.503 4 -5 U=2 $FUEL PIN CLAD
                       VOL=77.57637049
16     1    -0.660   #13 #14 #15 U=2 $UNIT CELL WATER
                       VOL=410.0341799
17     1    -0.660   (-20:21:-22:23:-90:91) -9 $OUTSIDE OF ASSMBLY
                       VOL=3518.23905
99            0      9    $VOID REGION OUTSIDE ASSEMBLY

20            PX    -10.8225
21            PX     10.8225
```

```
22             PY    -10.8225
23             PY     10.8225
C   OUTSIDE OF ASSEMBLY LATICE
30             PX    -0.7215
31             PX     0.7215
32             PY    -0.7215
33             PY     0.7215
C  OUTSIDE OF UNIT CELL (1.443 PITCH)
10             CZ     0.28575
C  WABA CENTER WATER ANNULUS
11             CZ     0.33909
C  WABA ANNULUS CLAD
12             CZ     0.35306
C  WABA GAP
13             CZ     0.40386
C  WABA BP
14             CZ     0.41783
C  WABA GAP
15             CZ     0.48387
C  WABA CLAD
4              CZ     0.4788
C  CYLINDER FUEL GAP RADIUS
5              CZ     0.5461
C  CYLINDER INTERIOR CLAD RADIUS
6              CZ     0.6320
C  CYLINDER WATER RADIUS GUIDE TUBE
7              CZ     0.6731
C  CYLINDER CLAD RADIUS GUIDE TUBE
8              CZ     0.4699
C  CYLINDER RADIUS OF FUEL PELLET
*9             RPP    -10.905 10.905 -10.905 10.905 -180 180
C  RECT PARALLEL PIPED OUTSIDE OF ASSEMBLY
90             PZ     -179
91             PZ      179

MODE    N
IMP:N   1.0 20R 0.0
KCODE   2000    1.3     5       55      500
KSRC    1.443     0.0     0.0
M1      8016.60C        -8.88100E+01        1001.60C     -1.11900E+01
MT1     LWTR.04T $H20 AT 600 K
M2      92235.54C       -4.10779E+00       92238.54C     -8.40421623E+01
        8016.54C      -1.18500E+01
        $UO2 4.66% at 881K EN
M3      40000.60C 1.0 $ZIRCONIUM (APPROX. FOR ZIRCALLOY)
M4      5010.50C   -0.55   5011.56C -2.22 6000.60C   -0.76   13027.60C
        -51.04   8016.54C   -45.43  $B4CAL2O3 BP MATERIAL
PRINT
```

The MONTEBURNS Input File B_4C/Al_2O_3 WABAs in Guide Tubes

```
RESEARCH 15 X 15 ASSEMBLY WITH B4CAL2O3 WABA'S 4.66% ENRICH NO BORON
PC          ! Type of Operating System
2           ! Two MCNP Materials to burn (fuel cells/BPRAs)
2           ! MCNP material number #2 (will burn all cells with this mat)
4           ! MCNP material number #4 (will burn all cells with this mat)
51654.376   ! Material #2 volume (cc)
691.937     ! Material #4 volume (cc)
17.75       ! Power in MWt (for the entire system in MCNP)
-180.88     ! Recov. energy/fis (MeV); if negative use for U235, ratio isos
1095.6      ! Total number of days burned (used if no feed)
6           ! Number of outer burn steps
60          ! Number of internal burn steps (multiple of 10)
```

```
1          ! Number of predictor steps (+1 on first step), 1 usually sufficient
0          ! Step number to restart after (0=beginning)
PWRU50     ! number of default origen2 lib - next line is origen2 lib location
c:\Origen2\Libs
.005       ! fractional importance (track isos with abs,fis,atom,mass fraction)
1          ! Intermediate keff calc. 0) No 1) Yes
2          ! Number of automatic tally isotopes, followed by list.
92235.54c
92238.54c
1
5010.50C
```

The MONTEBURNS Output File B_4C/Al_2O_3 WABAs in Guide Tubes

RESEARCH 15 X 15 ASSEMBLY WITH B4CAL2O3 WABA'S 4.66% ENRICH NO BORON

Total Power (MW) = 1.78E+01 Days = 1.10E+03
outer steps = 6, # inner steps = 60, # predictor steps = 1
Importance Fraction = 0.0050

Monteburns MCNP k-eff Versus Time

	days	k-eff	rel err	nu	avQfis	eta
0m	0.00	1.19856	0.00183	2.465	181.081	1.374
1m	91.30	1.16363	0.00233	2.504	181.830	1.280
1e	182.60	1.15535	0.00197	2.538		
2m	273.90	1.14174	0.00188	2.567	182.870	1.202
2e	365.20	1.14286	0.00210	2.588		
3m	456.50	1.13365	0.00215	2.613	183.696	1.135
3e	547.80	1.13589	0.00187	2.628		
4m	639.10	1.12301	0.00169	2.652	184.404	1.087
4e	730.40	1.10041	0.00175	2.665		
5m	821.70	1.07796	0.00201	2.693	185.008	1.032
5e	913.00	1.05378	0.00209	2.703		
6m	1004.30	1.03883	0.00212	2.720	185.597	0.986
6e	1095.60	1.00852	0.00225	2.735		

Monteburns Transport History

Monteburns Transport History for material 1

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.081	3.38E+14	3.51E-02	1.78E+01	3.443E+02	0.000E+00	3.84E-01	5.15E-01	1.34E+00	1.68E-03	1.415	1.15E+00	1.54E+00	1.35E+00	5.04E-03	1.418
1	181.830	3.51E+14	3.36E-02	1.77E+01	3.433E+02	6.971E+00	4.30E-01	4.92E-01	1.15E+00	1.62E-03	1.340	1.20E+00	1.48E+00	1.23E+00	4.87E-03	1.384
2	182.870	3.65E+14	3.23E-02	1.78E+01	3.452E+02	1.398E+01	4.86E-01	4.74E-01	9.77E-01	1.60E-03	1.272	1.33E+00	1.44E+00	1.08E+00	4.83E-03	1.338
3	183.696	3.73E+14	3.13E-02	1.78E+01	3.437E+02	2.096E+01	5.31E-01	4.61E-01	8.68E-01	1.49E-03	1.217	1.42E+00	1.40E+00	9.90E-01	4.54E-03	1.303
4	184.404	3.83E+14	3.05E-02	1.78E+01	3.453E+02	2.797E+01	5.62E-01	4.50E-01	8.00E-01	1.72E-03	1.182	1.49E+00	1.38E+00	9.26E-01	5.24E-03	1.279
5	185.008	4.06E+14	2.86E-02	1.78E+01	3.443E+02	3.496E+01	5.90E-01	4.22E-01	7.16E-01	1.67E-03	1.127	1.54E+00	1.30E+00	8.44E-01	5.13E-03	1.236
6	185.597	4.26E+14	2.72E-02	1.78E+01	3.441E+02	4.195E+01	6.09E-01	4.02E-01	6.60E-01	1.70E-03	1.085	1.58E+00	1.25E+00	7.89E-01	5.25E-03	1.203

Monteburns Transport History for material 2

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	3.01E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.31E+00	0.00E+00	0.00E+00	7.38E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	3.20E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.05E+00	0.00E+00	0.00E+00	1.67E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	3.47E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	6.97E-01	0.00E+00	0.00E+00	1.24E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	3.65E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	3.06E-01	0.00E+00	0.00E+00	8.48E-08	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	3.87E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	8.84E-02	0.00E+00	0.00E+00	1.17E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	4.13E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.25E-02	0.00E+00	0.00E+00	2.12E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
6	0.000	4.36E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.08E-02	0.00E+00	0.00E+00	1.49E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

Monteburns Flux Spectrum

Monteburns Flux Spectrum for material 1

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	3.21	7.26	11.43	27.10	26.53	24.47
1	2.98	6.90	11.49	27.27	26.73	24.63
2	3.00	6.60	11.58	27.34	26.64	24.84
3	3.19	6.49	11.49	27.33	26.62	24.88
4	3.45	6.58	11.57	27.27	26.36	24.77
5	3.62	6.56	11.48	27.15	26.37	24.82
6	3.84	6.66	11.41	27.17	26.14	24.79

Monteburns Flux Spectrum for material 2

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	1.32	4.57	12.18	30.45	27.61	23.87
1	1.55	5.07	12.41	30.05	27.30	23.63
2	2.43	6.23	12.90	29.14	26.07	23.23
3	3.66	7.35	12.94	28.31	25.27	22.46
4	4.77	8.11	12.69	27.72	24.64	22.07
5	5.44	8.28	12.70	27.42	24.30	21.86
6	5.48	8.34	12.86	27.45	24.29	21.59

Monteburns 1-group n,gamma Cross Sections

Monteburns 1-group n,gamma Cross Sections for material 1

	92235.54c	92238.54c
0	7.51E+00	8.32E-01
1	7.27E+00	8.25E-01
2	7.26E+00	8.31E-01
3	7.39E+00	8.39E-01
4	7.64E+00	8.41E-01
5	7.80E+00	8.49E-01
6	8.03E+00	8.47E-01

Monteburns 1-group n,gamma Cross Sections for material 2

	5010.50C
0	1.56E-02
1	1.73E-02
2	2.28E-02
3	2.98E-02
4	3.59E-02
5	3.89E-02
6	3.92E-02

Monteburns 1-group Fission Cross Sections

Monteburns 1-group Fission Cross Sections for material 1

	92235.54c	92238.54c
0	3.07E+01	1.03E-01
1	2.91E+01	1.04E-01
2	2.88E+01	1.04E-01
3	2.95E+01	1.04E-01
4	3.09E+01	1.05E-01
5	3.16E+01	1.05E-01
6	3.29E+01	1.05E-01

Monteburns 1-group Fission Cross Sections for material 2

	5010.50C
0	2.70E-03
1	2.65E-03
2	2.62E-03
3	2.54E-03
4	2.53E-03
5	2.50E-03
6	2.48E-03

Monteburns Fission-to-Capture Ratio

Monteburns Fission-to-Capture Ratio for material 1

	92235.54c	92238.54c
0	4.0832	0.1235
1	4.0017	0.1255
2	3.9663	0.1254
3	3.9946	0.1246
4	4.0416	0.1246
5	4.0530	0.1231
6	4.0922	0.1236

Monteburns Fission-to-Capture Ratio for material 2

	5010.50C
0	0.0000
1	0.0000
2	0.0000
3	0.0000
4	0.0000
5	0.0000
6	0.0000

Monteburns Grams of Material at Beginning of Steps

Monteburns Grams of Material at Begin. of Steps for material 1

	92235.54c	92238.54c	actinide
0	2.16E+04	4.43E+05	4.64E+05
1	2.16E+04	4.43E+05	4.64E+05
2	1.77E+04	4.41E+05	4.61E+05
3	1.44E+04	4.38E+05	4.57E+05
4	1.16E+04	4.36E+05	4.53E+05
5	9.17E+03	4.33E+05	4.50E+05
6	7.12E+03	4.31E+05	4.46E+05

Monteburns Grams of Material at Begin. of Steps for material 2

	5010.50C	actinide
0	6.77E+01	0.00E+00
1	6.77E+01	0.00E+00
2	3.45E+01	0.00E+00
3	1.32E+01	0.00E+00

```
  4  3.52E+00  0.00E+00
  5  6.54E-01  0.00E+00
  6  9.32E-02  0.00E+00

Monteburns Grams of Material at End of Steps

Monteburns Grams of Material at End of Steps for material  1
   92235.54c 92238.54c  actinide
  0  2.16E+04  4.43E+05  4.64E+05
  1  1.77E+04  4.41E+05  4.61E+05
  2  1.44E+04  4.38E+05  4.57E+05
  3  1.16E+04  4.36E+05  4.53E+05
  4  9.17E+03  4.33E+05  4.50E+05
  5  7.12E+03  4.31E+05  4.46E+05
  6  5.41E+03  4.28E+05  4.42E+05

Monteburns Grams of Material at End of Steps for material  2
   5010.50C   actinide
  0  6.77E+01  0.00E+00
  1  3.45E+01  0.00E+00
  2  1.32E+01  0.00E+00
  3  3.52E+00  0.00E+00
  4  6.54E-01  0.00E+00
  5  9.32E-02  0.00E+00
  6  1.17E-02  0.00E+00

Monteburns Activity (Ci) of Material at End of Steps

Monteburns Activities (Ci) for material  1
   92235.54c 92238.54c  actinide
  0  4.68E-02  1.49E-01  1.96E-01
  1  3.83E-02  1.48E-01  1.86E-01
  2  3.11E-02  1.47E-01  1.78E-01
  3  2.50E-02  1.46E-01  1.72E-01
  4  1.98E-02  1.46E-01  1.65E-01
  5  1.54E-02  1.45E-01  1.60E-01
  6  1.17E-02  1.44E-01  1.56E-01

Monteburns Activities (Ci) for material  2
   5010.50C   actinide
  0  0.00E+00  1.49E-01
  1  0.00E+00  1.48E-01
  2  0.00E+00  1.47E-01
  3  0.00E+00  1.46E-01
  4  0.00E+00  1.46E-01
  5  0.00E+00  1.45E-01
  6  0.00E+00  1.44E-01

Monteburns Heatload (W) of Material at End of Steps

Monteburns Heatloads (W) for material  1
   92235.54c 92238.54c  actinide
  0  1.23E-03  3.78E-03  5.00E-03
  1  1.00E-03  3.76E-03  4.76E-03
  2  8.14E-04  3.74E-03  4.55E-03
  3  6.55E-04  3.72E-03  4.37E-03
  4  5.19E-04  3.69E-03  4.21E-03
  5  4.03E-04  3.67E-03  4.08E-03
  6  3.06E-04  3.65E-03  3.95E-03

Monteburns Heatloads (W) for material  2
   5010.50C   actinide
  0  0.00E+00  3.78E-03
  1  0.00E+00  3.76E-03
  2  0.00E+00  3.74E-03
  3  0.00E+00  3.72E-03
  4  0.00E+00  3.69E-03
  5  0.00E+00  3.67E-03
  6  0.00E+00  3.65E-03

Monteburns Inhalation Toxicity (m^3 air) of Material at End of Steps

Monteburns Inhalation Toxicities (m^3 air) for material  1
   92235.54c 92238.54c  actinide
  0  2.34E+09  4.96E+10  5.20E+10
  1  1.91E+09  4.94E+10  5.13E+10
  2  1.55E+09  4.91E+10  5.07E+10
  3  1.25E+09  4.88E+10  5.01E+10
  4  9.91E+08  4.86E+10  4.95E+10
  5  7.70E+08  4.83E+10  4.90E+10
  6  5.85E+08  4.79E+10  4.85E+10

Monteburns Inhalation Toxicities (m^3 air) for material  2
   5010.50C   actinide
  0  0.00E+00  4.96E+10
  1  0.00E+00  4.94E+10
  2  0.00E+00  4.91E+10
  3  0.00E+00  4.88E+10
  4  0.00E+00  4.86E+10
  5  0.00E+00  4.83E+10
  6  0.00E+00  4.79E+10

 Monteburns Ingestion Toxicity (m^3 water) of Material at End of Steps

 Monteburns Ingestion Toxicities (m^3 water) for material  1
```

```
   92235.54c 92238.54c  actinide
  0  1.56E+03  3.72E+03  5.28E+03
  1  1.28E+03  3.70E+03  4.98E+03
  2  1.04E+03  3.68E+03  4.72E+03
  3  8.34E+02  3.66E+03  4.50E+03
  4  6.61E+02  3.64E+03  4.30E+03
  5  5.13E+02  3.62E+03  4.13E+03
  6  3.90E+02  3.60E+03  3.99E+03

 Monteburns Ingestion Toxicities (m^3 water) for material  2
   5010.50C   actinide
  0  0.00E+00  3.72E+03
  1  0.00E+00  3.70E+03
  2  0.00E+00  3.68E+03
  3  0.00E+00  3.66E+03
  4  0.00E+00  3.64E+03
  5  0.00E+00  3.62E+03
  6  0.00E+00  3.60E+03

Monteburns Inventory

Monteburns Grams of Feed per Step for material  1
mat #  days     92235.54c 92238.54c  actinide
  1   182.60    0.00E+00  0.00E+00  0.00E+00
  2   182.60    0.00E+00  0.00E+00  0.00E+00
  3   182.60    0.00E+00  0.00E+00  0.00E+00
  4   182.60    0.00E+00  0.00E+00  0.00E+00
  5   182.60    0.00E+00  0.00E+00  0.00E+00
  6   182.60    0.00E+00  0.00E+00  0.00E+00
tot 1095.60    0.00E+00  0.00E+00  0.00E+00

Monteburns Grams Produced (or Destroyed)  for material  1
   92235.54c 92238.54c  actinide
  1 -3.94E+03 -2.28E+03 -3.74E+03
  2 -3.32E+03 -2.38E+03 -3.76E+03
  3 -2.81E+03 -2.43E+03 -3.70E+03
  4 -2.40E+03 -2.50E+03 -3.70E+03
  5 -2.05E+03 -2.64E+03 -3.68E+03
  6 -1.71E+03 -2.76E+03 -3.67E+03
tot-1.71E+03 -2.76E+03 -3.67E+03

Summary of Inventory/Feed/Production for material  1 (MCNP Material Number  2)
   92235.54c 92238.54c  actinide
ini 2.16E+04  4.43E+05  4.64E+05
fin 5.41E+03  4.28E+05  4.42E+05
fed 0.00E+00  0.00E+00  0.00E+00
net-1.71E+03 -2.76E+03 -3.67E+03

Monteburns Grams of Feed per Step for material  2
mat #  days     5010.50C   actinide
  1   182.60    0.00E+00  0.00E+00
  2   182.60    0.00E+00  0.00E+00
  3   182.60    0.00E+00  0.00E+00
  4   182.60    0.00E+00  0.00E+00
  5   182.60    0.00E+00  0.00E+00
  6   182.60    0.00E+00  0.00E+00
tot 1095.60    0.00E+00  0.00E+00

Monteburns Grams Produced (or Destroyed)  for material  2
   5010.50C   actinide
  1 -3.32E+01  0.00E+00
  2 -2.13E+01  0.00E+00
  3 -9.71E+00  0.00E+00
  4 -2.87E+00  0.00E+00
  5 -5.61E-01  0.00E+00
  6 -8.15E-02  0.00E+00
tot-8.15E-02  0.00E+00

Summary of Inventory/Feed/Production for material  2 (MCNP Material Number  4)
   5010.50C   actinide
ini 6.77E+01  0.00E+00
fin 1.17E-02  0.00E+00
fed 0.00E+00  0.00E+00
net-8.15E-02  0.00E+00

Monteburns Inventory (cont.)

Feed Rate (g/day) for material  1 (MCNP Material Number  2)
   92235.54c 92238.54c  actinide
  1  0.00E+00  0.00E+00  0.00E+00
  2  0.00E+00  0.00E+00  0.00E+00
  3  0.00E+00  0.00E+00  0.00E+00
  4  0.00E+00  0.00E+00  0.00E+00
  5  0.00E+00  0.00E+00  0.00E+00
  6  0.00E+00  0.00E+00  0.00E+00

Production/Destruction Rate (g/day) for material  1 (MCNP Material Number  2)
   92235.54c 92238.54c  actinide
  1 -2.16E+01 -1.25E+01 -2.05E+01
  2 -1.82E+01 -1.30E+01 -2.06E+01
  3 -1.54E+01 -1.33E+01 -2.03E+01
  4 -1.31E+01 -1.37E+01 -2.03E+01
  5 -1.12E+01 -1.45E+01 -2.02E+01
  6 -9.37E+00 -1.51E+01 -2.01E+01
```

```
Feed Rate (g/day) for material  2 (MCNP Material Number  4)
   5010.50C   actinide
  1  0.00E+00  0.00E+00
  2  0.00E+00  0.00E+00
  3  0.00E+00  0.00E+00
  4  0.00E+00  0.00E+00
  5  0.00E+00  0.00E+00
  6  0.00E+00  0.00E+00

Production/Destruction Rate (g/day) for material  2 (MCNP Material Number  4)
   5010.50C   actinide
  1 -1.82E-01  0.00E+00
  2 -1.17E-01  0.00E+00
  3 -5.32E-02  0.00E+00
  4 -1.57E-02  0.00E+00
  5 -3.07E-03  0.00E+00
  6 -4.46E-04  0.00E+00
```

The MCNP Input File L-Carborane BPRAs in Guide Tubes

```
RESEARCH 15 X 15 ASSEMBLY WITH L-CARBORANE 4.66% ENRICH NO BORON
1       0 20 -21 22 -23 90 -91 FILL=1 VOL=1.712434E+05
2       1 -0.660 30 -31 32 -33 LAT=1 U=1 FILL=-7:7 -7:7 0:0  $ BOUNDRY OF
ASSEMBLY
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 2 2 2 3 2 2 2 3 2 2 2 2 2
        2 2 2 3 2 2 2 2 2 2 2 3 2 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 3 2 2 3 2 2 2 3 2 2 3 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 2 2 2 2 2 4 2 2 2 2 2 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 3 2 2 3 2 2 2 3 2 2 3 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 2 3 2 2 2 2 2 2 2 3 2 2 2
        2 2 2 2 2 3 2 2 2 3 2 2 2 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
        2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
3       1    -0.660     -4 U=4 $WATER HOLE
                        VOL=257.8345
4       3    -6.503 4 -5 U=4 $INTERIOR CLAD
                        VOL=77.57637
5       1    -0.660   5 -6 U=4 $GUIDE TUBE WATER RADIUS
                        VOL=113.8173
6       3    -6.503 6 -7 U=4 $GUIDE TUBE CLAD RADIUS
                        VOL=60.32794
7       1    -0.660   #3 #4 #5 #6 U=4 $UNIT CELL WATER
                        VOL=235.8889
8       4    -0.9     -4 U=3 $BPRA MATERIAL
                        VOL=257.8345
9       3    -6.503 4 -5 U=3 $INTERIOR CLAD
                        VOL=77.57637
10      1    -0.660   5 -6 U=3 $GUIDE TUBE WATER RADIUS
                        VOL=113.8173
11      3    -6.503 6 -7 U=3 $GUIDE TUBE CLAD RADIUS
                        VOL=60.32794
12      1    -0.660   #8 #9 #10 #11 U=3 $UNIT CELL WATER
                        VOL=235.8889
13      2    -10.201    -8 U=2 $UO2 FUEL PELLET
                        VOL=248.3383
14      0               8 -4 U=2 $GAP RADIUS
                        VOL=9.496242
15      3    -6.503 4 -5 U=2 $FUEL PIN CLAD
                        VOL=77.57637
16      1    -0.660   #13 #14 #15 U=2 $UNIT CELL WATER
                        VOL=410.0342
```

```
17     1    -0.660   (-20:21:-22:23:-90:91) -9 $OUTSIDE OF ASSMBLY
                     VOL=3518.23905
99             0      9    $VOID REGION OUTSIDE ASSEMBLY

20             PX    -10.8225
21             PX     10.8225
22             PY    -10.8225
23             PY     10.8225
C   OUTSIDE OF ASSEMBLY LATICE
30             PX    -0.7215
31             PX     0.7215
32             PY    -0.7215
33             PY     0.7215
C  OUTSIDE OF UNIT CELL (1.443 PITCH)
4              CZ     0.4788
C  CYLINDER BPRA / WATER HOLE / GAP RADIUS
5              CZ     0.5461
C  CYLINDER INTERIOR CLAD RADIUS
6              CZ     0.6320
C  CYLINDER WATER RADIUS GUIDE TUBE
7              CZ     0.6731
C  CYLINDER CLAD RADIUS GUIDE TUBE
8              CZ     0.4699
C  CYLINDER RADIUS OF FUEL PELLET
*9             RPP    -10.905 10.905 -10.905 10.905 -180 180
C  RECT PARALLEL PIPED OUTSIDE OF ASSEMBLY
90             PZ     -179
91             PZ      179

MODE    N
IMP:N   1.0 16R 0.0
KCODE   2000    1.3     5       55      500
KSRC    1.443     0.0     0.0
M1      8016.60C        -8.88100E+01        1001.60C     -1.11900E+01
MT1     LWTR.04T $H20 AT 600 K
M2      92235.54C       -4.10779E+00       92238.54C     -8.40421623E+01
        8016.54C      -1.18500E+01
        $UO2 4.66% at 881K EN
M3      40000.60C 1.0 $ZIRCONIUM (APPROX. FOR ZIRCALLOY)
M4      6000.60C  -46.40 14000.60C  -29.60 8016.54C -7.03
        5010.50C  -1.90 5011.56C -7.63 1001.60C  -7.44 $L-CARBORANE BP MATERIAL
PRINT
```

The MONTEBURNS Input File L-Carborane BPRAs in Guide Tubes

```
RESEARCH 15 X 15 ASSEMBLY WITH L-CARBORANE 4.66% ENRICH NO BORON
PC          ! Type of Operating System
2           ! Two MCNP Materials to burn (fuel cells/BPRAs)
2           ! MCNP material number #2 (will burn all cells with this mat)
4           ! MCNP material number #4 (will burn all cells with this mat)
51654.376   ! Material #2 volume (cc)
4125.353    ! Material #4 volume (cc)
17.75       ! Power in MWt (for the entire system in MCNP)
-180.88     ! Recov. energy/fis (MeV); if negative use for U235, ratio isos
657.36      ! Total number of days burned (used if no feed)
6           ! Number of outer burn steps
60          ! Number of internal burn steps (multiple of 10)
1           ! Number of predictor steps (+1 on first step), 1 usually sufficient
0           ! Step number to restart after (0=beginning)
PWRU50      ! number of default origen2 lib - next line is origen2 lib location
c:\Origen2\Libs
.005        ! fractional importance (track isos with abs,fis,atom,mass fraction)
1           ! Intermediate keff calc. 0) No 1) Yes
```

```
2          ! Number of automatic tally isotopes, followed by list.
92235.54c
92238.54c
1
5010.50C
```

The MONTEBURNS Output File L-Carborane BPRAs in Guide Tubes

RESEARCH 15 X 15 ASSEMBLY WITH L-CARBORANE 4.66% ENRICH NO BORON

Total Power (MW) = 1.78E+01 Days = 6.57E+02
outer steps = 6, # inner steps = 60, # predictor steps = 1
Importance Fraction = 0.0050

Monteburns MCNP k-eff Versus Time

	days	k-eff	rel err	nu	avQfis	eta
0m	0.00	1.16843	0.00241	2.461	181.088	1.390
1m	54.78	1.14333	0.00159	2.491	181.565	1.320
1e	109.56	1.14679	0.00218	2.516		
2m	164.34	1.14439	0.00201	2.533	182.306	1.273
2e	219.12	1.14328	0.00163	2.549		
3m	273.90	1.14204	0.00217	2.575	182.896	1.235
3e	328.68	1.14701	0.00225	2.581		
4m	383.46	1.15168	0.00198	2.596	183.390	1.197
4e	438.24	1.14953	0.00175	2.609		
5m	493.02	1.15067	0.00188	2.617	183.827	1.166
5e	547.80	1.14722	0.00177	2.632		
6m	602.58	1.13757	0.00208	2.638	184.214	1.133
6e	657.36	1.12390	0.00201	2.652		

Monteburns Transport History

Monteburns Transport History for material 1

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material					for actinide				
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	181.088	3.44E+14	3.42E-02	1.76E+01	3.416E+02	0.000E+00	3.80E-01	5.01E-01	1.32E+00	1.55E-03	1.404	1.13E+00	1.50E+00	1.33E+00	4.66E-03	1.407
1	181.565	3.54E+14	3.34E-02	1.77E+01	3.434E+02	4.184E+00	4.17E-01	4.89E-01	1.17E+00	1.60E-03	1.348	1.17E+00	1.47E+00	1.26E+00	4.82E-03	1.392
2	182.306	3.58E+14	3.28E-02	1.77E+01	3.429E+02	8.361E+00	4.51E-01	4.82E-01	1.07E+00	1.77E-03	1.312	1.25E+00	1.45E+00	1.16E+00	5.34E-03	1.364
3	182.896	3.65E+14	3.23E-02	1.79E+01	3.457E+02	1.257E+01	4.87E-01	4.75E-01	9.76E-01	1.61E-03	1.275	1.33E+00	1.44E+00	1.09E+00	4.86E-03	1.343
4	183.390	3.64E+14	3.21E-02	1.77E+01	3.435E+02	1.676E+01	5.16E-01	4.73E-01	9.16E-01	1.62E-03	1.244	1.39E+00	1.44E+00	1.03E+00	4.91E-03	1.323
5	183.827	3.68E+14	3.16E-02	1.77E+01	3.422E+02	2.093E+01	5.37E-01	4.65E-01	8.66E-01	1.63E-03	1.218	1.43E+00	1.42E+00	9.92E-01	4.97E-03	1.307
6	184.214	3.75E+14	3.10E-02	1.77E+01	3.436E+02	2.512E+01	5.60E-01	4.57E-01	8.17E-01	1.61E-03	1.189	1.48E+00	1.40E+00	9.43E-01	4.91E-03	1.284

Monteburns Transport History for material 2

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material					for actinide				
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	0.000	3.11E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.83E+00	0.00E+00	0.00E+00	7.01E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	3.24E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.61E+00	0.00E+00	0.00E+00	7.68E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	3.33E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.23E+00	0.00E+00	0.00E+00	7.28E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	3.48E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	8.55E-01	0.00E+00	0.00E+00	9.25E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	3.57E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	4.97E-01	0.00E+00	0.00E+00	9.19E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	3.67E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.23E-01	0.00E+00	0.00E+00	8.79E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
6	0.000	3.79E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	9.07E-02	0.00E+00	0.00E+00	1.08E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

Monteburns Flux Spectrum

Monteburns Flux Spectrum for material 1

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	3.10	7.07	11.47	27.03	26.61	24.73
1	2.91	6.92	11.55	27.10	26.51	25.02
2	2.92	6.68	11.59	27.19	26.68	24.94
3	2.99	6.56	11.55	27.22	26.56	25.12
4	3.18	6.58	11.50	27.18	26.53	25.03
5	3.36	6.56	11.47	27.19	26.43	24.99
6	3.55	6.62	11.49	27.12	26.32	24.89

Monteburns Flux Spectrum for material 2

	<.1eV	<1eV	<100eV	<100keV	<1MeV	<20MeV
0	1.56	4.71	12.65	30.48	26.58	24.02
1	1.72	5.22	12.70	30.01	26.37	23.97
2	2.36	5.75	13.12	29.49	25.90	23.38
3	3.31	6.53	13.07	28.86	25.12	23.10
4	4.65	7.04	13.14	28.17	24.61	22.40
5	5.61	7.45	12.91	27.74	23.98	22.31
6	6.39	7.85	12.96	27.26	23.61	21.95

Monteburns 1-group n,gamma Cross Sections

Monteburns 1-group n,gamma Cross Sections for material 1

	92235.54c	92238.54c
0	7.37E+00	8.25E-01
1	7.20E+00	8.25E-01
2	7.17E+00	8.22E-01
3	7.20E+00	8.27E-01
4	7.37E+00	8.31E-01
5	7.50E+00	8.33E-01
6	7.69E+00	8.40E-01

Monteburns 1-group n,gamma Cross Sections for material 2

	5010.50C
0	1.70E-02
1	1.85E-02
2	2.21E-02
3	2.75E-02
4	3.43E-02
5	3.96E-02
6	4.37E-02

Monteburns 1-group Fission Cross Sections

Monteburns 1-group Fission Cross Sections for material 1

	92235.54c	92238.54c
0	2.98E+01	1.04E-01
1	2.88E+01	1.05E-01
2	2.85E+01	1.05E-01
3	2.87E+01	1.06E-01
4	2.96E+01	1.05E-01
5	3.03E+01	1.05E-01
6	3.14E+01	1.05E-01

Monteburns 1-group Fission Cross Sections for material 2

	5010.50C
0	2.71E-03
1	2.71E-03
2	2.64E-03
3	2.64E-03
4	2.57E-03
5	2.56E-03
6	2.54E-03

Monteburns Fission-to-Capture Ratio

Monteburns Fission-to-Capture Ratio for material 1

	92235.54c	92238.54c
0	4.0430	0.1258
1	4.0013	0.1274
2	3.9749	0.1277
3	3.9819	0.1282
4	4.0121	0.1269
5	4.0472	0.1262
6	4.0760	0.1244

Monteburns Fission-to-Capture Ratio for material 2

	5010.50C
0	0.0000
1	0.0000
2	0.0000
3	0.0000
4	0.0000
5	0.0000
6	0.0000

Monteburns Grams of Material at Beginning of Steps

Monteburns Grams of Material at Begin. of Steps for material 1

	92235.54c	92238.54c	actinide
0	2.16E+04	4.43E+05	4.64E+05
1	2.16E+04	4.43E+05	4.64E+05
2	1.92E+04	4.41E+05	4.62E+05
3	1.70E+04	4.40E+05	4.60E+05
4	1.50E+04	4.39E+05	4.58E+05
5	1.32E+04	4.37E+05	4.56E+05
6	1.16E+04	4.36E+05	4.53E+05

Monteburns Grams of Material at Begin. of Steps for material 2

	5010.50C	actinide
0	7.05E+01	0.00E+00
1	7.05E+01	0.00E+00
2	4.56E+01	0.00E+00
3	2.67E+01	0.00E+00

```
  4  1.33E+01  0.00E+00
  5  5.46E+00  0.00E+00
  6  1.90E+00  0.00E+00

Monteburns Grams of Material at End of Steps

Monteburns Grams of Material at End of Steps for material  1
   92235.54c 92238.54c  actinide
  0  2.16E+04  4.43E+05  4.64E+05
  1  1.92E+04  4.41E+05  4.62E+05
  2  1.70E+04  4.40E+05  4.60E+05
  3  1.50E+04  4.39E+05  4.58E+05
  4  1.32E+04  4.37E+05  4.56E+05
  5  1.16E+04  4.36E+05  4.53E+05
  6  1.01E+04  4.34E+05  4.51E+05

Monteburns Grams of Material at End of Steps for material  2
   5010.50C   actinide
  0  7.05E+01  0.00E+00
  1  4.56E+01  0.00E+00
  2  2.67E+01  0.00E+00
  3  1.33E+01  0.00E+00
  4  5.46E+00  0.00E+00
  5  1.90E+00  0.00E+00
  6  5.70E-01  0.00E+00

Monteburns Activity (Ci) of Material at End of Steps

Monteburns Activities (Ci) for material  1
   92235.54c 92238.54c  actinide
  0  4.68E-02  1.49E-01  1.96E-01
  1  4.15E-02  1.48E-01  1.90E-01
  2  3.68E-02  1.48E-01  1.85E-01
  3  3.25E-02  1.47E-01  1.80E-01
  4  2.86E-02  1.47E-01  1.76E-01
  5  2.51E-02  1.47E-01  1.72E-01
  6  2.18E-02  1.46E-01  1.68E-01

Monteburns Activities (Ci) for material  2
   5010.50C   actinide
  0  0.00E+00  1.49E-01
  1  0.00E+00  1.48E-01
  2  0.00E+00  1.48E-01
  3  0.00E+00  1.47E-01
  4  0.00E+00  1.47E-01
  5  0.00E+00  1.47E-01
  6  0.00E+00  1.46E-01

Monteburns Heatload (W) of Material at End of Steps

Monteburns Heatloads (W) for material  1
   92235.54c 92238.54c  actinide
  0  1.23E-03  3.78E-03  5.00E-03
  1  1.09E-03  3.76E-03  4.85E-03
  2  9.63E-04  3.75E-03  4.72E-03
  3  8.50E-04  3.74E-03  4.59E-03
  4  7.49E-04  3.73E-03  4.48E-03
  5  6.56E-04  3.72E-03  4.37E-03
  6  5.71E-04  3.70E-03  4.28E-03

Monteburns Heatloads (W) for material  2
   5010.50C   actinide
  0  0.00E+00  3.78E-03
  1  0.00E+00  3.76E-03
  2  0.00E+00  3.75E-03
  3  0.00E+00  3.74E-03
  4  0.00E+00  3.73E-03
  5  0.00E+00  3.72E-03
  6  0.00E+00  3.70E-03

Monteburns Inhalation Toxicity (m^3 air) of Material at End of Steps

Monteburns Inhalation Toxicities (m^3 air) for material  1
   92235.54c 92238.54c  actinide
  0  2.34E+09  4.96E+10  5.20E+10
  1  2.07E+09  4.95E+10  5.15E+10
  2  1.84E+09  4.93E+10  5.12E+10
  3  1.62E+09  4.92E+10  5.08E+10
  4  1.43E+09  4.90E+10  5.04E+10
  5  1.25E+09  4.88E+10  5.01E+10
  6  1.09E+09  4.87E+10  4.98E+10

Monteburns Inhalation Toxicities (m^3 air) for material  2
   5010.50C   actinide
  0  0.00E+00  4.96E+10
  1  0.00E+00  4.95E+10
  2  0.00E+00  4.93E+10
  3  0.00E+00  4.92E+10
  4  0.00E+00  4.90E+10
  5  0.00E+00  4.88E+10
  6  0.00E+00  4.87E+10

 Monteburns Ingestion Toxicity (m^3 water) of Material at End of Steps

 Monteburns Ingestion Toxicities (m^3 water) for material  1
```

```
   92235.54c 92238.54c  actinide
  0  1.56E+03  3.72E+03  5.28E+03
  1  1.38E+03  3.71E+03  5.09E+03
  2  1.23E+03  3.70E+03  4.92E+03
  3  1.08E+03  3.69E+03  4.77E+03
  4  9.53E+02  3.67E+03  4.63E+03
  5  8.36E+02  3.66E+03  4.50E+03
  6  7.27E+02  3.65E+03  4.38E+03

 Monteburns Ingestion Toxicities (m^3 water) for material  2
   5010.50C   actinide
  0  0.00E+00  3.72E+03
  1  0.00E+00  3.71E+03
  2  0.00E+00  3.70E+03
  3  0.00E+00  3.69E+03
  4  0.00E+00  3.67E+03
  5  0.00E+00  3.66E+03
  6  0.00E+00  3.65E+03

Monteburns Inventory

Monteburns Grams of Feed per Step for material  1
mat #  days     92235.54c 92238.54c  actinide
  1   109.56    0.00E+00  0.00E+00  0.00E+00
  2   109.56    0.00E+00  0.00E+00  0.00E+00
  3   109.56    0.00E+00  0.00E+00  0.00E+00
  4   109.56    0.00E+00  0.00E+00  0.00E+00
  5   109.56    0.00E+00  0.00E+00  0.00E+00
  6   109.56    0.00E+00  0.00E+00  0.00E+00
tot  657.36    0.00E+00  0.00E+00  0.00E+00

Monteburns Grams Produced (or Destroyed)  for material  1
   92235.54c 92238.54c  actinide
  1 -2.46E+03 -1.38E+03 -2.24E+03
  2 -2.18E+03 -1.38E+03 -2.23E+03
  3 -1.98E+03 -1.43E+03 -2.26E+03
  4 -1.79E+03 -1.43E+03 -2.24E+03
  5 -1.63E+03 -1.43E+03 -2.21E+03
  6 -1.50E+03 -1.48E+03 -2.23E+03
tot-1.50E+03 -1.48E+03 -2.23E+03

Summary of Inventory/Feed/Production for material  1 (MCNP Material Number  2)
   92235.54c 92238.54c  actinide
ini 2.16E+04  4.43E+05  4.64E+05
fin 1.01E+04  4.34E+05  4.51E+05
fed 0.00E+00  0.00E+00  0.00E+00
net-1.50E+03 -1.48E+03 -2.23E+03

Monteburns Grams of Feed per Step for material  2
mat #  days     5010.50C   actinide
  1   109.56    0.00E+00  0.00E+00
  2   109.56    0.00E+00  0.00E+00
  3   109.56    0.00E+00  0.00E+00
  4   109.56    0.00E+00  0.00E+00
  5   109.56    0.00E+00  0.00E+00
  6   109.56    0.00E+00  0.00E+00
tot  657.36    0.00E+00  0.00E+00

Monteburns Grams Produced (or Destroyed)  for material  2
   5010.50C   actinide
  1 -2.50E+01  0.00E+00
  2 -1.89E+01  0.00E+00
  3 -1.34E+01  0.00E+00
  4 -7.85E+00  0.00E+00
  5 -3.56E+00  0.00E+00
  6 -1.33E+00  0.00E+00
tot-1.33E+00  0.00E+00

Summary of Inventory/Feed/Production for material  2 (MCNP Material Number  4)
   5010.50C   actinide
ini 7.05E+01  0.00E+00
fin 5.70E-01  0.00E+00
fed 0.00E+00  0.00E+00
net-1.33E+00  0.00E+00

Monteburns Inventory (cont.)

Feed Rate (g/day) for material  1 (MCNP Material Number  2)
   92235.54c 92238.54c  actinide
  1  0.00E+00  0.00E+00  0.00E+00
  2  0.00E+00  0.00E+00  0.00E+00
  3  0.00E+00  0.00E+00  0.00E+00
  4  0.00E+00  0.00E+00  0.00E+00
  5  0.00E+00  0.00E+00  0.00E+00
  6  0.00E+00  0.00E+00  0.00E+00

Production/Destruction Rate (g/day) for material  1 (MCNP Material Number  2)
   92235.54c 92238.54c  actinide
  1 -2.25E+01 -1.26E+01 -2.04E+01
  2 -1.99E+01 -1.26E+01 -2.04E+01
  3 -1.81E+01 -1.31E+01 -2.06E+01
  4 -1.63E+01 -1.31E+01 -2.04E+01
  5 -1.49E+01 -1.31E+01 -2.02E+01
  6 -1.37E+01 -1.35E+01 -2.04E+01
```

Feed Rate (g/day) for material 2 (MCNP Material Number 4)

	5010.50C	actinide
1	0.00E+00	0.00E+00
2	0.00E+00	0.00E+00
3	0.00E+00	0.00E+00
4	0.00E+00	0.00E+00
5	0.00E+00	0.00E+00
6	0.00E+00	0.00E+00

Production/Destruction Rate (g/day) for material 2 (MCNP Material Number 4)

	5010.50C	actinide
1	-2.28E-01	0.00E+00
2	-1.73E-01	0.00E+00
3	-1.22E-01	0.00E+00
4	-7.17E-02	0.00E+00
5	-3.25E-02	0.00E+00
6	-1.21E-02	0.00E+00

APPENDIX C
MULTIPLE ASSEMBLY (COLORSET) CASMO FILES

This appendix contains all of the input and output files for the multiple assembly depletion calculations for CASMO. The output files have been abbreviated to the final state point and final k_{eff} vs. burnup summary in order to save space.

The 2x2 Colorset CAMSO Input File B_4C/Al_2O_3 BPRAs.

```
TIT  *Crystal River-3 15x15 Assembly with WATER in guide
tubes
*2 x 2 COLORSET
BAS  3 0  *BASE 3 diagonal symmetry DEP and PDE refer to
average
TFU=990  TMO=583  BOR=0
FUE  1 10.4/4.66  *FUEL COMP. #, DENSITY/ENRICHMENT fresh
fuel
MI2  3.1/5010=0.55 6000=0.76 13000=51.04 8000=45.43
*  Mixture 2: B10, C, Al, O (BP Material)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  2 .4699 .4788 .5461 .632 .6731/ 'MI2' 'AIR' 'CAN'
'COO' 'CAN'/1,3,5
*  BPRA pin homogenized 'AIR+CAN' and 'COO+CAN'
PIN  3 .632 .6731/ 'COO' 'CAN'  *Center water hole / empty
shroud tube
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI
3
1 1                                *Common segment
information
1 1 3                              *Fresh fuel
1 1 1 1                            *NO BPRAs
1 1 1 1 3
1 1 3 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
PDE  33  *POWER DENSITY (W/Gu)
DEP  0.5 2.5 5 10 15 20 25 30 35 40 *Depletion steps
*
*  SEGMENT SPECIFIC INPUT
*
```

```
SEG 1  *+DEPLETED FUEL 2.268% NO BPRAs
FUE 1 10.4/2.268
LPI
3
1 1                                 *Segment information
1 1 3                               *Low Enrich depleted fuel
1 1 1 1                             *B4C-AL2O2 BPRAs
1 1 1 1 3
1 1 3 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
*
SEG 2 *+LOW ENRICHED DEPELTED FUEL NO BPRAs
*
SEG 3 *+MEDIUM ENRICHED DEPLETED FUEL NO BPRAs
FUE 1 10.4/3.4
LPI
3
1 1                                 *Segment information
1 1 3                               *Medium fuel
1 1 1 1
1 1 1 1 3
1 1 3 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
*
STA
END
```

The 2x2 Colorset CASMO Output File Water in Guide Tubes

```
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/04/15   20:38:09   JOB=SUN        STATE POINT NO = 11 PAGE =  129
 * Crystal River-3 15x15 Assembly with WATER in guide tubes
0      S U M M A R Y  O F  2 X 2  S E G M E N T  C A L C U L A T I O N
0      Crystal River-3 15x15 Assembly with WATER in guide tubes

       SEGMENT 1  Crystal River-3 15x15 Assembly with WATER in guide tubes    DEPLETED FUE
       SEGMENT 2  Crystal River-3 15x15 Assembly with WATER in guide tubes    LOW ENRICHED
       SEGMENT 3  Crystal River-3 15x15 Assembly with WATER in guide tubes    MEDIUM ENRIC
0           SEGMENT            1            2            3            4      AVERAGE

                 E       35.768       47.044       41.421       35.768       40.000
                 V        0.000        0.000        0.000        0.000        0.000
                TF      990.000      990.000      990.000      990.000      990.000
                TM      583.000      583.000      583.000      583.000      583.000
               BOR        0.000        0.000        0.000        0.000        0.000
           CONTROL

        NUFISS/ABS      0.88354      0.96681      0.92198      0.88354      0.91526
      2-GROUP K-INF     0.88834      0.95996      0.91899      0.88834      0.91391
      2-GROUP    M2       60.28        59.68        59.95        60.28        60.05
         POWER FRAC        0.925        1.137        1.012        0.925        1.000
         POWER DENS        0.925        1.137        1.012        0.925        1.000
0                                                                            TOTAL
         ABSORPTION  1.05797E+00  1.15918E+00  1.09524E+00  1.05797E+00  4.37036E+00
            FISSION  3.33114E-01  4.11871E-01  3.65473E-01  3.33114E-01  1.44357E+00
          NUFISSION  9.34752E-01  1.12071E+00  1.00979E+00  9.34752E-01  4.00000E+00
         NORM. FACT  9.34752E-01  1.12071E+00  1.00979E+00  9.34752E-01

 POWER DISTRIBUTION *W/CM* INCLUDING GAMMA SMEARING

             0.000 1.023 1.009 1.006 1.004 1.002 0.998 1.004 | 0.921 0.907 0.908 0.907 0.908 0.911 0.927 0.000
             1.023 1.025 1.023 1.015 1.014 1.017 1.007 1.005 | 0.922 0.917 0.925 0.918 0.919 0.927 0.929 0.927
             1.009 1.023 0.000 1.024 1.023 0.000 1.015 1.007 | 0.924 0.927 0.000 0.931 0.931 0.000 0.928 0.912
             1.006 1.015 1.024 1.028 1.032 1.028 1.010 1.006 | 0.924 0.920 0.939 0.942 0.935 0.932 0.921 0.911
             1.004 1.014 1.023 1.032 0.000 1.019 1.000 1.005 | 0.923 0.910 0.930 0.000 0.944 0.935 0.922 0.912
             1.002 1.017 0.000 1.028 1.019 1.009 0.997 1.005 | 0.922 0.908 0.920 0.932 0.943 0.000 0.931 0.914
             0.998 1.007 1.015 1.010 1.000 0.997 0.995 1.006 | 0.925 0.910 0.911 0.915 0.927 0.935 0.926 0.916
             1.004 1.005 1.007 1.006 1.005 1.005 1.006 1.015 | 0.939 0.928 0.928 0.931 0.934 0.935 0.934 0.933
              ---------------------------------------------------------------------------------------------
             0.921 0.922 0.924 0.924 0.923 0.922 0.925 0.939 | 1.119 1.116 1.119 1.122 1.125 1.126 1.125 1.124
             0.907 0.917 0.927 0.920 0.910 0.908 0.910 0.928 | 1.116 1.113 1.117 1.123 1.135 1.141 1.134 1.124
             0.908 0.925 0.000 0.939 0.930 0.920 0.911 0.928 | 1.119 1.117 1.133 1.145 1.157 0.000 1.146 1.131
             0.907 0.918 0.931 0.942 0.000 0.932 0.915 0.931 | 1.122 1.123 1.145 0.000 1.163 1.155 1.144 1.134
             0.908 0.919 0.931 0.935 0.944 0.943 0.927 0.934 | 1.125 1.135 1.157 1.163 1.161 1.157 1.148 1.137
```

```
             0.911 0.927 0.000 0.932 0.935 0.000 0.935 0.935 | 1.126 1.141 0.000 1.155 1.157 0.000 1.156 1.143
             0.927 0.929 0.928 0.921 0.922 0.931 0.926 0.934 | 1.125 1.134 1.146 1.144 1.148 1.156 1.160 1.158
             0.000 0.927 0.912 0.911 0.912 0.914 0.916 0.933 | 1.124 1.124 1.131 1.134 1.137 1.143 1.158 0.000


0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  35.7680 TYPE OF FILE = 470 STATEP =  12
0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  47.0450 TYPE OF FILE = 470 STATEP =  12
0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  41.4220 TYPE OF FILE = 470 STATEP =  12
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/04/15   20:38:09   JOB=SUN        STATE POINT NO = 12 PAGE =  130
 * Crystal River-3 15x15 Assembly with WATER in guide tubes
 END                                                                    INPUT CARD


  LIST OF WARNINGS ENCOUNTERED:
  -----------------------------
  ROUTINE      TEXT
  -------      ----
 MIXS  SUM OF WEIGHT PERCENTAGES LESS THAN 99.9
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/04/15   20:38:09   JOB=SUN             PAGE =  131
0       ** C A S M O -3   SUMMARY  ** SEGMENT NO = 1
0         Crystal River-3 15x15 Assembly with WATER in guide tubes    DEPLETED FUEL 2.268%
0       HVOI=  0.0 HTFU=  990.0 HTMO=  583.0 HBOR=    0.0
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                            MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

         1  0.0   990.0  583.0    0.0        0.000 1.25396 1.26725  60.27   1.076   2.268   0.000   0.000
         2                                   0.435 1.20264 1.21430  60.03   1.075   2.217   0.021   0.022
         3                                   2.181 1.18341 1.19398  59.82   1.072   2.027   0.117   0.124
         4                                   4.379 1.15464 1.16448  59.63   1.067   1.815   0.212   0.235
         5                                   8.790 1.10033 1.10926  59.52   1.056   1.453   0.348   0.414
         6                                  13.222 1.05358 1.06172  59.53   1.047   1.156   0.441   0.556
         7                                  17.676 1.01196 1.01940  59.62   1.038   0.911   0.506   0.672
         8                                  22.151 0.97441 0.98117  59.76   1.031   0.711   0.552   0.769
         9                                  26.654 0.94050 0.94659  59.92   1.026   0.548   0.583   0.850
        10                                  31.190 0.91017 0.91562  60.10   1.022   0.417   0.605   0.918
        11                                  35.768 0.88354 0.88834  60.28   1.020   0.314   0.620   0.977


  LIST OF WARNINGS ENCOUNTERED:
  -----------------------------
  ROUTINE      TEXT
  -------      ----
 MIXS  SUM OF WEIGHT PERCENTAGES LESS THAN 99.9
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/04/15   20:38:09   JOB=SUN             PAGE =  132
0       ** C A S M O -3   SUMMARY  ** SEGMENT NO = 2
0         Crystal River-3 15x15 Assembly with WATER in guide tubes    LOW ENRICHED DEPELTE
0       HVOI=  0.0 HTFU=  990.0 HTMO=  583.0 HBOR=    0.0
```

```
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                           MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

         1  0.0   990.0  583.0    0.0        0.000 1.43413 1.41720  58.15   1.110   4.660   0.000   0.000
         2                                   0.601 1.37493 1.36029  58.01   1.107   4.588   0.020   0.020
         3                                   3.000 1.34590 1.33255  57.96   1.097   4.309   0.113   0.118
         4                                   5.979 1.31201 1.29956  58.01   1.083   3.983   0.211   0.228
         5                                  11.918 1.24940 1.23795  58.18   1.062   3.389   0.365   0.417
         6                                  17.839 1.19408 1.18345  58.40   1.043   2.861   0.479   0.575
         7                                  23.742 1.14352 1.13363  58.65   1.033   2.390   0.564   0.708
         8                                  29.623 1.09600 1.08683  58.92   1.030   1.974   0.625   0.820
         9                                  35.474 1.05077 1.04236  59.18   1.027   1.608   0.668   0.914
        10                                  41.286 1.00768 1.00002  59.44   1.025   1.292   0.696   0.994
        11                                  47.044 0.96681 0.95996  59.68   1.022   1.022   0.713   1.061


  LIST OF WARNINGS ENCOUNTERED:
  -----------------------------
  ROUTINE      TEXT
  -------      ----
 MIXS  SUM OF WEIGHT PERCENTAGES LESS THAN 99.9
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/04/15   20:38:09   JOB=SUN             PAGE =  133
0       ** C A S M O -3   SUMMARY  ** SEGMENT NO = 3
0         Crystal River-3 15x15 Assembly with WATER in guide tubes    MEDIUM ENRICHED DEPL
0       HVOI=  0.0 HTFU=  990.0 HTMO=  583.0 HBOR=    0.0
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                           MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

         1  0.0   990.0  583.0    0.0        0.000 1.36997 1.36090  59.06   1.048   3.400   0.000   0.000
         2                                   0.528 1.31184 1.30385  58.88   1.047   3.337   0.020   0.021
         3                                   2.637 1.28456 1.27741  58.75   1.042   3.098   0.114   0.120
         4                                   5.264 1.25065 1.24403  58.70   1.040   2.823   0.209   0.229
         5                                  10.503 1.18812 1.18214  58.75   1.038   2.336   0.353   0.412
         6                                  15.717 1.13378 1.12835  58.89   1.035   1.917   0.455   0.560
         7                                  20.907 1.08473 1.07979  59.07   1.032   1.557   0.528   0.683
         8                                  26.075 1.03932 1.03488  59.28   1.028   1.249   0.580   0.785
         9                                  31.218 0.99695 0.99301  59.50   1.025   0.989   0.615   0.871
        10                                  36.333 0.95775 0.95428  59.73   1.022   0.772   0.638   0.943
        11                                  41.421 0.92198 0.91899  59.95   1.020   0.594   0.653   1.004
```

The 2x2 Colorset CASMO Input File B_4C/Al_2O_3 BPRAs in Guide Tubes

```
TIT  *Crystal River-3 15x15 Assembly with B4C-AL2O2 in
guide tubes
*2 x 2 COLORSET
BAS  3 0  *BASE 3 diagonal symmetry DEP and PDE refer to
average
TFU=990  TMO=583  BOR=0
FUE  1 10.4/4.66  *FUEL COMP. #, DENSITY/ENRICHMENT fresh
fuel
MI2  3.1/5010=0.55 6000=0.76 13000=51.04 8000=45.43
*  Mixture 2: B10, C, Al, O (BP Material)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  2 .4699 .4788 .5461 .632 .6731/ 'MI2' 'AIR' 'CAN'
'COO' 'CAN'/1,3,5
*  BPRA pin homogenized 'AIR+CAN' and 'COO+CAN'
PIN  3 .632 .6731/ 'COO' 'CAN'  *Center water hole / empty
shroud tube
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI
3
1 1                                *Common segment
information
1 1 2                              *Fresh fuel
1 1 1 1                            *B4C-AL2O2 BPRAs
1 1 1 1 2
1 1 2 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
PDE  33  *POWER DENSITY (W/Gu)
DEP  0.5 2.5 5 10 15 20 25 30 35 40 *Depletion steps
*
*  SEGMENT SPECIFIC INPUT
*
SEG 1  *+DEPLETED FUEL 2.268% NO BPRAs
FUE 1 10.4/2.268
LPI
3
1 1                                *Segment information
1 1 3                              *Low Enrich depleted fuel
1 1 1 1                            *No BPRAs
1 1 1 1 3
1 1 3 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
*
SEG 2 *+LOW ENRICHED DEPELTED FUEL NO BPRAs
```

```
*
SEG 3 *+MEDIUM ENRICHED DEPLETED FUEL NO BPRAs
FUE 1 10.4/3.4
LPI
3
1 1                                 *Segment information
1 1 3                               *Medium fuel
1 1 1 1
1 1 1 1 3
1 1 3 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
*
STA
END
```

The 2x2 Colorset CASMO Output File B_4C/Al_2O_3 BPRAs in Guide Tubes

```
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/04/15   20:37:12   JOB=SUN        STATE POINT NO = 11 PAGE =  129
 * Crystal River-3 15x15 Assembly with B4C-AL2O2 in guide tubes
0      S U M M A R Y   O F   2 X 2   S E G M E N T   C A L C U L A T I O N
0      Crystal River-3 15x15 Assembly with B4C-AL2O2 in guide tubes

       SEGMENT 1  Crystal River-3 15x15 Assembly with B4C-AL2O2 in guide tubes    DEPLETED
       SEGMENT 2  Crystal River-3 15x15 Assembly with B4C-AL2O2 in guide tubes    LOW ENRI
       SEGMENT 3  Crystal River-3 15x15 Assembly with B4C-AL2O2 in guide tubes    MEDIUM E
0            SEGMENT            1            2            3            4      AVERAGE

                   E       36.610       44.002       42.779       36.610       40.000
                   V        0.000        0.000        0.000        0.000        0.000
                  TF      990.000      990.000      990.000      990.000      990.000
                  TM      583.000      583.000      583.000      583.000      583.000
                 BOR        0.000        0.000        0.000        0.000        0.000
              CONTROL

          NUFISS/ABS      0.87906      0.98776      0.91301      0.87906      0.91611
       2-GROUP K-INF      0.88463      0.97860      0.91004      0.88463      0.91448
       2-GROUP    M2        60.11        61.67        59.84        60.11        60.43
          POWER FRAC        0.924        1.153        0.999        0.924        1.000
          POWER DENS        0.924        1.153        0.999        0.924        1.000
0                                                                             TOTAL
          ABSORPTION  1.06301E+00  1.14682E+00  1.09345E+00  1.06301E+00  4.36628E+00
             FISSION  3.32599E-01  4.18073E-01  3.60481E-01  3.32599E-01  1.44375E+00
           NUFISSION  9.34446E-01  1.13278E+00  9.98327E-01  9.34446E-01  4.00000E+00
          NORM. FACT  9.34444E-01  1.13278E+00  9.98327E-01  9.34444E-01

 POWER DISTRIBUTION *W/CM* INCLUDING GAMMA SMEARING

              0.000 1.005 0.992 0.990 0.988 0.988 0.984 0.991 | 0.915 0.902 0.903 0.903 0.905 0.908 0.924 0.000
              1.005 1.008 1.005 0.999 0.998 1.002 0.993 0.992 | 0.916 0.911 0.920 0.914 0.915 0.924 0.925 0.924
              0.992 1.005 0.000 1.008 1.007 0.000 1.001 0.994 | 0.918 0.922 0.000 0.927 0.928 0.000 0.926 0.910
              0.990 0.999 1.008 1.012 1.016 1.014 0.997 0.995 | 0.919 0.916 0.936 0.939 0.933 0.930 0.920 0.909
              0.988 0.998 1.007 1.016 0.000 1.005 0.988 0.995 | 0.919 0.907 0.928 0.000 0.943 0.934 0.922 0.912
              0.988 1.002 0.000 1.014 1.005 0.997 0.987 0.996 | 0.920 0.907 0.919 0.932 0.944 0.000 0.933 0.916
              0.984 0.993 1.001 0.997 0.988 0.987 0.987 0.998 | 0.923 0.909 0.912 0.917 0.929 0.938 0.929 0.919
              0.991 0.992 0.994 0.995 0.995 0.996 0.998 1.010 | 0.939 0.929 0.930 0.934 0.937 0.940 0.939 0.938
               ---------------------------------------------------------------------------------------------
              0.915 0.916 0.918 0.919 0.919 0.920 0.923 0.939 | 1.118 1.117 1.121 1.126 1.132 1.135 1.134 1.133
              0.902 0.911 0.922 0.916 0.907 0.907 0.909 0.929 | 1.117 1.115 1.122 1.131 1.148 1.165 1.147 1.135
              0.903 0.920 0.000 0.936 0.928 0.919 0.912 0.930 | 1.121 1.122 1.143 1.171 1.188 0.000 1.171 1.143
              0.903 0.914 0.927 0.939 0.000 0.932 0.917 0.934 | 1.126 1.131 1.171 0.000 1.198 1.186 1.160 1.145
              0.905 0.915 0.928 0.933 0.943 0.944 0.929 0.937 | 1.132 1.148 1.188 1.198 1.186 1.189 1.165 1.150
```

```
             0.908 0.924 0.000 0.930 0.934 0.000 0.938 0.940 | 1.135 1.165 0.000 1.186 1.189 0.000 1.186 1.160
             0.924 0.925 0.926 0.920 0.922 0.933 0.929 0.939 | 1.134 1.147 1.171 1.160 1.165 1.186 1.182 1.181
             0.000 0.924 0.910 0.909 0.912 0.916 0.919 0.938 | 1.133 1.135 1.143 1.145 1.150 1.160 1.181 0.000


0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  36.6110 TYPE OF FILE = 470 STATEP =  12
0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  44.0030 TYPE OF FILE = 470 STATEP =  12
0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  42.7800 TYPE OF FILE = 470 STATEP =  12
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/04/15   20:37:12   JOB=SUN        STATE POINT NO = 12 PAGE =  130
 * Crystal River-3 15x15 Assembly with B4C-AL2O2 in guide tubes
 END                                                                    INPUT CARD


  LIST OF WARNINGS ENCOUNTERED:
  -----------------------------
  ROUTINE      TEXT
  -------      ----
 MIXS  SUM OF WEIGHT PERCENTAGES LESS THAN 99.9
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/04/15   20:37:12   JOB=SUN             PAGE =  131
0       ** C A S M O -3   SUMMARY  ** SEGMENT NO = 1
0         Crystal River-3 15x15 Assembly with B4C-AL2O2 in guide tubes    DEPLETED FUEL 2.
0       HVOI=  0.0 HTFU=  990.0 HTMO=  583.0 HBOR=    0.0
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                           MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

         1  0.0   990.0  583.0    0.0        0.000 1.25229 1.26693  60.63   1.088   2.268   0.000   0.000
         2                                   0.462 1.20023 1.21302  60.35   1.088   2.214   0.023   0.023
         3                                   2.310 1.17977 1.19151  60.07   1.083   2.015   0.124   0.132
         4                                   4.625 1.14953 1.16051  59.84   1.075   1.793   0.222   0.247
         5                                   9.248 1.09376 1.10374  59.64   1.061   1.421   0.361   0.432
         6                                  13.846 1.04649 1.05560  59.57   1.048   1.120   0.454   0.576
         7                                  18.414 1.00494 1.01323  59.57   1.038   0.878   0.517   0.692
         8                                  22.955 0.96781 0.97535  59.64   1.031   0.681   0.561   0.787
         9                                  27.486 0.93453 0.94139  59.77   1.026   0.524   0.591   0.866
        10                                  32.032 0.90500 0.91117  59.93   1.023   0.399   0.611   0.933
        11                                  36.610 0.87906 0.88463  60.11   1.022   0.300   0.626   0.990


  LIST OF WARNINGS ENCOUNTERED:
  -----------------------------
  ROUTINE      TEXT
  -------      ----
 MIXS  SUM OF WEIGHT PERCENTAGES LESS THAN 99.9
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/04/15   20:37:12   JOB=SUN             PAGE =  132
0       ** C A S M O -3   SUMMARY  ** SEGMENT NO = 2
0         Crystal River-3 15x15 Assembly with B4C-AL2O2 in guide tubes    LOW ENRICHED DEP
0       HVOI=  0.0 HTFU=  990.0 HTMO=  583.0 HBOR=    0.0
```

```
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                           MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

         1  0.0   990.0  583.0    0.0        0.000 1.23846 1.21935  57.76   1.369   4.660   0.000   0.000
         2                                   0.495 1.19765 1.18115  57.78   1.355   4.600   0.019   0.019
         3                                   2.482 1.18613 1.17117  57.97   1.320   4.369   0.107   0.111
         4                                   4.984 1.17383 1.15998  58.22   1.275   4.094   0.203   0.217
         5                                  10.084 1.15140 1.13869  58.82   1.196   3.579   0.361   0.405
         6                                  15.377 1.13572 1.12357  59.47   1.125   3.099   0.486   0.569
         7                                  20.874 1.12041 1.10877  60.15   1.066   2.651   0.583   0.711
         8                                  26.551 1.09772 1.08658  60.71   1.023   2.237   0.655   0.833
         9                                  32.350 1.06490 1.05434  61.12   1.035   1.860   0.707   0.937
        10                                  38.187 1.02659 1.01674  61.43   1.038   1.524   0.743   1.025
        11                                  44.002 0.98776 0.97860  61.67   1.039   1.233   0.766   1.101


  LIST OF WARNINGS ENCOUNTERED:
  -----------------------------
  ROUTINE      TEXT
  -------      ----
 MIXS  SUM OF WEIGHT PERCENTAGES LESS THAN 99.9
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/04/15   20:37:12   JOB=SUN             PAGE =  133
0       ** C A S M O -3   SUMMARY  ** SEGMENT NO = 3
0         Crystal River-3 15x15 Assembly with B4C-AL2O2 in guide tubes    MEDIUM ENRICHED
0       HVOI=  0.0 HTFU=  990.0 HTMO=  583.0 HBOR=    0.0
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                           MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

         1  0.0   990.0  583.0    0.0        0.000 1.36875 1.36077  59.52   1.042   3.400   0.000   0.000
         2                                   0.581 1.30890 1.30175  59.28   1.043   3.331   0.022   0.023
         3                                   2.899 1.27952 1.27296  59.10   1.045   3.070   0.124   0.131
         4                                   5.767 1.24277 1.23662  59.00   1.044   2.773   0.226   0.249
         5                                  11.420 1.17714 1.17143  58.96   1.041   2.259   0.374   0.441
         6                                  16.931 1.12146 1.11619  59.00   1.036   1.829   0.475   0.592
         7                                  22.299 1.07220 1.06726  59.09   1.031   1.471   0.545   0.713
         8                                  27.539 1.02717 1.02265  59.23   1.026   1.172   0.592   0.811
         9                                  32.678 0.98567 0.98165  59.43   1.022   0.924   0.623   0.893
        10                                  37.750 0.94749 0.94404  59.62   1.020   0.719   0.643   0.961
        11                                  42.779 0.91301 0.91004  59.84   1.018   0.553   0.655   1.019
```

The 2x2 Colorset CASMO Input File B_4C/Al_2O_3 WABAs in Guide Tubes

```
TIT  *Crystal River-3 15x15 Assembly with B4C-AL2O3 WABA in
guide tubes
*2 x 2 COLORSET
BAS  3 0  *BASE 3 diagonal symmetry DEP and PDE refer to
average
TFU=990  TMO=583  BOR=0
FUE  1 10.4/4.66  *FUEL COMP. #, DENSITY/ENRICHMENT fresh
fuel
MI2  17.8/5010=0.55 5011=2.22 6000=0.76 13000=51.04
8000=45.43
*  Mixture 2: B10, C, Al, O (BP Material)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  2 .28575 .33909 .35306 .40386 .41783 .48387 .632
.6731/
'COO' 'CAN' 'AIR' 'MI2' 'AIR' 'CAN' 'COO' 'CAN'/3,4,8
*  WABA BPRA pin
PIN  3 .632 .6731/ 'COO' 'CAN'  *Center water hole / empty
shroud tube
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI
3
1 1                              *Common segment
information
1 1 2                            *Fresh fuel
1 1 1 1                          *CARBORANE BPRAs
1 1 1 1 2
1 1 2 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
PDE  33  *POWER DENSITY (W/Gu)
DEP  0.5 2.5 5 10 15 20 25 30 35 40 *Depletion steps
*
*  SEGMENT SPECIFIC INPUT
*
SEG 1  *+DEPLETED FUEL 2.268% NO BPRAs
FUE 1 10.4/2.268
LPI
3
1 1                              *Segment information
1 1 3                            *Low Enrich depleted fuel
1 1 1 1                          *No BPRAs
1 1 1 1 3
1 1 3 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
```

```
*
SEG 2 *+LOW ENRICHED DEPELTED FUEL NO BPRAs
*
*
SEG 3 *+MEDIUM ENRICHED DEPLETED FUEL NO BPRAs
FUE 1 10.4/3.4
LPI
3
1 1                                 *Segment information
1 1 3                               *Medium fuel
1 1 1 1
1 1 1 1 3
1 1 3 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
*
STA
END
```

The 2x2 Colorset CASMO Output File B_4C/Al_2O_3 WABAs in Guide Tubes

```
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/10/19   09:02:20   JOB=SUN        STATE POINT NO = 11 PAGE =  129
 * Crystal River-3 15x15 Assembly with B4C-AL2O3 WABA in guide tubes
0      S U M M A R Y   O F   2 X 2   S E G M E N T   C A L C U L A T I O N
0      Crystal River-3 15x15 Assembly with B4C-AL2O3 WABA in guide tubes

       SEGMENT 1  Crystal River-3 15x15 Assembly with B4C-AL2O3 WABA in guide tubes
       SEGMENT 2  Crystal River-3 15x15 Assembly with B4C-AL2O3 WABA in guide tubes
       SEGMENT 3  Crystal River-3 15x15 Assembly with B4C-AL2O3 WABA in guide tubes
0            SEGMENT            1            2            3            4      AVERAGE

                   E       36.428       44.603       42.542       36.428       40.000
                   V        0.000        0.000        0.000        0.000        0.000
                  TF      990.000      990.000      990.000      990.000      990.000
                  TM      583.000      583.000      583.000      583.000      583.000
                 BOR        0.000        0.000        0.000        0.000        0.000
              CONTROL

          NUFISS/ABS      0.88008      0.98436      0.91459      0.88008      0.91640
       2-GROUP K-INF      0.88538      0.97619      0.91158      0.88538      0.91463
       2-GROUP    M2        60.13        59.47        59.85        60.13        59.89
          POWER FRAC        0.921        1.162        0.996        0.921        1.000
          POWER DENS        0.921        1.162        0.996        0.921        1.000
0                                                                             TOTAL
          ABSORPTION  1.05816E+00  1.15986E+00  1.08872E+00  1.05816E+00  4.36491E+00
             FISSION  3.31560E-01  4.21195E-01  3.59693E-01  3.31560E-01  1.44401E+00
           NUFISSION  9.31272E-01  1.14173E+00  9.95731E-01  9.31272E-01  4.00000E+00
          NORM. FACT  9.31271E-01  1.14173E+00  9.95730E-01  9.31271E-01

 POWER DISTRIBUTION *W/CM* INCLUDING GAMMA SMEARING

              0.000 1.003 0.990 0.987 0.986 0.985 0.982 0.989 | 0.912 0.898 0.900 0.900 0.901 0.905 0.920 0.000
              1.003 1.006 1.003 0.997 0.996 0.999 0.991 0.990 | 0.913 0.908 0.917 0.911 0.912 0.921 0.922 0.921
              0.990 1.003 0.000 1.005 1.005 0.000 0.999 0.992 | 0.915 0.919 0.000 0.924 0.924 0.000 0.922 0.907
              0.987 0.997 1.005 1.009 1.014 1.011 0.994 0.992 | 0.916 0.913 0.932 0.936 0.929 0.927 0.916 0.906
              0.986 0.996 1.005 1.014 0.000 1.003 0.986 0.992 | 0.916 0.904 0.925 0.000 0.940 0.931 0.919 0.908
              0.985 0.999 0.000 1.011 1.003 0.994 0.984 0.993 | 0.916 0.904 0.916 0.929 0.941 0.000 0.930 0.913
              0.982 0.991 0.999 0.994 0.986 0.984 0.984 0.995 | 0.920 0.906 0.909 0.914 0.926 0.935 0.926 0.917
              0.989 0.990 0.992 0.992 0.992 0.993 0.995 1.007 | 0.936 0.926 0.928 0.931 0.935 0.938 0.937 0.936
               ---------------------------------------------------------------------------------------------
              0.912 0.913 0.915 0.916 0.916 0.916 0.920 0.936 | 1.117 1.117 1.122 1.128 1.134 1.138 1.137 1.136
              0.898 0.908 0.919 0.913 0.904 0.904 0.906 0.926 | 1.117 1.117 1.125 1.137 1.156 1.174 1.154 1.141
              0.900 0.917 0.000 0.932 0.925 0.916 0.909 0.928 | 1.122 1.125 1.151 1.183 1.202 0.000 1.183 1.152
              0.900 0.911 0.924 0.936 0.000 0.929 0.914 0.931 | 1.128 1.137 1.183 0.000 1.215 1.202 1.173 1.157
              0.901 0.912 0.924 0.929 0.940 0.941 0.926 0.935 | 1.134 1.156 1.202 1.215 1.203 1.206 1.179 1.162
```

```
              0.905 0.921 0.000 0.927 0.931 0.000 0.935 0.938 | 1.138 1.174 0.000 1.202 1.206 0.000 1.201 1.171
              0.920 0.922 0.922 0.916 0.919 0.930 0.926 0.937 | 1.137 1.154 1.183 1.173 1.179 1.201 1.194 1.189
              0.000 0.921 0.907 0.906 0.908 0.913 0.917 0.936 | 1.136 1.141 1.152 1.157 1.162 1.171 1.189 0.000


0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  36.4290 TYPE OF FILE = 470 STATEP =  12
0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  44.6040 TYPE OF FILE = 470 STATEP =  12
0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  42.5430 TYPE OF FILE = 470 STATEP =  12
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/10/19   09:02:20   JOB=SUN        STATE POINT NO = 12 PAGE =  130
 * Crystal River-3 15x15 Assembly with B4C-AL2O3 WABA in guide tubes
 END                                                                  INPUT CARD
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/10/19   09:02:20   JOB=SUN             PAGE =  131
0       ** C A S M O -3   SUMMARY  ** SEGMENT NO = 1
0         Crystal River-3 15x15 Assembly with B4C-AL2O3 WABA in guide tubes       DEPLETED
0       HVOI=  0.0 HTFU=  990.0 HTMO=  583.0 HBOR=    0.0
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                           MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

          1  0.0  990.0  583.0    0.0        0.000 1.25252 1.26700  60.62   1.088   2.268   0.000   0.000
          2                                  0.459 1.20053 1.21318  60.34   1.087   2.214   0.023   0.023
          3                                  2.297 1.18018 1.19178  60.07   1.082   2.016   0.123   0.131
          4                                  4.600 1.15009 1.16093  59.84   1.075   1.795   0.221   0.246
          5                                  9.200 1.09451 1.10435  59.64   1.061   1.424   0.359   0.430
          6                                 13.776 1.04736 1.05631  59.57   1.048   1.124   0.452   0.574
          7                                 18.321 1.00593 1.01403  59.57   1.038   0.882   0.516   0.690
          8                                 22.837 0.96891 0.97622  59.64   1.031   0.686   0.560   0.784
          9                                 27.344 0.93568 0.94228  59.77   1.026   0.528   0.589   0.863
         10                                 31.868 0.90610 0.91201  59.95   1.023   0.402   0.610   0.930
         11                                 36.428 0.88008 0.88538  60.13   1.022   0.303   0.624   0.987
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/10/19   09:02:20   JOB=SUN             PAGE =  132
0       ** C A S M O -3   SUMMARY  ** SEGMENT NO = 2
0         Crystal River-3 15x15 Assembly with B4C-AL2O3 WABA in guide tubes       LOW ENRI
0       HVOI=  0.0 HTFU=  990.0 HTMO=  583.0 HBOR=    0.0
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                           MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

          1  0.0  990.0  583.0    0.0        0.000 1.24423 1.22585  55.89   1.340   4.660   0.000   0.000
          2                                  0.504 1.20235 1.18645  55.89   1.327   4.599   0.019   0.019
          3                                  2.527 1.18978 1.17537  56.04   1.295   4.364   0.107   0.111
          4                                  5.072 1.17634 1.16302  56.26   1.252   4.084   0.203   0.217
          5                                 10.252 1.15235 1.14020  56.80   1.177   3.561   0.360   0.405
          6                                 15.619 1.13657 1.12504  57.41   1.108   3.074   0.483   0.567
          7                                 21.190 1.12227 1.11134  58.05   1.048   2.620   0.577   0.707
          8                                 26.952 1.09962 1.08934  58.58   1.040   2.200   0.646   0.826
          9                                 32.832 1.06494 1.05534  58.98   1.048   1.818   0.695   0.928
         10                                 38.734 1.02469 1.01580  59.25   1.048   1.481   0.727   1.013
         11                                 44.603 0.98436 0.97619  59.47   1.046   1.189   0.748   1.086
```

0 ** C A S M O -3 SUMMARY ** SEGMENT NO = 3

0 Crystal River-3 15x15 Assembly with B4C-AL2O3 WABA in guide tubes MEDIUM E

0 HVOI= 0.0 HTFU= 990.0 HTMO= 583.0 HBOR= 0.0

NO	VOID	TFU	TMO	BOR	CRD	BURNUP MWD/KG	K-INF	K-INF TWO-GROUP	M2	PIN PEAK	U-235 WT %	FISS PU WT %	TOT PU WT %
1	0.0	990.0	583.0	0.0		0.000	1.36886	1.36079	59.51	1.042	3.400	0.000	0.000
2						0.577	1.30910	1.30191	59.28	1.043	3.331	0.022	0.023
3						2.879	1.27990	1.27330	59.09	1.045	3.072	0.123	0.130
4						5.728	1.24337	1.23719	59.00	1.044	2.777	0.224	0.247
5						11.348	1.17801	1.17228	58.96	1.041	2.265	0.372	0.438
6						16.828	1.12251	1.11722	59.00	1.036	1.837	0.474	0.589
7						22.167	1.07341	1.06845	59.09	1.031	1.479	0.544	0.710
8						27.373	1.02864	1.02407	59.23	1.026	1.181	0.591	0.809
9						32.481	0.98728	0.98320	59.42	1.023	0.933	0.622	0.890
10						37.531	0.94911	0.94561	59.63	1.020	0.727	0.642	0.958
11						42.542	0.91459	0.91158	59.85	1.018	0.560	0.654	1.016

The 2x2 Colorset CASMO Input File L-Carborane BPRAs in Guide Tubes

```
TIT  *Crystal River-3 15x15 Assembly with CARBORANE in
guide tubes
*2 x 2 COLORSET
BAS  3 0  *BASE 3 diagonal symmetry DEP and PDE refer to
average
TFU=990  TMO=583  BOR=0
FUE  1 10.4/4.66  *FUEL COMP. #, DENSITY/ENRICHMENT fresh
fuel
MI2  0.9/6000=46.40 14000=29.60 8000=7.03 5010=1.90
1001=7.44
*  Mixture 2: C, Si, O, B10, H (CARBORANE BP Material)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  2 .4699 .4788 .5461 .632 .6731/ 'MI2' 'AIR' 'CAN'
'COO' 'CAN'/1,3,5
*  BPRA pin homogenized 'AIR+CAN' and 'COO+CAN'
PIN  3 .632 .6731/ 'COO' 'CAN'  *Center water hole / empty
shroud tube
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI
3
1 1                              *Common segment
information
1 1 2                            *Fresh fuel
1 1 1 1                          *CARBORANE BPRAs
1 1 1 1 2
1 1 2 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
PDE  33  *POWER DENSITY (W/Gu)
DEP  0.5 2.5 5 10 15 20 25 30 35 40 *Depletion steps
*
*  SEGMENT SPECIFIC INPUT
*
SEG 1  *+DEPLETED FUEL 2.268% NO BPRAs
FUE 1 10.4/2.268
LPI
3
1 1                              *Segment information
1 1 3                            *Low Enrich depleted fuel
1 1 1 1                          *No BPRAs
1 1 1 1 3
1 1 3 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
```

```
*
SEG 2 *+LOW ENRICHED DEPELTED FUEL NO BPRAs
*
*
SEG 3 *+MEDIUM ENRICHED DEPLETED FUEL NO BPRAs
FUE 1 10.4/3.4
LPI
3
1 1                                 *Segment information
1 1 3                               *Medium fuel
1 1 1 1
1 1 1 1 3
1 1 3 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
*
STA
END
```

The 2x2 Colorset CASMO Output File L-Carborane BPRAs in Guide Tubes

```
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/04/15   20:38:54   JOB=SUN        STATE POINT NO = 11 PAGE =  129
 * Crystal River-3 15x15 Assembly with CARBORANE in guide tubes
0      S U M M A R Y  O F  2 X 2  S E G M E N T  C A L C U L A T I O N
0      Crystal River-3 15x15 Assembly with CARBORANE in guide tubes

       SEGMENT 1  Crystal River-3 15x15 Assembly with CARBORANE in guide tubes    DEPLETED
       SEGMENT 2  Crystal River-3 15x15 Assembly with CARBORANE in guide tubes    LOW ENRI
       SEGMENT 3  Crystal River-3 15x15 Assembly with CARBORANE in guide tubes    MEDIUM E
0            SEGMENT            1            2            3            4      AVERAGE

                  E       36.396       44.703       42.505       36.396       40.000
                  V        0.000        0.000        0.000        0.000        0.000
                 TF      990.000      990.000      990.000      990.000      990.000
                 TM      583.000      583.000      583.000      583.000      583.000
                BOR        0.000        0.000        0.000        0.000        0.000
            CONTROL

         NUFISS/ABS      0.88031      0.98549      0.91483      0.88031      0.91692
       2-GROUP K-INF      0.88555      0.97753      0.91183      0.88555      0.91511
       2-GROUP    M2        60.16        60.64        59.86        60.16        60.20
          POWER FRAC        0.920        1.165        0.995        0.920        1.000
          POWER DENS        0.920        1.165        0.995        0.920        1.000
0                                                                             TOTAL
          ABSORPTION  1.05691E+00  1.16141E+00  1.08721E+00  1.05691E+00  4.36245E+00
             FISSION  3.31273E-01  4.22261E-01  3.59315E-01  3.31273E-01  1.44412E+00
           NUFISSION  9.30414E-01  1.14455E+00  9.94617E-01  9.30414E-01  4.00000E+00
          NORM. FACT  9.30413E-01  1.14455E+00  9.94616E-01  9.30413E-01

 POWER DISTRIBUTION *W/CM* INCLUDING GAMMA SMEARING

              0.000 1.002 0.989 0.986 0.985 0.984 0.981 0.988 | 0.911 0.897 0.899 0.899 0.900 0.903 0.919 0.000
              1.002 1.005 1.002 0.996 0.995 0.998 0.990 0.989 | 0.912 0.907 0.916 0.910 0.911 0.919 0.921 0.920
              0.989 1.002 0.000 1.004 1.004 0.000 0.997 0.991 | 0.914 0.918 0.000 0.923 0.923 0.000 0.921 0.906
              0.986 0.996 1.004 1.008 1.013 1.010 0.993 0.991 | 0.915 0.912 0.931 0.935 0.928 0.926 0.915 0.905
              0.985 0.995 1.004 1.013 0.000 1.002 0.985 0.991 | 0.915 0.903 0.924 0.000 0.939 0.930 0.918 0.908
              0.984 0.998 0.000 1.010 1.002 0.993 0.983 0.992 | 0.916 0.903 0.915 0.928 0.940 0.000 0.929 0.912
              0.981 0.990 0.997 0.993 0.985 0.983 0.983 0.995 | 0.919 0.906 0.908 0.913 0.926 0.935 0.926 0.916
              0.988 0.989 0.991 0.991 0.991 0.992 0.995 1.006 | 0.935 0.925 0.927 0.931 0.935 0.938 0.937 0.936
               ---------------------------------------------------------------------------------------------
              0.911 0.912 0.914 0.915 0.915 0.916 0.919 0.935 | 1.118 1.118 1.123 1.129 1.136 1.140 1.138 1.137
              0.897 0.907 0.918 0.912 0.903 0.903 0.906 0.925 | 1.118 1.118 1.127 1.139 1.159 1.177 1.157 1.143
              0.899 0.916 0.000 0.931 0.924 0.915 0.908 0.927 | 1.123 1.127 1.153 1.187 1.206 0.000 1.187 1.155
              0.899 0.910 0.923 0.935 0.000 0.928 0.913 0.931 | 1.129 1.139 1.187 0.000 1.220 1.207 1.177 1.160
              0.900 0.911 0.923 0.928 0.939 0.940 0.926 0.935 | 1.136 1.159 1.206 1.220 1.208 1.211 1.183 1.166
```

```
             0.903 0.919 0.000 0.926 0.930 0.000 0.935 0.938 | 1.140 1.177 0.000 1.207 1.211 0.000 1.205 1.175
             0.919 0.921 0.921 0.915 0.918 0.929 0.926 0.937 | 1.138 1.157 1.187 1.177 1.183 1.205 1.197 1.192
             0.000 0.920 0.906 0.905 0.908 0.912 0.916 0.936 | 1.137 1.143 1.155 1.160 1.166 1.175 1.192 0.000


0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  36.3970 TYPE OF FILE = 470 STATEP =  12
0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  44.7050 TYPE OF FILE = 470 STATEP =  12
0RESTART FILE NO. 12 WRITTEN. IDENTIFICATION =           EXPOSURE =  42.5060 TYPE OF FILE = 470 STATEP =  12
1* CASMO FLORIDA  01/09/17 STUDSVIK * EXECUTION **/04/15   20:38:54   JOB=SUN        STATE POINT NO = 12 PAGE =  130
 * Crystal River-3 15x15 Assembly with CARBORANE in guide tubes
 END                                                                    INPUT CARD


  LIST OF WARNINGS ENCOUNTERED:
  -----------------------------
  ROUTINE      TEXT
  -------      ----
 MIXS  SUM OF WEIGHT PERCENTAGES LESS THAN 99.9
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/04/15   20:38:54   JOB=SUN             PAGE =  131
0       ** C A S M O -3   SUMMARY  ** SEGMENT NO = 1
0         Crystal River-3 15x15 Assembly with CARBORANE in guide tubes    DEPLETED FUEL 2.
0       HVOI=  0.0 HTFU=  990.0 HTMO=  583.0 HBOR=    0.0
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                           MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

         1  0.0   990.0  583.0    0.0        0.000 1.25249 1.26703  60.67   1.089   2.268   0.000   0.000
         2                                   0.461 1.20045 1.21316  60.39   1.088   2.214   0.023   0.023
         3                                   2.305 1.18005 1.19169  60.11   1.083   2.015   0.124   0.131
         4                                   4.613 1.14991 1.16078  59.88   1.075   1.794   0.221   0.246
         5                                   9.221 1.09432 1.10416  59.67   1.061   1.423   0.360   0.431
         6                                  13.796 1.04727 1.05616  59.58   1.048   1.123   0.453   0.575
         7                                  18.331 1.00599 1.01401  59.57   1.038   0.881   0.516   0.690
         8                                  22.831 0.96908 0.97632  59.65   1.031   0.686   0.559   0.784
         9                                  27.325 0.93591 0.94243  59.80   1.026   0.529   0.589   0.863
        10                                  31.841 0.90633 0.91217  59.97   1.023   0.403   0.610   0.929
        11                                  36.396 0.88031 0.88555  60.16   1.022   0.304   0.624   0.987


  LIST OF WARNINGS ENCOUNTERED:
  -----------------------------
  ROUTINE      TEXT
  -------      ----
 MIXS  SUM OF WEIGHT PERCENTAGES LESS THAN 99.9
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/04/15   20:38:54   JOB=SUN             PAGE =  132
0       ** C A S M O -3   SUMMARY  ** SEGMENT NO = 2
0         Crystal River-3 15x15 Assembly with CARBORANE in guide tubes    LOW ENRICHED DEP
0       HVOI=  0.0 HTFU=  990.0 HTMO=  583.0 HBOR=    0.0
```

```
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                           MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

         1  0.0   990.0  583.0    0.0        0.000 1.22905 1.21120  56.75   1.359   4.660   0.000   0.000
         2                                   0.497 1.18871 1.17330  56.76   1.345   4.600   0.018   0.019
         3                                   2.494 1.17857 1.16462  56.95   1.308   4.367   0.107   0.110
         4                                   5.013 1.16835 1.15548  57.22   1.260   4.090   0.202   0.216
         5                                  10.159 1.15095 1.13912  57.84   1.176   3.570   0.358   0.403
         6                                  15.529 1.14182 1.13057  58.56   1.099   3.083   0.481   0.564
         7                                  21.141 1.13095 1.12020  59.25   1.036   2.625   0.574   0.704
         8                                  26.961 1.10602 1.09598  59.79   1.049   2.199   0.642   0.822
         9                                  32.888 1.06823 1.05879  60.16   1.053   1.814   0.690   0.923
        10                                  38.816 1.02645 1.01779  60.42   1.051   1.474   0.722   1.008
        11                                  44.703 0.98549 0.97753  60.64   1.047   1.181   0.742   1.081


  LIST OF WARNINGS ENCOUNTERED:
  -----------------------------
  ROUTINE      TEXT
  -------      ----
 MIXS  SUM OF WEIGHT PERCENTAGES LESS THAN 99.9
1       * C A S M O FLORIDA 01/09/17 STUDSVIK * EXECUTION **/04/15   20:38:54   JOB=SUN             PAGE =  133
0       ** C A S M O -3   SUMMARY  ** SEGMENT NO = 3
0         Crystal River-3 15x15 Assembly with CARBORANE in guide tubes    MEDIUM ENRICHED
0       HVOI=  0.0 HTFU=  990.0 HTMO=  583.0 HBOR=    0.0
0       NO VOID    TFU    TMO    BOR CRD   BURNUP   K-INF   K-INF     M2      PIN   U-235 FISS PU  TOT PU
                                           MWD/KG             TWO-GROUP     PEAK    WT %    WT %    WT %

         1  0.0   990.0  583.0    0.0        0.000 1.36877 1.36079  59.55   1.042   3.400   0.000   0.000
         2                                   0.581 1.30889 1.30177  59.32   1.044   3.331   0.022   0.023
         3                                   2.897 1.27955 1.27300  59.13   1.045   3.070   0.124   0.131
         4                                   5.761 1.24289 1.23674  59.02   1.044   2.774   0.225   0.248
         5                                  11.399 1.17740 1.17170  58.97   1.041   2.260   0.374   0.440
         6                                  16.878 1.12210 1.11677  58.99   1.036   1.833   0.475   0.590
         7                                  22.198 1.07319 1.06821  59.07   1.031   1.477   0.544   0.711
         8                                  27.377 1.02868 1.02408  59.22   1.026   1.181   0.591   0.809
         9                                  32.463 0.98737 0.98336  59.40   1.022   0.933   0.622   0.889
        10                                  37.502 0.94936 0.94585  59.63   1.020   0.728   0.642   0.958
        11                                  42.505 0.91483 0.91183  59.86   1.018   0.561   0.654   1.016
```

APPENDIX D
ONE-EIGHTH CORE EASCYC FILES

This appendix contains all of the input and output files for the 1/8th core EASCYC model. The first set of files are the CASMO input files used to generate the 10A3, 12A2, 13AE, and 14AE fuel cross section libraries. No CASMO output files are listed; instead, the appendix includes the ASCII file for the cross section library made by EASY for EASLIB. All of the files use the B_4C/Al_2O_3 BPRA.

The 10A3 CASMO Input File

```
TIT  TFU=990  TMO=583  BOR=0  *4.66% B4 W 15 X 15
*Crystal River-3 15x15 10A3 Assembly with WATER in guide
tubes
FUE  1 10.4/3.94  *FUEL COMP. #, DENSITY/ENRICHMENT
PDE  33  *POWER DENSITY (W/Gu)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  2 .632 .6731/ 'COO' 'CAN'  *Center hole empty guide
tube
SPA  0 0 583 0.705/1001=11.19,8000=88.81
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI
2
1 1
1 1 2
1 1 1 1
1 1 1 1 2
1 1 2 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
DEP 0 0.5 1 2 3 4 5 6 7 8 9 10 11 12 15 17.5 20
25 30 35 40 45 50 *Depletion steps
STA
END
```

The 12A2 CASMO Input File

```
TIT  TFU=990  TMO=583  BOR=0  *4.66% B4 W 15 X 15
*Crystal River-3 15x15 12A2 Assembly with WATER in guide
tubes
FUE  1 10.4/4.19  *FUEL COMP. #, DENSITY/ENRICHMENT
PDE  33  *POWER DENSITY (W/Gu)
MI2  3.1/5010=0.55 5011=2.22 6000=0.76 13000=51.04
8000=45.43
Mixture 2: B10, C, Al, O (BP Material)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  2 .632 .6731/ 'COO' 'CAN'  *Center water hole
SPA  0 0 583 0.705/1001=11.19,8000=88.81
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI
2
1 1
1 1 2
1 1 1 1
1 1 1 1 2
1 1 2 1 1 1
1 1 1 1 1 1 1
1 1 1 1 1 1 1 1
DEP 0 0.5 1 2 3 4 5 6 7 8 9 10 11 12 15 17.5 20
25 30 35 40 45 50 *Depletion steps
STA
END
```

The 13AE CASMO Input File

```
TIT  TFU=990  TMO=583  BOR=0  *4.66% B4 W 15 X 15
*Crystal River-3 15x15 13AE Assembly with WATER in guide
tubes
FUE  1 10.4/4.856  *FUEL COMP. #, DENSITY/ENRICHMENT
FUE  2 10.4/3.16 7300=6.0 *(GD ROD)
PDE  33  *POWER DENSITY (W/Gu)
MI2  3.1/5010=0.55 5011=2.22 6000=0.76 13000=51.04
8000=45.43
Mixture 2: B10, C, Al, O (BP Material)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  2 .632 .6731/ 'COO' 'CAN'  *Center water hole
PIN  3 .4699 .4788 .5461/ '2' 'AIR' 'CAN'
SPA  0 0 583 0.705/1001=11.19,8000=88.81
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI
2
```

```
1 1
1 1 2
1 1 1 1
1 1 1 1 2
1 1 2 1 1 1
1 1 1 1 3 1 1
1 1 1 1 1 1 1 1
DEP 0 0.5 1 2 3 4 5 6 7 8 9 10 11 12 15 17.5 20
25 30 35 40 45 50 *Depletion steps
STA
END
```

The 14AE CASMO Input File

```
TIT  TFU=990  TMO=583  BOR=0  *4.66% B4 W 15 X 15
*Crystal River-3 15x15 14AE Assembly with WATER in guide
tubes
FUE  1 10.4/4.613  *FUEL COMP. #, DENSITY/ENRICHMENT
FUE  2 10.4/3.16 7300=6.0 *(GD ROD)
PDE  33  *POWER DENSITY (W/Gu)
PIN  1 .4699 .4788 .5461/ '1' 'AIR' 'CAN'
PIN  2 .632 .6731/ 'COO' 'CAN'  *Center water hole
PIN  3 .4699 .4788 .5461/ '2' 'AIR' 'CAN'
SPA  0 0 583 0.705/1001=11.19,8000=88.81
PWR  15 1.443 21.81 * PWR with pitch 1.443
LPI
2
1 1
1 1 2
1 1 1 1
1 1 1 1 2
1 1 2 1 1 1
1 1 1 1 3 1 1
1 1 1 1 1 1 1 1
DEP 0 0.5 1 2 3 4 5 6 7 8 9 10 11 12 15 17.5 20
25 30 35 40 45 50 *Depletion steps
STA
END
```

The EASY Output Fuel Cross Section Library File

```
10A3    23   .667100    16.89    .709800   463.60    200.   .0394    .0    .0
10A3     1   3.56E-2   2.37E-2   6.64E-2  6.89E+10   5.16E+1  2.166E+3    2.8E-2
10A3     1   3.73E-1   1.22E+0    7.7E+0    5.9E+1   0.93E-3
10A3     1   .600E-3   2.88E-5   2.09E-5   1.09E-2   3.56E-6
10A3     1   .000000        0.  1.436700   .009548   .015191   .007794   .637527
10A3     1                      .384600   .095045   .158900 12.996892
10A3     2   .500000        0.  1.436400   .009566   .015219   .007755   .632822
10A3     2                      .384040   .096024   .158880 12.965562
10A3     3  1.000000        0.  1.436400   .009584   .015226   .007720   .628263
10A3     3                      .383360   .096987   .159710 12.997233
10A3     4  2.000000        0.  1.436600   .009628   .015219   .007646   .619076
10A3     4                      .382130   .098422   .161160 13.048864
10A3     5  3.000000        0.  1.436700   .009684   .015203   .007568   .609921
10A3     5                      .381040   .099606   .162280 13.078659
10A3     6  4.000000        0.  1.436700   .009747   .015183   .007487   .600859
10A3     6                      .380080   .100600   .163110 13.089640
10A3     7  5.000000        0.  1.436800   .009813   .015160   .007406   .591959
10A3     7                      .379220   .101430   .163690 13.083686
10A3     8  6.000000        0.  1.436900   .009881   .015136   .007325   .583309
10A3     8                      .378450   .102140   .164050 13.063386
10A3     9  7.000000        0.  1.436900   .009947   .015112   .007245   .574863
10A3     9                      .377760   .102720   .164230 13.031024
10A3    10  8.000000        0.  1.437000   .010012   .015089   .007166   .566653
10A3    10                      .377130   .103200   .164260 12.989087
10A3    11  9.000000        0.  1.437100   .010075   .015068   .007088   .558666
10A3    11                      .376570   .103590   .164140 12.937653
10A3    12 10.000000        0.  1.437100   .010134   .015048   .007010   .550780
10A3    12                      .376050   .103910   .163900 12.878639
10A3    13 11.000000        0.  1.437200   .010191   .015030   .006932   .543024
10A3    13                      .375580   .104150   .163540 12.811594
10A3    14 12.000000        0.  1.437300   .010245   .015014   .006855   .535450
10A3    14                      .375150   .104320   .163090 12.738918
10A3    15 15.000000        0.  1.437500   .010392   .014975   .006635   .514010
10A3    15                      .374100   .104510   .161210 12.488670
```

```
10A3    16 17.500000        0.  1.437800   .010506   .014947   .006459   .497160
10A3    16                      .373400   .104370   .159170 12.251385
10A3    17 20.000000        0.  1.438000   .010609   .014928   .006291   .481256
10A3    17                      .372850   .104010   .156780 11.994492
10A3    18 25.000000        0.  1.438600   .010789   .014905   .005980   .452297
10A3    18                      .372070   .102830   .151390 11.449423
10A3    19 30.000000        0.  1.439200   .010954   .014893   .005690   .425818
10A3    19                      .371600   .101140   .145220 10.867320
10A3    20 35.000000        0.  1.439900   .011103   .014894   .005418   .401430
10A3    20                      .371360   .099139   .138650 10.273414
10A3    21 40.000000        0.  1.440600   .011239   .014904   .005164   .379093
10A3    21                      .371280   .096980   .131990  9.689117
10A3    22 45.000000        0.  1.441300   .011368   .014917   .004936   .359211
10A3    22                      .371310   .094795   .125500  9.132919
10A3    23 50.000000        0.  1.442200   .011489   .014931   .004733   .341642
10A3    23                      .371420   .092687   .119380  8.617939
12A2    23   .667100    16.89    .709800   463.60    200.   .0419    .0     .0
12A2     1   3.56E-2   2.37E-2   6.64E-2  6.89E+10   5.16E+1  2.166E+3    2.8E-2
12A2     1   3.73E-1   1.22E+0    7.7E+0    5.9E+1   0.93E-3
12A2     1   .600E-3   2.88E-5   2.09E-5   1.09E-2   3.56E-6
12A2     1   .000000        0.  1.438000   .009696   .015044   .008091   .661811
12A2     1                      .384130   .098876   .166750 13.638966
12A2     2   .500000        0.  1.437700   .009713   .015072   .008051   .657111
12A2     2                      .383590   .099831   .166670 13.604048
12A2     3  1.000000        0.  1.437700   .009730   .015079   .008016   .652569
12A2     3                      .382930   .100780   .167430 13.631035
12A2     4  2.000000        0.  1.437800   .009771   .015075   .007940   .643350
12A2     4                      .381730   .102180   .168800 13.677430
12A2     5  3.000000        0.  1.437900   .009823   .015061   .007862   .634248
12A2     5                      .380670   .103330   .169870 13.704720
12A2     6  4.000000        0.  1.438000   .009883   .015043   .007782   .625295
12A2     6                      .379720   .104300   .170660 13.713138
12A2     7  5.000000        0.  1.438000   .009946   .015021   .007701   .616483
12A2     7                      .378870   .105120   .171210 13.705572
12A2     8  6.000000        0.  1.438100   .010009   .014999   .007619   .607753
12A2     8                      .378110   .105810   .171550 13.684043
12A2     9  7.000000        0.  1.438200   .010072   .014978   .007537   .599229
12A2     9                      .377430   .106390   .171720 13.651866
```

```
12A2    10  8.000000        0.  1.438200   .010133   .014957   .007457   .590918
12A2    10                      .376800   .106870   .171740 13.609636
12A2    11  9.000000        0.  1.438200   .010193   .014937   .007377   .582801
12A2    11                      .376240   .107260   .171620 13.558224
12A2    12 10.000000        0.  1.438300   .010250   .014919   .007298   .574858
12A2    12                      .375730   .107570   .171380 13.498740
12A2    13 11.000000        0.  1.438400   .010306   .014901   .007221   .567131
12A2    13                      .375260   .107820   .171030 13.432554
12A2    14 12.000000        0.  1.438500   .010359   .014885   .007144   .559524
12A2    14                      .374830   .108000   .170570 13.359179
12A2    15 15.000000        0.  1.438700   .010499   .014849   .006917   .537509
12A2    15                      .373760   .108200   .168710 13.109799
12A2    16 17.500000        0.  1.438900   .010607   .014824   .006735   .520107
12A2    16                      .373060   .108070   .166680 12.872533
12A2    17 20.000000        0.  1.439200   .010705   .014807   .006559   .503612
12A2    17                      .372500   .107720   .164300 12.614688
12A2    18 25.000000        0.  1.439700   .010876   .014787   .006234   .473389
12A2    18                      .371690   .106540   .158880 12.064239
12A2    19 30.000000        0.  1.440300   .011033   .014779   .005929   .445643
12A2    19                      .371210   .104830   .152630 11.471196
12A2    20 35.000000        0.  1.440900   .011176   .014781   .005645   .420202
12A2    20                      .370960   .102770   .145910 10.860843
12A2    21 40.000000        0.  1.441600   .011305   .014794   .005377   .396570
12A2    21                      .370870   .100510   .139000 10.252250
12A2    22 45.000000        0.  1.442300   .011427   .014812   .005130   .375095
12A2    22                      .370900   .098186   .132160  9.663644
12A2    23 50.000000        0.  1.443100   .011543   .014830   .004908   .355995
12A2    23                      .371020   .095890   .125600  9.110031
13AE    23   .667100    16.89    .709800   463.60    200.   .0486    .0     .0
13AE     1   3.56E-2   2.37E-2   6.64E-2  6.89E+10   5.16E+1  2.166E+3    2.8E-2
13AE     1   3.73E-1   1.22E+0    7.7E+0    5.9E+1   0.93E-3
13AE     1   .600E-3   2.88E-5   2.09E-5   1.09E-2   3.56E-6
13AE     1   .000000         0.  1.441100   .010088   .014671   .008874   .725893
13AE     1                      .382720   .108680   .186860 15.284446
13AE     2   .500000         0.  1.440900   .010103   .014698   .008833   .721205
13AE     2                      .382210   .109570   .186620 15.238017
13AE     3  1.000000         0.  1.440800   .010118   .014708   .008795   .716646
13AE     3                      .381600   .110490   .187230 15.255439
```

13AE	4	2.000000	0.	1.440900	.010150	.014709	.008715	.707255
13AE	4			.380490	.111820	.188410	15.290537	
13AE	5	3.000000	0.	1.440900	.010193	.014702	.008632	.697983
13AE	5			.379490	.112900	.189360	15.311098	
13AE	6	4.000000	0.	1.441000	.010242	.014689	.008549	.688836
13AE	6			.378590	.113820	.190060	15.314451	
13AE	7	5.000000	0.	1.441100	.010294	.014675	.008464	.679761
13AE	7			.377780	.114610	.190550	15.303992	
13AE	8	6.000000	0.	1.441100	.010348	.014658	.008379	.670860
13AE	8			.377050	.115270	.190860	15.281637	
13AE	9	7.000000	0.	1.441200	.010402	.014641	.008295	.662255
13AE	9			.376380	.115840	.191010	15.249082	
13AE	10	8.000000	0.	1.441200	.010456	.014624	.008213	.653847
13AE	10			.375780	.116310	.191010	15.205987	
13AE	11	9.000000	0.	1.441300	.010510	.014607	.008132	.645627
13AE	11			.375220	.116700	.190890	15.155413	
13AE	12	10.000000	0.	1.441300	.010562	.014591	.008052	.637574
13AE	12			.374710	.117020	.190660	15.097597	
13AE	13	11.000000	0.	1.441400	.010612	.014575	.007972	.629675
13AE	13			.374250	.117270	.190320	15.032582	
13AE	14	12.000000	0.	1.441500	.010659	.014562	.007892	.621833
13AE	14			.373820	.117460	.189890	14.961393	
13AE	15	15.000000	0.	1.441700	.010788	.014529	.007658	.599171
13AE	15			.372750	.117710	.188090	14.715800	
13AE	16	17.500000	0.	1.441900	.010887	.014507	.007468	.581108
13AE	16			.372020	.117630	.186130	14.482571	
13AE	17	20.000000	0.	1.442100	.010976	.014492	.007282	.563622
13AE	17			.371450	.117320	.183810	14.226780	
13AE	18	25.000000	0.	1.442600	.011126	.014481	.006925	.530631
13AE	18			.370600	.116190	.178440	13.673039	
13AE	19	30.000000	0.	1.443100	.011261	.014480	.006585	.499898
13AE	19			.370080	.114500	.172150	13.067901	
13AE	20	35.000000	0.	1.443700	.011384	.014489	.006266	.471434
13AE	20			.369800	.112400	.165240	12.431538	
13AE	21	40.000000	0.	1.444300	.011499	.014505	.005967	.445084
13AE	21			.369700	.110010	.157950	11.782038	
13AE	22	45.000000	0.	1.444900	.011606	.014528	.005685	.420611
13AE	22			.369730	.107460	.150510	11.134867	

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13AE    23 50.000000        0.  1.445600   .011703   .014558   .005420   .397754
13AE    23                      .369860   .104830   .143110 10.503101
14AE    23   .667100    16.89    .709800   463.60    200.   .0461    .0    .0
14AE     1   3.56E-2   2.37E-2   6.64E-2  6.89E+10   5.16E+1  2.166E+3    2.8E-2
14AE     1   3.73E-1   1.22E+0    7.7E+0    5.9E+1   0.93E-3
14AE     1   .600E-3   2.88E-5   2.09E-5   1.09E-2   3.56E-6
14AE     1   .000000        0.  1.440000   .009946   .014804   .008590   .702671
14AE     1                      .383260   .105170   .179650 14.694696
14AE     2   .500000        0.  1.439700   .009961   .014831   .008549   .697971
14AE     2                      .382750   .106080   .179470 14.652406
14AE     3  1.000000        0.  1.439700   .009977   .014840   .008513   .693406
14AE     3                      .382110   .107010   .180120 14.671934
14AE     4  2.000000        0.  1.439800   .010013   .014839   .008434   .684122
14AE     4                      .380970   .108360   .181380 14.712252
14AE     5  3.000000        0.  1.439800   .010057   .014831   .008352   .674835
14AE     5                      .379940   .109470   .182360 14.734376
14AE     6  4.000000        0.  1.439900   .010110   .014816   .008269   .665666
14AE     6                      .379030   .110410   .183090 14.739172
14AE     7  5.000000        0.  1.440000   .010166   .014799   .008186   .656769
14AE     7                      .378210   .111200   .183610 14.730635
14AE     8  6.000000        0.  1.440000   .010225   .014780   .008104   .648061
14AE     8                      .377460   .111880   .183930 14.708517
14AE     9  7.000000        0.  1.440100   .010282   .014761   .008022   .639558
14AE     9                      .376790   .112450   .184080 14.675330
14AE    10  8.000000        0.  1.440200   .010339   .014742   .007942   .631255
14AE    10                      .376180   .112920   .184090 14.632964
14AE    11  9.000000        0.  1.440200   .010395   .014724   .007861   .623073
14AE    11                      .375620   .113310   .183970 14.581699
14AE    12 10.000000        0.  1.440300   .010448   .014707   .007780   .614995
14AE    12                      .375110   .113630   .183730 14.522963
14AE    13 11.000000        0.  1.440300   .010499   .014692   .007700   .607032
14AE    13                      .374640   .113880   .183390 14.457803
14AE    14 12.000000        0.  1.440400   .010549   .014677   .007621   .599269
14AE    14                      .374210   .114060   .182950 14.386255
14AE    15 15.000000        0.  1.440600   .010683   .014643   .007391   .576964
14AE    15                      .373140   .114290   .181120 14.138402
14AE    16 17.500000        0.  1.440800   .010785   .014620   .007203   .559021
14AE    16                      .372420   .114190   .179140 13.903527
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14AE    17 20.000000        0.  1.441100   .010875   .014605   .007018   .541706
14AE    17                       .371850   .113860   .176790 13.646469
14AE    18 25.000000        0.  1.441600   .011032   .014591   .006671   .509602
14AE    18                       .371020   .112710   .171380 13.091437
14AE    19 30.000000        0.  1.442100   .011175   .014588   .006343   .479873
14AE    19                       .370510   .111000   .165080 12.488558
14AE    20 35.000000        0.  1.442700   .011305   .014594   .006037   .452494
14AE    20                       .370240   .108900   .158210 11.859376
14AE    21 40.000000        0.  1.443300   .011426   .014609   .005749   .427180
14AE    21                       .370140   .106550   .151020 11.221161
14AE    22 45.000000        0.  1.443900   .011538   .014632   .005477   .403573
14AE    22                       .370170   .104050   .143750 10.591269
14AE    23 50.000000        0.  1.444700   .011642   .014658   .005226   .381954
14AE    23                       .370300   .101520   .136600  9.983920
    1   .00450    .03440    -.0015     0.00       0.7     366.     .05
    2   .00450    .03440    -.0015     0.00       0.7     366.     .05
    3   .00450    .03440    -.0015     0.00       0.7     366.     .05
    4   .00450    .03440    -.0015     0.00       0.7     366.     .05
    5   .00450    .03440    -.0015     0.00       0.7     366.     .05
    6   .00450    .03440    -.0015     0.00       0.7     366.     .05
    7   .00450    .03440    -.0015     0.00       0.7     366.     .05
```

The EASYLIB Input File Reactor Geometry

```
CRYSTAL RIVER RELOAD #12 CORE WITH CASMO LIB (B4CAL2)
crystal3.asc
crystal1.out
   3    1    0    0    1    1    0    1    3
 177   29    3    6    4   -4   -12   3    4
   8    7    6    4    3    1
   1    2    3    4
   2    3    3    4    3    4    3    2
   3    4    3    4    3    4    2
   3    4    3    4    4    2
   3    4    3    3
   3    4    1
   1
2568.0,360.17,21.81,800.0,0.7232,1.2,1.0,1.0,0.0
    1 B-20 16.190E-6  4.500E+1  2.050E+3 0.9480E-0  1.170E-0  0.616E-0 -9.29E-04
    1       0.375E-3 -0.094E-6   0.00E-0   1.00E-0  1.000E+2  0.000E+0 4.394E-02
    2 B-16 36.351E-6  4.500E+1  2.050E+3 0.9643E-0  0.959E-0  0.701E-0 -7.43E-04
    2       0.300E-3 -0.075E-6   0.00E-0   1.00E-0  1.000E+2  0.000E+0 3.515E-02
    3 B-12  9.710E-6  4.500E+1  2.050E+3 0.9480E-0  1.170E-0  0.616E-0 -5.57E-04
    3       0.225E-3 -0.056E-6   0.00E-0   1.00E-0  1.000E+2  0.000E+0 2.636E-02
    4 B-08 13.336E-6  4.500E+1  2.050E+3 0.9810E-0  0.979E-0  0.748E-0 -3.72E-04
    4       0.150E-3 -0.375E-7   0.00E-0   1.00E-0  1.000E+2  0.000E+0 1.758E-02
3,2,0.0 5,7,0.0 7,6,0.0 9,2,0.0 11,4,0.0 13,5,0.0 16,6,0.0 18,8,0.0 20,1,0.0
22,5,0.0 24,3,0.0 26,7,0.0
*BRN
   38.784  24.686  28.930   0.000  24.537   0.000  28.395  40.206
           27.702   0.000  28.425   0.000  22.646   0.000  37.045
                   27.922   0.000  29.027   0.000   0.000  40.708
                           27.932   0.000  21.198  28.866
                                   27.655   0.000  38.450
                                           38.519
3,0.0 2,10.0 1,20.0
```

The EASCYC Output File B_4C/Al_2O_3 BPRAs

```
                                ***EASCYC***

          A TWO DIMENSIONAL, TWO GROUP NODAL/MODAL ANALYSIS SYSTEM FOR
          THE EVALUATION AND OPTIMIZATION OF A SEQUENCE OF FUEL CYCLES

                      COPYRIGHT 1985 - HARVEY W. GRAVES JR.
                     EMULATION VERSION T91-C02 (1/26/91)

                     EASSI TUTORIAL FORMAT - SERIAL NO. 7012

CRYSTAL RIVER RELOAD #12 CORE WITH CASMO LIB (B4CAL2) OLD G FACTORS         9/12/** (10:54)
          FUEL LIBRARY FILE  - CRYSTAL9.BIN            OUTPUT PRINT FILE  - CRYSTAL9.OUT

                                REACTOR DESCRIPTION

  RATED POWER LEVEL(MWT)       2990.      OPERATING LEVEL (%)      85.9
  TOTAL ASSEMBLIES              177       NUMBER OF FUEL TYPES        4
  ASSEMBLIES IN  EIGHTH CORE     29       ASSEMBLY PITCH(CM)       21.50
  ASSBY. ROWS IN  EIGHTH CORE     6       ASSEMBLY HEIGHT(CM)     366.00
  RELOAD SPARE ASSEMBLIES         3       BORON CONC. (PPM)         800.
  AVAILABLE CR POSITIONS         12       COOLANT DENSITY (g/cc)0.72320
  AXIAL BUCKLING(1/m-sq)       1.20


                              CONVERGENCE PARAMETERS

                     ITERATION LIMIT                            100
                     EIGENVALUE CONVERGENCE                0.000050
                     INITIAL DOMINANCE RATIO                  0.65
                     BORON SEARCH CONVERGENCE (PPM)             5.
                     ALLOWABLE ASSEMBLY BURNUP DELTA (MWD/KG)  0.100


                      REFERENCE FUEL PROPERTIES AT PROBLEM INITIATION

                                WATER DENSITY   ASSBY POWER     BORON CONC
                                    G/CC           MWT             PPM     ENRICHMENT
                     REACTOR REFERENCE    0.72320        14.508          800.0
                     10A3       1         0.70980        16.890            0.0    0.0394
                     12A2       2         0.70980        16.890            0.0    0.0419
                     13AE       3         0.70980        16.890            0.0    0.0486
                     14AE       4         0.70980        16.890            0.0    0.0461


                                  DATA LIBRARY NUCLEAR PROPERTIES

                                  FP DOPPLER       FP XENON      SHIM MICROS               WATER MICROS
  FUEL   FUEL   WATER      FUEL
PEAK
  NAME    NO.  FRACTION  MASS(KG)  VALUE  SLOPE  YIELD  SIG/LAM    FABS   TABS    FABS    TABS   FREM   FTR    TTR
SAMAR.
  10A3     1   0.66710    463.60  0.0117 0.813  0.06640.689E+11   51.60  2166.0 0.02800 0.3730  1.220  7.700  59.00
0.930E-03
  12A2     2   0.66710    463.60  0.0117 0.813  0.06640.689E+11   51.60  2166.0 0.02800 0.3730  1.220  7.700  59.00
0.930E-03
  13AE     3   0.66710    463.60  0.0117 0.813  0.06640.689E+11   51.60  2166.0 0.02800 0.3730  1.220  7.700  59.00
0.930E-03
  14AE     4   0.66710    463.60  0.0117 0.813  0.06640.689E+11   51.60  2166.0 0.02800 0.3730  1.220  7.700  59.00
0.930E-03
```

DATA LIBRARY TWO GROUP CONSTANTS

			FAST					THERMAL			
FUEL NO.	BURNUP	BORON	D COEFF	SIGMA-A	SIGMA-R	NU-SIGF	KAP-SIGF	D COEFF	SIGMA-A	NU-SIGF	KAP-SIGF
1	0.000	0.0	1.4367	0.009548	0.015191	0.007794	0.637527	0.38460	0.095045	0.158900	12.9969
1	0.500	0.0	1.4364	0.009566	0.015219	0.007755	0.632822	0.38404	0.096024	0.158880	12.9656
1	1.000	0.0	1.4364	0.009584	0.015226	0.007720	0.628263	0.38336	0.096987	0.159710	12.9972
1	2.000	0.0	1.4366	0.009628	0.015219	0.007646	0.619076	0.38213	0.098422	0.161160	13.0489
1	3.000	0.0	1.4367	0.009684	0.015203	0.007568	0.609921	0.38104	0.099606	0.162280	13.0787
1	4.000	0.0	1.4367	0.009747	0.015183	0.007487	0.600859	0.38008	0.100600	0.163110	13.0896
1	5.000	0.0	1.4368	0.009813	0.015160	0.007406	0.591959	0.37922	0.101430	0.163690	13.0837
1	6.000	0.0	1.4369	0.009881	0.015136	0.007325	0.583309	0.37845	0.102140	0.164050	13.0634
1	7.000	0.0	1.4369	0.009947	0.015112	0.007245	0.574863	0.37776	0.102720	0.164230	13.0310
1	8.000	0.0	1.4370	0.010012	0.015089	0.007166	0.566653	0.37713	0.103200	0.164260	12.9891
1	9.000	0.0	1.4371	0.010075	0.015068	0.007088	0.558666	0.37657	0.103590	0.164140	12.9377
1	10.000	0.0	1.4371	0.010134	0.015048	0.007010	0.550780	0.37605	0.103910	0.163900	12.8786
1	11.000	0.0	1.4372	0.010191	0.015030	0.006932	0.543024	0.37558	0.104150	0.163540	12.8116
1	12.000	0.0	1.4373	0.010245	0.015014	0.006855	0.535450	0.37515	0.104320	0.163090	12.7389
1	15.000	0.0	1.4375	0.010392	0.014975	0.006635	0.514010	0.37410	0.104510	0.161210	12.4887
1	17.500	0.0	1.4378	0.010506	0.014947	0.006459	0.497160	0.37340	0.104370	0.159170	12.2514
1	20.000	0.0	1.4380	0.010609	0.014928	0.006291	0.481256	0.37285	0.104010	0.156780	11.9945
1	25.000	0.0	1.4386	0.010789	0.014905	0.005980	0.452297	0.37207	0.102830	0.151390	11.4494
1	30.000	0.0	1.4392	0.010954	0.014893	0.005690	0.425818	0.37160	0.101140	0.145220	10.8673
1	35.000	0.0	1.4399	0.011103	0.014894	0.005418	0.401430	0.37136	0.099139	0.138650	10.2734
1	40.000	0.0	1.4406	0.011239	0.014904	0.005164	0.379093	0.37128	0.096980	0.131990	9.6891
1	45.000	0.0	1.4413	0.011368	0.014917	0.004936	0.359211	0.37131	0.094795	0.125500	9.1329
1	50.000	0.0	1.4422	0.011489	0.014931	0.004733	0.341642	0.37142	0.092687	0.119380	8.6179
2	0.000	0.0	1.4380	0.009696	0.015044	0.008091	0.661811	0.38413	0.098876	0.166750	13.6390
2	0.500	0.0	1.4377	0.009713	0.015072	0.008051	0.657111	0.38359	0.099831	0.166670	13.6040
2	1.000	0.0	1.4377	0.009730	0.015079	0.008016	0.652569	0.38293	0.100780	0.167430	13.6310
2	2.000	0.0	1.4378	0.009771	0.015075	0.007940	0.643350	0.38173	0.102180	0.168800	13.6774
2	3.000	0.0	1.4379	0.009823	0.015061	0.007862	0.634248	0.38067	0.103330	0.169870	13.7047
2	4.000	0.0	1.4380	0.009883	0.015043	0.007782	0.625295	0.37972	0.104300	0.170660	13.7131
2	5.000	0.0	1.4380	0.009946	0.015021	0.007701	0.616483	0.37887	0.105120	0.171210	13.7056
2	6.000	0.0	1.4381	0.010009	0.014999	0.007619	0.607753	0.37811	0.105810	0.171550	13.6840
2	7.000	0.0	1.4382	0.010072	0.014978	0.007537	0.599229	0.37743	0.106390	0.171720	13.6519
2	8.000	0.0	1.4382	0.010133	0.014957	0.007457	0.590918	0.37680	0.106870	0.171740	13.6096
2	9.000	0.0	1.4382	0.010193	0.014937	0.007377	0.582801	0.37624	0.107260	0.171620	13.5582
2	10.000	0.0	1.4383	0.010250	0.014919	0.007298	0.574858	0.37573	0.107570	0.171380	13.4987
2	11.000	0.0	1.4384	0.010306	0.014901	0.007221	0.567131	0.37526	0.107820	0.171030	13.4326
2	12.000	0.0	1.4385	0.010359	0.014885	0.007144	0.559524	0.37483	0.108000	0.170570	13.3592
2	15.000	0.0	1.4387	0.010499	0.014849	0.006917	0.537509	0.37376	0.108200	0.168710	13.1098
2	17.500	0.0	1.4389	0.010607	0.014824	0.006735	0.520107	0.37306	0.108070	0.166680	12.8725
2	20.000	0.0	1.4392	0.010705	0.014807	0.006559	0.503612	0.37250	0.107720	0.164300	12.6147
2	25.000	0.0	1.4397	0.010876	0.014787	0.006234	0.473389	0.37169	0.106540	0.158880	12.0642
2	30.000	0.0	1.4403	0.011033	0.014779	0.005929	0.445643	0.37121	0.104830	0.152630	11.4712
2	35.000	0.0	1.4409	0.011176	0.014781	0.005645	0.420202	0.37096	0.102770	0.145910	10.8608
2	40.000	0.0	1.4416	0.011305	0.014794	0.005377	0.396570	0.37087	0.100510	0.139000	10.2522
2	45.000	0.0	1.4423	0.011427	0.014812	0.005130	0.375095	0.37090	0.098186	0.132160	9.6636
2	50.000	0.0	1.4431	0.011543	0.014830	0.004908	0.355995	0.37102	0.095890	0.125600	9.1100

			FAST					THERMAL			
FUEL NO.	BURNUP	BORON	D COEFF	SIGMA-A	SIGMA-R	NU-SIGF	KAP-SIGF	D COEFF	SIGMA-A	NU-SIGF	KAP-SIGF
3	0.000	0.0	1.4411	0.010088	0.014671	0.008874	0.725893	0.38272	0.108680	0.186860	15.2844
3	0.500	0.0	1.4409	0.010103	0.014698	0.008833	0.721205	0.38221	0.109570	0.186620	15.2380
3	1.000	0.0	1.4408	0.010118	0.014708	0.008795	0.716646	0.38160	0.110490	0.187230	15.2554
3	2.000	0.0	1.4409	0.010150	0.014709	0.008715	0.707255	0.38049	0.111820	0.188410	15.2905
3	3.000	0.0	1.4409	0.010193	0.014702	0.008632	0.697983	0.37949	0.112900	0.189360	15.3111
3	4.000	0.0	1.4410	0.010242	0.014689	0.008549	0.688836	0.37859	0.113820	0.190060	15.3145
3	5.000	0.0	1.4411	0.010294	0.014675	0.008464	0.679761	0.37778	0.114610	0.190550	15.3040
3	6.000	0.0	1.4411	0.010348	0.014658	0.008379	0.670860	0.37705	0.115270	0.190860	15.2816
3	7.000	0.0	1.4412	0.010402	0.014641	0.008295	0.662255	0.37638	0.115840	0.191010	15.2491
3	8.000	0.0	1.4412	0.010456	0.014624	0.008213	0.653847	0.37578	0.116310	0.191010	15.2060
3	9.000	0.0	1.4413	0.010510	0.014607	0.008132	0.645627	0.37522	0.116700	0.190890	15.1554
3	10.000	0.0	1.4413	0.010562	0.014591	0.008052	0.637574	0.37471	0.117020	0.190660	15.0976
3	11.000	0.0	1.4414	0.010612	0.014575	0.007972	0.629675	0.37425	0.117270	0.190320	15.0326
3	12.000	0.0	1.4415	0.010659	0.014562	0.007892	0.621833	0.37382	0.117460	0.189890	14.9614
3	15.000	0.0	1.4417	0.010788	0.014529	0.007658	0.599171	0.37275	0.117710	0.188090	14.7158
3	17.500	0.0	1.4419	0.010887	0.014507	0.007468	0.581108	0.37202	0.117630	0.186130	14.4826
3	20.000	0.0	1.4421	0.010976	0.014492	0.007282	0.563622	0.37145	0.117320	0.183810	14.2268
3	25.000	0.0	1.4426	0.011126	0.014481	0.006925	0.530631	0.37060	0.116190	0.178440	13.6730
3	30.000	0.0	1.4431	0.011261	0.014480	0.006585	0.499898	0.37008	0.114500	0.172150	13.0679
3	35.000	0.0	1.4437	0.011384	0.014489	0.006266	0.471434	0.36980	0.112400	0.165240	12.4315
3	40.000	0.0	1.4443	0.011499	0.014505	0.005967	0.445084	0.36970	0.110010	0.157950	11.7820
3	45.000	0.0	1.4449	0.011606	0.014528	0.005685	0.420611	0.36973	0.107460	0.150510	11.1349
3	50.000	0.0	1.4456	0.011703	0.014558	0.005420	0.397754	0.36986	0.104830	0.143110	10.5031
4	0.000	0.0	1.4400	0.009946	0.014804	0.008590	0.702671	0.38326	0.105170	0.179650	14.6947
4	0.500	0.0	1.4397	0.009961	0.014831	0.008549	0.697971	0.38275	0.106080	0.179470	14.6524
4	1.000	0.0	1.4397	0.009977	0.014840	0.008513	0.693406	0.38211	0.107010	0.180120	14.6719
4	2.000	0.0	1.4398	0.010013	0.014839	0.008434	0.684122	0.38097	0.108360	0.181380	14.7123
4	3.000	0.0	1.4398	0.010057	0.014831	0.008352	0.674835	0.37994	0.109470	0.182360	14.7344
4	4.000	0.0	1.4399	0.010110	0.014816	0.008269	0.665666	0.37903	0.110410	0.183090	14.7392
4	5.000	0.0	1.4400	0.010166	0.014799	0.008186	0.656769	0.37821	0.111200	0.183610	14.7306
4	6.000	0.0	1.4400	0.010225	0.014780	0.008104	0.648061	0.37746	0.111880	0.183930	14.7085
4	7.000	0.0	1.4401	0.010282	0.014761	0.008022	0.639558	0.37679	0.112450	0.184080	14.6753
4	8.000	0.0	1.4402	0.010339	0.014742	0.007942	0.631255	0.37618	0.112920	0.184090	14.6330
4	9.000	0.0	1.4402	0.010395	0.014724	0.007861	0.623073	0.37562	0.113310	0.183970	14.5817
4	10.000	0.0	1.4403	0.010448	0.014707	0.007780	0.614995	0.37511	0.113630	0.183730	14.5230
4	11.000	0.0	1.4403	0.010499	0.014692	0.007700	0.607032	0.37464	0.113880	0.183390	14.4578
4	12.000	0.0	1.4404	0.010549	0.014677	0.007621	0.599269	0.37421	0.114060	0.182950	14.3863
4	15.000	0.0	1.4406	0.010683	0.014643	0.007391	0.576964	0.37314	0.114290	0.181120	14.1384
4	17.500	0.0	1.4408	0.010785	0.014620	0.007203	0.559021	0.37242	0.114190	0.179140	13.9035
4	20.000	0.0	1.4411	0.010875	0.014605	0.007018	0.541706	0.37185	0.113860	0.176790	13.6465
4	25.000	0.0	1.4416	0.011032	0.014591	0.006671	0.509602	0.37102	0.112710	0.171380	13.0914
4	30.000	0.0	1.4421	0.011175	0.014588	0.006343	0.479873	0.37051	0.111000	0.165080	12.4886
4	35.000	0.0	1.4427	0.011305	0.014594	0.006037	0.452494	0.37024	0.108900	0.158210	11.8594
4	40.000	0.0	1.4433	0.011426	0.014609	0.005749	0.427180	0.37014	0.106550	0.151020	11.2212
4	45.000	0.0	1.4439	0.011538	0.014632	0.005477	0.403573	0.37017	0.104050	0.143750	10.5913
4	50.000	0.0	1.4447	0.011642	0.014658	0.005226	0.381954	0.37030	0.101520	0.136600	9.9839

MOVEABLE CONTROL ROD ARRANGEMENT

GROUP	CORE LOCATIONS
1	20
2	3 9
3	24
4	11
5	13 22
6	7 16
7	5 26
8	18

CONTROL ROD NUCLEAR PROPERTIES

FUEL TYPE	FAST SIGA	THERM SIGA	FAST SIGR	S.H. FACTOR	CR COUP. FACTOR	LENGTH	VOL. FRAC.
1	0.004500	0.034400	-0.001500	0.000	0.700	366.00	0.05000
2	0.004500	0.034400	-0.001500	0.000	0.700	366.00	0.05000
3	0.004500	0.034400	-0.001500	0.000	0.700	366.00	0.05000
4	0.004500	0.034400	-0.001500	0.000	0.700	366.00	0.05000

BURNABLE POISON SUMMARY

INDEX NO.	BP NAME	ATOMS/CM IN ASSBY	MICRO FAST	MICRO THERM	SIGMAS G0	SELF SHIELDING A1	SELF SHIELDING A2	FIXED SIGMA-R	RESIDUAL SIGA-THERMAL	S.H. FACTOR	CR COUP. FACTOR	GEOMETRY LENGTH	GEOMETRY VOL. FRAC.	POSITION
1	B-20	0.1619E-04	45.00	2050.0	0.948	1.170	0.616	-0.000929	0.000375(-.940E-07)	0.000	1.000	100.00	.04394	0.00
2	B-16	0.3635E-04	45.00	2050.0	0.964	0.959	0.701	-0.000743	0.000300(-.750E-07)	0.000	1.000	100.00	.03515	0.00
3	B-12	0.9710E-05	45.00	2050.0	0.948	1.170	0.616	-0.000557	0.000225(-.560E-07)	0.000	1.000	100.00	.02636	0.00
4	B-08	0.1334E-04	45.00	2050.0	0.981	0.979	0.748	-0.000372	0.000150(-.375E-07)	0.000	1.000	100.00	.01758	0.00

THERMAL NEUTRON INLEAKAGE CORRECTION IN CONTROLLED ASSEMBLIES 0.000
MULTIPLICATION ABSORPTION 0.000

FUEL BATCH ASSIGNMENTS

BATCH INDEX	1	2	3	4
FUEL TYPE	1	2	3	4

SPARE FUEL ASSEMBLY TYPE AND BURNUP

INDEX NO.	1	2	3
FUEL TYPE	3	2	1
BURNUP	0.00	10.00	20.00

FUEL INVENTORY SELECTION PHASE SUMMARY

INITIAL FUEL AND BURNUP DISTRIBUTION

38.78(2)	24.69(3)	28.93(3)	0.00(4)	24.54(3)	0.00(4)	28.40(3)	40.21(2)
	27.70(3)	0.00(4)	28.42(3)	0.00(4)	22.65(3)	0.00(4)	37.04(2)
		27.92(3)	0.00(4)	29.03(3)	0.00(4)	0.00(4)	40.71(2)
AVG BURNUP = 18.05			27.93(3)	0.00(4)	21.20(3)	28.87(3)	
				27.66(3)	0.00(4)	38.45(1)	
					38.52(1)		

FINAL FUEL AND BURNUP DISTRIBUTION

38.78(2)	24.69(3)	28.93(3)	0.00(4)	24.54(3)	0.00(4)	28.40(3)	40.21(2)
	27.70(3)	0.00(4)	28.42(3)	0.00(4)	22.65(3)	0.00(4)	37.04(2)
		27.92(3)	0.00(4)	29.03(3)	0.00(4)	0.00(4)	40.71(2)
AVG BURNUP = 18.05			27.93(3)	0.00(4)	21.20(3)	28.87(3)	
				27.66(3)	0.00(4)	38.45(1)	
					38.52(1)		

BURNABLE POISON ASSEMBLY INVENTORY

INDEX	LOCATION	NAME	SIGAT
1	4	B-08	0.013621
2	6	B-08	0.013621
3	10	B-08	0.013621
4	12	B-08	0.013621
5	17	B-08	0.013621
6	19	B-08	0.013621
7	23	B-08	0.013621

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
1820.2 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG
1	12A2	38.784	52.649	.027108	.20076	.560075	2.980	.122045	1.15270	0.846353	1.15270	0.000000
2	13AE	24.686	53.612	.026642	.26077	.558284	2.650	.137174	1.30328	0.988370	1.30328	0.000000
3	13AE	28.930	53.399	.026756	.24883	.555842	2.674	.135787	1.27771	0.959035	1.27771	0.000000
4	14AE	0.000	54.809	.026014	.33020	.569897	2.884	.130259	1.24862	1.041783	1.37918	0.013621
5	13AE	24.537	53.619	.026638	.26121	.558384	2.650	.137208	1.30413	0.989415	1.30413	0.000000
6	14AE	0.000	54.809	.026014	.33020	.569897	2.884	.130259	1.24862	1.041783	1.37918	0.013621
7	13AE	28.395	53.425	.026742	.25032	.556145	2.671	.135966	1.28097	0.962731	1.28097	0.000000
8	12A2	40.206	52.578	.027149	.19768	.559386	2.996	.121403	1.14263	0.836853	1.14263	0.000000
9	13AE	27.702	53.460	.026723	.25226	.556538	2.667	.136198	1.28519	0.967518	1.28519	0.000000
10	14AE	0.000	54.809	.026014	.33020	.569897	2.884	.130259	1.24862	1.041783	1.37918	0.013621
11	13AE	28.425	53.424	.026743	.25024	.556128	2.671	.135956	1.28079	0.962524	1.28079	0.000000
12	14AE	0.000	54.809	.026014	.33020	.569897	2.884	.130259	1.24862	1.041783	1.37918	0.013621
13	13AE	22.646	53.719	.026585	.26680	.559648	2.644	.137630	1.31489	1.002676	1.31489	0.000000
14	14AE	0.000	55.278	.025794	.33303	.589196	2.877	.130568	1.37591	1.143707	1.37591	0.000000
15	12A2	37.045	52.736	.027059	.20457	.560932	2.962	.122827	1.16493	0.858013	1.16493	0.000000
16	13AE	27.922	53.449	.026729	.25165	.556413	2.668	.136125	1.28385	0.965999	1.28385	0.000000
17	14AE	0.000	54.809	.026014	.33020	.569897	2.884	.130259	1.24862	1.041783	1.37918	0.013621
18	13AE	29.027	53.394	.026759	.24856	.555787	2.674	.135754	1.27712	0.958365	1.27712	0.000000
19	14AE	0.000	54.809	.026014	.33020	.569897	2.884	.130259	1.24862	1.041783	1.37918	0.013621
20	14AE	0.000	55.278	.025794	.33303	.589196	2.877	.130568	1.37591	1.143707	1.37591	0.000000
21	12A2	40.708	52.553	.027163	.19667	.559162	3.002	.121171	1.13915	0.833638	1.13915	0.000000
22	13AE	27.932	53.448	.026730	.25162	.556408	2.668	.136121	1.28379	0.965930	1.28379	0.000000
23	14AE	0.000	54.809	.026014	.33020	.569897	2.884	.130259	1.24862	1.041783	1.37918	0.013621
24	13AE	21.198	53.795	.026545	.27110	.560619	2.639	.137954	1.32308	1.012845	1.32308	0.000000
25	13AE	28.866	53.402	.026755	.24901	.555878	2.673	.135808	1.27810	0.959477	1.27810	0.000000
26	13AE	27.655	53.462	.026722	.25239	.556565	2.666	.136214	1.28548	0.967843	1.28548	0.000000
27	14AE	0.000	55.278	.025794	.33303	.589196	2.877	.130568	1.37591	1.143707	1.37591	0.000000
28	10A3	38.450	52.547	.027141	.19316	.563447	3.069	.118645	1.12988	0.829791	1.12988	0.000000
29	10A3	38.519	52.543	.027143	.19302	.563410	3.070	.118615	1.12939	0.829328	1.12939	0.000000

FUEL ARRANGEMENT OPTIMIZATION SUMMARY
INITIAL POWER DISTRIBUTION

0.722	1.009	1.113	1.378	1.316	1.372	0.943	0.324
2/38.8	3/24.7	3/28.9	4/ 0.0	3/24.5	4/ 0.0	3/28.4	2/40.2
	1.049	1.290	1.201	1.392	1.306	1.302	0.358
	3/27.7	4/ 0.0	3/28.4	4/ 0.0	3/22.6	4/ 0.0	2/37.0
		1.181	1.333	1.147	1.269	1.152	0.261
		3/27.9	4/ 0.0	3/29.0	4/ 0.0	4/ 0.0	2/40.7
			1.144	1.226	1.024	0.554	
			3/27.9	4/ 0.0	3/21.2	3/28.9	
				0.972	0.937	0.240	
				3/27.7	4/ 0.0	1/38.5	
					0.284		
					1/38.5		

EGV = 1.000015
PMAX = 1.39
AT LOCATION 12

FINAL POWER DISTRIBUTION

0.722	1.009	1.113	1.378	1.316	1.372	0.943	0.324
2/38.8	3/24.7	3/28.9	4/ 0.0	3/24.5	4/ 0.0	3/28.4	2/40.2
	1.049	1.290	1.201	1.392	1.306	1.302	0.358
	3/27.7	4/ 0.0	3/28.4	4/ 0.0	3/22.6	4/ 0.0	2/37.0
		1.181	1.333	1.147	1.269	1.152	0.261
		3/27.9	4/ 0.0	3/29.0	4/ 0.0	4/ 0.0	2/40.7
			1.144	1.226	1.024	0.554	
			3/27.9	4/ 0.0	3/21.2	3/28.9	
				0.972	0.937	0.240	
				3/27.7	4/ 0.0	1/38.5	
					0.284		
					1/38.5		

EGV = 1.000015
PMAX = 1.39
AT LOCATION 12

ROD MOVEMENT/FUEL RELOCATION SUMMARY (1821.7 PPM)

STEP	GROUPS IN	PEAK/AVG	EGV	INTERCHANGE	
0	(N O N E)	1.392	1.000015	-	-

EASSI PROGRAM EASCYC (c)1988 CRYSTAL RIVER RELOAD #12 CORE WITH CASMO LIB (B4CAL2) OLD G FACTORS 9/12/** (10:54)
PAGE 8

OPERATING DATA FOR DEPLETION STEP 1

CORE POWER LEVEL 85.9 % OF F.P.

INPUT OPERATING VARIABLES

AVG. FUEL BURNUP - INITIAL 18.054 MWD/KG WATER DENSITY 0.7232 G/CC
BASE AX. BUCKLING CORRECTION 1.20E-04 BORON CONCENTRATION 1821.7 PPM

ITERATION SUMMARY

STAGE	ITER	EGV	ERROR	EPS	ALPH/BET	BORON	B-WORTH
INITIAL	3	0.999216	0.000168	.000300	1.68/0.13	1821.7	
BORON SEARCH	7	0.999992	0.000053	.000100	1.59/0.07	1810.8	-138.4
FINAL	9	1.000001	0.000042	.000050	1.48/0.00	1810.8	

0.724	1.009	1.112	1.376	1.315	1.374	0.944	0.325
2/38.8	3/24.7	3/28.9	4/ 0.0	3/24.5	4/ 0.0	3/28.4	2/40.2

1.049	1.290	1.199	1.391	1.306	1.302	0.359
3/27.7	4/ 0.0	3/28.4	4/ 0.0	3/22.6	4/ 0.0	2/37.0

1.179	1.332	1.146	1.271	1.153	0.262
3/27.9	4/ 0.0	3/29.0	4/ 0.0	4/ 0.0	2/40.7

1.142	1.226	1.025	0.555
3/27.9	4/ 0.0	3/21.2	3/28.9

0.973	0.938	0.240
3/27.7	4/ 0.0	1/38.5

0.284
1/38.5

EGV = 1.000001
PMAX = 1.39
AT LOCATION 12

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
1810.8 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG	BURPO
1	12A2	38.784	52.654	.027106	.20078	.560151	2.983	.121933	1.15375	0.847052	1.15375	0.000000	0.0000
2	13AE	24.686	53.617	.026640	.26079	.558362	2.652	.137061	1.30436	0.989098	1.30436	0.000000	0.0000
3	13AE	28.930	53.404	.026754	.24885	.555919	2.676	.135674	1.27877	0.959749	1.27877	0.000000	0.0000
4	14AE	0.000	54.798	.026019	.33014	.569820	2.877	.130558	1.24621	1.040257	1.37602	0.013599	1.0000
5	13AE	24.537	53.625	.026635	.26123	.558461	2.652	.137094	1.30521	0.990143	1.30521	0.000000	0.0000
6	14AE	0.000	54.798	.026019	.33014	.569820	2.877	.130558	1.24621	1.040257	1.37602	0.013599	1.0000
7	13AE	28.395	53.430	.026739	.25035	.556222	2.673	.135853	1.28204	0.963447	1.28204	0.000000	0.0000
8	12A2	40.206	52.583	.027146	.19770	.559462	2.999	.121291	1.14368	0.837547	1.14368	0.000000	0.0000
9	13AE	27.702	53.465	.026721	.25229	.556615	2.669	.136085	1.28626	0.968236	1.28626	0.000000	0.0000
10	14AE	0.000	54.798	.026019	.33014	.569820	2.877	.130558	1.24621	1.040257	1.37602	0.013599	1.0000
11	13AE	28.425	53.429	.026740	.25026	.556205	2.673	.135843	1.28186	0.963240	1.28186	0.000000	0.0000
12	14AE	0.000	54.798	.026019	.33014	.569820	2.877	.130558	1.24621	1.040257	1.37602	0.013599	1.0000
13	13AE	22.646	53.724	.026583	.26683	.559726	2.646	.137517	1.31597	1.003413	1.31597	0.000000	0.0000
14	14AE	0.000	55.283	.025791	.33306	.589285	2.877	.130555	1.37605	1.143948	1.37605	0.000000	0.0000
15	12A2	37.045	52.741	.027056	.20459	.561008	2.964	.122715	1.16599	0.858716	1.16599	0.000000	0.0000
16	13AE	27.922	53.454	.026727	.25167	.556490	2.670	.136012	1.28492	0.966716	1.28492	0.000000	0.0000
17	14AE	0.000	54.798	.026019	.33014	.569820	2.877	.130558	1.24621	1.040257	1.37602	0.013599	1.0000
18	13AE	29.027	53.399	.026756	.24858	.555864	2.677	.135641	1.27818	0.959078	1.27818	0.000000	0.0000
19	14AE	0.000	54.798	.026019	.33014	.569820	2.877	.130558	1.24621	1.040257	1.37602	0.013599	1.0000
20	14AE	0.000	55.283	.025791	.33306	.589285	2.877	.130555	1.37605	1.143948	1.37605	0.000000	0.0000
21	12A2	40.708	52.558	.027160	.19669	.559238	3.005	.121059	1.14020	0.834330	1.14020	0.000000	0.0000
22	13AE	27.932	53.453	.026727	.25164	.556485	2.670	.136008	1.28486	0.966647	1.28486	0.000000	0.0000
23	14AE	0.000	54.798	.026019	.33014	.569820	2.877	.130558	1.24621	1.040257	1.37602	0.013599	1.0000
24	13AE	21.198	53.800	.026543	.27113	.560698	2.641	.137840	1.32417	1.013586	1.32417	0.000000	0.0000
25	13AE	28.866	53.407	.026752	.24903	.555955	2.676	.135695	1.27917	0.960191	1.27917	0.000000	0.0000
26	13AE	27.655	53.467	.026720	.25242	.556642	2.669	.136101	1.28654	0.968561	1.28654	0.000000	0.0000
27	14AE	0.000	55.283	.025791	.33306	.589285	2.877	.130555	1.37605	1.143948	1.37605	0.000000	0.0000
28	10A3	38.450	52.552	.027139	.19318	.563524	3.072	.118534	1.13094	0.830494	1.13094	0.000000	0.0000
29	10A3	38.519	52.548	.027141	.19304	.563487	3.073	.118504	1.13045	0.830032	1.13045	0.000000	0.0000

EASSI PROGRAM EASCYC (c)1988 CRYSTAL RIVER RELOAD #12 CORE WITH CASMO LIB (B4CAL2) OLD G FACTORS 9/12/** (10:54)
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OPERATING DATA FOR DEPLETION STEP 2

CORE POWER LEVEL 85.9 % OF F.P.

INPUT OPERATING VARIABLES

AVG. FUEL BURNUP - INITIAL 20.054 MWD/KG WATER DENSITY 0.7232 G/CC
BASE AX. BUCKLING CORRECTION 1.20E-04 BORON CONCENTRATION 1710.8 PPM

ITERATION SUMMARY

STAGE	ITER	EGV	ERROR	EPS	ALPH/BET	BORON	B-WORTH
INITIAL	11	1.006299	0.000203	.000300	2.29/0.26	1710.8	
BORON SEARCH	16	1.000188	0.000100	.000100	1.67/0.09	1796.1	-139.5
FINAL	20	1.000212	0.000035	.000050	1.59/0.07	1796.1	

0.655	0.922	1.060	1.384	1.287	1.397	0.930	0.322
2/40.2	3/26.7	3/31.2	4/ 2.8	3/27.2	4/ 2.7	3/30.3	2/40.9
	0.981	1.281	1.172	1.415	1.286	1.312	0.361
	3/29.8	4/ 2.6	3/30.8	4/ 2.8	3/25.3	4/ 2.6	2/37.8
		1.149	1.354	1.137	1.313	1.185	0.266
		3/30.3	4/ 2.7	3/31.3	4/ 2.5	4/ 2.3	2/41.2
			1.134	1.265	1.025	0.556	
			3/30.2	4/ 2.5	3/23.2	3/30.0	
				0.975	0.959	0.243	
				3/29.6	4/ 1.9	1/38.9	
					0.290		
					1/39.1		

EGV = 1.000212
PMAX = 1.41
AT LOCATION 12

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
1796.1 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG	BURPO
1	12A2	40.232	52.589	.027143	.19768	.559531	3.003	.121110	1.14510	0.838396	1.14510	0.000000	0.0000
2	13AE	26.705	53.523	.026690	.25512	.557263	2.666	.136250	1.29390	0.976162	1.29390	0.000000	0.0000
3	13AE	31.154	53.303	.026809	.24288	.554840	2.695	.134664	1.26652	0.945594	1.26652	0.000000	0.0000
4	14AE	2.752	54.849	.025992	.32212	.571536	2.872	.129773	1.28797	1.058240	1.40335	0.011625	0.7468
5	13AE	27.166	53.500	.026702	.25382	.557001	2.669	.136096	1.29111	0.972974	1.29111	0.000000	0.0000
6	14AE	2.747	54.849	.025992	.32213	.571536	2.872	.129768	1.28796	1.058245	1.40337	0.011629	0.7472
7	13AE	30.283	53.345	.026786	.24517	.555259	2.688	.135028	1.27203	0.951470	1.27203	0.000000	0.0000
8	12A2	40.856	52.559	.027160	.19642	.559253	3.011	.120821	1.14077	0.834395	1.14077	0.000000	0.0000
9	13AE	29.800	53.368	.026773	.24647	.555508	2.685	.135213	1.27504	0.954760	1.27504	0.000000	0.0000
10	14AE	2.579	54.844	.025994	.32263	.571534	2.877	.129581	1.28735	1.058394	1.40412	0.011754	0.7614
11	13AE	30.823	53.319	.026800	.24375	.554999	2.692	.134803	1.26861	0.947827	1.26861	0.000000	0.0000
12	14AE	2.782	54.850	.025991	.32203	.571536	2.871	.129807	1.28808	1.058213	1.40321	0.011602	0.7443
13	13AE	25.258	53.596	.026651	.25918	.558087	2.658	.136736	1.30263	0.986160	1.30263	0.000000	0.0000
14	14AE	2.603	55.020	.025911	.32359	.587725	2.876	.129634	1.40373	1.148603	1.40373	0.000000	0.0000
15	12A2	37.763	52.713	.027073	.20304	.560735	2.976	.122223	1.16256	0.854934	1.16256	0.000000	0.0000
16	13AE	30.280	53.345	.026786	.24517	.555260	2.688	.135029	1.27204	0.951487	1.27204	0.000000	0.0000
17	14AE	2.664	54.846	.025993	.32238	.571536	2.875	.129675	1.28765	1.058319	1.40374	0.011691	0.7542
18	13AE	31.318	53.295	.026813	.24245	.554761	2.696	.134596	1.26548	0.944489	1.26548	0.000000	0.0000
19	14AE	2.542	54.843	.025995	.32274	.571534	2.879	.129540	1.28721	1.058427	1.40429	0.011782	0.7645
20	14AE	2.306	55.043	.025900	.32467	.588060	2.886	.129304	1.40506	1.150930	1.40506	0.000000	0.0000
21	12A2	41.232	52.540	.027171	.19566	.559086	3.015	.120648	1.13815	0.831981	1.13815	0.000000	0.0000
22	13AE	30.216	53.348	.026784	.24534	.555291	2.687	.135056	1.27245	0.951919	1.27245	0.000000	0.0000
23	14AE	2.453	54.840	.025996	.32301	.571532	2.882	.129441	1.28689	1.058506	1.40469	0.011848	0.7722
24	13AE	23.248	53.700	.026596	.26509	.559405	2.651	.137213	1.31417	1.000240	1.31417	0.000000	0.0000
25	13AE	29.975	53.360	.026778	.24598	.555409	2.686	.135154	1.27396	0.953546	1.27396	0.000000	0.0000
26	13AE	29.601	53.378	.026768	.24702	.555621	2.683	.135280	1.27626	0.956133	1.27626	0.000000	0.0000
27	14AE	1.875	55.075	.025885	.32621	.588510	2.901	.128796	1.40706	1.154277	1.40706	0.000000	0.0000
28	10A3	38.930	52.535	.027149	.19221	.563349	3.082	.118158	1.12912	0.828300	1.12912	0.000000	0.0000
29	10A3	39.088	52.527	.027153	.19189	.563265	3.084	.118091	1.12799	0.827243	1.12799	0.000000	0.0000

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OPERATING DATA FOR DEPLETION STEP 3

CORE POWER LEVEL 85.9 % OF F.P.

INPUT OPERATING VARIABLES

AVG. FUEL BURNUP - INITIAL 22.054 MWD/KG WATER DENSITY 0.7232 G/CC
BASE AX. BUCKLING CORRECTION 1.20E-04 BORON CONCENTRATION 1781.3 PPM

ITERATION SUMMARY

STAGE	ITER	EGV	ERROR	EPS	ALPH/BET	BORON	B-WORTH
INITIAL	10	0.989620	0.000256	.000300	2.16/0.22	1781.3	
BORON SEARCH	17	0.999707	0.000079	.000100	1.66/0.08	1639.9	-140.2
FINAL	20	0.999702	0.000042	.000050	1.68/0.13	1639.9	

0.667	0.930	1.070	1.404	1.272	1.387	0.908	0.320
2/41.5	3/28.5	3/33.3	4/ 5.5	3/29.7	4/ 5.5	3/32.1	2/41.5
	0.993	1.309	1.175	1.424	1.257	1.262	0.358
	3/31.8	4/ 5.1	3/33.2	4/ 5.6	3/27.8	4/ 5.2	2/38.5
		1.158	1.379	1.137	1.315	1.153	0.265
		3/32.6	4/ 5.4	3/33.6	4/ 5.2	4/ 4.7	2/41.8
			1.142	1.287	1.024	0.558	
			3/32.5	4/ 5.0	3/25.3	3/31.1	
				0.981	0.960	0.249	
				3/31.6	4/ 3.8	1/39.4	
					0.297		
					1/39.7		

EGV = 0.999702
PMAX = 1.42
AT LOCATION 12

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
1639.9 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG	BURPO
1	12A2	41.542	52.608	.027137	.19534	.559832	3.064	.118705	1.15320	0.840935	1.15320	0.000000	0.0000
2	13AE	28.548	53.517	.026697	.25036	.557111	2.713	.133834	1.29995	0.974573	1.29995	0.000000	0.0000
3	13AE	33.275	53.286	.026822	.23772	.554709	2.749	.131981	1.27006	0.942234	1.27006	0.000000	0.0000
4	14AE	5.521	54.985	.025931	.31404	.571173	2.840	.130403	1.31366	1.064362	1.40929	0.009494	0.5366
5	13AE	29.740	53.457	.026729	.24703	.556434	2.720	.133434	1.29260	0.966273	1.29260	0.000000	0.0000
6	14AE	5.541	54.985	.025931	.31397	.571159	2.840	.130417	1.31372	1.064316	1.40919	0.009478	0.5352
7	13AE	32.143	53.340	.026792	.24068	.555253	2.739	.132453	1.27735	0.949931	1.27735	0.000000	0.0000
8	12A2	41.500	52.610	.027135	.19542	.559851	3.064	.118725	1.15350	0.841211	1.15350	0.000000	0.0000
9	13AE	31.761	53.359	.026782	.24168	.555437	2.736	.132612	1.27979	0.952519	1.27979	0.000000	0.0000
10	14AE	5.142	54.984	.025932	.31523	.571439	2.848	.130145	1.31243	1.065199	1.41115	0.009790	0.5628
11	13AE	33.167	53.291	.026819	.23800	.554761	2.748	.132026	1.27076	0.942968	1.27076	0.000000	0.0000
12	14AE	5.612	54.985	.025931	.31375	.571108	2.839	.130466	1.31395	1.064157	1.40885	0.009422	0.5304
13	13AE	27.831	53.553	.026677	.25237	.557519	2.709	.134074	1.30434	0.979564	1.30434	0.000000	0.0000
14	14AE	5.227	54.906	.025968	.31452	.584897	2.847	.130160	1.41120	1.139924	1.41120	0.000000	0.0000
15	12A2	38.484	52.760	.027050	.20178	.561269	3.029	.120100	1.17482	0.861170	1.17482	0.000000	0.0000
16	13AE	32.577	53.320	.026804	.23954	.555044	2.743	.132272	1.27456	0.946976	1.27456	0.000000	0.0000
17	14AE	5.371	54.984	.025931	.31451	.571280	2.844	.130302	1.31317	1.064694	1.41003	0.009611	0.5468
18	13AE	33.592	53.271	.026830	.23689	.554557	2.751	.131849	1.26802	0.940077	1.26802	0.000000	0.0000
19	14AE	5.168	54.984	.025932	.31515	.571422	2.848	.130163	1.31251	1.065143	1.41103	0.009770	0.5610
20	14AE	4.675	54.951	.025947	.31653	.585767	2.860	.129749	1.41381	1.144699	1.41381	0.000000	0.0000
21	12A2	41.763	52.597	.027143	.19489	.559734	3.067	.118603	1.15164	0.839506	1.15164	0.000000	0.0000
22	13AE	32.484	53.324	.026801	.23978	.555089	2.742	.132311	1.27516	0.947610	1.27516	0.000000	0.0000
23	14AE	4.982	54.983	.025932	.31573	.571546	2.852	.130035	1.31190	1.065541	1.41194	0.009915	0.5741
24	13AE	25.297	53.680	.026609	.25949	.558965	2.694	.134923	1.31976	0.997184	1.31976	0.000000	0.0000
25	13AE	31.087	53.391	.026764	.24345	.555762	2.731	.132894	1.28410	0.957100	1.28410	0.000000	0.0000
26	13AE	31.552	53.369	.026777	.24223	.555538	2.735	.132700	1.28113	0.953942	1.28113	0.000000	0.0000
27	14AE	3.793	55.020	.025912	.31978	.587105	2.881	.129021	1.41790	1.152236	1.41790	0.000000	0.0000
28	10A3	39.417	52.593	.027120	.19150	.563981	3.135	.116150	1.14306	0.836168	1.14306	0.000000	0.0000
29	10A3	39.669	52.580	.027128	.19098	.563846	3.138	.116042	1.14123	0.834460	1.14123	0.000000	0.0000

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OPERATING DATA FOR DEPLETION STEP 4

CORE POWER LEVEL 85.9 % OF F.P.

INPUT OPERATING VARIABLES

AVG. FUEL BURNUP - INITIAL 24.054 MWD/KG WATER DENSITY 0.7232 G/CC
BASE AX. BUCKLING CORRECTION 1.20E-04 BORON CONCENTRATION 1483.7 PPM

ITERATION SUMMARY

STAGE	ITER	EGV	ERROR	EPS	ALPH/BET	BORON	B-WORTH
INITIAL	10	0.998840	0.000214	.000300	2.16/0.22	1483.7	
BORON SEARCH	15	0.999967	0.000087	.000100	1.83/0.12	1468.3	-132.1
FINAL	19	0.999960	0.000045	.000050	1.59/0.07	1468.3	

0.680	0.939	1.078	1.421	1.259	1.379	0.891	0.320
2/42.9	3/30.4	3/35.4	4/ 8.3	3/32.3	4/ 8.3	3/34.0	2/42.1
	1.003	1.334	1.177	1.432	1.231	1.220	0.357
	3/33.7	4/ 7.8	3/35.5	4/ 8.5	3/30.3	4/ 7.7	2/39.2
		1.165	1.399	1.135	1.317	1.126	0.265
		3/34.9	4/ 8.1	3/35.9	4/ 7.8	4/ 7.0	2/42.3
			1.146	1.306	1.023	0.560	
			3/34.8	4/ 7.6	3/27.3	3/32.2	
				0.984	0.959	0.255	
				3/33.5	4/ 5.7	1/39.9	
					0.304		
					1/40.3		

EGV = 0.999960
PMAX = 1.43
AT LOCATION 12

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
1468.3 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG	BURPO
1	12A2	42.876	52.633	.027127	.19298	.560201	3.133	.116115	1.16321	0.844609	1.16321	0.000000	0.0000
2	13AE	30.408	53.518	.026699	.24566	.557063	2.766	.131204	1.30779	0.974182	1.30779	0.000000	0.0000
3	13AE	35.414	53.277	.026831	.23261	.554671	2.810	.129091	1.27535	0.940009	1.27535	0.000000	0.0000
4	14AE	8.329	55.082	.025889	.30575	.570044	2.838	.129890	1.34152	1.070472	1.41698	0.007306	0.3664
5	13AE	32.284	53.427	.026749	.24073	.556155	2.782	.130421	1.29575	0.961370	1.29575	0.000000	0.0000
6	14AE	8.315	55.083	.025889	.30579	.570056	2.838	.129884	1.34148	1.070508	1.41705	0.007316	0.3671
7	13AE	33.959	53.347	.026793	.23635	.555347	2.796	.129722	1.28489	0.949907	1.28489	0.000000	0.0000
8	12A2	42.140	52.670	.027106	.19447	.560530	3.123	.116455	1.16846	0.849423	1.16846	0.000000	0.0000
9	13AE	33.747	53.357	.026787	.23690	.555449	2.795	.129811	1.28627	0.951361	1.28627	0.000000	0.0000
10	14AE	7.761	55.088	.025886	.30755	.570517	2.846	.129648	1.33987	1.071966	1.41990	0.007744	0.3973
11	13AE	35.517	53.272	.026834	.23236	.554627	2.811	.129043	1.27467	0.939325	1.27467	0.000000	0.0000
12	14AE	8.460	55.081	.025889	.30533	.569934	2.837	.129941	1.34189	1.070111	1.41629	0.007205	0.3595
13	13AE	30.344	53.521	.026698	.24583	.557094	2.766	.131230	1.30819	0.974613	1.30819	0.000000	0.0000
14	14AE	7.750	54.806	.026019	.30601	.581905	2.846	.129638	1.42001	1.132322	1.42001	0.000000	0.0000
15	12A2	39.199	52.816	.027024	.20056	.561885	3.088	.117805	1.18931	0.868819	1.18931	0.000000	0.0000
16	13AE	34.894	53.302	.026818	.23390	.554897	2.804	.129332	1.27877	0.943493	1.27877	0.000000	0.0000
17	14AE	8.128	55.085	.025887	.30639	.570210	2.841	.129811	1.34095	1.071013	1.41802	0.007460	0.3771
18	13AE	35.865	53.255	.026843	.23150	.554480	2.814	.128877	1.27237	0.937006	1.27237	0.000000	0.0000
19	14AE	7.798	55.088	.025886	.30743	.570485	2.845	.129666	1.33998	1.071871	1.41971	0.007715	0.3952
20	14AE	6.982	54.865	.025989	.30872	.583122	2.858	.129275	1.42392	1.139039	1.42392	0.000000	0.0000
21	12A2	42.292	52.662	.027111	.19416	.560462	3.125	.116385	1.16737	0.848426	1.16737	0.000000	0.0000
22	13AE	34.768	53.308	.026814	.23423	.554958	2.803	.129385	1.27960	0.944356	1.27960	0.000000	0.0000
23	14AE	7.557	55.089	.025885	.30819	.570685	2.849	.129552	1.33925	1.072477	1.42094	0.007902	0.4088
24	13AE	27.345	53.672	.026617	.25418	.558775	2.746	.132264	1.32682	0.995572	1.32682	0.000000	0.0000
25	13AE	32.202	53.431	.026747	.24095	.556195	2.781	.130455	1.29628	0.961933	1.29628	0.000000	0.0000
26	13AE	33.513	53.368	.026781	.23751	.555562	2.793	.129908	1.28779	0.952960	1.28779	0.000000	0.0000
27	14AE	5.712	54.965	.025941	.31331	.585154	2.881	.128518	1.43044	1.150343	1.43044	0.000000	0.0000
28	10A3	39.915	52.658	.027088	.19080	.564687	3.195	.113963	1.15918	0.845373	1.15918	0.000000	0.0000
29	10A3	40.264	52.641	.027098	.19013	.564511	3.199	.113812	1.15672	0.843106	1.15672	0.000000	0.0000

EASSI PROGRAM EASCYC (c)1988 CRYSTAL RIVER RELOAD #12 CORE WITH CASMO LIB (B4CAL2) OLD G FACTORS 9/12/** (10:54)
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OPERATING DATA FOR DEPLETION STEP 5

CORE POWER LEVEL 85.9 % OF F.P.

INPUT OPERATING VARIABLES

AVG. FUEL BURNUP - INITIAL 26.054 MWD/KG WATER DENSITY 0.7232 G/CC
BASE AX. BUCKLING CORRECTION 1.20E-04 BORON CONCENTRATION 1296.8 PPM

ITERATION SUMMARY

STAGE	ITER	EGV	ERROR	EPS	ALPH/BET	BORON	B-WORTH
INITIAL	9	1.000099	0.000245	.000300	2.07/0.19	1296.8	
BORON SEARCH	14	0.999996	0.000088	.000100	2.22/0.24	1298.1	-129.1
FINAL	18	0.999995	0.000045	.000050	1.59/0.07	1298.1	

0.691	0.945	1.082	1.431	1.245	1.373	0.879	0.322
2/44.2	3/32.3	3/37.6	4/11.2	3/34.8	4/11.1	3/35.7	2/42.8
	1.010	1.353	1.175	1.435	1.210	1.187	0.358
	3/35.8	4/10.4	3/37.9	4/11.3	3/32.8	4/10.2	2/39.9
		1.167	1.413	1.133	1.321	1.105	0.266
		3/37.2	4/10.9	3/38.1	4/10.4	4/ 9.2	2/42.8
			1.149	1.323	1.023	0.564	
			3/37.1	4/10.2	3/29.4	3/33.3	
				0.987	0.960	0.261	
				3/35.5	4/ 7.6	1/40.4	
					0.311		
					1/40.9		

EGV = 0.999995
PMAX = 1.44
AT LOCATION 12

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
1298.1 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG	BURPO
1	12A2	44.236	52.657	.027118	.19056	.560554	3.204	.113526	1.17334	0.848285	1.17334	0.000000	0.0000
2	13AE	32.285	53.521	.026702	.24115	.557123	2.825	.128462	1.31551	0.974049	1.31551	0.000000	0.0000
3	13AE	37.569	53.267	.026841	.22772	.554719	2.876	.126108	1.28060	0.938096	1.28060	0.000000	0.0000
4	14AE	11.171	55.132	.025867	.29715	.568699	2.852	.128793	1.36775	1.074993	1.42333	0.005233	0.2363
5	13AE	34.803	53.399	.026769	.23455	.555905	2.847	.127411	1.29904	0.956692	1.29904	0.000000	0.0000
6	14AE	11.074	55.134	.025866	.29746	.568781	2.852	.128775	1.36757	1.075311	1.42386	0.005300	0.2401
7	13AE	35.740	53.354	.026793	.23221	.555495	2.856	.126977	1.29284	0.950377	1.29284	0.000000	0.0000
8	12A2	42.780	52.729	.027077	.19351	.561206	3.185	.114200	1.18387	0.857900	1.18387	0.000000	0.0000
9	13AE	35.753	53.353	.026794	.23218	.555489	2.856	.126971	1.29275	0.950290	1.29275	0.000000	0.0000
10	14AE	10.430	55.150	.025859	.29954	.569319	2.858	.128618	1.36628	1.077386	1.42736	0.005749	0.2663
11	13AE	37.870	53.252	.026849	.22699	.554592	2.879	.125965	1.27858	0.936075	1.27858	0.000000	0.0000
12	14AE	11.324	55.129	.025869	.29666	.568570	2.851	.128821	1.36803	1.074483	1.42250	0.005130	0.2305
13	13AE	32.807	53.496	.026716	.23978	.556870	2.829	.128244	1.31211	0.970455	1.31211	0.000000	0.0000
14	14AE	10.189	54.719	.026062	.29793	.579285	2.860	.128558	1.42866	1.125534	1.42866	0.000000	0.0000
15	12A2	39.912	52.871	.026997	.19934	.562500	3.148	.115525	1.20425	0.876734	1.20425	0.000000	0.0000
16	13AE	37.223	53.283	.026832	.22857	.554866	2.872	.126273	1.28293	0.940428	1.28293	0.000000	0.0000
17	14AE	10.926	55.138	.025864	.29793	.568905	2.854	.128743	1.36729	1.075795	1.42466	0.005401	0.2459
18	13AE	38.136	53.240	.026856	.22634	.554479	2.882	.125839	1.27678	0.934283	1.27678	0.000000	0.0000
19	14AE	10.433	55.150	.025859	.29953	.569316	2.858	.128619	1.36629	1.077376	1.42734	0.005747	0.2661
20	14AE	9.234	54.789	.026028	.30129	.580662	2.870	.128264	1.43387	1.133885	1.43387	0.000000	0.0000
21	12A2	42.821	52.727	.027079	.19342	.561188	3.186	.114181	1.18357	0.857625	1.18357	0.000000	0.0000
22	13AE	37.061	53.291	.026828	.22897	.554935	2.870	.126350	1.28402	0.941516	1.28402	0.000000	0.0000
23	14AE	10.170	55.156	.025856	.30037	.569529	2.861	.128553	1.36571	1.078185	1.42877	0.005935	0.2774
24	13AE	29.391	53.663	.026625	.24887	.558581	2.801	.129619	1.33403	0.994041	1.33403	0.000000	0.0000
25	13AE	33.321	53.471	.026730	.23843	.556621	2.834	.128029	1.30876	0.966915	1.30876	0.000000	0.0000
26	13AE	35.481	53.366	.026786	.23285	.555605	2.854	.127100	1.29456	0.952111	1.29456	0.000000	0.0000
27	14AE	7.631	54.914	.025967	.30698	.583134	2.892	.127624	1.44241	1.148101	1.44241	0.000000	0.0000
28	10A3	40.424	52.723	.027056	.19015	.565401	3.257	.111782	1.17585	0.854977	1.17585	0.000000	0.0000
29	10A3	40.871	52.701	.027068	.18931	.565178	3.263	.111588	1.17270	0.852094	1.17270	0.000000	0.0000

OPERATING DATA FOR DEPLETION STEP 6

CORE POWER LEVEL 85.9 % OF F.P.

INPUT OPERATING VARIABLES

AVG. FUEL BURNUP - INITIAL 28.054 MWD/KG WATER DENSITY 0.7232 G/CC
BASE AX. BUCKLING CORRECTION 1.20E-04 BORON CONCENTRATION 1127.9 PPM

ITERATION SUMMARY

STAGE	ITER	EGV	ERROR	EPS	ALPH/BET	BORON	B-WORTH
INITIAL	7	0.999886	0.000258	.000300	1.70/0.09	1127.9	
BORON SEARCH	11	0.999999	0.000089	.000100	1.59/0.07	1126.4	-126.1
FINAL	14	1.000001	0.000047	.000050	1.68/0.13	1126.4	

0.700	0.947	1.081	1.433	1.230	1.367	0.874	0.327
2/45.6	3/34.2	3/39.7	4/14.0	3/37.3	4/13.8	3/37.5	2/43.4
	1.013	1.363	1.167	1.434	1.193	1.166	0.362
	3/37.8	4/13.1	3/40.2	4/14.2	3/35.2	4/12.6	2/40.6
		1.163	1.420	1.129	1.325	1.093	0.270
		3/39.6	4/13.8	3/40.4	4/13.1	4/11.4	2/43.4
			1.148	1.338	1.026	0.571	
			3/39.4	4/12.8	3/31.4	3/34.4	
				0.993	0.964	0.269	
				3/37.5	4/ 9.6	1/40.9	
					0.319		
					1/41.5		

EGV = 1.000001
PMAX = 1.43
AT LOCATION 12

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
1126.4 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG	BURPO
1	12A2	45.617	52.682	.027109	.18822	.560922	3.280	.110915	1.18424	0.852492	1.18424	0.000000	0.0000
2	13AE	34.175	53.524	.026705	.23661	.557185	2.886	.125697	1.32366	0.974131	1.32366	0.000000	0.0000
3	13AE	39.734	53.257	.026851	.22282	.554772	2.946	.123104	1.28622	0.936379	1.28622	0.000000	0.0000
4	14AE	14.033	55.153	.025861	.28866	.567445	2.881	.127129	1.39130	1.078147	1.42933	0.003475	0.1437
5	13AE	37.292	53.374	.026787	.22880	.555808	2.918	.124264	1.30285	0.952940	1.30285	0.000000	0.0000
6	14AE	13.819	55.161	.025858	.28934	.567620	2.882	.127112	1.39124	1.079031	1.43055	0.003592	0.1494
7	13AE	37.498	53.364	.026792	.22830	.555720	2.921	.124166	1.30146	0.951546	1.30146	0.000000	0.0000
8	12A2	43.424	52.789	.027048	.19254	.561890	3.250	.111926	1.20005	0.866833	1.20005	0.000000	0.0000
9	13AE	37.774	53.351	.026799	.22762	.555603	2.924	.124035	1.29960	0.949680	1.29960	0.000000	0.0000
10	14AE	13.136	55.183	.025847	.29149	.568165	2.885	.127058	1.39085	1.081720	1.43444	0.003982	0.1688
11	13AE	40.219	53.234	.026864	.22166	.554579	2.951	.122866	1.28290	0.933131	1.28290	0.000000	0.0000
12	14AE	14.194	55.148	.025864	.28815	.567311	2.880	.127142	1.39133	1.077469	1.42842	0.003389	0.1395
13	13AE	35.228	53.473	.026733	.23388	.556688	2.896	.125245	1.31668	0.966867	1.31668	0.000000	0.0000
14	14AE	12.564	54.649	.026098	.29036	.577192	2.887	.127013	1.43770	1.120183	1.43770	0.000000	0.0000
15	12A2	40.628	52.928	.026970	.19822	.563151	3.213	.113219	1.22012	0.885331	1.22012	0.000000	0.0000
16	13AE	39.557	53.265	.026846	.22325	.554847	2.944	.123188	1.28744	0.937582	1.28744	0.000000	0.0000
17	14AE	13.753	55.163	.025857	.28954	.567674	2.882	.127107	1.39121	1.079299	1.43093	0.003628	0.1512
18	13AE	40.402	53.225	.026868	.22124	.554512	2.953	.122773	1.28165	0.931930	1.28165	0.000000	0.0000
19	14AE	13.074	55.184	.025846	.29168	.568213	2.885	.127053	1.39080	1.081953	1.43479	0.004018	0.1707
20	14AE	11.445	54.726	.026060	.29412	.578606	2.894	.126868	1.44398	1.129620	1.44398	0.000000	0.0000
21	12A2	43.354	52.792	.027046	.19268	.561922	3.249	.111958	1.20055	0.867298	1.20055	0.000000	0.0000
22	13AE	39.358	53.275	.026841	.22374	.554931	2.941	.123282	1.28880	0.938932	1.28880	0.000000	0.0000
23	14AE	12.816	55.192	.025842	.29249	.568412	2.886	.127033	1.39058	1.082911	1.43626	0.004173	0.1786
24	13AE	31.437	53.657	.026633	.24381	.558516	2.861	.126839	1.34157	0.993096	1.34157	0.000000	0.0000
25	13AE	34.449	53.510	.026712	.23589	.557052	2.888	.125583	1.32185	0.972229	1.32185	0.000000	0.0000
26	13AE	37.456	53.366	.026791	.22840	.555738	2.920	.124186	1.30175	0.951833	1.30175	0.000000	0.0000
27	14AE	9.551	54.865	.025992	.30072	.581246	2.912	.126391	1.45452	1.146151	1.45452	0.000000	0.0000
28	10A3	40.947	52.789	.027023	.18950	.566121	3.323	.109579	1.19330	0.865051	1.19330	0.000000	0.0000
29	10A3	41.493	52.761	.027039	.18847	.565848	3.330	.109341	1.18941	0.861493	1.18941	0.000000	0.0000

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OPERATING DATA FOR DEPLETION STEP 7

CORE POWER LEVEL 85.9 % OF F.P.

INPUT OPERATING VARIABLES

AVG. FUEL BURNUP - INITIAL 30.054 MWD/KG WATER DENSITY 0.7232 G/CC
BASE AX. BUCKLING CORRECTION 1.20E-04 BORON CONCENTRATION 954.7 PPM

ITERATION SUMMARY

STAGE	ITER	EGV	ERROR	EPS	ALPH/BET	BORON	B-WORTH
INITIAL	7	0.999645	0.000261	.000300	1.69/0.09	954.7	
BORON SEARCH	13	1.000008	0.000078	.000100	1.94/0.15	950.4	-123.1
FINAL	16	1.000010	0.000049	.000050	1.68/0.13	950.4	

0.709	0.950	1.077	1.424	1.212	1.359	0.874	0.335
2/47.0	3/36.1	3/41.9	4/16.9	3/39.8	4/16.6	3/39.2	2/44.1
	1.013	1.364	1.157	1.424	1.180	1.154	0.371
	3/39.8	4/15.9	3/42.6	4/17.1	3/37.6	4/14.9	2/41.4
		1.156	1.417	1.124	1.330	1.088	0.277
		3/41.9	4/16.6	3/42.7	4/15.7	4/13.6	2/43.9
			1.145	1.348	1.032	0.581	
			3/41.7	4/15.5	3/33.5	3/35.6	
				0.999	0.973	0.279	
				3/39.4	4/11.5	1/41.5	
					0.330		
					1/42.1		

EGV = 1.000010
PMAX = 1.42
AT LOCATION 12

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
950.4 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG	BURPO
1	12A2	47.017	52.711	.027098	.18601	.561326	3.361	.108249	1.19645	0.857604	1.19645	0.000000	0.0000
2	13AE	36.070	53.529	.026707	.23223	.557331	2.953	.122819	1.33270	0.974984	1.33270	0.000000	0.0000
3	13AE	41.895	53.251	.026859	.21818	.554957	3.022	.119989	1.29286	0.935666	1.29286	0.000000	0.0000
4	14AE	16.899	55.146	.025869	.28019	.566174	2.921	.125108	1.41135	1.079263	1.43568	0.002157	0.0826
5	13AE	39.752	53.352	.026803	.22318	.555760	2.995	.121069	1.30762	0.949898	1.30762	0.000000	0.0000
6	14AE	16.553	55.160	.025861	.28128	.566459	2.921	.125121	1.41186	1.081037	1.43772	0.002292	0.0885
7	13AE	39.247	53.376	.026790	.22442	.555975	2.989	.121309	1.31110	0.953355	1.31110	0.000000	0.0000
8	12A2	44.078	52.851	.027018	.19156	.562596	3.319	.109597	1.21738	0.876449	1.21738	0.000000	0.0000
9	13AE	39.801	53.350	.026804	.22306	.555739	2.996	.121046	1.30728	0.949564	1.30728	0.000000	0.0000
10	14AE	15.862	55.188	.025847	.28344	.567015	2.922	.125148	1.41265	1.084436	1.44180	0.002582	0.1015
11	13AE	42.554	53.220	.026876	.21666	.554716	3.031	.119655	1.28828	0.931293	1.28828	0.000000	0.0000
12	14AE	17.061	55.139	.025872	.27968	.566039	2.920	.125102	1.41109	1.078412	1.43473	0.002096	0.0799
13	13AE	37.614	53.455	.026747	.22843	.556670	2.970	.122085	1.32227	0.964493	1.32227	0.000000	0.0000
14	14AE	14.895	54.593	.026128	.28319	.575520	2.924	.125170	1.44750	1.116252	1.44750	0.000000	0.0000
15	12A2	41.353	52.986	.026942	.19710	.563828	3.281	.110858	1.23717	0.894644	1.23717	0.000000	0.0000
16	13AE	41.884	53.251	.026859	.21821	.554962	3.022	.119995	1.29294	0.935742	1.29294	0.000000	0.0000
17	14AE	16.593	55.159	.025862	.28115	.566426	2.921	.125120	1.41181	1.080836	1.43749	0.002276	0.0878
18	13AE	42.660	53.215	.026879	.21642	.554677	3.032	.119602	1.28754	0.930587	1.28754	0.000000	0.0000
19	14AE	15.725	55.194	.025845	.28387	.567123	2.922	.125153	1.41278	1.085086	1.44260	0.002642	0.1042
20	14AE	13.630	54.678	.026085	.28736	.577004	2.929	.125071	1.45482	1.126801	1.45482	0.000000	0.0000
21	12A2	43.894	52.860	.027013	.19193	.562679	3.316	.109682	1.21873	0.877684	1.21873	0.000000	0.0000
22	13AE	41.654	53.262	.026853	.21874	.555046	3.019	.120112	1.29454	0.937267	1.29454	0.000000	0.0000
23	14AE	15.491	55.203	.025840	.28460	.567305	2.922	.125162	1.41296	1.086177	1.44398	0.002749	0.1091
24	13AE	33.490	53.654	.026639	.23884	.558524	2.927	.123957	1.34988	0.992780	1.34988	0.000000	0.0000
25	13AE	35.590	53.552	.026694	.23341	.557536	2.948	.123047	1.33591	0.978232	1.33591	0.000000	0.0000
26	13AE	39.441	53.367	.026795	.22394	.555892	2.991	.121216	1.30976	0.952024	1.30976	0.000000	0.0000
27	14AE	11.479	54.825	.026013	.29455	.579629	2.941	.124848	1.46722	1.144995	1.46722	0.000000	0.0000
28	10A3	41.485	52.856	.026990	.18882	.566861	3.393	.107319	1.21193	0.875814	1.21193	0.000000	0.0000
29	10A3	42.132	52.824	.027009	.18760	.566537	3.402	.107037	1.20727	0.871560	1.20727	0.000000	0.0000

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OPERATING DATA FOR DEPLETION STEP 8

CORE POWER LEVEL 85.9 % OF F.P.

INPUT OPERATING VARIABLES

AVG. FUEL BURNUP - INITIAL 32.054 MWD/KG WATER DENSITY 0.7232 G/CC
BASE AX. BUCKLING CORRECTION 1.20E-04 BORON CONCENTRATION 774.3 PPM

ITERATION SUMMARY

STAGE	ITER	EGV	ERROR	EPS	ALPH/BET	BORON	B-WORTH
INITIAL	9	0.999604	0.000293	.000300	2.11/0.20	774.3	
BORON SEARCH	15	1.000008	0.000085	.000100	1.94/0.16	769.6	-119.9
FINAL	19	1.000011	0.000046	.000050	1.59/0.07	769.6	

0.719	0.951	1.069	1.405	1.194	1.350	0.881	0.347
2/48.4	3/38.0	3/44.0	4/19.7	3/42.2	4/19.3	3/41.0	2/44.7
	1.012	1.356	1.142	1.407	1.169	1.151	0.383
	3/41.8	4/18.6	3/44.9	4/19.9	3/40.0	4/17.2	2/42.1
		1.144	1.404	1.118	1.333	1.091	0.286
		3/44.2	4/19.4	3/44.9	4/18.4	4/15.8	2/44.4
			1.139	1.355	1.042	0.596	
			3/43.9	4/18.2	3/35.6	3/36.8	
				1.010	0.988	0.291	
				3/41.4	4/13.4	1/42.0	
					0.344		
					1/42.8		

EGV = 1.000011
PMAX = 1.41
AT LOCATION 12

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
769.6 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG	BURPO
1	12A2	48.436	52.742	.027087	.18376	.561749	3.448	.105519	1.20976	0.863340	1.20976	0.000000	0.0000
2	13AE	37.969	53.537	.026707	.22798	.557548	3.026	.119836	1.34277	0.976636	1.34277	0.000000	0.0000
3	13AE	44.048	53.247	.026865	.21361	.555188	3.104	.116816	1.30055	0.935661	1.30055	0.000000	0.0000
4	14AE	19.746	55.127	.025883	.27187	.565115	2.972	.122714	1.42776	1.078714	1.44261	0.001277	0.0452
5	13AE	42.175	53.336	.026817	.21794	.555877	3.079	.117766	1.31373	0.948206	1.31373	0.000000	0.0000
6	14AE	19.272	55.149	.025872	.27334	.565473	2.972	.122776	1.42926	1.081548	1.44552	0.001397	0.0501
7	13AE	40.995	53.392	.026786	.22067	.556312	3.063	.118365	1.32192	0.956070	1.32192	0.000000	0.0000
8	12A2	44.749	52.914	.026988	.19055	.563323	3.393	.107206	1.23597	0.886800	1.23597	0.000000	0.0000
9	13AE	41.827	53.352	.026808	.21874	.556005	3.074	.117943	1.31615	0.950528	1.31615	0.000000	0.0000
10	14AE	18.591	55.179	.025856	.27546	.565975	2.971	.122864	1.43120	1.085482	1.44969	0.001587	0.0580
11	13AE	44.867	53.209	.026887	.21172	.554887	3.115	.116401	1.29473	0.930150	1.29473	0.000000	0.0000
12	14AE	19.909	55.120	.025887	.27136	.564992	2.972	.122693	1.42721	1.077726	1.44161	0.001238	0.0436
13	13AE	39.973	53.440	.026759	.22305	.556691	3.050	.118883	1.32895	0.962860	1.32895	0.000000	0.0000
14	14AE	17.203	54.551	.026151	.27629	.574172	2.970	.123015	1.45816	1.113524	1.45816	0.000000	0.0000
15	12A2	42.094	53.047	.026913	.19595	.564526	3.354	.108434	1.25547	0.904690	1.25547	0.000000	0.0000
16	13AE	44.195	53.240	.026869	.21327	.555134	3.106	.116742	1.29951	0.934673	1.29951	0.000000	0.0000
17	14AE	19.427	55.142	.025875	.27286	.565356	2.972	.122756	1.42878	1.080631	1.44457	0.001357	0.0484
18	13AE	44.908	53.207	.026888	.21163	.554872	3.116	.116380	1.29443	0.929873	1.29443	0.000000	0.0000
19	14AE	18.385	55.188	.025852	.27610	.566125	2.970	.122891	1.43174	1.086637	1.45095	0.001649	0.0606
20	14AE	15.807	54.639	.026107	.28078	.575638	2.971	.123068	1.46652	1.124963	1.46652	0.000000	0.0000
21	12A2	44.447	52.929	.026979	.19116	.563460	3.389	.107345	1.23821	0.888841	1.23821	0.000000	0.0000
22	13AE	43.943	53.252	.026863	.21385	.555226	3.103	.116870	1.30130	0.936370	1.30130	0.000000	0.0000
23	14AE	18.188	55.197	.025847	.27671	.566267	2.970	.122916	1.43223	1.087729	1.45216	0.001711	0.0632
24	13AE	35.554	53.653	.026643	.23394	.558585	2.998	.120983	1.35913	0.993127	1.35913	0.000000	0.0000
25	13AE	36.753	53.595	.026675	.23097	.558070	3.012	.120413	1.35105	0.984951	1.35105	0.000000	0.0000
26	13AE	41.440	53.371	.026797	.21964	.556148	3.069	.118140	1.31884	0.953109	1.31884	0.000000	0.0000
27	14AE	13.425	54.797	.026029	.28859	.578340	2.980	.122974	1.48064	1.144907	1.48064	0.000000	0.0000
28	10A3	42.043	52.925	.026957	.18811	.567620	3.468	.104995	1.23185	0.887336	1.23185	0.000000	0.0000
29	10A3	42.792	52.887	.026978	.18670	.567243	3.479	.104669	1.22640	0.882361	1.22640	0.000000	0.0000

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OPERATING DATA FOR DEPLETION STEP 9

CORE POWER LEVEL 85.9 % OF F.P.

INPUT OPERATING VARIABLES

AVG. FUEL BURNUP - INITIAL	34.054 MWD/KG	WATER DENSITY	0.7232 G/CC
BASE AX. BUCKLING CORRECTION	1.20E-04	BORON CONCENTRATION	588.8 PPM

ITERATION SUMMARY

STAGE	ITER	EGV	ERROR	EPS	ALPH/BET	BORON	B-WORTH
INITIAL	10	1.000103	0.000239	.000300	2.17/0.22	588.8	
BORON SEARCH	15	1.000012	0.000087	.000100	2.42/0.31	590.0	-116.5
FINAL	19	1.000015	0.000048	.000050	1.59/0.07	590.0	

0.729	0.953	1.061	1.385	1.177	1.342	0.891	0.361
2/49.9	3/39.9	3/46.2	4/22.6	3/44.6	4/22.0	3/42.8	2/45.4
	1.009	1.343	1.128	1.390	1.162	1.154	0.397
	3/43.9	4/21.3	3/47.2	4/22.7	3/42.3	4/19.5	2/42.9
		1.131	1.388	1.112	1.333	1.097	0.297
		3/46.5	4/22.2	3/47.1	4/21.1	4/18.0	2/45.0
			1.131	1.355	1.051	0.612	
			3/46.2	4/20.9	3/37.6	3/37.9	
				1.018	1.004	0.304	
				3/43.5	4/15.4	1/42.6	
					0.358		
					1/43.5		

EGV = 1.000015
PMAX = 1.39
AT LOCATION 12

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
590.0 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG	BURPO
1	12A2	49.875	52.771	.027076	.18147	.562157	3.540	.102794	1.22346	0.869249	1.22346	0.000000	0.0000
2	13AE	39.871	53.544	.026707	.22371	.557757	3.103	.116864	1.35317	0.978451	1.35317	0.000000	0.0000
3	13AE	46.186	53.246	.026871	.20923	.555493	3.191	.113646	1.30893	0.936332	1.30893	0.000000	0.0000
4	14AE	22.557	55.099	.025902	.26410	.564366	3.035	.120031	1.44087	1.077275	1.44982	0.000746	0.0237
5	13AE	44.563	53.321	.026829	.21281	.556014	3.167	.114488	1.32031	0.946922	1.32031	0.000000	0.0000
6	14AE	21.973	55.127	.025887	.26581	.564749	3.032	.120164	1.44345	1.081001	1.45348	0.000834	0.0271
7	13AE	42.757	53.406	.026782	.21699	.556680	3.142	.115405	1.33312	0.959112	1.33312	0.000000	0.0000
8	12A2	45.443	52.978	.026957	.18957	.564045	3.470	.104820	1.25528	0.897609	1.25528	0.000000	0.0000
9	13AE	43.851	53.355	.026811	.21446	.556276	3.157	.114849	1.32538	0.951736	1.32538	0.000000	0.0000
10	14AE	21.302	55.160	.025871	.26778	.565181	3.029	.120316	1.44625	1.085172	1.45766	0.000949	0.0317
11	13AE	47.152	53.203	.026895	.20713	.555201	3.206	.113140	1.30215	0.930091	1.30215	0.000000	0.0000
12	14AE	22.724	55.090	.025906	.26361	.564255	3.035	.119993	1.44011	1.076195	1.44878	0.000722	0.0227
13	13AE	42.312	53.428	.026771	.21802	.556845	3.136	.115630	1.33624	0.962100	1.33624	0.000000	0.0000
14	14AE	19.506	54.519	.026171	.26955	.573153	3.023	.120677	1.46883	1.111420	1.46883	0.000000	0.0000
15	12A2	42.860	53.106	.026885	.19474	.565208	3.431	.106013	1.27427	0.914968	1.27427	0.000000	0.0000
16	13AE	46.483	53.233	.026878	.20858	.555404	3.196	.113490	1.30686	0.934418	1.30686	0.000000	0.0000
17	14AE	22.235	55.114	.025894	.26504	.564577	3.033	.120104	1.44231	1.079337	1.45184	0.000793	0.0255
18	13AE	47.144	53.203	.026895	.20715	.555204	3.206	.113144	1.30221	0.930141	1.30221	0.000000	0.0000
19	14AE	21.051	55.172	.025865	.26852	.565341	3.028	.120374	1.44725	1.086706	1.45923	0.000997	0.0336
20	14AE	17.989	54.607	.026126	.27432	.574503	3.021	.120874	1.47824	1.123572	1.47824	0.000000	0.0000
21	12A2	45.019	52.998	.026946	.19035	.564227	3.464	.105014	1.25826	0.900297	1.25826	0.000000	0.0000
22	13AE	46.220	53.245	.026872	.20915	.555483	3.192	.113628	1.30869	0.936111	1.30869	0.000000	0.0000
23	14AE	20.897	55.179	.025861	.26897	.565439	3.027	.120409	1.44784	1.087633	1.46019	0.001027	0.0348
24	13AE	37.637	53.652	.026649	.22921	.558717	3.075	.117926	1.36861	0.993880	1.36861	0.000000	0.0000
25	13AE	37.946	53.637	.026657	.22845	.558584	3.079	.117779	1.36650	0.991756	1.36650	0.000000	0.0000
26	13AE	43.459	53.373	.026801	.21536	.556421	3.152	.115048	1.32816	0.954380	1.32816	0.000000	0.0000
27	14AE	15.401	54.768	.026045	.28262	.577150	3.023	.121016	1.49403	1.144899	1.49403	0.000000	0.0000
28	10A3	42.625	52.993	.026924	.18735	.568361	3.547	.102675	1.25233	0.899131	1.25233	0.000000	0.0000
29	10A3	43.479	52.949	.026948	.18574	.567931	3.559	.102303	1.24604	0.893406	1.24604	0.000000	0.0000

OPERATING DATA FOR DEPLETION STEP 10

CORE POWER LEVEL 85.9 % OF F.P.

INPUT OPERATING VARIABLES

AVG. FUEL BURNUP - INITIAL 36.054 MWD/KG WATER DENSITY 0.7232 G/CC
BASE AX. BUCKLING CORRECTION 1.20E-04 BORON CONCENTRATION 410.4 PPM

NODE BURNUP EXCEEDS CROSS SECTION TABLE LIMITS AT 1 NODES
EXTRAPOLATION USED TO COMPLETE CROSS SECTION TABLE FOR THIS TIME STEP

ITERATION SUMMARY

STAGE	ITER	EGV	ERROR	EPS	ALPH/BET	BORON	B-WORTH
INITIAL	10	1.000046	0.000276	.000300	2.20/0.23	410.4	
BORON SEARCH	16	1.000015	0.000071	.000100	2.36/0.29	410.9	-113.2
FINAL	19	1.000016	0.000047	.000050	1.68/0.13	410.9	

0.741	0.957	1.053	1.360	1.161	1.331	0.904	0.378
2/51.3	3/41.8	3/48.3	4/25.3	3/46.9	4/24.7	3/44.5	2/46.2
	1.008	1.327	1.113	1.368	1.156	1.162	0.413
	3/45.9	4/24.0	3/49.4	4/25.5	3/44.6	4/21.8	2/43.7
		1.117	1.366	1.104	1.331	1.106	0.309
		3/48.7	4/25.0	3/49.4	4/23.7	4/20.2	2/45.6
			1.123	1.352	1.060	0.630	
			3/48.5	4/23.6	3/39.7	3/39.2	
				1.027	1.021	0.318	
				3/45.5	4/17.4	1/43.2	
					0.373		
					1/44.2		

EGV = 1.000016
PMAX = 1.37
AT LOCATION 12

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
410.9 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG	BURPO
1	12A2	51.333	52.799	.027066	.17915	.562554	3.637	.100066	1.23769	0.875415	1.23769	0.000000	0.0000
2	13AE	41.777	53.551	.026708	.21966	.558063	3.185	.113840	1.36424	0.980994	1.36424	0.000000	0.0000
3	13AE	48.308	53.248	.026876	.20501	.555862	3.283	.110474	1.31809	0.937683	1.31809	0.000000	0.0000
4	14AE	25.326	55.060	.025925	.25650	.563587	3.102	.117304	1.45191	1.074779	1.45749	0.000450	0.0120
5	13AE	46.917	53.311	.026840	.20802	.556284	3.261	.111202	1.32797	0.946748	1.32797	0.000000	0.0000
6	14AE	24.656	55.095	.025907	.25842	.564017	3.097	.117493	1.45552	1.079360	1.46181	0.000508	0.0142
7	13AE	44.538	53.420	.026780	.21326	.557039	3.225	.112440	1.34470	0.962309	1.34470	0.000000	0.0000
8	12A2	46.165	53.040	.026928	.18859	.564761	3.552	.102429	1.27534	0.908852	1.27534	0.000000	0.0000
9	13AE	45.870	53.358	.026814	.21030	.556603	3.245	.111750	1.33532	0.953544	1.33532	0.000000	0.0000
10	14AE	23.988	55.130	.025889	.26039	.564473	3.094	.117645	1.45895	1.083926	1.46606	0.000573	0.0167
11	13AE	49.409	53.198	.026904	.20262	.555529	3.301	.109898	1.31018	0.930466	1.31018	0.000000	0.0000
12	14AE	25.503	55.051	.025929	.25600	.563482	3.103	.117244	1.45093	1.073575	1.45633	0.000437	0.0114
13	13AE	44.636	53.415	.026782	.21303	.557003	3.227	.112390	1.34399	0.961642	1.34399	0.000000	0.0000
14	14AE	21.813	54.491	.026189	.26317	.572453	3.084	.118140	1.47984	1.110313	1.47984	0.000000	0.0000
15	12A2	43.653	53.163	.026859	.19348	.565876	3.512	.103584	1.29366	0.925528	1.29366	0.000000	0.0000
16	13AE	48.744	53.228	.026887	.20406	.555730	3.290	.110246	1.31496	0.934826	1.31496	0.000000	0.0000
17	14AE	25.011	55.077	.025916	.25738	.563774	3.099	.117411	1.45365	1.076905	1.45954	0.000476	0.0130
18	13AE	49.367	53.200	.026903	.20271	.555542	3.300	.109919	1.31048	0.930738	1.31048	0.000000	0.0000
19	14AE	23.718	55.144	.025882	.26118	.564657	3.093	.117706	1.46031	1.085755	1.46778	0.000603	0.0178
20	14AE	20.182	54.582	.026142	.26797	.573652	3.077	.118511	1.49010	1.122768	1.49010	0.000000	0.0000
21	12A2	45.612	53.066	.026913	.18961	.564998	3.543	.102682	1.27927	0.912389	1.27927	0.000000	0.0000
22	13AE	48.483	53.240	.026880	.20463	.555809	3.286	.110382	1.31683	0.936534	1.31683	0.000000	0.0000
23	14AE	23.608	55.150	.025879	.26150	.564731	3.093	.117731	1.46085	1.086491	1.46848	0.000615	0.0183
24	13AE	39.739	53.649	.026655	.22445	.558838	3.157	.114866	1.37839	0.994745	1.37839	0.000000	0.0000
25	13AE	39.170	53.676	.026640	.22585	.559083	3.149	.115137	1.38236	0.998704	1.38236	0.000000	0.0000
26	13AE	45.496	53.375	.026804	.21111	.556717	3.239	.111946	1.33793	0.955963	1.33793	0.000000	0.0000
27	14AE	17.409	54.744	.026059	.27667	.576114	3.072	.118880	1.50751	1.145166	1.50751	0.000000	0.0000
28	10A3	43.233	53.058	.026892	.18654	.569088	3.629	.100349	1.27349	0.911273	1.27349	0.000000	0.0000
29	10A3	44.194	53.009	.026919	.18473	.568603	3.644	.099931	1.26633	0.904768	1.26633	0.000000	0.0000

OPERATING DATA FOR DEPLETION STEP 11

CORE POWER LEVEL 85.9 % OF F.P.

INPUT OPERATING VARIABLES

AVG. FUEL BURNUP - INITIAL 38.054 MWD/KG WATER DENSITY 0.7232 G/CC
BASE AX. BUCKLING CORRECTION 1.20E-04 BORON CONCENTRATION 231.8 PPM

NODE BURNUP EXCEEDS CROSS SECTION TABLE LIMITS AT 6 NODES
EXTRAPOLATION USED TO COMPLETE CROSS SECTION TABLE FOR THIS TIME STEP

ITERATION SUMMARY

STAGE	ITER	EGV	ERROR	EPS	ALPH/BET	BORON	B-WORTH
INITIAL	11	1.000338	0.000178	.000300	2.65/0.39	231.8	
BORON SEARCH	16	1.000010	0.000070	.000100	2.47/0.33	235.5	-109.9
FINAL	19	1.000013	0.000048	.000050	1.68/0.13	235.5	

0.752	0.960	1.044	1.334	1.146	1.322	0.920	0.396
2/52.8	3/43.7	3/50.4	4/28.0	3/49.2	4/27.3	3/46.3	2/46.9
	1.005	1.307	1.097	1.347	1.152	1.173	0.432
	3/47.9	4/26.6	3/51.6	4/28.2	3/46.9	4/24.1	2/44.5
		1.101	1.343	1.095	1.328	1.118	0.324
		3/51.0	4/27.7	3/51.6	4/26.4	4/22.4	2/46.2
			1.112	1.344	1.069	0.649	
			3/50.7	4/26.3	3/41.9	3/40.4	
				1.035	1.039	0.333	
				3/47.5	4/19.5	1/43.9	
					0.389		
					1/44.9		

EGV = 1.000013
PMAX = 1.35
AT LOCATION 12

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
235.5 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG	BURPO
1	12A2	52.815	52.824	.027058	.17677	.562920	3.738	.097370	1.25199	0.881540	1.25199	0.000000	0.0000
2	13AE	43.692	53.556	.026710	.21561	.558352	3.271	.110851	1.37533	0.983524	1.37533	0.000000	0.0000
3	13AE	50.413	53.248	.026881	.20081	.556215	3.379	.107353	1.32737	0.939118	1.32737	0.000000	0.0000
4	14AE	28.046	55.019	.025949	.24938	.562987	3.179	.114362	1.46124	1.072038	1.46502	0.000296	0.0058
5	13AE	49.239	53.301	.026851	.20335	.556572	3.360	.107968	1.33591	0.946885	1.33591	0.000000	0.0000
6	14AE	27.318	55.058	.025929	.25141	.563431	3.173	.114609	1.46565	1.077204	1.46986	0.000329	0.0071
7	13AE	46.345	53.433	.026778	.20964	.557454	3.313	.109483	1.35655	0.965852	1.35655	0.000000	0.0000
8	12A2	46.920	53.100	.026900	.18754	.565442	3.636	.100065	1.29556	0.920103	1.29556	0.000000	0.0000
9	13AE	47.885	53.362	.026817	.20629	.556984	3.337	.108677	1.34564	0.955790	1.34564	0.000000	0.0000
10	14AE	26.642	55.094	.025911	.25330	.563841	3.167	.114838	1.46967	1.081959	1.47435	0.000366	0.0085
11	13AE	51.635	53.193	.026912	.19818	.555845	3.400	.106714	1.31839	0.930994	1.31839	0.000000	0.0000
12	14AE	28.240	55.008	.025954	.24884	.562868	3.181	.114296	1.46004	1.070652	1.46372	0.000288	0.0055
13	13AE	46.947	53.405	.026793	.20833	.557270	3.322	.109168	1.35230	0.961926	1.35230	0.000000	0.0000
14	14AE	24.136	54.462	.026207	.25683	.571796	3.149	.115593	1.49070	1.109210	1.49070	0.000000	0.0000
15	12A2	44.480	53.217	.026834	.19214	.566508	3.595	.101184	1.31317	0.936059	1.31317	0.000000	0.0000
16	13AE	50.978	53.222	.026895	.19959	.556044	3.389	.107058	1.32323	0.935370	1.32323	0.000000	0.0000
17	14AE	27.743	55.035	.025941	.25023	.563172	3.177	.114465	1.46308	1.074192	1.46703	0.000309	0.0063
18	13AE	51.575	53.195	.026911	.19830	.555863	3.399	.106745	1.31883	0.931394	1.31883	0.000000	0.0000
19	14AE	26.380	55.107	.025904	.25403	.563999	3.165	.114927	1.47119	1.083779	1.47607	0.000381	0.0091
20	14AE	22.394	54.559	.026158	.26195	.573075	3.141	.115990	1.50186	1.122621	1.50186	0.000000	0.0000
21	12A2	46.231	53.132	.026881	.18881	.565739	3.624	.100380	1.30051	0.924554	1.30051	0.000000	0.0000
22	13AE	50.729	53.233	.026889	.20013	.556119	3.384	.107188	1.32506	0.937023	1.32506	0.000000	0.0000
23	14AE	26.312	55.111	.025902	.25422	.564041	3.164	.114950	1.47159	1.084257	1.47653	0.000386	0.0092
24	13AE	41.859	53.644	.026662	.21987	.559035	3.244	.111781	1.38828	0.995969	1.38828	0.000000	0.0000
25	13AE	40.430	53.713	.026625	.22321	.559571	3.223	.112506	1.39824	1.005621	1.39824	0.000000	0.0000
26	13AE	47.549	53.378	.026808	.20702	.557086	3.332	.108853	1.34803	0.957990	1.34803	0.000000	0.0000
27	14AE	19.452	54.725	.026073	.27073	.575330	3.128	.116605	1.52056	1.145549	1.52056	0.000000	0.0000
28	10A3	43.870	53.121	.026862	.18567	.569781	3.714	.098054	1.29487	0.923467	1.29487	0.000000	0.0000
29	10A3	44.940	53.066	.026892	.18365	.569240	3.732	.097588	1.28682	0.916155	1.28682	0.000000	0.0000

EASSI PROGRAM EASCYC (c)1988 CRYSTAL RIVER RELOAD #12 CORE WITH CASMO LIB (B4CAL2) OLD G FACTORS 9/12/** (10:54)
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OPERATING DATA FOR DEPLETION STEP 12

CORE POWER LEVEL 85.9 % OF F.P.

INPUT OPERATING VARIABLES

AVG. FUEL BURNUP - INITIAL	40.054 MWD/KG	WATER DENSITY	0.7232 G/CC
BASE AX. BUCKLING CORRECTION	1.20E-04	BORON CONCENTRATION	60.2 PPM

NODE BURNUP EXCEEDS CROSS SECTION TABLE LIMITS AT 7 NODES
EXTRAPOLATION USED TO COMPLETE CROSS SECTION TABLE FOR THIS TIME STEP

ITERATION SUMMARY

STAGE	ITER	EGV	ERROR	EPS	ALPH/BET	BORON	B-WORTH
INITIAL	11	1.000335	0.000189	.000300	2.66/0.40	60.2	
BORON SEARCH	16	1.000010	0.000076	.000100	2.49/0.33	63.7	-106.7
FINAL	20	1.000014	0.000044	.000050	1.59/0.07	63.7	

0.763 / 2/54.3	0.964 / 3/45.6	1.034 / 3/52.5	1.309 / 4/30.7	1.131 / 3/51.5	1.312 / 4/30.0	0.937 / 3/48.2	0.416 / 2/47.7
	1.003 / 3/49.9	1.286 / 4/29.3	1.081 / 3/53.8	1.325 / 4/30.9	1.148 / 3/49.3	1.185 / 4/26.5	0.452 / 2/45.3
		1.085 / 3/53.2	1.318 / 4/30.4	1.085 / 3/53.8	1.322 / 4/29.0	1.130 / 4/24.6	0.339 / 2/46.9
			1.100 / 3/53.0	1.334 / 4/29.0	1.078 / 3/44.0	0.669 / 3/41.7	
				1.043 / 3/49.6	1.059 / 4/21.5	0.349 / 1/44.5	
					0.406 / 1/45.7		

EGV = 1.000014
PMAX = 1.33
AT LOCATION 23

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
63.7 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG	BURPO
1	12A2	54.319	52.846	.027051	.17435	.563256	3.843	.094705	1.26638	0.887644	1.26638	0.000000	0.0000
2	13AE	45.613	53.560	.026712	.21161	.558658	3.361	.107889	1.38663	0.986262	1.38663	0.000000	0.0000
3	13AE	52.501	53.247	.026887	.19665	.556553	3.479	.104284	1.33683	0.940670	1.33683	0.000000	0.0000
4	14AE	30.715	54.976	.025974	.24252	.562420	3.261	.111423	1.46983	1.069181	1.47274	0.000221	0.0028
5	13AE	51.531	53.291	.026862	.19875	.556848	3.462	.104791	1.34405	0.947178	1.34405	0.000000	0.0000
6	14AE	29.963	55.015	.025954	.24449	.562825	3.252	.111734	1.47471	1.074488	1.47785	0.000239	0.0034
7	13AE	48.185	53.443	.026777	.20600	.557868	3.404	.106543	1.36843	0.969404	1.36843	0.000000	0.0000
8	12A2	47.713	53.155	.026874	.18641	.566088	3.723	.097725	1.31594	0.931347	1.31594	0.000000	0.0000
9	13AE	49.896	53.365	.026821	.20229	.557346	3.434	.105647	1.35606	0.958083	1.35606	0.000000	0.0000
10	14AE	29.255	55.054	.025935	.24646	.563262	3.246	.111974	1.47923	1.079654	1.48264	0.000258	0.0042
11	13AE	53.829	53.187	.026921	.19379	.556150	3.503	.103588	1.32682	0.931705	1.32682	0.000000	0.0000
12	14AE	30.933	54.965	.025980	.24195	.562304	3.264	.111332	1.46840	1.067636	1.47125	0.000217	0.0026
13	13AE	49.252	53.394	.026804	.20368	.557542	3.423	.105985	1.36074	0.962357	1.36074	0.000000	0.0000
14	14AE	26.481	54.431	.026227	.25066	.571246	3.221	.112917	1.50122	1.108223	1.50122	0.000000	0.0000
15	12A2	45.344	53.268	.026810	.19077	.567113	3.682	.098809	1.33297	0.946719	1.33297	0.000000	0.0000
16	13AE	53.180	53.216	.026904	.19519	.556347	3.491	.103928	1.33172	0.936090	1.33172	0.000000	0.0000
17	14AE	30.429	54.991	.025967	.24327	.562573	3.258	.111543	1.47169	1.071198	1.47469	0.000227	0.0030
18	13AE	53.765	53.190	.026919	.19393	.556170	3.502	.103622	1.32731	0.932139	1.32731	0.000000	0.0000
19	14AE	29.036	55.066	.025929	.24707	.563398	3.244	.112049	1.48062	1.081250	1.48413	0.000265	0.0044
20	14AE	24.630	54.532	.026174	.25585	.572459	3.206	.113504	1.51343	1.122223	1.51343	0.000000	0.0000
21	12A2	46.878	53.195	.026851	.18795	.566449	3.708	.098107	1.32199	0.936782	1.32199	0.000000	0.0000
22	13AE	52.953	53.226	.026899	.19568	.556416	3.487	.104047	1.33343	0.937620	1.33343	0.000000	0.0000
23	14AE	28.999	55.067	.025928	.24717	.563420	3.244	.112061	1.48085	1.081517	1.48437	0.000266	0.0045
24	13AE	43.998	53.636	.026670	.21528	.559220	3.335	.108718	1.39811	0.997129	1.39811	0.000000	0.0000
25	13AE	41.727	53.745	.026611	.22057	.560071	3.300	.109871	1.41421	1.012626	1.41421	0.000000	0.0000
26	13AE	49.620	53.377	.026814	.20289	.557430	3.429	.105792	1.35807	0.959915	1.35807	0.000000	0.0000
27	14AE	21.530	54.706	.026086	.26496	.574742	3.191	.114209	1.53345	1.146303	1.53345	0.000000	0.0000
28	10A3	44.536	53.180	.026834	.18474	.570440	3.802	.095787	1.31649	0.935713	1.31649	0.000000	0.0000
29	10A3	45.717	53.123	.026866	.18264	.569868	3.822	.095284	1.30791	0.927974	1.30791	0.000000	0.0000

EASSI PROGRAM EASCYC (c)1988 CRYSTAL RIVER RELOAD #12 CORE WITH CASMO LIB (B4CAL2) OLD G FACTORS 9/12/** (10:54)
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OPERATING DATA FOR DEPLETION STEP 13

CORE POWER LEVEL 85.9 % OF F.P.

INPUT OPERATING VARIABLES

AVG. FUEL BURNUP - INITIAL	40.812 MWD/KG	WATER DENSITY	0.7232 G/CC
BASE AX. BUCKLING CORRECTION	1.20E-04	BORON CONCENTRATION	0.0 PPM

NODE BURNUP EXCEEDS CROSS SECTION TABLE LIMITS AT 10 NODES
EXTRAPOLATION USED TO COMPLETE CROSS SECTION TABLE FOR THIS TIME STEP

ITERATION SUMMARY

STAGE	ITER	EGV	ERROR	EPS	ALPH/BET	BORON	B-WORTH
INITIAL	6	1.000021	0.000229	.000300	1.71/0.09	0.0	
BORON SEARCH	12	1.000013	0.000085	.000100	2.57/0.37	0.2	-105.5
FINAL	16	1.000015	0.000045	.000050	1.59/0.07	0.2	

0.768	0.967	1.031	1.301	1.126	1.309	0.943	0.424
2/54.9	3/46.3	3/53.3	4/31.7	3/52.4	4/31.0	3/48.9	2/48.0
	1.003	1.280	1.075	1.317	1.147	1.189	0.460
	3/50.7	4/30.2	3/54.6	4/31.9	3/50.1	4/27.4	2/45.7
		1.080	1.310	1.081	1.319	1.134	0.344
		3/54.0	4/31.4	3/54.6	4/30.0	4/25.5	2/47.1
			1.096	1.329	1.080	0.676	
			3/53.8	4/30.0	3/44.8	3/42.2	
				1.045	1.065	0.355	
				3/50.4	4/22.3	1/44.8	
					0.412		
					1/46.0		

EGV = 1.000015
PMAX = 1.33
AT LOCATION 23

NODAL MULTIPLICATION DIFFUSION AND CONTROL PROPERTIES
0.2 PPM AND .7232 G/CC

ASSB	NAME	BURNUP	F-LSQ	F-SIGT	K-FAST	P	T-LSQ	T-SIGA	K-THERM	K-INFIN	K-NC	CONTSIG	BURPO
1	12A2	54.898	52.853	.027049	.17341	.563371	3.884	.093710	1.27174	0.889870	1.27174	0.000000	0.0000
2	13AE	46.343	53.562	.026713	.21015	.558796	3.397	.106776	1.39097	0.987417	1.39097	0.000000	0.0000
3	13AE	53.284	53.246	.026890	.19509	.556674	3.518	.103142	1.34038	0.941245	1.34038	0.000000	0.0000
4	14AE	31.706	54.961	.025983	.24010	.562265	3.294	.110280	1.47293	1.068275	1.47566	0.000205	0.0021
5	13AE	52.387	53.286	.026867	.19703	.556947	3.502	.103612	1.34711	0.947296	1.34711	0.000000	0.0000
6	14AE	30.957	55.000	.025963	.24205	.562666	3.285	.110592	1.47788	1.073608	1.48080	0.000218	0.0026
7	13AE	48.895	53.445	.026778	.20459	.558013	3.440	.105440	1.37277	0.970617	1.37277	0.000000	0.0000
8	12A2	48.028	53.175	.026865	.18595	.566318	3.757	.096850	1.32356	0.935506	1.32356	0.000000	0.0000
9	13AE	50.656	53.365	.026823	.20077	.557475	3.471	.104519	1.35995	0.958909	1.35995	0.000000	0.0000
10	14AE	30.230	55.038	.025944	.24395	.563055	3.277	.110896	1.48263	1.078746	1.48575	0.000234	0.0032
11	13AE	54.648	53.184	.026924	.19216	.556261	3.543	.102429	1.33001	0.931991	1.33001	0.000000	0.0000
12	14AE	31.937	54.949	.025990	.23950	.562142	3.297	.110183	1.47139	1.066628	1.47408	0.000201	0.0019
13	13AE	50.122	53.389	.026809	.20193	.557638	3.462	.104798	1.36386	0.962469	1.36386	0.000000	0.0000
14	14AE	27.379	54.418	.026234	.24834	.571055	3.250	.111881	1.50501	1.107778	1.50501	0.000000	0.0000
15	12A2	45.686	53.286	.026802	.19027	.567331	3.715	.097921	1.34047	0.950754	1.34047	0.000000	0.0000
16	13AE	54.003	53.213	.026908	.19354	.556456	3.531	.102766	1.33493	0.936377	1.33493	0.000000	0.0000
17	14AE	31.428	54.976	.025976	.24082	.562414	3.291	.110396	1.47478	1.070261	1.47758	0.000209	0.0022
18	13AE	54.587	53.187	.026923	.19229	.556279	3.542	.102460	1.33048	0.932403	1.33048	0.000000	0.0000
19	14AE	30.038	55.048	.025939	.24445	.563157	3.274	.110976	1.48387	1.080100	1.48706	0.000239	0.0033
20	14AE	25.486	54.521	.026181	.25358	.572257	3.233	.112524	1.51761	1.122044	1.51761	0.000000	0.0000
21	12A2	47.134	53.217	.026841	.18760	.566704	3.741	.097259	1.33005	0.941342	1.33005	0.000000	0.0000
22	13AE	53.787	53.223	.026902	.19401	.556522	3.527	.102879	1.33657	0.937837	1.33657	0.000000	0.0000
23	14AE	30.010	55.050	.025938	.24452	.563172	3.274	.110988	1.48405	1.080297	1.48725	0.000239	0.0034
24	13AE	44.815	53.632	.026674	.21352	.559279	3.371	.107573	1.40170	0.997459	1.40170	0.000000	0.0000
25	13AE	42.234	53.756	.026607	.21953	.560246	3.330	.108883	1.42012	1.015145	1.42012	0.000000	0.0000
26	13AE	50.410	53.376	.026817	.20130	.557549	3.467	.104647	1.36175	0.960545	1.36175	0.000000	0.0000
27	14AE	22.333	54.697	.026091	.26277	.574532	3.215	.113296	1.53815	1.146490	1.53815	0.000000	0.0000
28	10A3	44.801	53.201	.026824	.18435	.570674	3.836	.094940	1.32461	0.940272	1.32461	0.000000	0.0000
29	10A3	46.025	53.143	.026857	.18224	.570091	3.857	.094424	1.31583	0.932382	1.31583	0.000000	0.0000

DEPLETION PHASE SUMMARY

STEP NO.	BORON CONC. (PPM)	BURNUP MWD/KG START	BURNUP MWD/KG INCR.	PK/AVG	K-EFF	ROD GROUPS INSERTED
1	1810.8	18.05	2.00	1.391	1.00000	
2	1796.1	20.05	2.00	1.415	1.00021	
3	1639.9	22.05	2.00	1.424	0.99970	
4	1468.3	24.05	2.00	1.432	0.99996	
5	1298.1	26.05	2.00	1.435	0.99999	
6	1126.4	28.05	2.00	1.434	1.00000	
7	950.4	30.05	2.00	1.424	1.00001	
8	769.6	32.05	2.00	1.407	1.00001	
9	590.0	34.05	2.00	1.390	1.00001	
10	410.9	36.05	2.00	1.368	1.00002	
11	235.5	38.05	2.00	1.347	1.00001	
12	63.7	40.05	0.76	1.334	1.00001	
13	0.2	40.81	0.00	1.329	1.00001	

CYCLE BURNUP AT END OF STEP 13 = 22.8 MWD/KG

FULL CORE FUEL INVENTORY SUMMARY (BORON = 0.2 PPM)

BATCH SIZE	BATCH NO.	BATCH NAME	BATCH ENR.	BURNUP AVG	BURNUP MAX	AVG K-INF
CENTER	2	12A2	.0419	54.90		0.88987
12	1	10A3	.0394	45.21	46.02	0.93764
20	2	12A2	.0419	46.73	48.03	0.94394
72	3	13AE	.0486	50.14	54.65	0.96218
72	4	14AE	.0461	28.91	31.94	1.09148
TOTAL	-	-	-	40.81	54.90	1.01064

APPENDIX E
ONE-EIGHTH CORE MCNP/MONTEBURNS FILES

This appendix contains all of the input and output files for the 1/8th core MCNP/MONTEBURNS model. The CASMO input files used to generate the 10A3, 12A2, and 13A - 13E depleted fuel approximate compositions for the primary, Gd_2O_3/UO_2 mixed fuel, and blanket fuels are similar to those used to generate the cross section libraries for EASCYC and are not included in this appendix. No CASMO output files are listed instead the appendix includes the fuel compositions in the material cards of the MCNP input files. All of the MCNP input, MONTEBURNS input, and MONTEBURNS output files are listed for the B_4C/Al_2O_3 BPRA, L-Carborane, and J-Carborane models. The MONTEBURNS output files have been abbreviated to include only the k-effective vs. time and the transport history information.

The MCNP Input File 1/8th core B_4C/Al_2O_3 BPRAs

```
RESEARCH 1/8th CORE WITH B4CAL2O3 BPRA'S
C    CRYSTAL RIVER REACTOR #1
C      box -200 200 -200 200 -200 200
1     0 -1 13 -14 19 20 FILL=1  VOL=6333455.62
2     1  -0.660 9 -10 11 -12 LAT=1 U=1 FILL=-8:1 -8:1 0:0
        1  1  1  1  1  1  1  1  1  1
        1  1  1  1  1  1  2  2  2  1
        1  1  1  1  2  4 11 12  4  1
        1  1  1  2 10  5 13  5  9  1
        1  1  1  1  4 13  4  9  5  1
        1  1  1  1  1  4  9  4  9  1
        1  1  1  1  1  1  4 13  4  1
        1  1  1  1  1  1  1  4  5  1
        1  1  1  1  1  1  1  1  2  1
        1  1  1  1  1  1  1  1  1  1
c 201    0 9 -10 11 -12 LAT=1 U=22 FILL=2
C    10A & 12A2 MARK-B4Z ASSMBLY WITH 0 GD AND 0 BPRAS (33 TOTAL)
200    1 -0.660 30 -31 32 -33 LAT=1 VOL=2581.227 U=2 FILL=-8:8 -8:8 0:0
       2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 14 20 20 20 14 20 20 20 20  2
       2 20 20 20 14 20 20 20 20 20 20 14 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 14 20 20 14 20 20 20 14 20 20 14 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
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```
       2 20 20 20 20 20 20 20 14 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 14 20 20 14 20 20 20 14 20 20 14 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 14 20 20 20 20 20 20 20 14 20 20 20  2
       2 20 20 20 20 20 14 20 20 20 14 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
C    13A 13D MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (48 TOTAL)
202    1 -0.660 30 -31 32 -33 LAT=1 U=4 VOL=2581.227 FILL=-8:8 -8:8 0:0
       4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 14 40 40 40 14 40 40 40 40 40  4
       4 40 40 40 14 40 40 40 40 40 40 40 14 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 14 40 40 14 40 40 40 14 40 40 14 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 14 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 14 40 40 14 40 40 40 14 40 40 14 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 14 40 40 40 40 40 40 40 14 40 40 40  4
       4 40 40 40 40 40 14 40 40 40 14 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4
C    13B C E MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (8 TOTAL)
203    1 -0.660 30 -31 32 -33 LAT=1 U=5 VOL=2581.227 FILL=-8:8 -8:8 0:0
       5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 14 50 50 50 14 50 50 50 50 50  5
       5 50 50 50 14 50 50 50 50 50 50 50 14 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 14 50 50 14 50 50 50 14 50 50 14 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 14 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 14 50 50 14 50 50 50 14 50 50 14 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 14 50 50 50 50 50 50 50 14 50 50 50  5
       5 50 50 50 50 50 14 50 50 50 14 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
C    14A MARK-B10I ASSMBLY WITH 8 GD AND 8 BPRAS (24 TOTAL)
207    1 -0.660 30 -31 32 -33 LAT=1 U=9 VOL=2581.227 FILL=-8:8 -8:8 0:0
       9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 90 91 90 90 90 90 90 90 91 90 90 90 90  9
       9 90 90 90 90 90 15 90 90 90 15 90 90 90 90 90  9
       9 90 91 90 14 90 90 90 90 90 90 14 90 91 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 15 90 90 14 90 90 90 14 90 90 15 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 90 90 90 90 90 14 90 90 90 90 90 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 15 90 90 14 90 90 90 14 90 90 15 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 91 90 14 90 90 90 90 90 90 14 90 91 90 90  9
       9 90 90 90 90 90 15 90 90 90 15 90 90 90 90 90  9
       9 90 90 90 91 90 90 90 90 90 90 90 91 90 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9
C    14B MARK-B10I ASSMBLY WITH 0 GD AND 0 BPRAS (8 TOTAL)
208    1 -0.660 30 -31 32 -33 LAT=1 U=10 VOL=2581.227 FILL=-8:8 -8:8 0:0
       10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
```

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       10 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  10
       10 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  10
       10 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10
C    14C MARK-B10I ASSMBLY WITH 4 GD AND 0 BPRAS (8 TOTAL)
209    1 -0.660 30 -31 32 -33 LAT=1 U=11 VOL=2581.227 FILL=-8:8 -8:8 0:0
       11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 111 100 100 100 100 100 100 100 100 100 100 100 111 100  11
       11 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  11
       11 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  11
       11 100 100 100 100 100 100  14 100 100 100  14 100 100 100 100  11
       11 100 111 100 100 100 100 100 100 100 100 100 100 100 111 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
C    14D MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (8 TOTAL)
210    1 -0.660 30 -31 32 -33 LAT=1 U=12 VOL=2581.227 FILL=-8:8 -8:8 0:0
       12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100 100 111 100 100 100 100 100 100 111 100 100 100 100  12
       12 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  12
       12 100 111 100  14 100 100 100 100 100 100 100  14 100 111 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 111 100  14 100 100 100 100 100 100 100  14 100 111 100  12
       12 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  12
       12 100 100 100 111 100 100 100 100 100 100 100 111 100 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12
C    14E MARK-B10I ASSMBLY WITH 8 GD AND 8 BPRAS (24 TOTAL)
211      1 -0.660 30 -31 32 -33 LAT=1 U=13 VOL=2581.227 FILL=-8:8 -8:8 0:0
         13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13
         13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
         13 100 100 100  91 100 100 100 100 100 100 100  91 100 100 100  13
         13 100 100 100 100 100  15 100 100 100  15 100 100 100 100 100  13
         13 100  91 100  14 100 100 100 100 100 100 100  14 100  91 100  13
         13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
         13 100 100  15 100 100  14 100 100 100  14 100 100  15 100 100  13
         13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
         13 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  13
         13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
         13 100 100  15 100 100  14 100 100 100  14 100 100  15 100 100  13
         13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
         13 100  91 100  14 100 100 100 100 100 100 100  14 100  91 100  13
         13 100 100 100 100 100  15 100 100 100  15 100 100 100 100 100  13
         13 100 100 100  91 100 100 100 100 100 100 100  91 100 100 100  13
         13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
         13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13
```

```
C      UNIVERSE 14 EMPTY GUIDE TUBE
3      1    -0.660     -4 U=14 $WATER HOLE
                       VOL=259.275
4      3    -6.503 4 -5 U=14 $INTERIOR CLAD
                       VOL=78.0098
5      1    -0.660   5 -6 U=14 $GUIDE TUBE WATER RADIUS
                       VOL=114.4531
6      3    -6.503 6 -7 U=14 $GUIDE TUBE CLAD RADIUS
                       VOL=60.665
7      1    -0.660   #3 #4 #5 #6 U=14 $UNIT CELL WATER
                       VOL=237.207
C      UNIVERSE 15 BPRA
8      4    -3.1     -4 U=15 $BPRA MATERIAL
                       VOL=259.275
9      3    -6.503 4 -5 U=15 $INTERIOR CLAD
                       VOL=78.0098
10     1    -0.660   5 -6 U=15 $GUIDE TUBE WATER RADIUS
                       VOL=114.453
11     3    -6.503 6 -7 U=15 $GUIDE TUBE CLAD RADIUS
                       VOL=60.665
12     1    -0.660   #8 #9 #10 #11 U=15 $UNIT CELL WATER
                       VOL=237.207
C      UNIVERSE 20  FUEL FOR 10A3 &12A2 ASSEMBLY (PRIMARY)
13     26   -10.201    -8 15 -16 U=20 $UO2 FUEL PELLET (PRIMARY)
                       VOL=228.638
14     34   -10.201    -8 -15 U=20  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
15     34   -10.201    -8 16  U=20  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
16     0             8 -4 U=20 $GAP RADIUS
                       VOL=9.5493
17     3    -6.503 4 -5 U=20 $FUEL PIN CLAD
                       VOL=78.00976
18     1    -0.660   #13 #14 #15 #16 #17 U=20 $UNIT CELL WATER
                       VOL=412.3249
C      UNIVERSE 40  FUEL FOR 13A & 13D ASSEMBLY (PRIMARY)
25     30    -10.201    -8 15 -16 U=40 $UO2 FUEL PELLET (PRIMARY)
                       VOL=228.638
26     34   -10.201    -8 -15 U=40  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
27     34   -10.201    -8 16  U=40  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
28     0             8 -4 U=40 $GAP RADIUS
                       VOL=9.5493
29     3    -6.503 4 -5 U=40 $FUEL PIN CLAD
                       VOL=78.00976
30     1    -0.660   #25 #26 #27 #28 #29 U=40 $UNIT CELL WATER
                       VOL=412.3249
C      UNIVERSE 50  FUEL FOR 13B C E ASSEMBLY (PRIMARY)
37     33  -10.201    -8 15 -16 U=50 $UO2 FUEL PELLET (PRIMARY)
                       VOL=228.638
38     34   -10.201    -8 -15 U=50  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
39     34   -10.201    -8 16  U=50  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
40     0             8 -4 U=50 $GAP RADIUS
                       VOL=9.5493
41     3    -6.503 4 -5 U=50 $FUEL PIN CLAD
                       VOL=78.00976
42     1    -0.660   #37 #38 #39 #40 #41 U=50 $UNIT CELL WATER
                       VOL=412.3249
C      UNIVERSE 90  FUEL FOR 14A ASSEMBLY (PRIMARY)
79     2    -10.201    -8 15 -16 U=90 $UO2 FUEL PELLET (PRIMARY)
                       VOL=228.638
80     22   -10.201    -8 -15 U=90  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
81     22   -10.201    -8 16  U=90  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
82     0             8 -4 U=90 $GAP RADIUS
                       VOL=9.5493
83     3    -6.503 4 -5 U=90 $FUEL PIN CLAD
```

```
                    VOL=78.00976
84      1    -0.660   #79 #80 #81 #82 #83 U=90 $UNIT CELL WATER
                    VOL=412.3249
C       UNIVERSE 91 GD FUEL ROD FOR 14A AND 14E
85      25   -9.635    -8 17 -18 U=91 $UO2 GDO FUEL PELLET (PRIMARY)
                    VOL=215.2219
86      22   -10.201    -8 -17 U=91  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
87      22   -10.201    -8 18  U=91  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
88      0            8 -4 U=91 $GAP RADIUS
                    VOL=9.549294
89      3    -6.503 4 -5 U=91 $FUEL PIN CLAD
                    VOL=78.00976
90      1    -0.660   #85 #86 #87 #88 #89 U=91 $UNIT CELL WATER
                    VOL=412.3249
C       UNIVERSE 100 FUEL FOR 14B 14C 14D 14E ASSEMBLIES
91      23   -10.201    -8 15 -16 U=100 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.6378
92      22   -10.201    -8 -15 U=100  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.54397
93      22   -10.201    -8 16  U=100  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.54397
94      0            8 -4 U=100 $GAP RADIUS
                    VOL=54929
95      3    -6.503 4 -5 U=100 $FUEL PIN CLAD
                    VOL=78.00976
96      1    -0.660   #91 #92 #93 #94 #95 U=100 $UNIT CELL WATER
                    VOL=412.3249
C       UNIVERSE 111 GD FUEL ROD FOR 14C AND 14D
97      24   -9.635    -8 17 -18 U=111 $UO2 GDO FUEL PELLET (PRIMARY)
                    VOL=215.2219
98      22   -10.201    -8 -17 U=111  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
99      22   -10.201    -8 18  U=111  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
100      0            8 -4 U=111 $GAP RADIUS
                    VOL=9.549294
101      3    -6.503 4 -5 U=111 $FUEL PIN CLAD
                    VOL=78.00976
102      1    -0.660   #97 #98 #99 #100 #101 U=111 $UNIT CELL WATER
                    VOL=412.3249
C       REACTOR BOUNDARY
997      1    -0.660   -1 -2 14 19 20  $AXIAL RELECTORS
                    VOL=2035752.04
998      1    -0.660   -1  3 -13 19 20
                    VOL=2035752.04
999             0      1:-3:2:-19:-20 $VOID REGION OUTSIDE REACTOR VESSEL

*1              CZ     180    $ REACTOR VESSEL
*2              PZ     200
*3              PZ    -200
30             PX    -0.7215
31             PX     0.7215
32             PY    -0.7215
33             PY     0.7215
C  OUTSIDE OF UNIT CELL (1.443 PITCH)
4              CZ     0.4788
C  CYLINDER BPRA / WATER HOLE / GAP RADIUS
5              CZ     0.5461
C  CYLINDER INTERIOR CLAD RADIUS
6              CZ     0.6320
C  CYLINDER WATER RADIUS GUIDE TUBE
7              CZ     0.6731
C  CYLINDER CLAD RADIUS GUIDE TUBE
8              CZ     0.4699
C  CYLINDER RADIUS OF FUEL PELLET
9              PX    -10.905
10             PX     10.905
11             PY    -10.905
12             PY     10.905
```

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13             PZ    -180
14             PZ     180
C  PLANES OUTSIDE OF ASSEMBLY
15             PZ    -164.8
16             PZ     164.8
17             PZ    -155.13
18             PZ     155.13
*19             PX      0
*20             P       0 0 0 10.905 10.905 0 10.905 10.905 10.905
C  PLANES FOR AXIAL BLANKET

MODE    N
IMP:N   1.0 63R 0.0
KCODE   30000    1.5     10       50      5000
KSRC    1.443 2.886 0
        1.443 21.8 0
        20.357 21.8 0
        1.443 43.6 0
        20.357 43.6 0
        42.157 43.6 0
        1.443 65.4 0
        20.357 65.4 0
        42.157 65.4 0
        63.957 65.4 0
        1.443 87.2 0
        20.357 87.2 0
        42.157 87.2 0
        63.957 87.2 0
        85.757 87.2 0
        1.443 109 0
        20.357 109 0
        42.157 109 0
        63.957 109 0
        85.757 109 0
        107.557 109 0
        1.443 130.8 0
        20.357 130.8 0
        42.157 130.8 0
        63.957 130.8 0
        85.757 130.8 0
        1.443 152.6 0
        20.357 152.6 0
        42.157 152.6 0
M1      8016.60C        -8.88100E+01        1001.60C     -1.11900E+01
MT1     LWTR.04T $H20 AT 600 K
C   FUEL FOR 14A  (PRIMARY)  0.0452 ENRICH
M2      92235.54C    0.015066652
        92238.54C    0.318266348
        8016.54C     0.666666
C   FUEL FOR 14A -E (BLANKET)  0.02 ENRICH
M22     92235.54C    0.00666666
        92238.54C    0.32666634
        8016.54C     0.666666
C   FUEL FOR 14B -E (PRIMARY)  0.0466 ENRICH
M23     92235.54C    0.015533318
        92238.54C    0.317799682
        8016.54C     0.666666
C   FUEL FOR 14C & D (GdO MIX) 0.0396 ENRICH 0.03 GdO
M24     92235.54C    0.012804
        92238.54C    0.310529333
        8016.54C     0.664666667
        64154.60C    0.000325035
        64155.60C    0.00224584
        64156.60C    0.00314201
        64157.60C    0.00242074
        64158.60C    0.003866374
C   FUEL FOR 14A & E (GdO MIX) 0.0316 ENRICH 0.06 GdO
M25     92235.54C    0.009901333
        92238.54C    0.303432
        8016.54C     0.662666667
        64154.60C    0.000650071
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        64155.60C    0.004491681
        64156.60C    0.006284019
        64157.60C    0.004841481
        64158.60C    0.007732749
C FUEL FOR 10A3 - 13E (BLANKET)
M34     92235.54C        -0.0096
        92236.60C        -0.0187
        92238.54C        -0.965939
        94239.15C        -0.00525
        94240.60C        -0.00131
        8016.54C         -0.000799
C FUEL FOR 10A3 (PRIMARY) 0.01082  ENRICH
M26    92235.54C       0.003606663
       92238.54C       0.329726337
        8016.54C       0.666666
C FUEL FOR 13D (PRIMARY) 0.0155 ENRICH
M30    92235.54C       0.005166662
       92238.54C       0.328166339
        8016.54C       0.666666
C FUEL FOR 13E (PRIMARY) 0.01833 ENRICH
M33    92235.54C       0.006109994
       92238.54C       0.327223006
        8016.54C       0.666666
M3      40000.60C 1.0 $ZIRCONIUM (APPROX. FOR ZIRCALLOY)
M4      5010.50C   -0.55   5011.56C -2.22 6000.60C   -0.76   13027.60C
        -51.04   8016.54C   -45.43  $B4CAL2O3 BP MATERIAL
PRINT
```

The MCNP Input File 1/8th core L-Carborane BPRAs

```
RESEARCH 1/8th CORE WITH L-CARBORANE BPRA'S
C    CRYSTAL RIVER REACTOR #1
C      box -200 200 -200 200 -200 200
1     0 -1 13 -14 19 20 FILL=1  VOL=6333455.62
2     1  -0.660 9 -10 11 -12 LAT=1 U=1 FILL=-8:1 -8:1 0:0
        1  1  1  1  1  1  1  1  1  1
        1  1  1  1  1  1  2  2  2  1
        1  1  1  1  2  4 11 12  4  1
        1  1  1  2 10  5 13  5  9  1
        1  1  1  1  4 13  4  9  5  1
        1  1  1  1  1  4  9  4  9  1
        1  1  1  1  1  1  4 13  4  1
        1  1  1  1  1  1  1  4  5  1
        1  1  1  1  1  1  1  1  2  1
        1  1  1  1  1  1  1  1  1  1
c 201    0 9 -10 11 -12 LAT=1 U=22 FILL=2
C    10A & 12A2 MARK-B4Z ASSMBLY WITH 0 GD AND 0 BPRAS (33 TOTAL)
200    1 -0.660 30 -31 32 -33 LAT=1 VOL=2581.227 U=2 FILL=-8:8 -8:8 0:0
       2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 14 20 20 20 14 20 20 20 20  2
       2 20 20 20 14 20 20 20 20 20 20 20 14 20 20  2
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       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 14 20 20 14 20 20 20 14 20 20 14 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 14 20 20 20 20 20 20 20 14 20 20  2
       2 20 20 20 20 20 14 20 20 20 14 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
C    13A 13D MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (48 TOTAL)
202    1 -0.660 30 -31 32 -33 LAT=1 U=4 VOL=2581.227 FILL=-8:8 -8:8 0:0
       4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 14 40 40 40 14 40 40 40 40  4
```

```
       4 40 40 40 14 40 40 40 40 40 40 40 14 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 14 40 40 14 40 40 40 14 40 40 14 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 14 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 14 40 40 14 40 40 40 14 40 40 14 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 14 40 40 40 40 40 40 40 14 40 40 40  4
       4 40 40 40 40 40 40 14 40 40 40 14 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4
C    13B C E MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (8 TOTAL)
203    1 -0.660 30 -31 32 -33 LAT=1 U=5 VOL=2581.227 FILL=-8:8 -8:8 0:0
       5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 14 50 50 50 14 50 50 50 50 50  5
       5 50 50 50 14 50 50 50 50 50 50 50 14 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 14 50 50 14 50 50 50 14 50 50 14 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 14 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 14 50 50 14 50 50 50 14 50 50 14 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 14 50 50 50 50 50 50 50 14 50 50 50  5
       5 50 50 50 50 50 14 50 50 50 14 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
C    14A MARK-B10I ASSMBLY WITH 8 GD AND 8 BPRAS (24 TOTAL)
207    1 -0.660 30 -31 32 -33 LAT=1 U=9 VOL=2581.227 FILL=-8:8 -8:8 0:0
       9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 90 91 90 90 90 90 90 90 90 91 90 90 90  9
       9 90 90 90 90 90 15 90 90 90 15 90 90 90 90 90  9
       9 90 91 90 14 90 90 90 90 90 90 90 14 90 91 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 15 90 90 14 90 90 90 14 90 90 15 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 90 90 90 90 90 14 90 90 90 90 90 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 15 90 90 14 90 90 90 14 90 90 15 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 91 90 14 90 90 90 90 90 90 90 14 90 91 90  9
       9 90 90 90 90 90 15 90 90 90 15 90 90 90 90 90  9
       9 90 90 90 91 90 90 90 90 90 90 90 91 90 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9
C    14B MARK-B10I ASSMBLY WITH 0 GD AND 0 BPRAS (8 TOTAL)
208    1 -0.660 30 -31 32 -33 LAT=1 U=10 VOL=2581.227 FILL=-8:8 -8:8 0:0
      10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  10
      10 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  10
      10 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10
C    14C MARK-B10I ASSMBLY WITH 4 GD AND 0 BPRAS (8 TOTAL)
```

```
209    1 -0.660 30 -31 32 -33 LAT=1 U=11 VOL=2581.227 FILL=-8:8 -8:8 0:0
       11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 111 100 100 100 100 100 100 100 100 100 100 100 111 100  11
       11 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  11
       11 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  11
       11 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  11
       11 100 111 100 100 100 100 100 100 100 100 100 100 100 111 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
C    14D MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (8 TOTAL)
210    1 -0.660 30 -31 32 -33 LAT=1 U=12 VOL=2581.227 FILL=-8:8 -8:8 0:0
       12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100 100 111 100 100 100 100 100 100 100 111 100 100 100  12
       12 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  12
       12 100 111 100  14 100 100 100 100 100 100 100  14 100 111 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 111 100  14 100 100 100 100 100 100 100  14 100 111 100  12
       12 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  12
       12 100 100 100 111 100 100 100 100 100 100 100 111 100 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12
C    14E MARK-B10I ASSMBLY WITH 8 GD AND 8 BPRAS (24 TOTAL)
211     1 -0.660 30 -31 32 -33 LAT=1 U=13 VOL=2581.227 FILL=-8:8 -8:8 0:0
        13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100 100 100  91 100 100 100 100 100 100 100  91 100 100 100  13
        13 100 100 100 100 100  15 100 100 100  15 100 100 100 100 100  13
        13 100  91 100  14 100 100 100 100 100 100 100  14 100  91 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100 100  15 100 100  14 100 100 100  14 100 100  15 100 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100 100  15 100 100  14 100 100 100  14 100 100  15 100 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100  91 100  14 100 100 100 100 100 100 100  14 100  91 100  13
        13 100 100 100 100 100  15 100 100 100  15 100 100 100 100 100  13
        13 100 100 100  91 100 100 100 100 100 100 100  91 100 100 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13
C      UNIVERSE 14 EMPTY GUIDE TUBE
3      1    -0.660     -4 U=14 $WATER HOLE
                       VOL=259.275
4      3    -6.503 4 -5 U=14 $INTERIOR CLAD
                       VOL=78.0098
5      1    -0.660   5 -6 U=14 $GUIDE TUBE WATER RADIUS
                       VOL=114.4531
6      3    -6.503 6 -7 U=14 $GUIDE TUBE CLAD RADIUS
                       VOL=60.665
7      1    -0.660   #3 #4 #5 #6 U=14 $UNIT CELL WATER
                       VOL=237.207
C      UNIVERSE 15 BPRA
8      4    -0.9     -4 U=15 $BPRA MATERIAL
                       VOL=259.275
9      3    -6.503 4 -5 U=15 $INTERIOR CLAD
```

```
                    VOL=78.0098
10      1    -0.660   5 -6 U=15 $GUIDE TUBE WATER RADIUS
                    VOL=114.453
11      3    -6.503 6 -7 U=15 $GUIDE TUBE CLAD RADIUS
                    VOL=60.665
12      1    -0.660   #8 #9 #10 #11 U=15 $UNIT CELL WATER
                    VOL=237.207
C       UNIVERSE 20  FUEL FOR 10A3 &12A2 ASSEMBLY (PRIMARY)
13      26   -10.201    -8 15 -16 U=20 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.638
14      34   -10.201    -8 -15 U=20  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
15      34   -10.201    -8 16  U=20  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
16      0            8 -4 U=20 $GAP RADIUS
                    VOL=9.5493
17      3    -6.503 4 -5 U=20 $FUEL PIN CLAD
                    VOL=78.00976
18      1    -0.660   #13 #14 #15 #16 #17 U=20 $UNIT CELL WATER
                    VOL=412.3249
C       UNIVERSE 40  FUEL FOR 13A & 13D ASSEMBLY (PRIMARY)
25      30    -10.201    -8 15 -16 U=40 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.638
26      34   -10.201    -8 -15 U=40  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
27      34   -10.201    -8 16  U=40  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
28      0            8 -4 U=40 $GAP RADIUS
                    VOL=9.5493
29      3    -6.503 4 -5 U=40 $FUEL PIN CLAD
                    VOL=78.00976
30      1    -0.660   #25 #26 #27 #28 #29 U=40 $UNIT CELL WATER
                    VOL=412.3249
C       UNIVERSE 50  FUEL FOR 13B C E ASSEMBLY (PRIMARY)
37      33  -10.201    -8 15 -16 U=50 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.638
38      34   -10.201    -8 -15 U=50  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
39      34   -10.201    -8 16  U=50  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
40      0            8 -4 U=50 $GAP RADIUS
                    VOL=9.5493
41      3    -6.503 4 -5 U=50 $FUEL PIN CLAD
                    VOL=78.00976
42      1    -0.660   #37 #38 #39 #40 #41 U=50 $UNIT CELL WATER
                    VOL=412.3249
C       UNIVERSE 90  FUEL FOR 14A ASSEMBLY (PRIMARY)
79      2    -10.201    -8 15 -16 U=90 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.638
80      22   -10.201    -8 -15 U=90  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
81      22   -10.201    -8 16  U=90  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
82      0            8 -4 U=90 $GAP RADIUS
                    VOL=9.5493
83      3    -6.503 4 -5 U=90 $FUEL PIN CLAD
                    VOL=78.00976
84      1    -0.660   #79 #80 #81 #82 #83 U=90 $UNIT CELL WATER
                    VOL=412.3249
C       UNIVERSE 91 GD FUEL ROD FOR 14A AND 14E
85      25   -9.635    -8 17 -18 U=91 $UO2 GDO FUEL PELLET (PRIMARY)
                    VOL=215.2219
86      22   -10.201    -8 -17 U=91  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
87      22   -10.201    -8 18  U=91  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
88      0            8 -4 U=91 $GAP RADIUS
                    VOL=9.549294
89      3    -6.503 4 -5 U=91 $FUEL PIN CLAD
                    VOL=78.00976
90      1    -0.660   #85 #86 #87 #88 #89 U=91 $UNIT CELL WATER
```

```
                    VOL=412.3249
C      UNIVERSE 100 FUEL FOR 14B 14C 14D 14E ASSEMBLIES
91     23   -10.201    -8 15 -16 U=100 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.6378
92     22   -10.201    -8 -15 U=100  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.54397
93     22   -10.201    -8 16  U=100  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.54397
94     0             8 -4 U=100 $GAP RADIUS
                    VOL=54929
95     3    -6.503 4 -5 U=100 $FUEL PIN CLAD
                    VOL=78.00976
96     1    -0.660   #91 #92 #93 #94 #95 U=100 $UNIT CELL WATER
                    VOL=412.3249
C      UNIVERSE 111 GD FUEL ROD FOR 14C AND 14D
97     24   -9.635    -8 17 -18 U=111 $UO2 GDO FUEL PELLET (PRIMARY)
                    VOL=215.2219
98     22   -10.201    -8 -17 U=111  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
99     22   -10.201    -8 18  U=111  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
100     0             8 -4 U=111 $GAP RADIUS
                    VOL=9.549294
101     3    -6.503 4 -5 U=111 $FUEL PIN CLAD
                    VOL=78.00976
102     1    -0.660   #97 #98 #99 #100 #101 U=111 $UNIT CELL WATER
                    VOL=412.3249
C      REACTOR BOUNDARY
997     1    -0.660   -1 -2 14 19 20  $AXIAL RELECTORS
                    VOL=2035752.04
998     1    -0.660   -1  3 -13 19 20
                    VOL=2035752.04
999             0      1:-3:2:-19:-20 $VOID REGION OUTSIDE REACTOR VESSEL

*1              CZ     180    $ REACTOR VESSEL
*2              PZ     200
*3              PZ    -200
30             PX    -0.7215
31             PX     0.7215
32             PY    -0.7215
33             PY     0.7215
C  OUTSIDE OF UNIT CELL (1.443 PITCH)
4              CZ     0.4788
C  CYLINDER BPRA / WATER HOLE / GAP RADIUS
5              CZ     0.5461
C  CYLINDER INTERIOR CLAD RADIUS
6              CZ     0.6320
C  CYLINDER WATER RADIUS GUIDE TUBE
7              CZ     0.6731
C  CYLINDER CLAD RADIUS GUIDE TUBE
8              CZ     0.4699
C  CYLINDER RADIUS OF FUEL PELLET
9              PX    -10.905
10             PX     10.905
11             PY    -10.905
12             PY     10.905
13             PZ    -180
14             PZ     180
C  PLANES OUTSIDE OF ASSEMBLY
15             PZ    -164.8
16             PZ     164.8
17             PZ    -155.13
18             PZ     155.13
*19             PX      0
*20             P       0 0 0 10.905 10.905 0 10.905 10.905 10.905
C  PLANES FOR AXIAL BLANKET

MODE    N
IMP:N   1.0 63R 0.0
KCODE   30000    1.5     10       50      5000
KSRC    1.443 2.886 0
```

```
        1.443 21.8 0
        20.357 21.8 0
        1.443 43.6 0
        20.357 43.6 0
        42.157 43.6 0
        1.443 65.4 0
        20.357 65.4 0
        42.157 65.4 0
        63.957 65.4 0
        1.443 87.2 0
        20.357 87.2 0
        42.157 87.2 0
        63.957 87.2 0
        85.757 87.2 0
        1.443 109 0
        20.357 109 0
        42.157 109 0
        63.957 109 0
        85.757 109 0
        107.557 109 0
        1.443 130.8 0
        20.357 130.8 0
        42.157 130.8 0
        63.957 130.8 0
        85.757 130.8 0
        1.443 152.6 0
        20.357 152.6 0
        42.157 152.6 0
M1      8016.60C        -8.88100E+01        1001.60C     -1.11900E+01
MT1     LWTR.04T $H20 AT 600 K
C   FUEL FOR 14A  (PRIMARY)  0.0452 ENRICH
M2      92235.54C    0.015066652
        92238.54C    0.318266348
        8016.54C     0.666666
C   FUEL FOR 14A -E (BLANKET)  0.02 ENRICH
M22     92235.54C    0.00666666
        92238.54C    0.32666634
        8016.54C     0.666666
C   FUEL FOR 14B -E (PRIMARY)  0.0466 ENRICH
M23     92235.54C    0.015533318
        92238.54C    0.317799682
        8016.54C     0.666666
C   FUEL FOR 14C & D (GdO MIX) 0.0396 ENRICH 0.03 GdO
M24     92235.54C    0.012804
        92238.54C    0.310529333
        8016.54C     0.664666667
        64154.60C    0.000325035
        64155.60C    0.00224584
        64156.60C    0.00314201
        64157.60C    0.00242074
        64158.60C    0.003866374
C   FUEL FOR 14A & E (GdO MIX) 0.0316 ENRICH 0.06 GdO
M25     92235.54C    0.009901333
        92238.54C    0.303432
        8016.54C     0.662666667
        64154.60C    0.000650071
        64155.60C    0.004491681
        64156.60C    0.006284019
        64157.60C    0.004841481
        64158.60C    0.007732749
C FUEL FOR 10A3 - 13E (BLANKET)
M34     92235.54C        -0.0096
        92236.60C        -0.0187
        92238.54C        -0.965939
        94239.15C        -0.00525
        94240.60C        -0.00131
        8016.54C         -0.000799
C FUEL FOR 10A3 (PRIMARY) 0.01082  ENRICH
M26    92235.54C       0.003606663
       92238.54C       0.329726337
        8016.54C       0.666666
```

```
C FUEL FOR 13D (PRIMARY) 0.0155 ENRICH
M30    92235.54C       0.005166662
       92238.54C       0.328166339
        8016.54C       0.666666
C FUEL FOR 13E (PRIMARY) 0.01833 ENRICH
M33    92235.54C       0.006109994
       92238.54C       0.327223006
        8016.54C       0.666666
M3      40000.60C 1.0 $ZIRCONIUM (APPROX. FOR ZIRCALLOY)
M4      6000.60C  -46.40 14000.60C  -29.60 8016.54C -7.03
        5010.50C  -1.90 5011.56C -7.63 1001.60C  -7.44 $CARBORANE BP MATERIAL
PRINT
```

The MCNP Input File 1/8th core J-Carborane BPRAs

```
RESEARCH 1/8th CORE WITH J-CARBORANE BPRA'S
C    CRYSTAL RIVER REACTOR #1
C      box -200 200 -200 200 -200 200
1     0 -1 13 -14 19 20 FILL=1  VOL=6333455.62
2     1  -0.660 9 -10 11 -12 LAT=1 U=1 FILL=-8:1 -8:1 0:0
        1  1  1  1  1  1  1  1  1  1
        1  1  1  1  1  1  2  2  2  1
        1  1  1  1  2  4 11 12  4  1
        1  1  1  2 10  5 13  5  9  1
        1  1  1  1  4 13  4  9  5  1
        1  1  1  1  1  4  9  4  9  1
        1  1  1  1  1  1  4 13  4  1
        1  1  1  1  1  1  1  4  5  1
        1  1  1  1  1  1  1  1  2  1
        1  1  1  1  1  1  1  1  1  1
c 201    0 9 -10 11 -12 LAT=1 U=22 FILL=2
C    10A & 12A2 MARK-B4Z ASSMBLY WITH 0 GD AND 0 BPRAS (33 TOTAL)
200    1 -0.660 30 -31 32 -33 LAT=1 VOL=2581.227 U=2 FILL=-8:8 -8:8 0:0
       2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 14 20 20 20 14 20 20 20 20  2
       2 20 20 20 14 20 20 20 20 20 20 20 14 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 14 20 20 14 20 20 20 14 20 20 14 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 14 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 14 20 20 14 20 20 20 14 20 20 14 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 14 20 20 20 20 20 20 20 14 20 20  2
       2 20 20 20 20 20 14 20 20 20 14 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
C    13A 13D MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (48 TOTAL)
202    1 -0.660 30 -31 32 -33 LAT=1 U=4 VOL=2581.227 FILL=-8:8 -8:8 0:0
       4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 14 40 40 40 14 40 40 40 40  4
       4 40 40 40 14 40 40 40 40 40 40 40 14 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 14 40 40 14 40 40 40 40 14 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 14 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 14 40 40 14 40 40 40 14 40 40 14 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 14 40 40 40 40 40 40 40 14 40 40  4
       4 40 40 40 40 40 14 40 40 40 14 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4
C    13B C E MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (8 TOTAL)
203    1 -0.660 30 -31 32 -33 LAT=1 U=5 VOL=2581.227 FILL=-8:8 -8:8 0:0
```

```
       5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 14 50 50 50 14 50 50 50 50 50  5
       5 50 50 50 14 50 50 50 50 50 50 50 14 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 14 50 50 14 50 50 50 14 50 50 14 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 14 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 14 50 50 14 50 50 50 14 50 50 14 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 14 50 50 50 50 50 50 50 14 50 50 50  5
       5 50 50 50 50 50 14 50 50 50 14 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
C    14A MARK-B10I ASSMBLY WITH 8 GD AND 8 BPRAS (24 TOTAL)
207    1 -0.660 30 -31 32 -33 LAT=1 U=9 VOL=2581.227 FILL=-8:8 -8:8 0:0
       9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 90 91 90 90 90 90 90 90 90 91 90 90 90  9
       9 90 90 90 90 90 15 90 90 90 15 90 90 90 90 90  9
       9 90 91 90 14 90 90 90 90 90 90 90 14 90 91 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 15 90 90 14 90 90 90 14 90 90 15 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 90 90 90 90 90 14 90 90 90 90 90 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 15 90 90 14 90 90 90 14 90 90 15 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 91 90 14 90 90 90 90 90 90 90 14 90 91 90  9
       9 90 90 90 90 90 15 90 90 90 15 90 90 90 90 90  9
       9 90 90 90 91 90 90 90 90 90 90 90 91 90 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9
C    14B MARK-B10I ASSMBLY WITH 0 GD AND 0 BPRAS (8 TOTAL)
208    1 -0.660 30 -31 32 -33 LAT=1 U=10 VOL=2581.227 FILL=-8:8 -8:8 0:0
      10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  10
      10 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  10
      10 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
      10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10
C    14C MARK-B10I ASSMBLY WITH 4 GD AND 0 BPRAS (8 TOTAL)
209    1 -0.660 30 -31 32 -33 LAT=1 U=11 VOL=2581.227 FILL=-8:8 -8:8 0:0
      11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
      11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
      11 100 111 100 100 100 100 100 100 100 100 100 100 100 111 100  11
      11 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  11
      11 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  11
      11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
      11 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  11
      11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
      11 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  11
      11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
      11 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  11
      11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
      11 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  11
      11 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  11
```

```
       11 100 111 100 100 100 100 100 100 100 100 100 100 100 111 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
C    14D MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (8 TOTAL)
210    1 -0.660 30 -31 32 -33 LAT=1 U=12 VOL=2581.227 FILL=-8:8 -8:8 0:0
       12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100 100 111 100 100 100 100 100 100 100 111 100 100 100  12
       12 100 100 100 100 100 100  14 100 100 100  14 100 100 100 100  12
       12 100 111 100  14 100 100 100 100 100 100 100  14 100 111 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 111 100  14 100 100 100 100 100 100 100  14 100 111 100  12
       12 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  12
       12 100 100 100 111 100 100 100 100 100 100 100 111 100 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12
C    14E MARK-B10I ASSMBLY WITH 8 GD AND 8 BPRAS (24 TOTAL)
211     1 -0.660 30 -31 32 -33 LAT=1 U=13 VOL=2581.227 FILL=-8:8 -8:8 0:0
        13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100 100 100  91 100 100 100 100 100 100 100  91 100 100 100  13
        13 100 100 100 100 100  15 100 100 100  15 100 100 100 100 100  13
        13 100  91 100  14 100 100 100 100 100 100 100  14 100  91 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100 100  15 100 100  14 100 100 100  14 100 100  15 100 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100 100  15 100 100  14 100 100 100  14 100 100  15 100 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100  91 100  14 100 100 100 100 100 100 100  14 100  91 100  13
        13 100 100 100 100 100 100  15 100 100 100  15 100 100 100 100  13
        13 100 100 100  91 100 100 100 100 100 100 100  91 100 100 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13
C      UNIVERSE 14 EMPTY GUIDE TUBE
3      1    -0.660     -4 U=14 $WATER HOLE
                       VOL=259.275
4      3    -6.503 4 -5 U=14 $INTERIOR CLAD
                       VOL=78.0098
5      1    -0.660   5 -6 U=14 $GUIDE TUBE WATER RADIUS
                       VOL=114.4531
6      3    -6.503 6 -7 U=14 $GUIDE TUBE CLAD RADIUS
                       VOL=60.665
7      1    -0.660   #3 #4 #5 #6 U=14 $UNIT CELL WATER
                       VOL=237.207
C      UNIVERSE 15 BPRA
8      4    -1.0     -4 U=15 $BPRA MATERIAL
                       VOL=259.275
9      3    -6.503 4 -5 U=15 $INTERIOR CLAD
                       VOL=78.0098
10     1    -0.660   5 -6 U=15 $GUIDE TUBE WATER RADIUS
                       VOL=114.453
11     3    -6.503 6 -7 U=15 $GUIDE TUBE CLAD RADIUS
                       VOL=60.665
12     1    -0.660   #8 #9 #10 #11 U=15 $UNIT CELL WATER
                       VOL=237.207
C      UNIVERSE 20  FUEL FOR 10A3 &12A2 ASSEMBLY (PRIMARY)
13     26   -10.201    -8 15 -16 U=20 $UO2 FUEL PELLET (PRIMARY)
                       VOL=228.638
14     34   -10.201    -8 -15 U=20  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
15     34   -10.201    -8 16  U=20  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
16     0             8 -4 U=20 $GAP RADIUS
```

```
                    VOL=9.5493
17      3    -6.503 4 -5 U=20 $FUEL PIN CLAD
                    VOL=78.00976
18      1    -0.660   #13 #14 #15 #16 #17 U=20 $UNIT CELL WATER
                    VOL=412.3249
C       UNIVERSE 40  FUEL FOR 13A & 13D ASSEMBLY (PRIMARY)
25      30    -10.201    -8 15 -16 U=40 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.638
26      34   -10.201    -8 -15 U=40  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
27      34   -10.201    -8 16  U=40  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
28      0             8 -4 U=40 $GAP RADIUS
                    VOL=9.5493
29      3    -6.503 4 -5 U=40 $FUEL PIN CLAD
                    VOL=78.00976
30      1    -0.660   #25 #26 #27 #28 #29 U=40 $UNIT CELL WATER
                    VOL=412.3249
C       UNIVERSE 50  FUEL FOR 13B C E ASSEMBLY (PRIMARY)
37      33  -10.201    -8 15 -16 U=50 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.638
38      34   -10.201    -8 -15 U=50  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
39      34   -10.201    -8 16  U=50  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
40      0             8 -4 U=50 $GAP RADIUS
                    VOL=9.5493
41      3    -6.503 4 -5 U=50 $FUEL PIN CLAD
                    VOL=78.00976
42      1    -0.660   #37 #38 #39 #40 #41 U=50 $UNIT CELL WATER
                    VOL=412.3249
C       UNIVERSE 90  FUEL FOR 14A ASSEMBLY (PRIMARY)
79      2    -10.201    -8 15 -16 U=90 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.638
80      22   -10.201    -8 -15 U=90  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
81      22   -10.201    -8 16  U=90  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
82      0             8 -4 U=90 $GAP RADIUS
                    VOL=9.5493
83      3    -6.503 4 -5 U=90 $FUEL PIN CLAD
                    VOL=78.00976
84      1    -0.660   #79 #80 #81 #82 #83 U=90 $UNIT CELL WATER
                    VOL=412.3249
C       UNIVERSE 91 GD FUEL ROD FOR 14A AND 14E
85      25   -9.635    -8 17 -18 U=91 $UO2 GDO FUEL PELLET (PRIMARY)
                    VOL=215.2219
86      22   -10.201    -8 -17 U=91  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
87      22   -10.201    -8 18  U=91  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
88      0             8 -4 U=91 $GAP RADIUS
                    VOL=9.549294
89      3    -6.503 4 -5 U=91 $FUEL PIN CLAD
                    VOL=78.00976
90      1    -0.660   #85 #86 #87 #88 #89 U=91 $UNIT CELL WATER
                    VOL=412.3249
C       UNIVERSE 100 FUEL FOR 14B 14C 14D 14E ASSEMBLIES
91      23   -10.201    -8 15 -16 U=100 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.6378
92      22   -10.201    -8 -15 U=100  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.54397
93      22   -10.201    -8 16  U=100  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.54397
94      0             8 -4 U=100 $GAP RADIUS
                    VOL=54929
95      3    -6.503 4 -5 U=100 $FUEL PIN CLAD
                    VOL=78.00976
96      1    -0.660   #91 #92 #93 #94 #95 U=100 $UNIT CELL WATER
                    VOL=412.3249
C       UNIVERSE 111 GD FUEL ROD FOR 14C AND 14D
```

```
97     24   -9.635    -8 17 -18 U=111 $UO2 GDO FUEL PELLET (PRIMARY)
                     VOL=215.2219
98     22   -10.201     -8 -17 U=111  $UO2 FUEL PELLET (BLANKET)
                     VOL=17.25188
99     22   -10.201     -8 18  U=111  $UO2 FUEL PELLET (BLANKET)
                     VOL=17.25188
100     0             8 -4 U=111 $GAP RADIUS
                     VOL=9.549294
101     3    -6.503 4 -5 U=111 $FUEL PIN CLAD
                     VOL=78.00976
102     1    -0.660   #97 #98 #99 #100 #101 U=111 $UNIT CELL WATER
                     VOL=412.3249
C      REACTOR BOUNDARY
997     1    -0.660   -1 -2 14 19 20  $AXIAL RELECTORS
                     VOL=2035752.04
998     1    -0.660   -1  3 -13 19 20
                     VOL=2035752.04
999             0      1:-3:2:-19:-20 $VOID REGION OUTSIDE REACTOR VESSEL

*1              CZ     180    $ REACTOR VESSEL
*2              PZ     200
*3              PZ    -200
30             PX    -0.7215
31             PX     0.7215
32             PY    -0.7215
33             PY     0.7215
C  OUTSIDE OF UNIT CELL (1.443 PITCH)
4              CZ     0.4788
C  CYLINDER BPRA / WATER HOLE / GAP RADIUS
5              CZ     0.5461
C  CYLINDER INTERIOR CLAD RADIUS
6              CZ     0.6320
C  CYLINDER WATER RADIUS GUIDE TUBE
7              CZ     0.6731
C  CYLINDER CLAD RADIUS GUIDE TUBE
8              CZ     0.4699
C  CYLINDER RADIUS OF FUEL PELLET
9              PX    -10.905
10             PX     10.905
11             PY    -10.905
12             PY     10.905
13             PZ    -180
14             PZ     180
C  PLANES OUTSIDE OF ASSEMBLY
15             PZ    -164.8
16             PZ     164.8
17             PZ    -155.13
18             PZ     155.13
*19             PX      0
*20             P       0 0 0 10.905 10.905 0 10.905 10.905 10.905
C  PLANES FOR AXIAL BLANKET

MODE    N
IMP:N   1.0 63R 0.0
KCODE   30000    1.5     10       50      5000
KSRC    1.443 2.886 0
        1.443 21.8 0
        20.357 21.8 0
        1.443 43.6 0
        20.357 43.6 0
        42.157 43.6 0
        1.443 65.4 0
        20.357 65.4 0
        42.157 65.4 0
        63.957 65.4 0
        1.443 87.2 0
        20.357 87.2 0
        42.157 87.2 0
        63.957 87.2 0
        85.757 87.2 0
        1.443 109 0
```

```
        20.357 109 0
        42.157 109 0
        63.957 109 0
        85.757 109 0
        107.557 109 0
        1.443 130.8 0
        20.357 130.8 0
        42.157 130.8 0
        63.957 130.8 0
        85.757 130.8 0
        1.443 152.6 0
        20.357 152.6 0
        42.157 152.6 0
M1      8016.60C        -8.88100E+01        1001.60C     -1.11900E+01
MT1     LWTR.04T $H20 AT 600 K
C   FUEL FOR 14A  (PRIMARY)  0.0452 ENRICH
M2      92235.54C    0.015066652
        92238.54C    0.318266348
        8016.54C     0.666666
C   FUEL FOR 14A -E (BLANKET)  0.02 ENRICH
M22     92235.54C    0.00666666
        92238.54C    0.32666634
        8016.54C     0.666666
C   FUEL FOR 14B -E (PRIMARY)  0.0466 ENRICH
M23     92235.54C    0.015533318
        92238.54C    0.317799682
        8016.54C     0.666666
C   FUEL FOR 14C & D (GdO MIX) 0.0396 ENRICH 0.03 GdO
M24     92235.54C    0.012804
        92238.54C    0.310529333
        8016.54C     0.664666667
        64154.60C    0.000325035
        64155.60C    0.00224584
        64156.60C    0.00314201
        64157.60C    0.00242074
        64158.60C    0.003866374
C   FUEL FOR 14A & E (GdO MIX) 0.0316 ENRICH 0.06 GdO
M25     92235.54C    0.009901333
        92238.54C    0.303432
        8016.54C     0.662666667
        64154.60C    0.000650071
        64155.60C    0.004491681
        64156.60C    0.006284019
        64157.60C    0.004841481
        64158.60C    0.007732749
C FUEL FOR 10A3 - 13E (BLANKET)
M34     92235.54C        -0.0096
        92236.60C        -0.0187
        92238.54C        -0.965939
        94239.15C        -0.00525
        94240.60C        -0.00131
        8016.54C         -0.000799
C FUEL FOR 10A3 (PRIMARY) 0.01082  ENRICH
M26    92235.54C       0.003606663
       92238.54C       0.329726337
        8016.54C       0.666666
C FUEL FOR 13D (PRIMARY) 0.0155 ENRICH
M30    92235.54C       0.005166662
       92238.54C       0.328166339
        8016.54C       0.666666
C FUEL FOR 13E (PRIMARY) 0.01833 ENRICH
M33    92235.54C       0.006109994
       92238.54C       0.327223006
        8016.54C       0.666666
M3      40000.60C 1.0 $ZIRCONIUM (APPROX. FOR ZIRCALLOY)
M4      6000.60C  -0.37 14000.60C  -0.25 8016.54C -0.07
        5010.50C  -0.048 5011.56C -0.192 1001.60C  -0.08 $CARBORANE BP MATERIAL
PRINT
```

The MONTEBURNS Input File 1/8th core B_4C/Al_2O_3 BPRAs

```
RESEARCH CRYSTAL RIVER 1/8 CORE WITH B4CAL2O3 BPRA'S 4.66% ENRICH NO BORON
PC          ! Type of Operating System
10          ! Number of MCNP Materials to burn (fuel cells/BPRAs)
2           ! MCNP material number #2 (will burn all cells with this mat)
22          ! MCNP material number #22 (will burn all cells with this mat)
23
24
25
34
26
30
33
4
142670      ! Material #2 volume (cc)
40285.32    !#22
277109.01   !#23
2582.664    !#24
10330.66    !#25
58380.164   !#34
196171.234 !#26
284696.016 !#30
142508.996 !#33
7259.7      ! Material #4 volume (cc)
318         ! Power in MWt (for the entire system in MCNP)
-180.88     ! Recov. energy/fis (MeV); if negative use for U235, ratio other isos
670        ! Total number of days burned (used if no feed)
5          ! Number of outer burn steps
50         ! Number of internal burn steps (multiple of 10)
1           ! Number of predictor steps (+1 on first step), 1 usually sufficient
0           ! Step number to restart after (0=beginning)
PWRU50      ! number of default origen2 lib - next line is origen2 lib location
c:\Origen2\Libs
.005        ! fractional importance (track isos with abs,fis,atom,mass fraction)
1           ! Intermediate keff calc. 0) No 1) Yes
2           ! Number of automatic tally isotopes, followed by list.
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
1
5010.50C
```

The MONTEBURNS Input File 1/8th core L-Carborane BPRAs

```
RESEARCH CRYSTAL RIVER 1/8 CORE WITH L-CARBORANE BPRA'S 4.66% ENRICH NO BORON
PC          ! Type of Operating System
10          ! Number of MCNP Materials to burn (fuel cells/BPRAs)
2           ! MCNP material number #2 (will burn all cells with this mat)
22          ! MCNP material number #22 (will burn all cells with this mat)
23
24
25
34
26
30
33
4
142670      ! Material #2 volume (cc)
40285.32    !#22
277109.01   !#23
2582.664    !#24
10330.66    !#25
58380.164   !#34
196171.234 !#26
284696.016 !#30
142508.996 !#33
7259.7      ! Material #4 volume (cc)
318         ! Power in MWt (for the entire system in MCNP)
-180.88     ! Recov. energy/fis (MeV); if negative use for U235, ratio other isos
670        ! Total number of days burned (used if no feed)
5          ! Number of outer burn steps
50         ! Number of internal burn steps (multiple of 10)
1           ! Number of predictor steps (+1 on first step), 1 usually sufficient
0           ! Step number to restart after (0=beginning)
PWRU50      ! number of default origen2 lib - next line is origen2 lib location
c:\Origen2\Libs
.005        ! fractional importance (track isos with abs,fis,atom,mass fraction)
1           ! Intermediate keff calc. 0) No 1) Yes
2           ! Number of automatic tally isotopes, followed by list.
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
1
5010.50C
```

The MONTEBURNS Input File 1/8th core J-Carborane BPRAs

```
RESEARCH CRYSTAL RIVER 1/8 CORE WITH J-CARBORANE BPRA'S 4.66% ENRICH NO BORON
PC          ! Type of Operating System
10          ! Number of MCNP Materials to burn (fuel cells/BPRAs)
2           ! MCNP material number #2 (will burn all cells with this mat)
22          ! MCNP material number #22 (will burn all cells with this mat)
23
24
25
34
26
30
33
4
142670      ! Material #2 volume (cc)
40285.32    !#22
277109.01   !#23
2582.664    !#24
10330.66    !#25
58380.164   !#34
196171.234 !#26
284696.016 !#30
142508.996 !#33
7259.7      ! Material #4 volume (cc)
318         ! Power in MWt (for the entire system in MCNP)
-180.88     ! Recov. energy/fis (MeV); if negative use for U235, ratio other isos
670        ! Total number of days burned (used if no feed)
5          ! Number of outer burn steps
50         ! Number of internal burn steps (multiple of 10)
1           ! Number of predictor steps (+1 on first step), 1 usually sufficient
0           ! Step number to restart after (0=beginning)
PWRU50      ! number of default origen2 lib - next line is origen2 lib location
c:\Origen2\Libs
.005        ! fractional importance (track isos with abs,fis,atom,mass fraction)
1           ! Intermediate keff calc. 0) No 1) Yes
2           ! Number of automatic tally isotopes, followed by list.
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
1
5010.50C
```

The MONTEBURNS Output File 1/8th core B_4C/Al_2O_3 BPRAs

RESEARCH CRYSTAL RIVER 1/8 CORE WITH B4CAL2O3 BPRA'S 4.66% ENRICH NO BOR

Total Power (MW) = 3.18E+02 Days = 6.70E+02
outer steps = 5, # inner steps = 50, # predictor steps = 1
Importance Fraction = 0.0050

Monteburns MCNP k-eff Versus Time

	days	k-eff	rel err	nu	avQfis	eta
0m	0.00	1.17163	0.00056	2.462	181.098	0.826
1m	67.00	1.13578	0.00050	2.522	182.118	0.897
1e	134.00	1.12883	0.00053	2.562		
2m	201.00	1.11527	0.00056	2.594	183.381	1.032
2e	268.00	1.10591	0.00061	2.621		
3m	335.00	1.09039	0.00059	2.642	184.236	1.155
3e	402.00	1.07364	0.00059	2.664		
4m	469.00	1.05521	0.00065	2.685	184.934	1.146
4e	536.00	1.03353	0.00058	2.701		
5m	603.00	1.01491	0.00056	2.718	185.529	1.112
5e	670.00	0.99753	0.00056	2.733		

Monteburns Transport History

Monteburns Transport History for material 1

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.065	3.73E+14	3.84E-02	5.93E+01	4.159E+02	0.000E+00	3.91E-01	5.63E-01	1.44E+00	1.59E-03	1.456	1.17E+00	1.69E+00	1.45E+00	4.77E-03	1.459
1	181.745	3.93E+14	3.65E-02	5.98E+01	4.189E+02	6.242E+00	4.40E-01	5.35E-01	1.22E+00	1.57E-03	1.387	1.22E+00	1.61E+00	1.32E+00	4.72E-03	1.437
2	182.675	4.30E+14	3.48E-02	6.26E+01	4.389E+02	1.278E+01	4.89E-01	5.11E-01	1.04E+00	1.66E-03	1.328	1.33E+00	1.54E+00	1.16E+00	5.03E-03	1.397
3	183.486	4.57E+14	3.33E-02	6.40E+01	4.487E+02	1.947E+01	5.29E-01	4.90E-01	9.25E-01	1.67E-03	1.273	1.41E+00	1.49E+00	1.06E+00	5.08E-03	1.360
4	184.204	4.81E+14	3.15E-02	6.40E+01	4.485E+02	2.615E+01	5.59E-01	4.64E-01	8.29E-01	1.71E-03	1.220	1.47E+00	1.42E+00	9.64E-01	5.22E-03	1.321
5	184.849	4.89E+14	2.94E-02	6.09E+01	4.269E+02	3.251E+01	5.91E-01	4.33E-01	7.33E-01	1.68E-03	1.153	1.54E+00	1.33E+00	8.68E-01	5.14E-03	1.267

Monteburns Transport History for material 2

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.104	1.85E+13	2.94E-02	6.36E-01	1.578E+01	0.000E+00	3.78E-01	4.31E-01	1.14E+00	1.76E-03	1.316	1.13E+00	1.29E+00	1.15E+00	5.29E-03	1.319
1	181.184	1.69E+13	2.94E-02	5.83E-01	1.446E+01	2.155E-01	4.02E-01	4.30E-01	1.07E+00	1.52E-03	1.307	1.17E+00	1.29E+00	1.10E+00	4.57E-03	1.324
2	181.322	1.89E+13	2.99E-02	6.69E-01	1.660E+01	4.629E-01	4.04E-01	4.38E-01	1.09E+00	1.36E-03	1.353	1.18E+00	1.32E+00	1.12E+00	4.09E-03	1.373
3	181.485	2.52E+13	3.05E-02	9.12E-01	2.264E+01	8.003E-01	4.18E-01	4.47E-01	1.07E+00	1.86E-03	1.370	1.21E+00	1.34E+00	1.10E+00	5.58E-03	1.391
4	181.717	2.65E+13	3.02E-02	9.53E-01	2.365E+01	1.153E+00	4.10E-01	4.42E-01	1.08E+00	1.52E-03	1.396	1.19E+00	1.33E+00	1.12E+00	4.58E-03	1.420
5	181.886	2.67E+13	3.05E-02	9.76E-01	2.424E+01	1.514E+00	4.08E-01	4.47E-01	1.09E+00	1.76E-03	1.424	1.18E+00	1.34E+00	1.14E+00	5.29E-03	1.450

Monteburns Transport History for material 3

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.059	3.44E+14	3.98E-02	1.10E+02	3.973E+02	0.000E+00	3.93E-01	5.83E-01	1.48E+00	1.58E-03	1.474	1.17E+00	1.75E+00	1.49E+00	4.75E-03	1.477
1	181.640	3.53E+14	3.78E-02	1.08E+02	3.889E+02	5.795E+00	4.39E-01	5.54E-01	1.26E+00	1.64E-03	1.411	1.22E+00	1.67E+00	1.37E+00	4.94E-03	1.461
2	182.502	3.59E+14	3.58E-02	1.04E+02	3.769E+02	1.141E+01	4.83E-01	5.25E-01	1.09E+00	1.59E-03	1.354	1.32E+00	1.59E+00	1.21E+00	4.81E-03	1.422
3	183.179	3.70E+14	3.43E-02	1.04E+02	3.750E+02	1.700E+01	5.20E-01	5.05E-01	9.72E-01	1.62E-03	1.305	1.39E+00	1.53E+00	1.10E+00	4.92E-03	1.389
4	183.786	3.85E+14	3.26E-02	1.03E+02	3.714E+02	2.253E+01	5.44E-01	4.80E-01	8.81E-01	1.69E-03	1.261	1.44E+00	1.46E+00	1.02E+00	5.15E-03	1.357
5	184.340	4.07E+14	3.08E-02	1.03E+02	3.731E+02	2.809E+01	5.67E-01	4.55E-01	8.01E-01	1.74E-03	1.213	1.49E+00	1.39E+00	9.37E-01	5.30E-03	1.319

Monteburns Transport History for material 4

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.349	2.84E+14	1.45E-02	3.08E-01	1.193E+02	0.000E+00	2.10E+00	2.24E-01	1.07E-01	1.70E-03	0.239	9.27E-01	6.91E-01	7.46E-01	5.13E-03	1.058
1	181.880	2.99E+14	1.90E-02	4.27E-01	1.654E+02	2.675E+00	1.54E+00	2.92E-01	1.89E-01	1.54E-03	0.403	1.01E+00	9.05E-01	8.98E-01	4.69E-03	1.198
2	182.545	3.23E+14	2.75E-02	6.75E-01	2.613E+02	6.901E+00	8.50E-01	4.25E-01	5.00E-01	1.65E-03	0.867	1.19E+00	1.32E+00	1.11E+00	5.08E-03	1.366
3	183.098	3.31E+14	3.06E-02	7.74E-01	2.996E+02	1.175E+01	5.35E-01	4.73E-01	8.85E-01	1.58E-03	1.244	1.37E+00	1.48E+00	1.08E+00	4.86E-03	1.375

4	183.729	3.54E+14	3.02E-02	8.18E-01	3.168E+02	1.687E+01	5.51E-01	4.68E-01	8.50E-01	1.72E-03	1.237	1.43E+00	1.46E+00	1.03E+00	5.32E-03	1.363
5	184.240	3.65E+14	2.73E-02	7.65E-01	2.962E+02	2.166E+01	5.54E-01	4.23E-01	7.64E-01	1.67E-03	1.180	1.42E+00	1.33E+00	9.36E-01	5.17E-03	1.318

Monteburns Transport History for material 5 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.519	3.52E+14	1.05E-02	1.11E+00	1.077E+02	0.000E+00	2.32E+00	1.61E-01	6.96E-02	1.64E-03	0.162	9.11E-01	5.15E-01	5.65E-01	4.99E-03	0.896
1	182.382	3.82E+14	1.31E-02	1.50E+00	1.455E+02	2.414E+00	1.93E+00	2.00E-01	1.04E-01	1.53E-03	0.239	9.78E-01	6.39E-01	6.53E-01	4.73E-03	1.002
2	183.401	4.26E+14	1.90E-02	2.45E+00	2.376E+02	6.354E+00	1.35E+00	2.91E-01	2.15E-01	1.61E-03	0.461	1.16E+00	9.32E-01	8.06E-01	5.01E-03	1.162
3	183.946	4.73E+14	2.65E-02	3.82E+00	3.696E+02	1.248E+01	6.96E-01	4.07E-01	5.85E-01	1.58E-03	0.978	1.37E+00	1.31E+00	9.55E-01	4.95E-03	1.294
4	184.654	5.01E+14	2.65E-02	4.05E+00	3.924E+02	1.899E+01	5.82E-01	4.07E-01	6.99E-01	1.63E-03	1.108	1.46E+00	1.32E+00	9.05E-01	5.14E-03	1.279
5	185.252	5.21E+14	2.43E-02	3.89E+00	3.763E+02	2.523E+01	6.02E-01	3.75E-01	6.22E-01	1.63E-03	1.046	1.51E+00	1.22E+00	8.09E-01	5.18E-03	1.219

Monteburns Transport History for material 6 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	185.098	1.41E+13	3.41E-02	8.17E-01	1.400E+01	0.000E+00	1.50E+00	1.31E+00	8.70E-01	6.07E-03	1.150	1.52E+00	1.32E+00	8.70E-01	6.14E-03	1.150
1	185.141	1.43E+13	3.46E-02	8.43E-01	1.443E+01	1.897E-01	1.52E+00	1.33E+00	8.72E-01	6.50E-03	1.179	1.52E+00	1.34E+00	8.81E-01	6.58E-03	1.186
2	185.124	1.48E+13	3.29E-02	8.36E-01	1.432E+01	3.779E-01	1.53E+00	1.26E+00	8.19E-01	4.24E-03	1.171	1.52E+00	1.27E+00	8.36E-01	4.29E-03	1.184
3	185.166	1.87E+13	3.30E-02	1.07E+00	1.827E+01	6.180E-01	1.51E+00	1.27E+00	8.42E-01	5.92E-03	1.212	1.49E+00	1.28E+00	8.58E-01	6.00E-03	1.225
4	185.199	2.02E+13	3.21E-02	1.12E+00	1.920E+01	8.704E-01	1.51E+00	1.23E+00	8.14E-01	5.54E-03	1.209	1.50E+00	1.25E+00	8.32E-01	5.61E-03	1.223
5	185.235	1.97E+13	3.23E-02	1.10E+00	1.891E+01	1.119E+00	1.51E+00	1.24E+00	8.21E-01	6.39E-03	1.230	1.49E+00	1.25E+00	8.40E-01	6.47E-03	1.245

Monteburns Transport History for material 7 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.113	1.59E+14	2.44E-02	2.20E+01	1.123E+02	0.000E+00	4.00E-01	3.58E-01	8.94E-01	1.25E-03	1.165	1.20E+00	1.07E+00	8.97E-01	3.76E-03	1.168
1	182.192	1.62E+14	2.44E-02	2.26E+01	1.151E+02	1.715E+00	4.35E-01	3.58E-01	8.21E-01	1.37E-03	1.140	1.24E+00	1.07E+00	8.69E-01	4.10E-03	1.176
2	183.635	1.55E+14	2.44E-02	2.18E+01	1.111E+02	3.371E+00	4.70E-01	3.56E-01	7.57E-01	1.43E-03	1.122	1.34E+00	1.07E+00	8.00E-01	4.29E-03	1.157
3	184.558	1.56E+14	2.42E-02	2.18E+01	1.113E+02	5.030E+00	4.88E-01	3.55E-01	7.29E-01	1.46E-03	1.118	1.39E+00	1.07E+00	7.68E-01	4.40E-03	1.151
4	185.182	1.64E+14	2.38E-02	2.27E+01	1.158E+02	6.755E+00	5.10E-01	3.49E-01	6.85E-01	1.49E-03	1.095	1.44E+00	1.05E+00	7.32E-01	4.49E-03	1.139
5	185.740	1.78E+14	2.35E-02	2.43E+01	1.240E+02	8.603E+00	5.23E-01	3.45E-01	6.59E-01	1.58E-03	1.083	1.47E+00	1.04E+00	7.06E-01	4.78E-03	1.129

Monteburns Transport History for material 8 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.120	3.67E+14	2.57E-02	7.79E+01	2.738E+02	0.000E+00	3.86E-01	3.76E-01	9.76E-01	1.34E-03	1.220	1.15E+00	1.13E+00	9.80E-01	4.03E-03	1.222
1	182.743	3.83E+14	2.53E-02	8.04E+01	2.824E+02	4.209E+00	4.39E-01	3.70E-01	8.42E-01	1.42E-03	1.157	1.24E+00	1.11E+00	8.98E-01	4.28E-03	1.197
2	184.528	3.98E+14	2.44E-02	8.13E+01	2.854E+02	8.462E+00	4.86E-01	3.59E-01	7.39E-01	1.49E-03	1.106	1.37E+00	1.08E+00	7.90E-01	4.50E-03	1.148
3	185.609	4.06E+14	2.34E-02	7.98E+01	2.803E+02	1.264E+01	5.29E-01	3.43E-01	6.50E-01	1.55E-03	1.044	1.45E+00	1.04E+00	7.15E-01	4.68E-03	1.106
4	186.381	4.23E+14	2.26E-02	8.07E+01	2.834E+02	1.686E+01	5.57E-01	3.33E-01	5.97E-01	1.56E-03	1.007	1.50E+00	1.01E+00	6.73E-01	4.72E-03	1.084
5	186.962	4.43E+14	2.18E-02	8.19E+01	2.877E+02	2.115E+01	5.75E-01	3.21E-01	5.59E-01	1.62E-03	0.978	1.54E+00	9.80E-01	6.35E-01	4.94E-03	1.060

Monteburns Transport History for material 9 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.106	3.91E+14	2.80E-02	4.53E+01	3.175E+02	0.000E+00	3.86E-01	4.10E-01	1.06E+00	1.40E-03	1.272	1.15E+00	1.23E+00	1.07E+00	4.19E-03	1.275
1	182.558	3.98E+14	2.71E-02	4.48E+01	3.142E+02	4.683E+00	4.38E-01	3.96E-01	9.05E-01	1.49E-03	1.201	1.23E+00	1.19E+00	9.69E-01	4.47E-03	1.245
2	184.253	4.02E+14	2.57E-02	4.32E+01	3.032E+02	9.202E+00	4.88E-01	3.77E-01	7.73E-01	1.49E-03	1.134	1.37E+00	1.14E+00	8.28E-01	4.49E-03	1.179
3	185.311	4.05E+14	2.45E-02	4.18E+01	2.932E+02	1.357E+01	5.31E-01	3.60E-01	6.78E-01	1.52E-03	1.071	1.45E+00	1.09E+00	7.54E-01	4.59E-03	1.139
4	186.075	4.18E+14	2.36E-02	4.16E+01	2.918E+02	1.792E+01	5.58E-01	3.47E-01	6.22E-01	1.55E-03	1.033	1.50E+00	1.06E+00	7.04E-01	4.71E-03	1.112
5	186.680	4.34E+14	2.26E-02	4.15E+01	2.911E+02	2.226E+01	5.74E-01	3.32E-01	5.79E-01	1.58E-03	1.000	1.54E+00	1.02E+00	6.60E-01	4.82E-03	1.084

Monteburns Transport History for material 10 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	5.39E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.40E+00	0.00E+00	0.00E+00	1.16E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	5.89E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.02E+00	0.00E+00	0.00E+00	7.17E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	6.60E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	4.71E-01	0.00E+00	0.00E+00	1.08E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	7.27E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	9.99E-02	0.00E+00	0.00E+00	9.60E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	7.70E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.58E-02	0.00E+00	0.00E+00	8.07E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	7.95E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	9.52E-03	0.00E+00	0.00E+00	5.24E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

The MONTEBURNS Output File 1/8th core L-Carborane BPRAs

RESEARCH CRYSTAL RIVER 1/8 CORE WITH L-CARBORANE BPRA'S 4.66% ENRICH NO BO

Total Power (MW) = 3.18E+02 Days = 6.70E+02
outer steps = 5, # inner steps = 50, # predictor steps = 1
Importance Fraction = 0.0050

Monteburns MCNP k-eff Versus Time

	days	k-eff	rel err	nu	avQfis	eta
0m	0.00	1.17026	0.00074	2.464	181.097	0.834
1m	67.00	1.13629	0.00063	2.524	182.111	0.898
1e	134.00	1.12974	0.00044	2.563		
2m	201.00	1.11575	0.00051	2.593	183.369	1.035
2e	268.00	1.10959	0.00081	2.621		
3m	335.00	1.09368	0.00066	2.642	184.227	1.157
3e	402.00	1.07498	0.00057	2.664		
4m	469.00	1.05698	0.00049	2.682	184.925	1.144
4e	536.00	1.03438	0.00065	2.699		
5m	603.00	1.01593	0.00058	2.716	185.518	1.112
5e	670.00	0.99816	0.00051	2.730		

Monteburns Transport History

Monteburns Transport History for material 1

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.063	3.78E+14	3.88E-02	6.08E+01	4.261E+02	0.000E+00	3.93E-01	5.68E-01	1.45E+00	1.57E-03	1.460	1.17E+00	1.71E+00	1.45E+00	4.70E-03	1.463
1	181.726	4.00E+14	3.69E-02	6.14E+01	4.302E+02	6.410E+00	4.39E-01	5.41E-01	1.23E+00	1.61E-03	1.396	1.22E+00	1.63E+00	1.34E+00	4.85E-03	1.447
2	182.678	4.30E+14	3.53E-02	6.37E+01	4.463E+02	1.306E+01	4.94E-01	5.19E-01	1.05E+00	1.65E-03	1.332	1.34E+00	1.57E+00	1.17E+00	4.99E-03	1.401
3	183.498	4.62E+14	3.37E-02	6.55E+01	4.594E+02	1.991E+01	5.36E-01	4.96E-01	9.25E-01	1.68E-03	1.273	1.42E+00	1.51E+00	1.06E+00	5.10E-03	1.365
4	184.228	4.75E+14	3.17E-02	6.37E+01	4.466E+02	2.657E+01	5.64E-01	4.67E-01	8.29E-01	1.70E-03	1.219	1.48E+00	1.43E+00	9.66E-01	5.20E-03	1.321
5	184.862	4.82E+14	2.95E-02	6.04E+01	4.232E+02	3.288E+01	5.93E-01	4.36E-01	7.34E-01	1.70E-03	1.153	1.54E+00	1.34E+00	8.71E-01	5.21E-03	1.268

Monteburns Transport History for material 2

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.103	1.65E+13	3.00E-02	5.77E-01	1.432E+01	0.000E+00	3.76E-01	4.39E-01	1.17E+00	1.46E-03	1.331	1.12E+00	1.32E+00	1.17E+00	4.38E-03	1.334
1	181.201	1.95E+13	2.94E-02	6.74E-01	1.674E+01	2.494E-01	3.95E-01	4.31E-01	1.09E+00	1.24E-03	1.320	1.15E+00	1.29E+00	1.12E+00	3.73E-03	1.338
2	181.351	1.99E+13	3.01E-02	7.10E-01	1.761E+01	5.119E-01	4.01E-01	4.41E-01	1.10E+00	1.45E-03	1.362	1.17E+00	1.32E+00	1.14E+00	4.34E-03	1.383
3	181.526	2.26E+13	3.06E-02	8.24E-01	2.045E+01	8.166E-01	4.03E-01	4.49E-01	1.12E+00	1.64E-03	1.397	1.17E+00	1.35E+00	1.15E+00	4.93E-03	1.420
4	181.696	2.43E+13	3.06E-02	8.88E-01	2.204E+01	1.145E+00	4.10E-01	4.48E-01	1.09E+00	1.59E-03	1.403	1.19E+00	1.34E+00	1.13E+00	4.77E-03	1.427
5	181.873	3.15E+13	3.08E-02	1.16E+00	2.881E+01	1.574E+00	4.15E-01	4.52E-01	1.09E+00	1.96E-03	1.420	1.20E+00	1.36E+00	1.13E+00	5.90E-03	1.445

Monteburns Transport History for material 3

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.059	3.40E+14	4.00E-02	1.09E+02	3.944E+02	0.000E+00	3.94E-01	5.85E-01	1.49E+00	1.60E-03	1.476	1.18E+00	1.76E+00	1.49E+00	4.81E-03	1.479
1	181.646	3.51E+14	3.79E-02	1.08E+02	3.883E+02	5.786E+00	4.40E-01	5.56E-01	1.26E+00	1.60E-03	1.413	1.22E+00	1.67E+00	1.37E+00	4.80E-03	1.464
2	182.492	3.56E+14	3.60E-02	1.04E+02	3.771E+02	1.140E+01	4.85E-01	5.29E-01	1.09E+00	1.63E-03	1.356	1.32E+00	1.60E+00	1.21E+00	4.92E-03	1.423
3	183.175	3.67E+14	3.45E-02	1.04E+02	3.739E+02	1.697E+01	5.21E-01	5.08E-01	9.75E-01	1.67E-03	1.308	1.39E+00	1.54E+00	1.11E+00	5.07E-03	1.392
4	183.775	3.84E+14	3.28E-02	1.03E+02	3.727E+02	2.252E+01	5.45E-01	4.82E-01	8.84E-01	1.66E-03	1.262	1.44E+00	1.47E+00	1.02E+00	5.07E-03	1.359
5	184.331	4.04E+14	3.09E-02	1.03E+02	3.715E+02	2.805E+01	5.68E-01	4.56E-01	8.03E-01	1.71E-03	1.213	1.49E+00	1.40E+00	9.40E-01	5.22E-03	1.320

Monteburns Transport History for material 4

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.352	2.92E+14	1.44E-02	3.16E-01	1.223E+02	0.000E+00	2.03E+00	2.23E-01	1.10E-01	1.66E-03	0.245	9.20E-01	6.89E-01	7.48E-01	5.03E-03	1.061
1	181.922	3.11E+14	1.92E-02	4.49E-01	1.740E+02	2.814E+00	1.54E+00	2.96E-01	1.92E-01	1.60E-03	0.409	1.03E+00	9.16E-01	8.88E-01	4.89E-03	1.192
2	182.620	3.18E+14	2.76E-02	6.65E-01	2.576E+02	6.981E+00	8.25E-01	4.26E-01	5.17E-01	1.71E-03	0.886	1.21E+00	1.32E+00	1.10E+00	5.23E-03	1.361
3	183.072	3.34E+14	3.09E-02	7.87E-01	3.047E+02	1.191E+01	5.38E-01	4.77E-01	8.87E-01	1.60E-03	1.245	1.37E+00	1.49E+00	1.09E+00	4.92E-03	1.379

4	183.715	3.34E+14	2.88E-02	7.38E-01	2.857E+02	1.653E+01	5.54E-01	4.46E-01	8.06E-01	1.56E-03	1.200	1.43E+00	1.40E+00	9.81E-01	4.82E-03	1.332
5	184.246	3.67E+14	2.85E-02	8.03E-01	3.110E+02	2.156E+01	5.72E-01	4.42E-01	7.72E-01	1.77E-03	1.187	1.46E+00	1.39E+00	9.53E-01	5.51E-03	1.329

Monteburns Transport History for material 5

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.523	3.54E+14	1.04E-02	1.10E+00	1.067E+02	0.000E+00	2.31E+00	1.59E-01	6.89E-02	1.60E-03	0.160	9.17E-01	5.08E-01	5.54E-01	4.87E-03	0.885
1	182.351	3.81E+14	1.31E-02	1.50E+00	1.454E+02	2.411E+00	1.94E+00	2.00E-01	1.03E-01	1.61E-03	0.237	9.95E-01	6.39E-01	6.43E-01	4.95E-03	0.994
2	183.440	4.30E+14	1.93E-02	2.52E+00	2.437E+02	6.453E+00	1.38E+00	2.96E-01	2.15E-01	1.59E-03	0.460	1.17E+00	9.47E-01	8.09E-01	4.94E-03	1.164
3	183.969	4.78E+14	2.67E-02	3.90E+00	3.771E+02	1.271E+01	6.90E-01	4.11E-01	5.95E-01	1.66E-03	0.989	1.37E+00	1.32E+00	9.63E-01	5.20E-03	1.300
4	184.642	5.01E+14	2.65E-02	4.06E+00	3.931E+02	1.923E+01	5.83E-01	4.07E-01	6.99E-01	1.60E-03	1.106	1.46E+00	1.32E+00	9.03E-01	5.07E-03	1.276
5	185.307	5.16E+14	2.48E-02	3.93E+00	3.806E+02	2.554E+01	6.10E-01	3.82E-01	6.27E-01	1.73E-03	1.050	1.52E+00	1.24E+00	8.19E-01	5.48E-03	1.227

Monteburns Transport History for material 6

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	185.149	1.30E+13	3.49E-02	7.67E-01	1.314E+01	0.000E+00	1.54E+00	1.34E+00	8.67E-01	3.96E-03	1.147	1.56E+00	1.35E+00	8.67E-01	4.01E-03	1.147
1	185.151	1.58E+13	3.37E-02	9.07E-01	1.553E+01	2.041E-01	1.48E+00	1.29E+00	8.70E-01	4.18E-03	1.177	1.49E+00	1.31E+00	8.79E-01	4.23E-03	1.184
2	185.175	1.65E+13	3.34E-02	9.46E-01	1.621E+01	4.172E-01	1.53E+00	1.28E+00	8.34E-01	3.95E-03	1.182	1.52E+00	1.29E+00	8.53E-01	4.00E-03	1.196
3	185.154	1.75E+13	3.30E-02	9.93E-01	1.701E+01	6.408E-01	1.52E+00	1.26E+00	8.33E-01	5.37E-03	1.205	1.50E+00	1.28E+00	8.51E-01	5.44E-03	1.219
4	185.185	1.82E+13	3.22E-02	1.01E+00	1.736E+01	8.691E-01	1.48E+00	1.24E+00	8.33E-01	5.66E-03	1.224	1.47E+00	1.25E+00	8.52E-01	5.72E-03	1.238
5	185.204	2.43E+13	3.19E-02	1.34E+00	2.299E+01	1.171E+00	1.48E+00	1.22E+00	8.23E-01	5.25E-03	1.230	1.47E+00	1.24E+00	8.41E-01	5.31E-03	1.245

Monteburns Transport History for material 7

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.111	1.57E+14	2.44E-02	2.19E+01	1.114E+02	0.000E+00	4.01E-01	3.57E-01	8.90E-01	1.30E-03	1.164	1.20E+00	1.07E+00	8.94E-01	3.90E-03	1.166
1	182.227	1.59E+14	2.44E-02	2.23E+01	1.136E+02	1.693E+00	4.37E-01	3.58E-01	8.19E-01	1.28E-03	1.140	1.24E+00	1.07E+00	8.67E-01	3.83E-03	1.176
2	183.620	1.51E+14	2.44E-02	2.12E+01	1.079E+02	3.301E+00	4.70E-01	3.56E-01	7.57E-01	1.42E-03	1.120	1.34E+00	1.07E+00	7.99E-01	4.27E-03	1.155
3	184.519	1.51E+14	2.43E-02	2.12E+01	1.081E+02	4.911E+00	4.89E-01	3.56E-01	7.29E-01	1.44E-03	1.118	1.40E+00	1.07E+00	7.68E-01	4.34E-03	1.151
4	185.139	1.62E+14	2.40E-02	2.27E+01	1.156E+02	6.634E+00	5.07E-01	3.53E-01	6.95E-01	1.50E-03	1.103	1.44E+00	1.06E+00	7.36E-01	4.52E-03	1.141
5	185.694	1.80E+14	2.35E-02	2.46E+01	1.254E+02	8.502E+00	5.23E-01	3.44E-01	6.59E-01	1.47E-03	1.082	1.47E+00	1.04E+00	7.07E-01	4.43E-03	1.128

Monteburns Transport History for material 8

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.121	3.68E+14	2.57E-02	7.82E+01	2.747E+02	0.000E+00	3.86E-01	3.77E-01	9.78E-01	1.37E-03	1.222	1.15E+00	1.13E+00	9.82E-01	4.10E-03	1.224
1	182.726	3.80E+14	2.53E-02	7.99E+01	2.806E+02	4.181E+00	4.39E-01	3.70E-01	8.44E-01	1.45E-03	1.159	1.24E+00	1.11E+00	9.00E-01	4.35E-03	1.199
2	184.509	3.97E+14	2.44E-02	8.09E+01	2.843E+02	8.418E+00	4.86E-01	3.58E-01	7.36E-01	1.47E-03	1.103	1.37E+00	1.08E+00	7.87E-01	4.44E-03	1.145
3	185.609	4.05E+14	2.34E-02	7.96E+01	2.795E+02	1.258E+01	5.28E-01	3.44E-01	6.51E-01	1.55E-03	1.045	1.45E+00	1.04E+00	7.16E-01	4.70E-03	1.106
4	186.368	4.22E+14	2.26E-02	8.05E+01	2.827E+02	1.679E+01	5.57E-01	3.33E-01	5.98E-01	1.56E-03	1.007	1.50E+00	1.01E+00	6.74E-01	4.75E-03	1.084
5	186.954	4.38E+14	2.19E-02	8.10E+01	2.845E+02	2.103E+01	5.75E-01	3.22E-01	5.60E-01	1.61E-03	0.978	1.54E+00	9.82E-01	6.36E-01	4.91E-03	1.060

Monteburns Transport History for material 9

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.106	3.93E+14	2.80E-02	4.54E+01	3.185E+02	0.000E+00	3.87E-01	4.10E-01	1.06E+00	1.38E-03	1.271	1.16E+00	1.23E+00	1.06E+00	4.13E-03	1.273
1	182.550	3.96E+14	2.70E-02	4.45E+01	3.124E+02	4.656E+00	4.40E-01	3.95E-01	8.99E-01	1.49E-03	1.199	1.23E+00	1.19E+00	9.63E-01	4.47E-03	1.242
2	184.250	3.99E+14	2.58E-02	4.32E+01	3.028E+02	9.170E+00	4.89E-01	3.79E-01	7.75E-01	1.49E-03	1.135	1.38E+00	1.14E+00	8.31E-01	4.50E-03	1.180
3	185.293	4.00E+14	2.45E-02	4.11E+01	2.886E+02	1.347E+01	5.31E-01	3.59E-01	6.76E-01	1.54E-03	1.070	1.45E+00	1.09E+00	7.51E-01	4.66E-03	1.137
4	186.062	4.14E+14	2.36E-02	4.12E+01	2.889E+02	1.778E+01	5.55E-01	3.47E-01	6.24E-01	1.57E-03	1.034	1.49E+00	1.05E+00	7.06E-01	4.77E-03	1.114
5	186.660	4.34E+14	2.26E-02	4.16E+01	2.919E+02	2.213E+01	5.76E-01	3.33E-01	5.78E-01	1.66E-03	0.999	1.54E+00	1.02E+00	6.60E-01	5.06E-03	1.083

Monteburns Transport History for material 10

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	5.35E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.01E+00	0.00E+00	0.00E+00	7.99E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	5.90E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.43E+00	0.00E+00	0.00E+00	7.61E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	6.70E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	6.01E-01	0.00E+00	0.00E+00	8.68E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	7.35E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	7.17E-02	0.00E+00	0.00E+00	9.06E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	7.69E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.06E-02	0.00E+00	0.00E+00	9.88E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	7.94E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.94E-02	0.00E+00	0.00E+00	9.66E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

The MONTEBURNS Output File 1/8th core J-Carborane BPRAs

RESEARCH CRYSTAL RIVER 1/8 CORE WITH J-CARBORANE BPRA'S 4.66% ENRICH NO BO

Total Power (MW) = 3.18E+02 Days = 6.70E+02
outer steps = 5, # inner steps = 50, # predictor steps = 1
Importance Fraction = 0.0050

Monteburns MCNP k-eff Versus Time

	days	k-eff	rel err	nu	avQfis	eta
0m	0.00	1.15523	0.00057	2.464	181.099	0.827
1m	67.00	1.11566	0.00057	2.522	182.130	0.900
1e	134.00	1.10479	0.00067	2.564		
2m	201.00	1.08698	0.00057	2.596	183.406	1.041
2e	268.00	1.07932	0.00060	2.622		
3m	335.00	1.06627	0.00062	2.645	184.259	1.143
3e	402.00	1.06143	0.00056	2.666		
4m	469.00	1.04972	0.00069	2.683	184.945	1.138
4e	536.00	1.03869	0.00052	2.700		
5m	603.00	1.02110	0.00060	2.717	185.528	1.108
5e	670.00	1.00189	0.00051	2.731		

Monteburns Transport History

Monteburns Transport History for material 1

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.067	3.37E+14	3.80E-02	5.30E+01	3.717E+02	0.000E+00	3.91E-01	5.57E-01	1.43E+00	1.59E-03	1.452	1.17E+00	1.67E+00	1.43E+00	4.78E-03	1.455
1	181.699	3.74E+14	3.59E-02	5.59E+01	3.920E+02	5.842E+00	4.35E-01	5.26E-01	1.21E+00	1.59E-03	1.385	1.21E+00	1.58E+00	1.31E+00	4.79E-03	1.434
2	182.620	3.98E+14	3.40E-02	5.68E+01	3.981E+02	1.177E+01	4.82E-01	4.99E-01	1.04E+00	1.66E-03	1.325	1.32E+00	1.51E+00	1.15E+00	5.01E-03	1.390
3	183.393	4.44E+14	3.30E-02	6.17E+01	4.325E+02	1.821E+01	5.20E-01	4.85E-01	9.34E-01	1.63E-03	1.281	1.39E+00	1.47E+00	1.06E+00	4.94E-03	1.364
4	184.092	4.78E+14	3.20E-02	6.45E+01	4.524E+02	2.495E+01	5.58E-01	4.71E-01	8.44E-01	1.66E-03	1.231	1.47E+00	1.44E+00	9.78E-01	5.06E-03	1.330
5	184.742	5.02E+14	3.02E-02	6.44E+01	4.514E+02	3.168E+01	5.87E-01	4.46E-01	7.60E-01	1.65E-03	1.176	1.53E+00	1.37E+00	9.00E-01	5.04E-03	1.290

Monteburns Transport History for material 2

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.102	1.73E+13	2.90E-02	5.87E-01	1.457E+01	0.000E+00	3.94E-01	4.25E-01	1.08E+00	1.26E-03	1.282	1.18E+00	1.28E+00	1.08E+00	3.79E-03	1.285
1	181.203	2.03E+13	2.78E-02	6.65E-01	1.650E+01	2.459E-01	3.93E-01	4.08E-01	1.04E+00	1.26E-03	1.287	1.15E+00	1.22E+00	1.06E+00	3.77E-03	1.303
2	181.375	2.04E+13	2.94E-02	7.11E-01	1.765E+01	5.089E-01	3.90E-01	4.31E-01	1.11E+00	1.44E-03	1.367	1.13E+00	1.29E+00	1.14E+00	4.31E-03	1.389
3	181.535	2.27E+13	3.00E-02	8.10E-01	2.010E+01	8.083E-01	4.04E-01	4.39E-01	1.09E+00	1.92E-03	1.381	1.17E+00	1.32E+00	1.12E+00	5.76E-03	1.403
4	181.719	2.77E+13	2.99E-02	9.88E-01	2.452E+01	1.174E+00	4.10E-01	4.38E-01	1.07E+00	1.64E-03	1.389	1.19E+00	1.32E+00	1.10E+00	4.92E-03	1.412
5	181.904	2.72E+13	3.01E-02	9.78E-01	2.429E+01	1.536E+00	4.22E-01	4.40E-01	1.04E+00	1.52E-03	1.391	1.22E+00	1.32E+00	1.08E+00	4.56E-03	1.416

Monteburns Transport History for material 3

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.060	3.59E+14	3.97E-02	1.14E+02	4.131E+02	0.000E+00	3.93E-01	5.81E-01	1.48E+00	1.57E-03	1.474	1.17E+00	1.74E+00	1.49E+00	4.71E-03	1.477
1	181.656	3.60E+14	3.73E-02	1.08E+02	3.910E+02	5.826E+00	4.37E-01	5.46E-01	1.25E+00	1.62E-03	1.405	1.21E+00	1.64E+00	1.36E+00	4.87E-03	1.455
2	182.524	3.72E+14	3.51E-02	1.06E+02	3.836E+02	1.154E+01	4.80E-01	5.15E-01	1.07E+00	1.65E-03	1.347	1.31E+00	1.56E+00	1.19E+00	4.98E-03	1.413
3	183.232	3.78E+14	3.37E-02	1.04E+02	3.768E+02	1.716E+01	5.18E-01	4.96E-01	9.58E-01	1.63E-03	1.298	1.39E+00	1.51E+00	1.09E+00	4.96E-03	1.381
4	183.829	3.82E+14	3.25E-02	1.02E+02	3.685E+02	2.265E+01	5.45E-01	4.79E-01	8.78E-01	1.70E-03	1.258	1.44E+00	1.46E+00	1.01E+00	5.17E-03	1.354
5	184.357	3.95E+14	3.11E-02	1.01E+02	3.649E+02	2.809E+01	5.69E-01	4.59E-01	8.06E-01	1.71E-03	1.215	1.49E+00	1.41E+00	9.43E-01	5.23E-03	1.322

Monteburns Transport History for material 4

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.348	3.21E+14	1.44E-02	3.47E-01	1.344E+02	0.000E+00	2.05E+00	2.22E-01	1.09E-01	1.51E-03	0.243	9.26E-01	6.88E-01	7.43E-01	4.58E-03	1.056
1	181.965	3.41E+14	1.97E-02	5.06E-01	1.958E+02	3.166E+00	1.44E+00	3.04E-01	2.11E-01	1.52E-03	0.441	1.06E+00	9.40E-01	8.90E-01	4.63E-03	1.192
2	182.698	3.73E+14	2.86E-02	8.10E-01	3.135E+02	8.236E+00	7.39E-01	4.42E-01	5.98E-01	1.84E-03	0.974	1.27E+00	1.37E+00	1.08E+00	5.66E-03	1.350
3	183.381	3.80E+14	3.05E-02	8.85E-01	3.427E+02	1.378E+01	5.49E-01	4.72E-01	8.60E-01	1.56E-03	1.226	1.41E+00	1.47E+00	1.04E+00	4.81E-03	1.355

4	184.060	3.41E+14	2.82E-02	7.37E-01	2.854E+02	1.840E+01	5.70E-01	4.37E-01	7.67E-01	1.83E-03	1.168	1.47E+00	1.37E+00	9.33E-01	5.64E-03	1.299
5	184.495	3.44E+14	2.74E-02	7.23E-01	2.801E+02	2.293E+01	5.68E-01	4.25E-01	7.47E-01	1.69E-03	1.165	1.44E+00	1.34E+00	9.29E-01	5.25E-03	1.312

Monteburns Transport History for material 5 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.518	3.32E+14	1.04E-02	1.04E+00	1.006E+02	0.000E+00	2.31E+00	1.60E-01	6.94E-02	1.66E-03	0.161	9.17E-01	5.11E-01	5.57E-01	5.04E-03	0.888
1	182.316	3.69E+14	1.28E-02	1.42E+00	1.375E+02	2.280E+00	1.93E+00	1.95E-01	1.01E-01	1.57E-03	0.233	9.69E-01	6.24E-01	6.44E-01	4.83E-03	0.994
2	183.387	4.04E+14	1.83E-02	2.25E+00	2.176E+02	5.889E+00	1.39E+00	2.81E-01	2.02E-01	1.63E-03	0.439	1.16E+00	9.01E-01	7.78E-01	5.07E-03	1.141
3	183.915	4.60E+14	2.55E-02	3.57E+00	3.457E+02	1.162E+01	7.36E-01	3.91E-01	5.32E-01	1.54E-03	0.921	1.34E+00	1.26E+00	9.36E-01	4.84E-03	1.283
4	184.572	5.01E+14	2.68E-02	4.10E+00	3.972E+02	1.821E+01	5.80E-01	4.12E-01	7.09E-01	1.58E-03	1.117	1.45E+00	1.33E+00	9.19E-01	4.98E-03	1.289
5	185.211	5.27E+14	2.51E-02	4.06E+00	3.928E+02	2.472E+01	5.98E-01	3.86E-01	6.46E-01	1.66E-03	1.070	1.48E+00	1.26E+00	8.51E-01	5.24E-03	1.253

Monteburns Transport History for material 6 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	185.130	1.43E+13	3.39E-02	8.23E-01	1.409E+01	0.000E+00	1.50E+00	1.30E+00	8.69E-01	4.54E-03	1.149	1.51E+00	1.31E+00	8.69E-01	4.59E-03	1.149
1	185.117	1.71E+13	3.37E-02	9.81E-01	1.681E+01	2.210E-01	1.48E+00	1.29E+00	8.70E-01	6.19E-03	1.178	1.49E+00	1.31E+00	8.79E-01	6.26E-03	1.185
2	185.148	1.66E+13	3.33E-02	9.51E-01	1.629E+01	4.351E-01	1.50E+00	1.27E+00	8.46E-01	4.71E-03	1.193	1.49E+00	1.29E+00	8.66E-01	4.77E-03	1.208
3	185.147	1.84E+13	3.25E-02	1.03E+00	1.768E+01	6.675E-01	1.49E+00	1.25E+00	8.38E-01	5.35E-03	1.210	1.47E+00	1.26E+00	8.56E-01	5.41E-03	1.224
4	185.193	1.99E+13	3.23E-02	1.11E+00	1.908E+01	9.183E-01	1.48E+00	1.24E+00	8.39E-01	5.27E-03	1.228	1.46E+00	1.25E+00	8.58E-01	5.33E-03	1.243
5	185.236	2.07E+13	3.17E-02	1.14E+00	1.950E+01	1.175E+00	1.50E+00	1.22E+00	8.09E-01	5.35E-03	1.219	1.49E+00	1.23E+00	8.27E-01	5.41E-03	1.234

Monteburns Transport History for material 7 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.112	1.83E+14	2.44E-02	2.55E+01	1.299E+02	0.000E+00	4.01E-01	3.58E-01	8.92E-01	1.24E-03	1.165	1.20E+00	1.07E+00	8.95E-01	3.72E-03	1.167
1	182.359	1.77E+14	2.42E-02	2.45E+01	1.251E+02	1.864E+00	4.40E-01	3.55E-01	8.06E-01	1.37E-03	1.129	1.25E+00	1.07E+00	8.54E-01	4.12E-03	1.165
2	183.836	1.88E+14	2.43E-02	2.63E+01	1.342E+02	3.864E+00	4.71E-01	3.57E-01	7.58E-01	1.40E-03	1.123	1.34E+00	1.07E+00	8.01E-01	4.22E-03	1.158
3	184.809	1.78E+14	2.41E-02	2.49E+01	1.268E+02	5.754E+00	4.97E-01	3.54E-01	7.12E-01	1.45E-03	1.104	1.42E+00	1.07E+00	7.51E-01	4.37E-03	1.139
4	185.471	1.61E+14	2.37E-02	2.22E+01	1.131E+02	7.440E+00	5.18E-01	3.48E-01	6.72E-01	1.56E-03	1.082	1.46E+00	1.05E+00	7.20E-01	4.70E-03	1.127
5	185.914	1.63E+14	2.33E-02	2.22E+01	1.132E+02	9.126E+00	5.29E-01	3.42E-01	6.47E-01	1.48E-03	1.071	1.49E+00	1.03E+00	6.95E-01	4.48E-03	1.117

Monteburns Transport History for material 8 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.120	3.58E+14	2.58E-02	7.63E+01	2.680E+02	0.000E+00	3.85E-01	3.78E-01	9.80E-01	1.39E-03	1.224	1.15E+00	1.13E+00	9.85E-01	4.17E-03	1.226
1	182.701	3.80E+14	2.52E-02	7.96E+01	2.796E+02	4.166E+00	4.37E-01	3.69E-01	8.45E-01	1.42E-03	1.159	1.23E+00	1.11E+00	9.01E-01	4.27E-03	1.199
2	184.506	3.93E+14	2.43E-02	7.98E+01	2.803E+02	8.344E+00	4.84E-01	3.57E-01	7.37E-01	1.48E-03	1.105	1.37E+00	1.08E+00	7.88E-01	4.48E-03	1.147
3	185.581	4.04E+14	2.33E-02	7.91E+01	2.777E+02	1.248E+01	5.26E-01	3.43E-01	6.51E-01	1.51E-03	1.047	1.45E+00	1.04E+00	7.17E-01	4.57E-03	1.108
4	186.352	4.25E+14	2.26E-02	8.11E+01	2.848E+02	1.672E+01	5.56E-01	3.33E-01	5.98E-01	1.53E-03	1.008	1.50E+00	1.01E+00	6.74E-01	4.65E-03	1.084
5	186.950	4.44E+14	2.19E-02	8.23E+01	2.890E+02	2.103E+01	5.75E-01	3.23E-01	5.60E-01	1.59E-03	0.979	1.55E+00	9.84E-01	6.37E-01	4.84E-03	1.061

Monteburns Transport History for material 9 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.107	4.00E+14	2.79E-02	4.61E+01	3.238E+02	0.000E+00	3.85E-01	4.09E-01	1.06E+00	1.35E-03	1.273	1.15E+00	1.23E+00	1.07E+00	4.05E-03	1.276
1	182.602	4.12E+14	2.70E-02	4.62E+01	3.245E+02	4.837E+00	4.39E-01	3.95E-01	9.01E-01	1.42E-03	1.199	1.23E+00	1.19E+00	9.65E-01	4.28E-03	1.242
2	184.315	4.10E+14	2.54E-02	4.36E+01	3.060E+02	9.398E+00	4.92E-01	3.73E-01	7.58E-01	1.55E-03	1.123	1.37E+00	1.13E+00	8.23E-01	4.67E-03	1.176
3	185.349	4.12E+14	2.43E-02	4.20E+01	2.948E+02	1.379E+01	5.29E-01	3.57E-01	6.74E-01	1.55E-03	1.068	1.44E+00	1.08E+00	7.48E-01	4.69E-03	1.136
4	186.115	4.18E+14	2.35E-02	4.14E+01	2.906E+02	1.812E+01	5.59E-01	3.45E-01	6.18E-01	1.61E-03	1.028	1.50E+00	1.05E+00	6.99E-01	4.88E-03	1.108
5	186.715	4.34E+14	2.27E-02	4.17E+01	2.923E+02	2.248E+01	5.77E-01	3.34E-01	5.78E-01	1.56E-03	0.998	1.55E+00	1.02E+00	6.59E-01	4.75E-03	1.083

Monteburns Transport History for material 10 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	4.70E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.58E+00	0.00E+00	0.00E+00	7.68E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	5.21E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.26E+00	0.00E+00	0.00E+00	6.94E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	5.71E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.76E+00	0.00E+00	0.00E+00	1.18E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	6.54E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.08E+00	0.00E+00	0.00E+00	9.61E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	7.53E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	3.19E-01	0.00E+00	0.00E+00	1.04E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	8.09E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	3.02E-02	0.00E+00	0.00E+00	9.30E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

APPENDIX F
ONE-EIGHTH CORE WITH CHEMICAL SHIM MCNP/MONTEBURNS FILES

This appendix contains all of the input and output files for the 1/8th core chemical shim MCNP/MONTEBURNS models. As with Appendix E, the CASMO input files used to generate the 10A3, 12A2, and 13A - 13E depleted fuel approximate compositions for the primary, Gd_2O_3/UO_2 mixed fuel, and blanket fuels are similar to those used to generate the cross section libraries for EASCYC and are not included in this appendix. No CASMO output files are listed instead the appendix includes the fuel compositions in the material cards of the MCNP input files. Only the the MCNP input, MONTEBURNS input, and MONTEBURNS feed file for the B_4C/Al_2O_3 BPRA models are listed because the only difference for the other models is the BP material compositions which are the same as those in Appendix E. MONTEBURNS output files are listed for the B_4C/Al_2O_3 BPRA, L-Carborane, and J-Carborane models. The MONTEBURNS output files have been abbreviated to include only the k-effective vs. time and the transport history information.

The MCNP Input File Chem Shim Power Peak #4 B_4C/Al_2O_3 BPRAs

```
RESEARCH 15 X 15 ASSEMBLY WITH B4CAL2O3 BPRA'S
C    CRYSTAL RIVER REACTOR #1
C      box -200 200 -200 200 -200 200
1     0 -1 13 -14 19 20 FILL=1  VOL=6333455.62
2     1  -0.660 9 -10 11 -12 LAT=1 U=1 FILL=-8:1 -8:1 0:0
        1  1  1  1  1  1  1  1  1  1
        1  1  1  1  1  1  2  2  2  1
        1  1  1  1  2  4 11 12  4  1
        1  1  1  2 10  5 13  5  9  1
        1  1  1  1  4 13  4  9  5  1
        1  1  1  1  1  4  9  4  3  1
        1  1  1  1  1  1  4 13  4  1
        1  1  1  1  1  1  1  4  5  1
        1  1  1  1  1  1  1  1  2  1
        1  1  1  1  1  1  1  1  1  1
C    10A & 12A2 MARK-B4Z ASSMBLY WITH 0 GD AND 0 BPRAS (33 TOTAL)
200    1 -0.660 30 -31 32 -33 LAT=1 VOL=2581.227 U=2 FILL=-8:8 -8:8 0:0
```

```
       2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 14 20 20 20 14 20 20 20 20 20  2
       2 20 20 20 14 20 20 20 20 20 20 20 14 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 14 20 20 14 20 20 20 14 20 20 14 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 14 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 14 20 20 14 20 20 20 14 20 20 14 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 14 20 20 20 20 20 20 20 14 20 20 20  2
       2 20 20 20 20 20 14 20 20 20 14 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
C    14A MARK-B10I POWER PEAKING TEST ASSEMBLY 1 TOTAL
201    1 -0.660 30 -31 32 -33 LAT=1 U=3 VOL=2581.227 FILL=-8:8 -8:8 0:0
       3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3
       3 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30  3
       3 30 30 30 31 30 30 30 30 30 30 31 30 30 30 30  3
       3 30 30 30 30 30 15 30 30 30 15 30 30 30 30 30  3
       3 30 31 30 14 30 30 30 30 30 30 30 14 30 31 30  3
       3 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30  3
       3 30 30 15 30 30 14 30 30 30 14 30 30 15 30 30  3
       3 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30  3
       3 30 30 30 30 30 30 30 14 30 30 30 30 30 30 30  3
       3 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30  3
       3 30 30 15 30 30 14 30 30 30 14 30 30 15 30 30  3
       3 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30  3
       3 30 31 30 14 30 30 30 30 30 30 30 14 30 31 30  3
       3 30 30 30 30 30 15 30 30 30 15 30 30 30 30 30  3
       3 30 30 30 31 30 30 30 30 30 30 30 31 30 30 30  3
       3 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30  3
       3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3
C    13A 13D MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (48 TOTAL)
202    1 -0.660 30 -31 32 -33 LAT=1 U=4 VOL=2581.227 FILL=-8:8 -8:8 0:0
       4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 14 40 40 40 14 40 40 40 40 40  4
       4 40 40 40 14 40 40 40 40 40 40 40 14 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 14 40 40 14 40 40 40 14 40 40 14 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 14 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 14 40 40 14 40 40 40 14 40 40 14 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 14 40 40 40 40 40 40 40 14 40 40 40  4
       4 40 40 40 40 40 14 40 40 40 14 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4
C    13B C E MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (8 TOTAL)
203    1 -0.660 30 -31 32 -33 LAT=1 U=5 VOL=2581.227 FILL=-8:8 -8:8 0:0
       5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 14 50 50 50 14 50 50 50 50 50  5
       5 50 50 50 14 50 50 50 50 50 50 50 14 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 14 50 50 14 50 50 50 14 50 50 14 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 14 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 14 50 50 14 50 50 50 14 50 50 14 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 14 50 50 50 50 50 50 50 14 50 50 50  5
       5 50 50 50 50 50 14 50 50 50 14 50 50 50 50 50  5
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       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
C    14A MARK-B10I ASSMBLY WITH 8 GD AND 8 BPRAS (24 TOTAL)
207    1 -0.660 30 -31 32 -33 LAT=1 U=9 VOL=2581.227 FILL=-8:8 -8:8 0:0
       9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 90 91 90 90 90 90 90 90 90 91 90 90  9
       9 90 90 90 90 90 15 90 90 90 15 90 90 90 90  9
       9 90 91 90 14 90 90 90 90 90 90 90 14 90 91 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 15 90 90 14 90 90 90 14 90 90 15 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 90 90 90 90 90 14 90 90 90 90 90 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 15 90 90 14 90 90 90 14 90 90 15 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 91 90 14 90 90 90 90 90 90 90 14 90 91 90  9
       9 90 90 90 90 90 15 90 90 90 15 90 90 90 90 90  9
       9 90 90 90 91 90 90 90 90 90 90 90 91 90 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9
C    14B MARK-B10I ASSMBLY WITH 0 GD AND 0 BPRAS (8 TOTAL)
208    1 -0.660 30 -31 32 -33 LAT=1 U=10 VOL=2581.227 FILL=-8:8 -8:8 0:0
       10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  10
       10 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  10
       10 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10
C    14C MARK-B10I ASSMBLY WITH 4 GD AND 0 BPRAS (8 TOTAL)
209    1 -0.660 30 -31 32 -33 LAT=1 U=11 VOL=2581.227 FILL=-8:8 -8:8 0:0
       11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 111 100 100 100 100 100 100 100 100 100 100 100 111 100  11
       11 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  11
       11 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  11
       11 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  11
       11 100 111 100 100 100 100 100 100 100 100 100 100 100 111 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
C    14D MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (8 TOTAL)
210    1 -0.660 30 -31 32 -33 LAT=1 U=12 VOL=2581.227 FILL=-8:8 -8:8 0:0
       12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100 100 111 100 100 100 100 100 100 100 111 100 100 100  12
       12 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  12
       12 100 111 100  14 100 100 100 100 100 100 100  14 100 111 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  12
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       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 111 100  14 100 100 100 100 100 100 100  14 100 111 100  12
       12 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  12
       12 100 100 100 111 100 100 100 100 100 100 100 111 100 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12
C    14E MARK-B10I ASSMBLY WITH 8 GD AND 8 BPRAS (24 TOTAL)
211     1 -0.660 30 -31 32 -33 LAT=1 U=13 VOL=2581.227 FILL=-8:8 -8:8 0:0
        13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100 100 100  91 100 100 100 100 100 100 100  91 100 100  13
        13 100 100 100 100 100  15 100 100 100  15 100 100 100 100  13
        13 100  91 100  14 100 100 100 100 100 100 100  14 100  91 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100 100  15 100 100  14 100 100 100  14 100 100  15 100 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100 100 100 100 100 100 100  14 100 100 100 100 100 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100 100  15 100 100  14 100 100 100  14 100 100  15 100 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13 100  91 100  14 100 100 100 100 100 100 100  14 100  91 100  13
        13 100 100 100 100 100  15 100 100 100  15 100 100 100 100  13
        13 100 100 100  91 100 100 100 100 100 100 100  91 100 100  13
        13 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
        13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13
C      UNIVERSE 14 EMPTY GUIDE TUBE
3      1    -0.660     -4 U=14 $WATER HOLE
                       VOL=259.275
4      3    -6.503 4 -5 U=14 $INTERIOR CLAD
                       VOL=78.0098
5      1    -0.660   5 -6 U=14 $GUIDE TUBE WATER RADIUS
                       VOL=114.4531
6      3    -6.503 6 -7 U=14 $GUIDE TUBE CLAD RADIUS
                       VOL=60.665
7      1    -0.660   #3 #4 #5 #6 U=14 $UNIT CELL WATER
                       VOL=237.207
C      UNIVERSE 15 BPRA
8      4    -3.1     -4 U=15 $BPRA MATERIAL
                       VOL=259.275
9      3    -6.503 4 -5 U=15 $INTERIOR CLAD
                       VOL=78.0098
10     1    -0.660   5 -6 U=15 $GUIDE TUBE WATER RADIUS
                       VOL=114.453
11     3    -6.503 6 -7 U=15 $GUIDE TUBE CLAD RADIUS
                       VOL=60.665
12     1    -0.660   #8 #9 #10 #11 U=15 $UNIT CELL WATER
                       VOL=237.207
C      UNIVERSE 20  FUEL FOR 10A3 &12A2 ASSEMBLY (PRIMARY)
13     26   -10.201    -8 15 -16 U=20 $UO2 FUEL PELLET (PRIMARY)
                       VOL=228.638
14     34   -10.201    -8 -15 U=20  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
15     34   -10.201    -8 16  U=20  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
16     0             8 -4 U=20 $GAP RADIUS
                       VOL=9.5493
17     3    -6.503 4 -5 U=20 $FUEL PIN CLAD
                       VOL=78.00976
18     1    -0.660   #13 #14 #15 #16 #17 U=20 $UNIT CELL WATER
                       VOL=412.3249
C      UNIVERSE 30  FUEL FOR 14A PIN TEST ASSEMBLY (PRIMARY)
19     21   -10.201    -8 15 -16 U=30 $UO2 FUEL PELLET (PRIMARY)
                       VOL=228.638
20     22   -10.201    -8 -15 U=30  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
21     22   -10.201    -8 16  U=30  $UO2 FUEL PELLET (BLANKET)
                       VOL=10.544
22     0             8 -4 U=30 $GAP RADIUS
                       VOL=9.5493
```

```
23     3    -6.503 4 -5 U=30 $FUEL PIN CLAD
                    VOL=78.00976
24     1    -0.660   #79 #80 #81 #82 #83 U=30 $UNIT CELL WATER
                    VOL=412.3249
C      UNIVERSE 31 GD FUEL ROD FOR PIN TEST 14A AND 14E
31     27   -9.635    -8 17 -18 U=31 $UO2 GDO FUEL PELLET (PRIMARY)
                    VOL=215.2219
32     22   -10.201    -8 -17 U=31  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
33     22   -10.201    -8 18  U=31  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
34     0            8 -4 U=31 $GAP RADIUS
                    VOL=9.549294
35     3    -6.503 4 -5 U=31 $FUEL PIN CLAD
                    VOL=78.00976
36     1    -0.660   #85 #86 #87 #88 #89 U=31 $UNIT CELL WATER
                    VOL=412.3249
C      UNIVERSE 40  FUEL FOR 13A & 13D ASSEMBLY (PRIMARY)
25     30    -10.201    -8 15 -16 U=40 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.638
26     34   -10.201    -8 -15 U=40  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
27     34   -10.201    -8 16  U=40  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
28     0            8 -4 U=40 $GAP RADIUS
                    VOL=9.5493
29     3    -6.503 4 -5 U=40 $FUEL PIN CLAD
                    VOL=78.00976
30     1    -0.660   #25 #26 #27 #28 #29 U=40 $UNIT CELL WATER
                    VOL=412.3249
C      UNIVERSE 50  FUEL FOR 13B C E ASSEMBLY (PRIMARY)
37     33  -10.201    -8 15 -16 U=50 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.638
38     34   -10.201    -8 -15 U=50  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
39     34   -10.201    -8 16  U=50  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
40     0            8 -4 U=50 $GAP RADIUS
                    VOL=9.5493
41     3    -6.503 4 -5 U=50 $FUEL PIN CLAD
                    VOL=78.00976
42     1    -0.660   #37 #38 #39 #40 #41 U=50 $UNIT CELL WATER
                    VOL=412.3249
C      UNIVERSE 90  FUEL FOR 14A ASSEMBLY (PRIMARY)
79     2    -10.201    -8 15 -16 U=90 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.638
80     22   -10.201    -8 -15 U=90  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
81     22   -10.201    -8 16  U=90  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
82     0            8 -4 U=90 $GAP RADIUS
                    VOL=9.5493
83     3    -6.503 4 -5 U=90 $FUEL PIN CLAD
                    VOL=78.00976
84     1    -0.660   #79 #80 #81 #82 #83 U=90 $UNIT CELL WATER
                    VOL=412.3249
C      UNIVERSE 91 GD FUEL ROD FOR 14A AND 14E
85     25   -9.635    -8 17 -18 U=91 $UO2 GDO FUEL PELLET (PRIMARY)
                    VOL=215.2219
86     22   -10.201    -8 -17 U=91  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
87     22   -10.201    -8 18  U=91  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
88     0            8 -4 U=91 $GAP RADIUS
                    VOL=9.549294
89     3    -6.503 4 -5 U=91 $FUEL PIN CLAD
                    VOL=78.00976
90     1    -0.660   #85 #86 #87 #88 #89 U=91 $UNIT CELL WATER
                    VOL=412.3249
C      UNIVERSE 100 FUEL FOR 14B 14C 14D 14E ASSEMBLIES
91     23   -10.201    -8 15 -16 U=100 $UO2 FUEL PELLET (PRIMARY)
```

```
                    VOL=228.6378
92     22   -10.201    -8 -15 U=100  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.54397
93     22   -10.201    -8 16  U=100  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.54397
94     0            8 -4 U=100 $GAP RADIUS
                    VOL=54929
95     3    -6.503 4 -5 U=100 $FUEL PIN CLAD
                    VOL=78.00976
96     1    -0.660   #91 #92 #93 #94 #95 U=100 $UNIT CELL WATER
                    VOL=412.3249
C      UNIVERSE 111 GD FUEL ROD FOR 14C AND 14D
97     24   -9.635    -8 17 -18 U=111 $UO2 GDO FUEL PELLET (PRIMARY)
                    VOL=215.2219
98     22   -10.201    -8 -17 U=111  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
99     22   -10.201    -8 18  U=111  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
100     0            8 -4 U=111 $GAP RADIUS
                    VOL=9.549294
101     3    -6.503 4 -5 U=111 $FUEL PIN CLAD
                    VOL=78.00976
102     1    -0.660   #97 #98 #99 #100 #101 U=111 $UNIT CELL WATER
                    VOL=412.3249
C      REACTOR BOUNDARY
997     1    -0.660   -1 -2 14 19 20  $AXIAL RELECTORS
                    VOL=2035752.04
998     1    -0.660   -1  3 -13 19 20
                    VOL=2035752.04
999            0      1:-3:2:-19:-20 $VOID REGION OUTSIDE REACTOR VESSEL

*1              CZ     180    $ REACTOR VESSEL
*2              PZ     200
*3              PZ    -200
30             PX    -0.7215
31             PX     0.7215
32             PY    -0.7215
33             PY     0.7215
C  OUTSIDE OF UNIT CELL (1.443 PITCH)
4              CZ     0.4788
C  CYLINDER BPRA / WATER HOLE / GAP RADIUS
5              CZ     0.5461
C  CYLINDER INTERIOR CLAD RADIUS
6              CZ     0.6320
C  CYLINDER WATER RADIUS GUIDE TUBE
7              CZ     0.6731
C  CYLINDER CLAD RADIUS GUIDE TUBE
8              CZ     0.4699
C  CYLINDER RADIUS OF FUEL PELLET
9              PX    -10.905
10             PX     10.905
11             PY    -10.905
12             PY     10.905
13             PZ    -180
14             PZ     180
C  PLANES OUTSIDE OF ASSEMBLY
15             PZ    -164.8
16             PZ     164.8
17             PZ    -155.13
18             PZ     155.13
*19             PX      0
*20             P       0 0 0 10.905 10.905 0 10.905 10.905 10.905
C  PLANES FOR AXIAL BLANKET

MODE    N
IMP:N   1.0 76R 0.0
KCODE   30000    1.5     10       50      5000
KSRC    1.443 2.886 0
        1.443 21.8 0
        20.357 21.8 0
        1.443 43.6 0
```

```
        20.357 43.6 0
        42.157 43.6 0
        1.443 65.4 0
        20.357 65.4 0
        42.157 65.4 0
        63.957 65.4 0
        1.443 87.2 0
        20.357 87.2 0
        42.157 87.2 0
        63.957 87.2 0
        85.757 87.2 0
        1.443 109 0
        20.357 109 0
        42.157 109 0
        63.957 109 0
        85.757 109 0
        107.557 109 0
        1.443 130.8 0
        20.357 130.8 0
        42.157 130.8 0
        63.957 130.8 0
        85.757 130.8 0
        1.443 152.6 0
        20.357 152.6 0
        42.157 152.6 0
M1      8016.60C         3.30E-01     1001.60C     6.65E-01
        5010.50C         1.90E-04     5011.56C     4.82E-03
C  water with boron
MT1     LWTR.04T $H20 AT 600 K
C   FUEL FOR 14A  (PRIMARY)  0.0452 ENRICH
M2      92235.54C    0.015066652
        92238.54C    0.318266348
        8016.54C     0.666666
C   FUEL FOR 14A  PIN TEST (PRIMARY)  0.0452 ENRICH
M21      92235.54C    0.015066652
        92238.54C    0.318266348
        8016.54C     0.666666
C   FUEL FOR 14A -E (BLANKET)  0.02 ENRICH
M22     92235.54C    0.00666666
        92238.54C    0.32666634
        8016.54C     0.666666
C   FUEL FOR 14B -E (PRIMARY)  0.0466 ENRICH
M23     92235.54C    0.015533318
        92238.54C    0.317799682
        8016.54C     0.666666
C   FUEL FOR 14C & D (GdO MIX) 0.0396 ENRICH 0.03 GdO
M24     92235.54C    0.012804
        92238.54C    0.310529333
        8016.54C     0.664666667
        64154.60C    0.000325035
        64155.60C    0.00224584
        64156.60C    0.00314201
        64157.60C    0.00242074
        64158.60C    0.003866374
C   FUEL FOR 14A & E (GdO MIX) 0.0316 ENRICH 0.06 GdO
M25     92235.54C    0.009901333
        92238.54C    0.303432
        8016.54C     0.662666667
        64154.60C    0.000650071
        64155.60C    0.004491681
        64156.60C    0.006284019
        64157.60C    0.004841481
        64158.60C    0.007732749
C   FUEL FOR 14A & E PIN TEST (GdO MIX) 0.0316 ENRICH 0.06 GdO
M27     92235.54C    0.009901333
        92238.54C    0.303432
        8016.54C     0.662666667
        64154.60C    0.000650071
        64155.60C    0.004491681
        64156.60C    0.006284019
        64157.60C    0.004841481
```

```
        64158.60C    0.007732749
C FUEL FOR 10A3 - 13E (BLANKET)
M34     92235.54C        -0.0096
        92236.60C        -0.0187
        92238.54C        -0.965939
        94239.15C        -0.00525
        94240.60C        -0.00131
        8016.54C         -0.000799
C FUEL FOR 10A3 (PRIMARY) 0.01082  ENRICH
M26    92235.54C       0.003606663
       92238.54C       0.329726337
        8016.54C       0.666666
C FUEL FOR 13D (PRIMARY) 0.0155 ENRICH
M30    92235.54C       0.005166662
       92238.54C       0.328166339
        8016.54C       0.666666
C FUEL FOR 13E (PRIMARY) 0.01833 ENRICH
M33    92235.54C       0.006109994
       92238.54C       0.327223006
        8016.54C       0.666666
M3      40000.60C 1.0 $ZIRCONIUM (APPROX. FOR ZIRCALLOY)
M4      5010.50C   -0.55   5011.56C -2.22 6000.60C   -0.76   13027.60C
        -51.04   8016.54C   -45.43  $B4CAL2O3 BP MATERIAL
PRINT
```

The MCNP Input File Chem Shim Power Peak #12 B_4C/Al_2O_3 BPRAs

```
RESEARCH 15 X 15 ASSEMBLY WITH B4CAL2O3 BPRA'S
C    CRYSTAL RIVER REACTOR #1
C      box -200 200 -200 200 -200 200
1     0 -1 13 -14 19 20 FILL=1  VOL=6333455.62
2     1  -0.660 9 -10 11 -12 LAT=1 U=1 FILL=-8:1 -8:1 0:0
        1  1  1  1  1  1  1  1  1  1
        1  1  1  1  1  1  2  2  2  1
        1  1  1  1  2  4 11 12  4  1
        1  1  1  2 10  5 13  5  9  1
        1  1  1  1  4 13  4  3  5  1
        1  1  1  1  1  4  9  4  9  1
        1  1  1  1  1  1  4 13  4  1
        1  1  1  1  1  1  1  4  5  1
        1  1  1  1  1  1  1  1  2  1
        1  1  1  1  1  1  1  1  1  1
C    10A & 12A2 MARK-B4Z ASSMBLY WITH 0 GD AND 0 BPRAS (33 TOTAL)
200    1 -0.660 30 -31 32 -33 LAT=1 VOL=2581.227 U=2 FILL=-8:8 -8:8 0:0
       2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 14 20 20 20 14 20 20 20 20  2
       2 20 20 20 14 20 20 20 20 20 20 20 14 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 14 20 20 14 20 20 20 14 20 20 14 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 14 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 14 20 20 14 20 20 20 14 20 20 14 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 14 20 20 20 20 20 20 20 14 20 20  2
       2 20 20 20 20 20 14 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2 20 20 20 20 20 20 20 20 20 20 20 20 20 20  2
       2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
C    14A MARK-B10I POWER PEAKING TEST ASSEMBLY 1 TOTAL
201    1 -0.660 30 -31 32 -33 LAT=1 U=3 VOL=2581.227 FILL=-8:8 -8:8 0:0
       3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3
       3 30 30 30 30 30 30 30 30 30 30 30 30 30 30  3
       3 30 30 30 31 30 30 30 30 30 30 30 31 30 30  3
       3 30 30 30 30 30 15 30 30 30 15 30 30 30 30  3
       3 30 31 30 14 30 30 30 30 30 30 14 30 31 30  3
       3 30 30 30 30 30 30 30 30 30 30 30 30 30 30  3
       3 30 30 15 30 30 14 30 30 30 14 30 30 15 30  3
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       3 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30  3
       3 30 30 30 30 30 30 30 14 30 30 30 30 30 30 30  3
       3 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30  3
       3 30 30 15 30 30 14 30 30 30 14 30 30 15 30 30  3
       3 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30  3
       3 30 31 30 14 30 30 30 30 30 30 30 14 30 31 30  3
       3 30 30 30 30 30 15 30 30 30 15 30 30 30 30 30  3
       3 30 30 30 31 30 30 30 30 30 30 30 31 30 30 30  3
       3 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30  3
       3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3
C    13A 13D MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (48 TOTAL)
202    1 -0.660 30 -31 32 -33 LAT=1 U=4 VOL=2581.227 FILL=-8:8 -8:8 0:0
       4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 14 40 40 40 14 40 40 40 40 40  4
       4 40 40 40 14 40 40 40 40 40 40 40 14 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 14 40 40 14 40 40 40 14 40 40 14 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 14 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 14 40 40 14 40 40 40 14 40 40 14 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 14 40 40 40 40 40 40 40 14 40 40 40  4
       4 40 40 40 40 40 14 40 40 40 14 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4 40 40 40 40 40 40 40 40 40 40 40 40 40 40 40  4
       4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4  4
C    13B C E MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (8 TOTAL)
203    1 -0.660 30 -31 32 -33 LAT=1 U=5 VOL=2581.227 FILL=-8:8 -8:8 0:0
       5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 14 50 50 50 14 50 50 50 50 50  5
       5 50 50 50 14 50 50 50 50 50 50 50 14 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 14 50 50 14 50 50 50 14 50 50 14 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 14 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 14 50 50 14 50 50 50 14 50 50 14 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 14 50 50 50 50 50 50 50 14 50 50 50  5
       5 50 50 50 50 50 14 50 50 50 14 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50  5
       5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
C    14A MARK-B10I ASSMBLY WITH 8 GD AND 8 BPRAS (24 TOTAL)
207    1 -0.660 30 -31 32 -33 LAT=1 U=9 VOL=2581.227 FILL=-8:8 -8:8 0:0
       9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 90 91 90 90 90 90 90 90 90 91 90 90 90  9
       9 90 90 90 90 90 15 90 90 90 15 90 90 90 90 90  9
       9 90 91 90 14 90 90 90 90 90 90 90 14 90 91 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 15 90 90 14 90 90 90 14 90 90 15 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 90 90 90 90 90 14 90 90 90 90 90 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 90 15 90 90 14 90 90 90 14 90 90 15 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9 90 91 90 14 90 90 90 90 90 90 90 14 90 91 90  9
       9 90 90 90 90 90 15 90 90 90 15 90 90 90 90 90  9
       9 90 90 90 91 90 90 90 90 90 90 90 91 90 90 90  9
       9 90 90 90 90 90 90 90 90 90 90 90 90 90 90 90  9
       9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9  9
C    14B MARK-B10I ASSMBLY WITH 0 GD AND 0 BPRAS (8 TOTAL)
208    1 -0.660 30 -31 32 -33 LAT=1 U=10 VOL=2581.227 FILL=-8:8 -8:8 0:0
       10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
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       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  10
       10 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  10
       10 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  10
       10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10
C    14C MARK-B10I ASSMBLY WITH 4 GD AND 0 BPRAS (8 TOTAL)
209    1 -0.660 30 -31 32 -33 LAT=1 U=11 VOL=2581.227 FILL=-8:8 -8:8 0:0
       11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 111 100 100 100 100 100 100 100 100 100 100 100 111 100  11
       11 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  11
       11 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11 100 100 100  14 100 100 100 100 100 100 100  14 100 100 100  11
       11 100 100 100 100 100 100  14 100 100 100  14 100 100 100 100  11
       11 100 111 100 100 100 100 100 100 100 100 100 100 100 111 100  11
       11 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  11
       11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
C    14D MARK-B10I ASSMBLY WITH 8 GD AND 0 BPRAS (8 TOTAL)
210    1 -0.660 30 -31 32 -33 LAT=1 U=12 VOL=2581.227 FILL=-8:8 -8:8 0:0
       12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100 100 111 100 100 100 100 100 100 100 100 111 100 100  12
       12 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  12
       12 100 111 100  14 100 100 100 100 100 100 100  14 100 111 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 100  14 100 100  14 100 100 100  14 100 100  14 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12 100 111 100  14 100 100 100 100 100 100 100  14 100 111 100  12
       12 100 100 100 100 100  14 100 100 100  14 100 100 100 100 100  12
       12 100 100 100 111 100 100 100 100 100 100 100 111 100 100 100  12
       12 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  12
       12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12  12
C    14E MARK-B10I ASSMBLY WITH 8 GD AND 8 BPRAS (24 TOTAL)
211      1 -0.660 30 -31 32 -33 LAT=1 U=13 VOL=2581.227 FILL=-8:8 -8:8 0:0
         13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13
         13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
         13 100 100 100  91 100 100 100 100 100 100 100  91 100 100 100  13
         13 100 100 100 100 100  15 100 100 100  15 100 100 100 100 100  13
         13 100  91 100  14 100 100 100 100 100 100 100  14 100  91 100  13
         13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
         13 100 100  15 100 100  14 100 100 100  14 100 100  15 100 100  13
         13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
         13 100 100 100 100 100 100 100  14 100 100 100 100 100 100 100  13
         13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
         13 100 100  15 100 100  14 100 100 100  14 100 100  15 100 100  13
         13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
         13 100  91 100  14 100 100 100 100 100 100 100  14 100  91 100  13
         13 100 100 100 100 100  15 100 100 100  15 100 100 100 100 100  13
         13 100 100 100  91 100 100 100 100 100 100 100  91 100 100 100  13
         13 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100  13
```

```
       13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13  13
C      UNIVERSE 14 EMPTY GUIDE TUBE
3      1    -0.660     -4 U=14 $WATER HOLE
                     VOL=259.275
4      3    -6.503 4 -5 U=14 $INTERIOR CLAD
                     VOL=78.0098
5      1    -0.660   5 -6 U=14 $GUIDE TUBE WATER RADIUS
                     VOL=114.4531
6      3    -6.503 6 -7 U=14 $GUIDE TUBE CLAD RADIUS
                     VOL=60.665
7      1    -0.660   #3 #4 #5 #6 U=14 $UNIT CELL WATER
                     VOL=237.207
C      UNIVERSE 15 BPRA
8      4    -3.1     -4 U=15 $BPRA MATERIAL
                     VOL=259.275
9      3    -6.503 4 -5 U=15 $INTERIOR CLAD
                     VOL=78.0098
10     1    -0.660   5 -6 U=15 $GUIDE TUBE WATER RADIUS
                     VOL=114.453
11     3    -6.503 6 -7 U=15 $GUIDE TUBE CLAD RADIUS
                     VOL=60.665
12     1    -0.660   #8 #9 #10 #11 U=15 $UNIT CELL WATER
                     VOL=237.207
C      UNIVERSE 20  FUEL FOR 10A3 &12A2 ASSEMBLY (PRIMARY)
13     26   -10.201    -8 15 -16 U=20 $UO2 FUEL PELLET (PRIMARY)
                     VOL=228.638
14     34   -10.201    -8 -15 U=20  $UO2 FUEL PELLET (BLANKET)
                     VOL=10.544
15     34   -10.201    -8 16  U=20  $UO2 FUEL PELLET (BLANKET)
                     VOL=10.544
16     0            8 -4 U=20 $GAP RADIUS
                     VOL=9.5493
17     3    -6.503 4 -5 U=20 $FUEL PIN CLAD
                     VOL=78.00976
18     1    -0.660   #13 #14 #15 #16 #17 U=20 $UNIT CELL WATER
                     VOL=412.3249
C      UNIVERSE 30  FUEL FOR 14A PIN TEST ASSEMBLY (PRIMARY)
19     21   -10.201    -8 15 -16 U=30 $UO2 FUEL PELLET (PRIMARY)
                     VOL=228.638
20     22   -10.201    -8 -15 U=30  $UO2 FUEL PELLET (BLANKET)
                     VOL=10.544
21     22   -10.201    -8 16  U=30  $UO2 FUEL PELLET (BLANKET)
                     VOL=10.544
22     0            8 -4 U=30 $GAP RADIUS
                     VOL=9.5493
23     3    -6.503 4 -5 U=30 $FUEL PIN CLAD
                     VOL=78.00976
24     1    -0.660   #79 #80 #81 #82 #83 U=30 $UNIT CELL WATER
                     VOL=412.3249
C      UNIVERSE 31 GD FUEL ROD FOR PIN TEST 14A AND 14E
31     27   -9.635    -8 17 -18 U=31 $UO2 GDO FUEL PELLET (PRIMARY)
                     VOL=215.2219
32     22   -10.201    -8 -17 U=31  $UO2 FUEL PELLET (BLANKET)
                     VOL=17.25188
33     22   -10.201    -8 18  U=31  $UO2 FUEL PELLET (BLANKET)
                     VOL=17.25188
34     0            8 -4 U=31 $GAP RADIUS
                     VOL=9.549294
35     3    -6.503 4 -5 U=31 $FUEL PIN CLAD
                     VOL=78.00976
36     1    -0.660   #85 #86 #87 #88 #89 U=31 $UNIT CELL WATER
                     VOL=412.3249
C      UNIVERSE 40  FUEL FOR 13A & 13D ASSEMBLY (PRIMARY)
25     30    -10.201    -8 15 -16 U=40 $UO2 FUEL PELLET (PRIMARY)
                     VOL=228.638
26     34   -10.201    -8 -15 U=40  $UO2 FUEL PELLET (BLANKET)
                     VOL=10.544
27     34   -10.201    -8 16  U=40  $UO2 FUEL PELLET (BLANKET)
                     VOL=10.544
28     0            8 -4 U=40 $GAP RADIUS
                     VOL=9.5493
```

```
29     3    -6.503 4 -5 U=40 $FUEL PIN CLAD
                    VOL=78.00976
30     1    -0.660   #25 #26 #27 #28 #29 U=40 $UNIT CELL WATER
                    VOL=412.3249
C      UNIVERSE 50  FUEL FOR 13B C E ASSEMBLY (PRIMARY)
37     33  -10.201    -8 15 -16 U=50 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.638
38     34   -10.201    -8 -15 U=50  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
39     34   -10.201    -8 16  U=50  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
40     0             8 -4 U=50 $GAP RADIUS
                    VOL=9.5493
41     3    -6.503 4 -5 U=50 $FUEL PIN CLAD
                    VOL=78.00976
42     1    -0.660   #37 #38 #39 #40 #41 U=50 $UNIT CELL WATER
                    VOL=412.3249
C      UNIVERSE 90  FUEL FOR 14A ASSEMBLY (PRIMARY)
79     2    -10.201    -8 15 -16 U=90 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.638
80     22   -10.201    -8 -15 U=90  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
81     22   -10.201    -8 16  U=90  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.544
82     0             8 -4 U=90 $GAP RADIUS
                    VOL=9.5493
83     3    -6.503 4 -5 U=90 $FUEL PIN CLAD
                    VOL=78.00976
84     1    -0.660   #79 #80 #81 #82 #83 U=90 $UNIT CELL WATER
                    VOL=412.3249
C      UNIVERSE 91 GD FUEL ROD FOR 14A AND 14E
85     25   -9.635    -8 17 -18 U=91 $UO2 GDO FUEL PELLET (PRIMARY)
                    VOL=215.2219
86     22   -10.201    -8 -17 U=91  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
87     22   -10.201    -8 18  U=91  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
88     0             8 -4 U=91 $GAP RADIUS
                    VOL=9.549294
89     3    -6.503 4 -5 U=91 $FUEL PIN CLAD
                    VOL=78.00976
90     1    -0.660   #85 #86 #87 #88 #89 U=91 $UNIT CELL WATER
                    VOL=412.3249
C      UNIVERSE 100 FUEL FOR 14B 14C 14D 14E ASSEMBLIES
91     23   -10.201    -8 15 -16 U=100 $UO2 FUEL PELLET (PRIMARY)
                    VOL=228.6378
92     22   -10.201    -8 -15 U=100  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.54397
93     22   -10.201    -8 16  U=100  $UO2 FUEL PELLET (BLANKET)
                    VOL=10.54397
94     0             8 -4 U=100 $GAP RADIUS
                    VOL=54929
95     3    -6.503 4 -5 U=100 $FUEL PIN CLAD
                    VOL=78.00976
96     1    -0.660   #91 #92 #93 #94 #95 U=100 $UNIT CELL WATER
                    VOL=412.3249
C      UNIVERSE 111 GD FUEL ROD FOR 14C AND 14D
97     24   -9.635    -8 17 -18 U=111 $UO2 GDO FUEL PELLET (PRIMARY)
                    VOL=215.2219
98     22   -10.201    -8 -17 U=111  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
99     22   -10.201    -8 18  U=111  $UO2 FUEL PELLET (BLANKET)
                    VOL=17.25188
100     0             8 -4 U=111 $GAP RADIUS
                    VOL=9.549294
101     3    -6.503 4 -5 U=111 $FUEL PIN CLAD
                    VOL=78.00976
102     1    -0.660   #97 #98 #99 #100 #101 U=111 $UNIT CELL WATER
                    VOL=412.3249
C      REACTOR BOUNDARY
997     1    -0.660   -1 -2 14 19 20  $AXIAL RELECTORS
```

```
                    VOL=2035752.04
998     1    -0.660   -1  3 -13 19 20
                    VOL=2035752.04
999             0      1:-3:2:-19:-20 $VOID REGION OUTSIDE REACTOR VESSEL

*1              CZ     180    $ REACTOR VESSEL
*2              PZ     200
*3              PZ    -200
30             PX    -0.7215
31             PX     0.7215
32             PY    -0.7215
33             PY     0.7215
C  OUTSIDE OF UNIT CELL (1.443 PITCH)
4              CZ     0.4788
C  CYLINDER BPRA / WATER HOLE / GAP RADIUS
5              CZ     0.5461
C  CYLINDER INTERIOR CLAD RADIUS
6              CZ     0.6320
C  CYLINDER WATER RADIUS GUIDE TUBE
7              CZ     0.6731
C  CYLINDER CLAD RADIUS GUIDE TUBE
8              CZ     0.4699
C  CYLINDER RADIUS OF FUEL PELLET
9              PX    -10.905
10             PX     10.905
11             PY    -10.905
12             PY     10.905
13             PZ    -180
14             PZ     180
C  PLANES OUTSIDE OF ASSEMBLY
15             PZ    -164.8
16             PZ     164.8
17             PZ    -155.13
18             PZ     155.13
*19             PX      0
*20             P       0 0 0 10.905 10.905 0 10.905 10.905 10.905
C  PLANES FOR AXIAL BLANKET

MODE    N
IMP:N   1.0 76R 0.0
KCODE   30000    1.5     10       50      5000
KSRC    1.443 2.886 0
        1.443 21.8 0
        20.357 21.8 0
        1.443 43.6 0
        20.357 43.6 0
        42.157 43.6 0
        1.443 65.4 0
        20.357 65.4 0
        42.157 65.4 0
        63.957 65.4 0
        1.443 87.2 0
        20.357 87.2 0
        42.157 87.2 0
        63.957 87.2 0
        85.757 87.2 0
        1.443 109 0
        20.357 109 0
        42.157 109 0
        63.957 109 0
        85.757 109 0
        107.557 109 0
        1.443 130.8 0
        20.357 130.8 0
        42.157 130.8 0
        63.957 130.8 0
        85.757 130.8 0
        1.443 152.6 0
        20.357 152.6 0
        42.157 152.6 0
M1      8016.60C         3.30E-01     1001.60C     6.65E-01
```

```
        5010.50C         1.90E-04     5011.56C     4.82E-03
C  water with boron
C   FUEL FOR 14A  (PRIMARY)  0.0452 ENRICH
M2      92235.54C    0.015066652
        92238.54C    0.318266348
        8016.54C     0.666666
C   FUEL FOR 14A  PIN TEST (PRIMARY)  0.0452 ENRICH
M21      92235.54C    0.015066652
        92238.54C    0.318266348
        8016.54C     0.666666
C   FUEL FOR 14A -E (BLANKET)  0.02 ENRICH
M22     92235.54C    0.00666666
        92238.54C    0.32666634
        8016.54C     0.666666
C   FUEL FOR 14B -E (PRIMARY)  0.0466 ENRICH
M23     92235.54C    0.015533318
        92238.54C    0.317799682
        8016.54C     0.666666
C   FUEL FOR 14C & D (GdO MIX) 0.0396 ENRICH 0.03 GdO
M24     92235.54C    0.012804
        92238.54C    0.310529333
        8016.54C     0.664666667
        64154.60C    0.000325035
        64155.60C    0.00224584
        64156.60C    0.00314201
        64157.60C    0.00242074
        64158.60C    0.003866374
C   FUEL FOR 14A & E (GdO MIX) 0.0316 ENRICH 0.06 GdO
M25     92235.54C    0.009901333
        92238.54C    0.303432
        8016.54C     0.662666667
        64154.60C    0.000650071
        64155.60C    0.004491681
        64156.60C    0.006284019
        64157.60C    0.004841481
        64158.60C    0.007732749
C   FUEL FOR 14A & E PIN TEST (GdO MIX) 0.0316 ENRICH 0.06 GdO
M27     92235.54C    0.009901333
        92238.54C    0.303432
        8016.54C     0.662666667
        64154.60C    0.000650071
        64155.60C    0.004491681
        64156.60C    0.006284019
        64157.60C    0.004841481
        64158.60C    0.007732749
C FUEL FOR 10A3 - 13E (BLANKET)
M34     92235.54C        -0.0096
        92236.60C        -0.0187
        92238.54C        -0.965939
        94239.15C        -0.00525
        94240.60C        -0.00131
        8016.54C         -0.000799
C FUEL FOR 10A3 (PRIMARY) 0.01082  ENRICH
M26    92235.54C       0.003606663
       92238.54C       0.329726337
        8016.54C       0.666666
C FUEL FOR 13D (PRIMARY) 0.0155 ENRICH
M30    92235.54C       0.005166662
       92238.54C       0.328166339
        8016.54C       0.666666
C FUEL FOR 13E (PRIMARY) 0.01833 ENRICH
M33    92235.54C       0.006109994
       92238.54C       0.327223006
        8016.54C       0.666666
M3      40000.60C 1.0 $ZIRCONIUM (APPROX. FOR ZIRCALLOY)
M4      5010.50C   -0.55   5011.56C -2.22 6000.60C   -0.76   13027.60C
        -51.04   8016.54C   -45.43  $B4CAL2O3 BP MATERIAL
PRINT
```

The MONTEBURNS Input File Chem Shim Power Peak #4 B_4C/Al_2O_3 BPRAs

```
RESEARCH CRYSTAL RIVER 1/8 CORE WITH B4CAL2O3 BPRA'S 4.66% ENRICH B let down
PC          ! Type of Operating System
13          ! Number of MCNP Materials to burn (fuel cells/BPRAs/chem shim)
1           ! MCNP material number 1 water and chem shim
2           ! MCNP material number #2 (will burn all cells with this mat)
21
22          ! MCNP material number #22 (will burn all cells with this mat)
23
24
25
27
34
26
30
33
4
3121196.0  ! volume of water
114318.98  ! Material #2 volume (cc)
22863.78   ! PIN TEST MATERIAL PRIMARY
40285.32   !#22
277109.01  !#23
2582.664   !#24
9469.7636  !#25
860.8876   !#27 PIN TEST MAT GD
58380.164  !#34
196171.234 !#26
284696.016 !#30
142508.996 !#33
7259.7      ! Material #4 volume (cc)
318         ! Power in MWt (for the entire system in MCNP)
-180.88     ! Recov. energy/fis (MeV); if negative use for U235, ratio other isos
0           ! Total number of days burned (used if no feed)
5           ! Number of outer burn steps
50          ! Number of internal burn steps (multiple of 10)
1           ! Number of predictor steps (+1 on first step), 1 usually sufficient
0           ! Step number to restart after (0=beginning)
PWRU50      ! number of default origen2 lib - next line is origen2 lib location
c:\Origen2\Libs
.005        ! fractional importance (track isos with abs,fis,atom,mass fraction)
0           ! Intermediate keff calc. 0) No 1) Yes
1           ! Number of automatic tally isotopes, followed by list.
5010.50c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
```

```
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
1
5010.50C
```

The MONTEBURNS Input File Chem Shim Power Peak #12 B_4C/Al_2O_3 BPRAs

```
RESEARCH CRYSTAL RIVER 1/8 CORE WITH B4CAL2O3 BPRA'S 4.66% ENRICH B let down
PC          ! Type of Operating System
13          ! Number of MCNP Materials to burn (fuel cells/BPRAs)
1           ! Water with chem shim
2           ! MCNP material number #2 (will burn all cells with this mat)
21
22          ! MCNP material number #22 (will burn all cells with this mat)
23
24
25
27
34
26
30
33
4
3121196.0  ! volume of water
91455.2    ! Material #2 volume (cc)
45727.56   ! PIN TEST MATERIAL PRIMARY
40285.32   !#22
277109.01  !#23
2582.664   !#24
9469.7636  !#25
860.8876   !#27 PIN TEST MAT GD
58380.164  !#34
196171.234 !#26
284696.016 !#30
142508.996 !#33
7259.7     ! Material #4 volume (cc)
318        ! Power in MWt (for the entire system in MCNP)
-180.88    ! Recov. energy/fis (MeV); if negative use for U235, ratio other isos
0          ! Total number of days burned (used if no feed)
5          ! Number of outer burn steps
50         ! Number of internal burn steps (multiple of 10)
1          ! Number of predictor steps (+1 on first step), 1 usually sufficient
0          ! Step number to restart after (0=beginning)
PWRU50     ! number of default origen2 lib - next line is origen2 lib location
c:\Origen2\Libs
.005       ! fractional importance (track isos with abs,fis,atom,mass fraction)
0          ! Intermediate keff calc. 0) No 1) Yes
1          ! Number of automatic tally isotopes, followed by list.
5010.50c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
```

```
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
2
92235.54c
92238.54c
1
5010.50C
```

The MONTEBURNS Feed File Chem Shim Power Peak #4 B_4C/Al_2O_3 BPRAs

Time Step	Days Burned	Power Fract.	MBMat #	Feed #	Begin&EndRates Removed grams/day		Remov. Group#	Fraction F.P.Removed
1	134	1.000	1	1	17.11	16.66	0	0.000
			2	0	0.0	0.0	0	0.000
			3	0	0.0	0.0	0	0.000
			4	0	0.0	0.0	0	0.000
			5	0	0.0	0.0	0	0.000
			6	0	0.0	0.0	0	0.000
			7	0	0.0	0.0	0	0.000
			8	0	0.0	0.0	0	0.000
			9	0	0.0	0.0	0	0.000
			10	0	0.0	0.0	0	0.000
			11	0	0.0	0.0	0	0.000
			12	0	0.0	0.0	0	0.000
			13	0	0.0	0.0	0	0.000
2	134	1.000	1	1	-1.0	13.88	0	0.000
			2	0	0.0	0.0	0	0.000
			3	0	0.0	0.0	0	0.000
			4	0	0.0	0.0	0	0.000
			5	0	0.0	0.0	0	0.000
			6	0	0.0	0.0	0	0.000
			7	0	0.0	0.0	0	0.000
			8	0	0.0	0.0	0	0.000
			9	0	0.0	0.0	0	0.000
			10	0	0.0	0.0	0	0.000
			11	0	0.0	0.0	0	0.000
			12	0	0.0	0.0	0	0.000
			13	0	0.0	0.0	0	0.000
3	134	1.000	1	1	-1.0	9.292	0	0.000
			2	0	0.0	0.0	0	0.000
			3	0	0.0	0.0	0	0.000
			4	0	0.0	0.0	0	0.000
			5	0	0.0	0.0	0	0.000
			6	0	0.0	0.0	0	0.000
			7	0	0.0	0.0	0	0.000
			8	0	0.0	0.0	0	0.000
			9	0	0.0	0.0	0	0.000
			10	0	0.0	0.0	0	0.000
			11	0	0.0	0.0	0	0.000
			12	0	0.0	0.0	0	0.000
			13	0	0.0	0.0	0	0.000
4	134	1.000	1	1	-1.0	4.819	0	0.000
			2	0	0.0	0.0	0	0.000
			3	0	0.0	0.0	0	0.000
			4	0	0.0	0.0	0	0.000
			5	0	0.0	0.0	0	0.000
			6	0	0.0	0.0	0	0.000
			7	0	0.0	0.0	0	0.000

```
                     8   0     0.0     0.0    0    0.000
                     9   0     0.0     0.0    0    0.000
                    10   0     0.0     0.0    0    0.000
                    11   0     0.0     0.0    0    0.000
                    12   0     0.0     0.0    0    0.000
                    13   0     0.0     0.0    0    0.000
   5  134     1.000   1   1    -1.0   0.000    0    0.000
                     2   0     0.0     0.0    0    0.000
                     3   0     0.0     0.0    0    0.000
                     4   0     0.0     0.0    0    0.000
                     5   0     0.0     0.0    0    0.000
                     6   0     0.0     0.0    0    0.000
                     7   0     0.0     0.0    0    0.000
                     8   0     0.0     0.0    0    0.000
                     9   0     0.0     0.0    0    0.000
                    10   0     0.0     0.0    0    0.000
                    11   0     0.0     0.0    0    0.000
                    12   0     0.0     0.0    0    0.000
                    13   0     0.0     0.0    0    0.000
   1                              ! # of feed specs
   1                              ! # of isos in Feed #1
5010  1.0
```

The MONTEBURNS Feed File Chem Shim Power Peak #12 B_4C/Al_2O_3 BPRAs

```
Time   Days   Power MBMat Feed Begin&EndRates Remov. Fraction F.P.Removed
 Step Burned  Fract.  #   #       grams/day    Group#
   1  134     1.000   1   1   17.11   16.66     0    0.000
                      2   0     0.0     0.0     0    0.000
                      3   0     0.0     0.0     0    0.000
                      4   0     0.0     0.0     0    0.000
                      5   0     0.0     0.0     0    0.000
                      6   0     0.0     0.0     0    0.000
                      7   0     0.0     0.0     0    0.000
                      8   0     0.0     0.0     0    0.000
                      9   0     0.0     0.0     0    0.000
                     10   0     0.0     0.0     0    0.000
                     11   0     0.0     0.0     0    0.000
                     12   0     0.0     0.0     0    0.000
                     13   0     0.0     0.0     0    0.000
   2  134     1.000   1   1    -1.0   13.88     0    0.000
                      2   0     0.0     0.0     0    0.000
                      3   0     0.0     0.0     0    0.000
                      4   0     0.0     0.0     0    0.000
                      5   0     0.0     0.0     0    0.000
                      6   0     0.0     0.0     0    0.000
                      7   0     0.0     0.0     0    0.000
                      8   0     0.0     0.0     0    0.000
                      9   0     0.0     0.0     0    0.000
                     10   0     0.0     0.0     0    0.000
                     11   0     0.0     0.0     0    0.000
                     12   0     0.0     0.0     0    0.000
                     13   0     0.0     0.0     0    0.000
   3  134     1.000   1   1    -1.0   9.292     0    0.000
                      2   0     0.0     0.0     0    0.000
                      3   0     0.0     0.0     0    0.000
                      4   0     0.0     0.0     0    0.000
                      5   0     0.0     0.0     0    0.000
                      6   0     0.0     0.0     0    0.000
                      7   0     0.0     0.0     0    0.000
                      8   0     0.0     0.0     0    0.000
                      9   0     0.0     0.0     0    0.000
                     10   0     0.0     0.0     0    0.000
                     11   0     0.0     0.0     0    0.000
                     12   0     0.0     0.0     0    0.000
                     13   0     0.0     0.0     0    0.000
   4  134     1.000   1   1    -1.0   4.819     0    0.000
                      2   0     0.0     0.0     0    0.000
                      3   0     0.0     0.0     0    0.000
                      4   0     0.0     0.0     0    0.000
```

```
                    5   0      0.0      0.0     0    0.000
                    6   0      0.0      0.0     0    0.000
                    7   0      0.0      0.0     0    0.000
                    8   0      0.0      0.0     0    0.000
                    9   0      0.0      0.0     0    0.000
                   10   0      0.0      0.0     0    0.000
                   11   0      0.0      0.0     0    0.000
                   12   0      0.0      0.0     0    0.000
                   13   0      0.0      0.0     0    0.000
   5  134     1.000    1   1    -1.0    0.000     0    0.000
                    2   0      0.0      0.0     0    0.000
                    3   0      0.0      0.0     0    0.000
                    4   0      0.0      0.0     0    0.000
                    5   0      0.0      0.0     0    0.000
                    6   0      0.0      0.0     0    0.000
                    7   0      0.0      0.0     0    0.000
                    8   0      0.0      0.0     0    0.000
                    9   0      0.0      0.0     0    0.000
                   10   0      0.0      0.0     0    0.000
                   11   0      0.0      0.0     0    0.000
                   12   0      0.0      0.0     0    0.000
                   13   0      0.0      0.0     0    0.000
   1                             ! # of feed specs
   1                             ! # of isos in Feed #1
5010  1.0
```

The MONTEBURNS Output File Chem Shim Peak #4 B_4C/Al_2O_3 BPRAs

RESEARCH CRYSTAL RIVER 1/8 CORE WITH B4CAL2O3 BPRA'S 4.66% ENRICH B let

Total Power (MW) = 3.18E+02 Days = 6.70E+02
outer steps = 5, # inner steps = 50, # predictor steps = 1
Importance Fraction = 0.0050

Monteburns MCNP k-eff Versus Time

	days	k-eff	rel err	nu	avQfis	eta
0m	0.00	0.99567	0.00069	2.469	181.133	0.734
1m	67.00	0.99777	0.00064	2.528	182.208	0.817
2m	201.00	0.99833	0.00064	2.604	183.524	0.965
3m	335.00	0.99795	0.00069	2.657	184.405	1.113
4m	469.00	0.99812	0.00064	2.693	185.088	1.109
5m	603.00	0.99844	0.00048	2.723	185.638	1.091

Monteburns Transport History

Monteburns Transport History for material 1

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	1.07E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	8.60E-02	0.00E+00	0.00E+00	3.00E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	1.08E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	7.33E-02	0.00E+00	0.00E+00	3.72E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	1.10E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	6.58E-02	0.00E+00	0.00E+00	3.75E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	1.11E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	5.72E-02	0.00E+00	0.00E+00	3.80E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	1.13E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	4.50E-02	0.00E+00	0.00E+00	3.71E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	1.15E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	3.17E-02	0.00E+00	0.00E+00	3.81E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

Monteburns Transport History for material 2

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.092	4.90E+14	3.40E-02	5.53E+01	4.839E+02	0.000E+00	3.74E-01	4.98E-01	1.33E+00	1.61E-03	1.414	1.12E+00	1.50E+00	1.34E+00	4.84E-03	1.418
1	181.888	5.09E+14	3.28E-02	5.57E+01	4.877E+02	7.267E+00	4.27E-01	4.81E-01	1.13E+00	1.66E-03	1.343	1.19E+00	1.45E+00	1.21E+00	5.01E-03	1.390
2	182.998	5.20E+14	3.14E-02	5.49E+01	4.806E+02	1.443E+01	4.84E-01	4.62E-01	9.55E-01	1.67E-03	1.276	1.31E+00	1.40E+00	1.07E+00	5.04E-03	1.347
3	183.858	5.32E+14	3.06E-02	5.50E+01	4.807E+02	2.159E+01	5.27E-01	4.50E-01	8.54E-01	1.68E-03	1.227	1.40E+00	1.37E+00	9.80E-01	5.11E-03	1.318
4	184.559	5.09E+14	2.93E-02	5.05E+01	4.422E+02	2.818E+01	5.64E-01	4.32E-01	7.66E-01	1.68E-03	1.172	1.48E+00	1.33E+00	8.96E-01	5.12E-03	1.276
5	185.142	5.00E+14	2.85E-02	4.84E+01	4.237E+02	3.449E+01	5.91E-01	4.21E-01	7.13E-01	1.71E-03	1.136	1.54E+00	1.30E+00	8.41E-01	5.26E-03	1.248

Monteburns Transport History for material 3

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.092	4.97E+14	3.41E-02	1.13E+01	4.922E+02	0.000E+00	3.79E-01	5.00E-01	1.32E+00	1.53E-03	1.408	1.13E+00	1.50E+00	1.33E+00	4.58E-03	1.411
1	181.911	5.16E+14	3.27E-02	1.13E+01	4.921E+02	7.333E+00	4.24E-01	4.79E-01	1.13E+00	1.56E-03	1.344	1.18E+00	1.44E+00	1.22E+00	4.71E-03	1.392
2	183.003	5.41E+14	3.13E-02	1.14E+01	4.979E+02	1.475E+01	4.88E-01	4.60E-01	9.43E-01	1.65E-03	1.267	1.32E+00	1.39E+00	1.05E+00	4.98E-03	1.338
3	183.917	5.68E+14	3.03E-02	1.16E+01	5.094E+02	2.234E+01	5.33E-01	4.47E-01	8.37E-01	1.70E-03	1.214	1.42E+00	1.36E+00	9.60E-01	5.16E-03	1.305
4	184.704	5.38E+14	2.91E-02	1.06E+01	4.654E+02	2.927E+01	5.69E-01	4.30E-01	7.55E-01	1.73E-03	1.162	1.49E+00	1.32E+00	8.84E-01	5.30E-03	1.268
5	185.266	5.47E+14	2.85E-02	1.06E+01	4.631E+02	3.617E+01	5.96E-01	4.20E-01	7.05E-01	1.68E-03	1.129	1.56E+00	1.30E+00	8.35E-01	5.17E-03	1.242

Monteburns Transport History for material 4

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.151	1.55E+13	2.42E-02	4.39E-01	1.091E+01	0.000E+00	3.61E-01	3.55E-01	9.85E-01	1.30E-03	1.228	1.08E+00	1.07E+00	9.89E-01	3.89E-03	1.231
1	181.246	1.64E+13	2.38E-02	4.61E-01	1.143E+01	1.704E-01	3.62E-01	3.49E-01	9.65E-01	1.89E-03	1.247	1.07E+00	1.05E+00	9.80E-01	5.67E-03	1.256
2	181.360	2.01E+13	2.52E-02	6.01E-01	1.493E+01	3.928E-01	3.90E-01	3.70E-01	9.47E-01	2.05E-03	1.272	1.14E+00	1.11E+00	9.70E-01	6.14E-03	1.288
3	181.552	2.06E+13	2.56E-02	6.28E-01	1.559E+01	6.251E-01	3.84E-01	3.76E-01	9.79E-01	1.68E-03	1.318	1.12E+00	1.13E+00	1.01E+00	5.03E-03	1.337
4	181.687	1.94E+13	2.70E-02	6.27E-01	1.556E+01	8.569E-01	3.98E-01	3.96E-01	9.95E-01	1.72E-03	1.348	1.16E+00	1.19E+00	1.02E+00	5.15E-03	1.367
5	181.818	2.51E+13	2.94E-02	8.85E-01	2.196E+01	1.184E+00	3.97E-01	4.30E-01	1.08E+00	1.82E-03	1.421	1.15E+00	1.29E+00	1.12E+00	5.45E-03	1.443

Monteburns Transport History for material 5

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta

	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.088	4.18E+14	3.50E-02	1.18E+02	4.250E+02	0.000E+00	3.76E-01	5.13E-01	1.36E+00	1.64E-03	1.428	1.12E+00	1.54E+00	1.37E+00	4.91E-03	1.431
1	181.737	4.05E+14	3.38E-02	1.11E+02	4.001E+02	5.963E+00	4.21E-01	4.96E-01	1.18E+00	1.66E-03	1.371	1.17E+00	1.49E+00	1.27E+00	5.01E-03	1.418
2	182.661	4.04E+14	3.25E-02	1.07E+02	3.864E+02	1.172E+01	4.69E-01	4.78E-01	1.02E+00	1.68E-03	1.317	1.29E+00	1.44E+00	1.12E+00	5.07E-03	1.381
3	183.376	4.05E+14	3.16E-02	1.05E+02	3.783E+02	1.736E+01	5.07E-01	4.65E-01	9.17E-01	1.74E-03	1.274	1.36E+00	1.41E+00	1.04E+00	5.27E-03	1.356
4	183.972	4.12E+14	3.09E-02	1.05E+02	3.781E+02	2.299E+01	5.35E-01	4.55E-01	8.51E-01	1.71E-03	1.242	1.42E+00	1.39E+00	9.80E-01	5.22E-03	1.337
5	184.487	4.11E+14	3.01E-02	1.02E+02	3.678E+02	2.847E+01	5.66E-01	4.43E-01	7.82E-01	1.76E-03	1.199	1.49E+00	1.36E+00	9.14E-01	5.38E-03	1.304

Monteburns Transport History for material 6 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.374	3.68E+14	1.41E-02	3.89E-01	1.505E+02	0.000E+00	1.83E+00	2.17E-01	1.19E-01	1.89E-03	0.264	9.29E-01	6.72E-01	7.24E-01	5.73E-03	1.044
1	182.029	3.56E+14	1.82E-02	4.88E-01	1.888E+02	3.054E+00	1.30E+00	2.80E-01	2.15E-01	1.53E-03	0.450	9.96E-01	8.67E-01	8.70E-01	4.67E-03	1.182
2	182.726	3.68E+14	2.50E-02	6.98E-01	2.704E+02	7.427E+00	7.47E-01	3.86E-01	5.17E-01	2.01E-03	0.891	1.18E+00	1.20E+00	1.02E+00	6.17E-03	1.319
3	183.316	3.48E+14	2.80E-02	7.44E-01	2.881E+02	1.209E+01	5.20E-01	4.33E-01	8.33E-01	1.55E-03	1.210	1.32E+00	1.35E+00	1.02E+00	4.76E-03	1.346
4	183.896	3.60E+14	2.70E-02	7.44E-01	2.882E+02	1.675E+01	5.42E-01	4.18E-01	7.71E-01	1.71E-03	1.176	1.42E+00	1.31E+00	9.24E-01	5.31E-03	1.298
5	184.408	3.58E+14	2.73E-02	7.50E-01	2.905E+02	2.145E+01	5.62E-01	4.22E-01	7.52E-01	1.94E-03	1.173	1.43E+00	1.33E+00	9.26E-01	6.00E-03	1.314

Monteburns Transport History for material 7 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.545	4.39E+14	1.00E-02	1.21E+00	1.278E+02	0.000E+00	2.01E+00	1.54E-01	7.66E-02	1.65E-03	0.177	9.04E-01	4.91E-01	5.43E-01	5.01E-03	0.876
1	182.462	4.65E+14	1.26E-02	1.61E+00	1.705E+02	2.828E+00	1.69E+00	1.92E-01	1.14E-01	1.64E-03	0.261	9.71E-01	6.15E-01	6.33E-01	5.07E-03	0.987
2	183.660	4.95E+14	1.82E-02	2.50E+00	2.645E+02	7.215E+00	1.19E+00	2.79E-01	2.34E-01	1.59E-03	0.496	1.16E+00	8.94E-01	7.72E-01	4.97E-03	1.139
3	184.269	5.34E+14	2.46E-02	3.67E+00	3.878E+02	1.365E+01	6.50E-01	3.78E-01	5.81E-01	1.59E-03	0.980	1.37E+00	1.22E+00	8.87E-01	4.98E-03	1.253
4	184.943	5.30E+14	2.53E-02	3.76E+00	3.969E+02	2.023E+01	5.90E-01	3.89E-01	6.59E-01	1.67E-03	1.074	1.47E+00	1.26E+00	8.57E-01	5.26E-03	1.247
5	185.512	5.24E+14	2.41E-02	3.56E+00	3.755E+02	2.646E+01	6.09E-01	3.71E-01	6.10E-01	1.65E-03	1.035	1.52E+00	1.21E+00	7.94E-01	5.24E-03	1.209

Monteburns Transport History for material 8 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.543	4.61E+14	1.01E-02	1.17E-01	1.354E+02	0.000E+00	2.12E+00	1.55E-01	7.33E-02	1.64E-03	0.170	9.37E-01	4.95E-01	5.29E-01	4.98E-03	0.861
1	182.511	4.96E+14	1.29E-02	1.61E-01	1.869E+02	3.100E+00	1.74E+00	1.98E-01	1.14E-01	1.61E-03	0.260	1.01E+00	6.31E-01	6.25E-01	4.97E-03	0.979
2	183.805	5.41E+14	1.94E-02	2.66E-01	3.088E+02	8.222E+00	1.20E+00	2.98E-01	2.48E-01	1.85E-03	0.520	1.25E+00	9.56E-01	7.67E-01	5.78E-03	1.136
3	184.496	5.82E+14	2.51E-02	3.72E-01	4.322E+02	1.539E+01	6.31E-01	3.87E-01	6.13E-01	1.73E-03	1.013	1.42E+00	1.25E+00	8.78E-01	5.45E-03	1.246
4	185.136	5.68E+14	2.50E-02	3.62E-01	4.209E+02	2.237E+01	5.94E-01	3.85E-01	6.48E-01	1.71E-03	1.062	1.47E+00	1.25E+00	8.49E-01	5.41E-03	1.241
5	185.703	5.81E+14	2.45E-02	3.65E-01	4.239E+02	2.940E+01	6.44E-01	3.78E-01	5.88E-01	1.67E-03	1.011	1.62E+00	1.23E+00	7.63E-01	5.27E-03	1.182

Monteburns Transport History for material 9 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	185.076	1.16E+13	2.85E-02	5.61E-01	9.610E+00	0.000E+00	1.39E+00	1.09E+00	7.87E-01	3.87E-03	1.090	1.40E+00	1.11E+00	7.87E-01	3.91E-03	1.090
1	185.156	1.24E+13	2.88E-02	6.07E-01	1.040E+01	1.368E-01	1.40E+00	1.10E+00	7.87E-01	4.28E-03	1.117	1.41E+00	1.12E+00	7.92E-01	4.33E-03	1.121
2	185.204	1.49E+13	2.87E-02	7.33E-01	1.256E+01	3.019E-01	1.43E+00	1.10E+00	7.66E-01	5.39E-03	1.134	1.43E+00	1.11E+00	7.77E-01	5.46E-03	1.143
3	185.177	1.55E+13	2.85E-02	7.64E-01	1.308E+01	4.738E-01	1.42E+00	1.09E+00	7.70E-01	5.87E-03	1.160	1.41E+00	1.11E+00	7.82E-01	5.94E-03	1.171
4	185.214	1.47E+13	2.93E-02	7.45E-01	1.276E+01	6.415E-01	1.45E+00	1.12E+00	7.76E-01	4.69E-03	1.180	1.44E+00	1.14E+00	7.90E-01	4.75E-03	1.192
5	185.210	1.99E+13	3.10E-02	1.07E+00	1.836E+01	8.828E-01	1.48E+00	1.19E+00	8.02E-01	5.62E-03	1.216	1.47E+00	1.20E+00	8.17E-01	5.69E-03	1.228

Monteburns Transport History for material 10 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.197	1.36E+14	1.92E-02	1.49E+01	7.599E+01	0.000E+00	3.76E-01	2.82E-01	7.51E-01	1.36E-03	1.063	1.12E+00	8.46E-01	7.54E-01	4.09E-03	1.065
1	182.143	1.33E+14	1.99E-02	1.52E+01	7.748E+01	1.155E+00	4.00E-01	2.92E-01	7.30E-01	1.45E-03	1.071	1.15E+00	8.76E-01	7.65E-01	4.35E-03	1.100
2	183.364	1.32E+14	2.07E-02	1.58E+01	8.077E+01	2.359E+00	4.30E-01	3.03E-01	7.06E-01	1.56E-03	1.082	1.23E+00	9.11E-01	7.39E-01	4.70E-03	1.111
3	184.194	1.31E+14	2.14E-02	1.63E+01	8.324E+01	3.600E+00	4.51E-01	3.15E-01	6.98E-01	1.63E-03	1.096	1.29E+00	9.46E-01	7.31E-01	4.90E-03	1.126
4	184.770	1.56E+14	2.24E-02	2.03E+01	1.035E+02	5.142E+00	4.69E-01	3.29E-01	7.01E-01	1.56E-03	1.114	1.35E+00	9.91E-01	7.35E-01	4.69E-03	1.145
5	185.339	1.71E+14	2.34E-02	2.33E+01	1.185E+02	6.909E+00	5.02E-01	3.43E-01	6.83E-01	1.55E-03	1.109	1.42E+00	1.03E+00	7.29E-01	4.66E-03	1.152

Monteburns Transport History for material 11 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.176	4.07E+14	2.17E-02	7.28E+01	2.559E+02	0.000E+00	3.66E-01	3.18E-01	8.67E-01	1.41E-03	1.151	1.09E+00	9.53E-01	8.71E-01	4.22E-03	1.154
1	182.862	4.20E+14	2.22E-02	7.77E+01	2.728E+02	4.065E+00	4.19E-01	3.25E-01	7.76E-01	1.46E-03	1.109	1.19E+00	9.78E-01	8.23E-01	4.40E-03	1.146

2	184.661	4.33E+14	2.22E-02	8.03E+01	2.821E+02	8.269E+00	4.65E-01	3.26E-01	7.01E-01	1.61E-03	1.077	1.32E+00	9.83E-01	7.46E-01	4.86E-03	1.117
3	185.693	4.44E+14	2.20E-02	8.22E+01	2.887E+02	1.257E+01	5.13E-01	3.24E-01	6.31E-01	1.57E-03	1.032	1.41E+00	9.80E-01	6.95E-01	4.75E-03	1.093
4	186.432	4.47E+14	2.21E-02	8.34E+01	2.929E+02	1.694E+01	5.45E-01	3.25E-01	5.96E-01	1.59E-03	1.010	1.47E+00	9.88E-01	6.71E-01	4.83E-03	1.085
5	186.958	4.53E+14	2.21E-02	8.46E+01	2.972E+02	2.137E+01	5.71E-01	3.25E-01	5.69E-01	1.64E-03	0.991	1.53E+00	9.91E-01	6.46E-01	5.00E-03	1.073

Monteburns Transport History for material 12

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.157	4.40E+14	2.37E-02	4.32E+01	3.028E+02	0.000E+00	3.68E-01	3.47E-01	9.45E-01	1.44E-03	1.203	1.10E+00	1.04E+00	9.49E-01	4.33E-03	1.206
1	182.703	4.42E+14	2.39E-02	4.40E+01	3.090E+02	4.606E+00	4.21E-01	3.50E-01	8.31E-01	1.53E-03	1.151	1.19E+00	1.05E+00	8.85E-01	4.60E-03	1.191
2	184.419	4.40E+14	2.34E-02	4.32E+01	3.028E+02	9.120E+00	4.73E-01	3.44E-01	7.26E-01	1.53E-03	1.099	1.33E+00	1.04E+00	7.79E-01	4.62E-03	1.144
3	185.437	4.38E+14	2.30E-02	4.23E+01	2.970E+02	1.355E+01	5.14E-01	3.38E-01	6.57E-01	1.62E-03	1.057	1.41E+00	1.02E+00	7.26E-01	4.91E-03	1.121
4	186.154	4.40E+14	2.29E-02	4.26E+01	2.990E+02	1.801E+01	5.45E-01	3.37E-01	6.18E-01	1.58E-03	1.032	1.47E+00	1.03E+00	6.98E-01	4.81E-03	1.111
5	186.701	4.41E+14	2.29E-02	4.29E+01	3.010E+02	2.250E+01	5.73E-01	3.38E-01	5.89E-01	1.72E-03	1.014	1.53E+00	1.03E+00	6.72E-01	5.23E-03	1.099

Monteburns Transport History for material 13

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	6.82E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.25E+00	0.00E+00	0.00E+00	2.51E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	7.16E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	8.96E-01	0.00E+00	0.00E+00	5.10E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	7.72E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	3.70E-01	0.00E+00	0.00E+00	2.13E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	8.20E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	6.54E-02	0.00E+00	0.00E+00	3.07E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	8.08E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.28E-02	0.00E+00	0.00E+00	6.36E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	8.00E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	9.09E-03	0.00E+00	0.00E+00	1.59E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

The MONTEBURNS Output File Chem Shim Peak #12 B_4C/Al_2O_3 BPRAs

RESEARCH CRYSTAL RIVER 1/8 CORE WITH B4CAL2O3 BPRA'S 4.66% ENRICH B let

Total Power (MW) = 3.18E+02 Days = 6.70E+02
outer steps = 5, # inner steps = 50, # predictor steps = 1
Importance Fraction = 0.0050

Monteburns MCNP k-eff Versus Time

	days	k-eff	rel err	nu	avQfis	eta
0m	0.00	1.00155	0.00054	2.468	181.130	0.757
1m	67.00	1.00410	0.00048	2.520	182.021	0.844
2m	201.00	1.00116	0.00078	2.592	183.269	1.006
3m	335.00	1.00383	0.00069	2.642	184.180	1.110
4m	469.00	1.00881	0.00073	2.681	184.891	1.118
5m	603.00	1.01047	0.00063	2.717	185.493	1.101

Monteburns Transport History

Monteburns Transport History for material 1

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	1.03E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	8.98E-02	0.00E+00	0.00E+00	2.25E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	1.04E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	7.72E-02	0.00E+00	0.00E+00	3.46E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	1.07E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	7.03E-02	0.00E+00	0.00E+00	2.94E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	1.08E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	6.07E-02	0.00E+00	0.00E+00	3.54E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	1.09E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	4.81E-02	0.00E+00	0.00E+00	4.67E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	1.11E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	3.48E-02	0.00E+00	0.00E+00	4.23E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

Monteburns Transport History for material 2

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.091	4.70E+14	3.51E-02	4.38E+01	4.787E+02	0.000E+00	3.83E-01	5.14E-01	1.34E+00	1.67E-03	1.418	1.14E+00	1.54E+00	1.35E+00	5.00E-03	1.421
1	181.745	4.94E+14	3.40E-02	4.48E+01	4.901E+02	7.304E+00	4.27E-01	4.98E-01	1.17E+00	1.64E-03	1.360	1.19E+00	1.50E+00	1.26E+00	4.95E-03	1.410
2	182.767	4.99E+14	3.23E-02	4.33E+01	4.737E+02	1.436E+01	4.82E-01	4.75E-01	9.87E-01	1.70E-03	1.291	1.30E+00	1.44E+00	1.11E+00	5.13E-03	1.365
3	183.615	5.26E+14	3.14E-02	4.46E+01	4.879E+02	2.163E+01	5.20E-01	4.63E-01	8.89E-01	1.75E-03	1.247	1.37E+00	1.41E+00	1.03E+00	5.32E-03	1.342

4	184.366	5.10E+14	3.03E-02	4.18E+01	4.574E+02	2.845E+01	5.57E-01	4.46E-01	8.02E-01	1.71E-03	1.197	1.45E+00	1.37E+00	9.45E-01	5.21E-03	1.306
5	185.011	4.98E+14	2.94E-02	3.97E+01	4.343E+02	3.492E+01	5.92E-01	4.34E-01	7.33E-01	1.73E-03	1.153	1.53E+00	1.34E+00	8.78E-01	5.30E-03	1.274

Monteburns Transport History for material 3 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.091	5.10E+14	3.49E-02	2.36E+01	5.167E+02	0.000E+00	3.79E-01	5.11E-01	1.35E+00	1.68E-03	1.421	1.13E+00	1.53E+00	1.36E+00	5.04E-03	1.424
1	181.775	5.25E+14	3.40E-02	2.38E+01	5.196E+02	7.743E+00	4.29E-01	4.97E-01	1.16E+00	1.62E-03	1.357	1.19E+00	1.50E+00	1.26E+00	4.89E-03	1.407
2	182.843	5.25E+14	3.23E-02	2.27E+01	4.973E+02	1.515E+01	4.81E-01	4.74E-01	9.87E-01	1.74E-03	1.291	1.29E+00	1.44E+00	1.11E+00	5.26E-03	1.367
3	183.706	5.23E+14	3.13E-02	2.21E+01	4.827E+02	2.234E+01	5.29E-01	4.61E-01	8.71E-01	1.65E-03	1.233	1.40E+00	1.40E+00	1.01E+00	5.01E-03	1.329
4	184.446	5.04E+14	3.01E-02	2.06E+01	4.497E+02	2.904E+01	5.61E-01	4.44E-01	7.91E-01	1.70E-03	1.187	1.46E+00	1.36E+00	9.33E-01	5.18E-03	1.297
5	185.066	4.75E+14	2.92E-02	1.89E+01	4.128E+02	3.519E+01	5.93E-01	4.32E-01	7.29E-01	1.74E-03	1.149	1.53E+00	1.33E+00	8.74E-01	5.34E-03	1.271

Monteburns Transport History for material 4 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.156	1.63E+13	2.60E-02	4.95E-01	1.229E+01	0.000E+00	3.77E-01	3.81E-01	1.01E+00	1.57E-03	1.245	1.13E+00	1.14E+00	1.02E+00	4.70E-03	1.248
1	181.211	1.80E+13	2.60E-02	5.49E-01	1.363E+01	2.031E-01	3.74E-01	3.80E-01	1.02E+00	1.27E-03	1.274	1.10E+00	1.14E+00	1.04E+00	3.81E-03	1.287
2	181.321	1.72E+13	2.69E-02	5.48E-01	1.359E+01	4.056E-01	4.03E-01	3.94E-01	9.78E-01	1.63E-03	1.286	1.18E+00	1.18E+00	1.00E+00	4.88E-03	1.302
3	181.424	1.94E+13	2.84E-02	6.55E-01	1.626E+01	6.479E-01	4.08E-01	4.16E-01	1.02E+00	1.47E-03	1.338	1.19E+00	1.25E+00	1.05E+00	4.41E-03	1.357
4	181.535	2.36E+13	2.96E-02	8.34E-01	2.069E+01	9.562E-01	4.09E-01	4.33E-01	1.06E+00	1.67E-03	1.383	1.19E+00	1.30E+00	1.09E+00	5.01E-03	1.404
5	181.669	2.88E+13	3.13E-02	1.08E+00	2.680E+01	1.356E+00	4.18E-01	4.58E-01	1.10E+00	1.53E-03	1.425	1.21E+00	1.38E+00	1.14E+00	4.60E-03	1.449

Monteburns Transport History for material 5 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.087	4.02E+14	3.60E-02	1.16E+02	4.201E+02	0.000E+00	3.82E-01	5.27E-01	1.38E+00	1.65E-03	1.435	1.14E+00	1.58E+00	1.39E+00	4.94E-03	1.438
1	181.618	3.90E+14	3.50E-02	1.10E+02	3.977E+02	5.925E+00	4.24E-01	5.13E-01	1.21E+00	1.65E-03	1.384	1.18E+00	1.54E+00	1.31E+00	4.95E-03	1.433
2	182.442	3.99E+14	3.35E-02	1.09E+02	3.932E+02	1.178E+01	4.65E-01	4.93E-01	1.06E+00	1.71E-03	1.337	1.27E+00	1.49E+00	1.18E+00	5.15E-03	1.404
3	183.151	3.97E+14	3.27E-02	1.06E+02	3.825E+02	1.748E+01	5.01E-01	4.80E-01	9.58E-01	1.74E-03	1.296	1.34E+00	1.46E+00	1.09E+00	5.28E-03	1.381
4	183.744	4.02E+14	3.20E-02	1.05E+02	3.805E+02	2.315E+01	5.31E-01	4.71E-01	8.87E-01	1.75E-03	1.264	1.40E+00	1.44E+00	1.03E+00	5.32E-03	1.364
5	184.301	4.01E+14	3.11E-02	1.03E+02	3.700E+02	2.866E+01	5.61E-01	4.58E-01	8.17E-01	1.71E-03	1.225	1.46E+00	1.41E+00	9.63E-01	5.21E-03	1.337

Monteburns Transport History for material 6 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.448	3.65E+14	1.22E-02	3.32E-01	1.286E+02	0.000E+00	1.73E+00	1.87E-01	1.08E-01	1.63E-03	0.243	9.54E-01	5.79E-01	6.07E-01	4.93E-03	0.939
1	181.933	3.39E+14	1.57E-02	4.01E-01	1.553E+02	2.511E+00	1.39E+00	2.42E-01	1.74E-01	1.38E-03	0.375	9.74E-01	7.49E-01	7.69E-01	4.20E-03	1.100
2	182.487	3.58E+14	2.50E-02	6.77E-01	2.622E+02	6.752E+00	8.52E-01	3.85E-01	4.52E-01	1.71E-03	0.810	1.19E+00	1.20E+00	1.01E+00	5.25E-03	1.304
3	183.105	3.48E+14	2.98E-02	7.91E-01	3.061E+02	1.170E+01	5.07E-01	4.61E-01	9.10E-01	1.58E-03	1.262	1.28E+00	1.44E+00	1.12E+00	4.89E-03	1.399
4	183.583	3.50E+14	2.89E-02	7.73E-01	2.991E+02	1.654E+01	5.40E-01	4.47E-01	8.28E-01	1.90E-03	1.218	1.38E+00	1.40E+00	1.01E+00	5.85E-03	1.354
5	184.115	3.65E+14	2.84E-02	7.94E-01	3.076E+02	2.151E+01	5.64E-01	4.40E-01	7.80E-01	1.89E-03	1.195	1.43E+00	1.38E+00	9.65E-01	5.84E-03	1.339

Monteburns Transport History for material 7 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.616	3.89E+14	9.27E-03	9.91E-01	1.046E+02	0.000E+00	1.93E+00	1.42E-01	7.38E-02	1.61E-03	0.171	8.97E-01	4.53E-01	5.05E-01	4.90E-03	0.836
1	182.307	4.09E+14	1.09E-02	1.23E+00	1.297E+02	2.152E+00	1.72E+00	1.67E-01	9.66E-02	1.65E-03	0.224	9.49E-01	5.33E-01	5.61E-01	5.08E-03	0.913
2	183.316	4.32E+14	1.50E-02	1.80E+00	1.905E+02	5.312E+00	1.40E+00	2.31E-01	1.65E-01	1.64E-03	0.369	1.09E+00	7.38E-01	6.80E-01	5.12E-03	1.055
3	183.812	4.68E+14	2.42E-02	3.16E+00	3.342E+02	1.085E+01	8.03E-01	3.72E-01	4.63E-01	1.67E-03	0.839	1.29E+00	1.19E+00	9.24E-01	5.23E-03	1.273
4	184.418	4.75E+14	2.69E-02	3.59E+00	3.791E+02	1.714E+01	5.77E-01	4.14E-01	7.18E-01	1.68E-03	1.124	1.42E+00	1.34E+00	9.41E-01	5.28E-03	1.304
5	185.012	4.66E+14	2.60E-02	3.41E+00	3.603E+02	2.312E+01	5.95E-01	4.01E-01	6.74E-01	1.69E-03	1.097	1.46E+00	1.30E+00	8.91E-01	5.35E-03	1.284

Monteburns Transport History for material 8 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.613	9.58E+14	9.35E-03	2.24E-01	2.602E+02	0.000E+00	1.98E+00	1.43E-01	7.25E-02	1.71E-03	0.168	9.33E-01	4.57E-01	4.90E-01	5.20E-03	0.819
1	182.950	1.04E+15	1.52E-02	3.94E-01	4.581E+02	7.599E+00	1.35E+00	2.32E-01	1.72E-01	1.66E-03	0.372	1.05E+00	7.42E-01	7.09E-01	5.16E-03	1.051
2	184.456	1.10E+15	2.60E-02	7.25E-01	8.425E+02	2.157E+01	6.26E-01	3.99E-01	6.38E-01	1.60E-03	1.013	1.34E+00	1.29E+00	9.58E-01	5.01E-03	1.272
3	185.773	1.08E+15	2.30E-02	6.30E-01	7.321E+02	3.371E+01	6.11E-01	3.55E-01	5.81E-01	1.72E-03	0.975	1.49E+00	1.16E+00	7.76E-01	5.47E-03	1.159
4	186.793	1.04E+15	2.22E-02	5.88E-01	6.827E+02	4.503E+01	6.63E-01	3.43E-01	5.18E-01	1.82E-03	0.918	1.60E+00	1.13E+00	7.07E-01	5.84E-03	1.115
5	187.455	9.84E+14	2.08E-02	5.24E-01	6.084E+02	5.512E+01	6.82E-01	3.22E-01	4.72E-01	1.53E-03	0.875	1.63E+00	1.07E+00	6.59E-01	4.96E-03	1.083

Monteburns Transport History for material 9

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	total material n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	for actinide n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	184.689	1.19E+13	2.81E-02	5.69E-01	9.753E+00	0.000E+00	1.40E+00	1.08E+00	7.71E-01	5.53E-03	1.079	1.42E+00	1.09E+00	7.71E-01	5.59E-03	1.079
1	184.693	1.38E+13	2.88E-02	6.78E-01	1.162E+01	1.527E-01	1.37E+00	1.10E+00	8.04E-01	5.02E-03	1.127	1.38E+00	1.12E+00	8.10E-01	5.08E-03	1.132
2	184.707	1.27E+13	2.88E-02	6.27E-01	1.075E+01	2.940E-01	1.38E+00	1.10E+00	7.97E-01	4.72E-03	1.153	1.38E+00	1.11E+00	8.10E-01	4.78E-03	1.163
3	184.700	1.43E+13	2.91E-02	7.17E-01	1.229E+01	4.555E-01	1.43E+00	1.11E+00	7.75E-01	5.31E-03	1.158	1.42E+00	1.12E+00	7.87E-01	5.37E-03	1.168
4	184.726	1.82E+13	3.03E-02	9.55E-01	1.636E+01	6.705E-01	1.44E+00	1.16E+00	8.05E-01	5.46E-03	1.200	1.43E+00	1.17E+00	8.20E-01	5.53E-03	1.212
5	184.754	2.19E+13	3.22E-02	1.22E+00	2.098E+01	9.463E-01	1.47E+00	1.24E+00	8.41E-01	4.45E-03	1.244	1.45E+00	1.25E+00	8.60E-01	4.50E-03	1.260

Monteburns Transport History for material 10

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	total material n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	for actinide n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	181.193	1.26E+14	2.06E-02	1.48E+01	7.533E+01	0.000E+00	3.91E-01	3.01E-01	7.71E-01	1.43E-03	1.079	1.17E+00	9.04E-01	7.75E-01	4.30E-03	1.082
1	181.932	1.22E+14	2.12E-02	1.48E+01	7.552E+01	1.125E+00	4.17E-01	3.10E-01	7.43E-01	1.48E-03	1.079	1.20E+00	9.31E-01	7.79E-01	4.44E-03	1.108
2	182.993	1.27E+14	2.16E-02	1.58E+01	8.073E+01	2.328E+00	4.37E-01	3.16E-01	7.24E-01	1.59E-03	1.093	1.25E+00	9.50E-01	7.59E-01	4.78E-03	1.122
3	183.844	1.27E+14	2.26E-02	1.66E+01	8.464E+01	3.589E+00	4.55E-01	3.31E-01	7.27E-01	1.57E-03	1.116	1.31E+00	9.95E-01	7.62E-01	4.71E-03	1.147
4	184.461	1.41E+14	2.34E-02	1.92E+01	9.764E+01	5.044E+00	4.74E-01	3.43E-01	7.23E-01	1.59E-03	1.129	1.36E+00	1.03E+00	7.59E-01	4.78E-03	1.161
5	185.038	1.66E+14	2.44E-02	2.36E+01	1.204E+02	6.838E+00	5.06E-01	3.58E-01	7.08E-01	1.57E-03	1.130	1.43E+00	1.08E+00	7.57E-01	4.75E-03	1.175

Monteburns Transport History for material 11

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	total material n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	for actinide n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	181.172	3.83E+14	2.29E-02	7.24E+01	2.544E+02	0.000E+00	3.78E-01	3.35E-01	8.87E-01	1.49E-03	1.164	1.13E+00	1.01E+00	8.91E-01	4.47E-03	1.167
1	182.574	4.05E+14	2.32E-02	7.78E+01	2.734E+02	4.074E+00	4.24E-01	3.39E-01	8.00E-01	1.50E-03	1.124	1.20E+00	1.02E+00	8.49E-01	4.51E-03	1.161
2	184.376	4.15E+14	2.28E-02	7.92E+01	2.780E+02	8.217E+00	4.67E-01	3.35E-01	7.18E-01	1.56E-03	1.087	1.32E+00	1.01E+00	7.66E-01	4.69E-03	1.128
3	185.503	4.29E+14	2.26E-02	8.13E+01	2.855E+02	1.247E+01	5.11E-01	3.31E-01	6.49E-01	1.68E-03	1.043	1.40E+00	1.00E+00	7.19E-01	5.06E-03	1.109
4	186.314	4.30E+14	2.26E-02	8.21E+01	2.883E+02	1.677E+01	5.43E-01	3.33E-01	6.13E-01	1.63E-03	1.022	1.46E+00	1.01E+00	6.92E-01	4.94E-03	1.101
5	186.901	4.34E+14	2.28E-02	8.37E+01	2.940E+02	2.115E+01	5.71E-01	3.35E-01	5.87E-01	1.68E-03	1.009	1.53E+00	1.02E+00	6.70E-01	5.12E-03	1.094

Monteburns Transport History for material 12

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	total material n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	for actinide n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	181.153	4.30E+14	2.50E-02	4.45E+01	3.122E+02	0.000E+00	3.78E-01	3.66E-01	9.69E-01	1.48E-03	1.218	1.13E+00	1.10E+00	9.73E-01	4.44E-03	1.221
1	182.445	4.28E+14	2.49E-02	4.44E+01	3.113E+02	4.640E+00	4.25E-01	3.65E-01	8.59E-01	1.54E-03	1.168	1.20E+00	1.10E+00	9.16E-01	4.64E-03	1.209
2	184.147	4.32E+14	2.41E-02	4.36E+01	3.058E+02	9.198E+00	4.73E-01	3.54E-01	7.48E-01	1.64E-03	1.113	1.33E+00	1.07E+00	8.05E-01	4.93E-03	1.160
3	185.269	4.19E+14	2.36E-02	4.16E+01	2.919E+02	1.355E+01	5.15E-01	3.47E-01	6.74E-01	1.63E-03	1.067	1.40E+00	1.05E+00	7.50E-01	4.92E-03	1.136
4	186.031	4.23E+14	2.35E-02	4.20E+01	2.949E+02	1.795E+01	5.46E-01	3.46E-01	6.34E-01	1.65E-03	1.044	1.46E+00	1.05E+00	7.19E-01	5.02E-03	1.126
5	186.643	4.29E+14	2.36E-02	4.29E+01	3.008E+02	2.243E+01	5.74E-01	3.47E-01	6.06E-01	1.70E-03	1.029	1.53E+00	1.06E+00	6.94E-01	5.17E-03	1.118

Monteburns Transport History for material 13

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	total material n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	for actinide n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	0.000	6.68E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.18E+00	0.00E+00	0.00E+00	3.38E-08	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	7.06E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	8.92E-01	0.00E+00	0.00E+00	1.35E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	7.54E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	4.03E-01	0.00E+00	0.00E+00	5.54E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	7.99E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	7.48E-02	0.00E+00	0.00E+00	8.41E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	7.90E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.33E-02	0.00E+00	0.00E+00	1.50E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	7.74E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	9.83E-03	0.00E+00	0.00E+00	5.94E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

The MONTEBURNS Output File Chem Shim Peak #4 L-Carborane BPRAs

Importance Fraction = 0.0050

Monteburns MCNP k-eff Versus Time

	days	k-eff	rel err	nu	avQfis	eta
0m	0.00	0.99372	0.00046	2.469	181.133	0.738
1m	67.00	0.99884	0.00063	2.526	182.199	0.826
2m	201.00	0.99986	0.00075	2.604	183.508	0.964
3m	335.00	1.00138	0.00058	2.652	184.393	1.119

4m	469.00	0.99984	0.00059	2.692	185.074	1.116
5m	603.00	0.99842	0.00062	2.725	185.624	1.092

Monteburns Transport History

Monteburns Transport History for material 1

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	1.07E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	8.65E-02	0.00E+00	0.00E+00	2.64E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	1.08E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	7.37E-02	0.00E+00	0.00E+00	3.64E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	1.09E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	6.63E-02	0.00E+00	0.00E+00	3.71E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	1.11E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	5.75E-02	0.00E+00	0.00E+00	3.66E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	1.12E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	4.51E-02	0.00E+00	0.00E+00	3.24E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	1.15E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	3.20E-02	0.00E+00	0.00E+00	5.12E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

Monteburns Transport History for material 2

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.092	4.83E+14	3.44E-02	5.51E+01	4.819E+02	0.000E+00	3.75E-01	5.03E-01	1.34E+00	1.67E-03	1.419	1.12E+00	1.51E+00	1.35E+00	5.00E-03	1.422
1	181.881	4.96E+14	3.32E-02	5.49E+01	4.805E+02	7.160E+00	4.28E-01	4.86E-01	1.14E+00	1.68E-03	1.348	1.19E+00	1.46E+00	1.23E+00	5.06E-03	1.396
2	182.962	5.26E+14	3.20E-02	5.66E+01	4.950E+02	1.454E+01	4.87E-01	4.70E-01	9.64E-01	1.72E-03	1.282	1.32E+00	1.42E+00	1.08E+00	5.20E-03	1.354
3	183.847	5.32E+14	3.08E-02	5.53E+01	4.838E+02	2.175E+01	5.29E-01	4.54E-01	8.57E-01	1.71E-03	1.228	1.40E+00	1.38E+00	9.86E-01	5.19E-03	1.321
4	184.556	5.19E+14	2.98E-02	5.24E+01	4.581E+02	2.858E+01	5.66E-01	4.39E-01	7.76E-01	1.75E-03	1.180	1.48E+00	1.35E+00	9.08E-01	5.33E-03	1.285
5	185.150	4.99E+14	2.87E-02	4.87E+01	4.257E+02	3.492E+01	5.99E-01	4.23E-01	7.07E-01	1.72E-03	1.132	1.55E+00	1.31E+00	8.41E-01	5.27E-03	1.248

Monteburns Transport History for material 3

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.093	4.70E+14	3.42E-02	1.07E+01	4.664E+02	0.000E+00	3.76E-01	5.01E-01	1.33E+00	1.73E-03	1.415	1.12E+00	1.50E+00	1.34E+00	5.19E-03	1.418
1	181.914	4.96E+14	3.34E-02	1.11E+01	4.834E+02	7.203E+00	4.31E-01	4.88E-01	1.13E+00	1.58E-03	1.345	1.20E+00	1.47E+00	1.22E+00	4.76E-03	1.394
2	182.971	5.49E+14	3.19E-02	1.18E+01	5.159E+02	1.489E+01	4.87E-01	4.69E-01	9.63E-01	1.78E-03	1.281	1.32E+00	1.42E+00	1.07E+00	5.39E-03	1.353
3	183.897	5.62E+14	3.07E-02	1.17E+01	5.103E+02	2.249E+01	5.35E-01	4.52E-01	8.46E-01	1.67E-03	1.219	1.42E+00	1.38E+00	9.75E-01	5.08E-03	1.313
4	184.666	5.59E+14	2.94E-02	1.11E+01	4.869E+02	2.975E+01	5.72E-01	4.33E-01	7.57E-01	1.80E-03	1.164	1.49E+00	1.33E+00	8.90E-01	5.51E-03	1.272
5	185.292	5.37E+14	2.85E-02	1.04E+01	4.558E+02	3.654E+01	6.09E-01	4.21E-01	6.92E-01	1.66E-03	1.117	1.58E+00	1.30E+00	8.24E-01	5.09E-03	1.235

Monteburns Transport History for material 4

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.160	1.77E+13	2.41E-02	5.00E-01	1.242E+01	0.000E+00	3.68E-01	3.53E-01	9.61E-01	1.25E-03	1.213	1.10E+00	1.06E+00	9.65E-01	3.75E-03	1.216
1	181.228	1.74E+13	2.48E-02	5.06E-01	1.257E+01	1.873E-01	3.65E-01	3.63E-01	9.93E-01	1.56E-03	1.263	1.08E+00	1.09E+00	1.01E+00	4.69E-03	1.272
2	181.379	1.74E+13	2.53E-02	5.22E-01	1.296E+01	3.805E-01	3.84E-01	3.71E-01	9.66E-01	1.66E-03	1.284	1.12E+00	1.11E+00	9.92E-01	4.99E-03	1.301
3	181.509	1.88E+13	2.70E-02	6.04E-01	1.499E+01	6.038E-01	3.95E-01	3.96E-01	1.00E+00	1.57E-03	1.332	1.15E+00	1.19E+00	1.03E+00	4.70E-03	1.351
4	181.660	2.13E+13	2.73E-02	6.95E-01	1.724E+01	8.607E-01	3.78E-01	3.99E-01	1.06E+00	1.68E-03	1.388	1.10E+00	1.20E+00	1.09E+00	5.03E-03	1.408
5	181.791	2.73E+13	2.87E-02	9.40E-01	2.332E+01	1.208E+00	3.98E-01	4.20E-01	1.06E+00	1.73E-03	1.404	1.16E+00	1.26E+00	1.09E+00	5.20E-03	1.427

Monteburns Transport History for material 5

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.087	4.22E+14	3.52E-02	1.19E+02	4.303E+02	0.000E+00	3.77E-01	5.15E-01	1.37E+00	1.63E-03	1.429	1.12E+00	1.54E+00	1.37E+00	4.88E-03	1.432
1	181.733	4.09E+14	3.41E-02	1.13E+02	4.070E+02	6.065E+00	4.22E-01	5.00E-01	1.19E+00	1.64E-03	1.374	1.18E+00	1.50E+00	1.28E+00	4.93E-03	1.422
2	182.667	3.99E+14	3.28E-02	1.07E+02	3.852E+02	1.180E+01	4.72E-01	4.82E-01	1.02E+00	1.65E-03	1.319	1.29E+00	1.46E+00	1.13E+00	4.98E-03	1.384
3	183.365	3.99E+14	3.19E-02	1.04E+02	3.764E+02	1.741E+01	5.09E-01	4.69E-01	9.23E-01	1.66E-03	1.276	1.37E+00	1.43E+00	1.04E+00	5.03E-03	1.358
4	183.950	4.06E+14	3.11E-02	1.04E+02	3.742E+02	2.299E+01	5.37E-01	4.58E-01	8.53E-01	1.69E-03	1.242	1.42E+00	1.40E+00	9.82E-01	5.15E-03	1.337
5	184.477	4.10E+14	3.04E-02	1.03E+02	3.706E+02	2.851E+01	5.67E-01	4.48E-01	7.89E-01	1.76E-03	1.205	1.49E+00	1.37E+00	9.22E-01	5.36E-03	1.311

Monteburns Transport History for material 6

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.373	3.93E+14	1.38E-02	4.06E-01	1.574E+02	0.000E+00	1.74E+00	2.13E-01	1.22E-01	1.37E-03	0.270	9.38E-01	6.58E-01	7.01E-01	4.14E-03	1.023
1	182.008	3.68E+14	1.80E-02	4.99E-01	1.933E+02	3.126E+00	1.27E+00	2.78E-01	2.18E-01	1.60E-03	0.455	1.02E+00	8.60E-01	8.40E-01	4.88E-03	1.159
2	182.826	3.43E+14	2.60E-02	6.77E-01	2.622E+02	7.367E+00	7.99E-01	4.02E-01	5.03E-01	1.56E-03	0.874	1.27E+00	1.25E+00	9.82E-01	4.78E-03	1.294
3	183.403	3.53E+14	2.86E-02	7.68E-01	2.974E+02	1.218E+01	5.24E-01	4.41E-01	8.42E-01	1.38E-03	1.215	1.35E+00	1.38E+00	1.02E+00	4.26E-03	1.341
4	183.928	3.47E+14	2.81E-02	7.47E-01	2.893E+02	1.686E+01	5.45E-01	4.35E-01	7.99E-01	1.77E-03	1.200	1.40E+00	1.36E+00	9.76E-01	5.45E-03	1.334

5	184.336	3.62E+14	2.74E-02	7.62E-01	2.951E+02	2.163E+01	5.63E-01	4.25E-01	7.54E-01	1.50E-03	1.175	1.44E+00	1.34E+00	9.30E-01	4.66E-03	1.316

Monteburns Transport History for material 7

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.552	4.33E+14	1.01E-02	1.21E+00	1.273E+02	0.000E+00	2.02E+00	1.55E-01	7.69E-02	1.77E-03	0.178	8.95E-01	4.95E-01	5.53E-01	5.38E-03	0.887
1	182.495	4.60E+14	1.26E-02	1.61E+00	1.695E+02	2.811E+00	1.69E+00	1.93E-01	1.15E-01	1.58E-03	0.262	9.79E-01	6.18E-01	6.31E-01	4.89E-03	0.984
2	183.654	5.00E+14	1.85E-02	2.57E+00	2.714E+02	7.313E+00	1.22E+00	2.83E-01	2.33E-01	1.65E-03	0.494	1.17E+00	9.08E-01	7.74E-01	5.15E-03	1.141
3	184.270	5.32E+14	2.51E-02	3.73E+00	3.942E+02	1.385E+01	6.48E-01	3.86E-01	5.95E-01	1.64E-03	0.993	1.37E+00	1.24E+00	9.06E-01	5.15E-03	1.265
4	184.929	5.34E+14	2.53E-02	3.79E+00	4.001E+02	2.049E+01	5.81E-01	3.89E-01	6.70E-01	1.69E-03	1.083	1.45E+00	1.26E+00	8.72E-01	5.34E-03	1.258
5	185.502	5.21E+14	2.42E-02	3.56E+00	3.759E+02	2.672E+01	6.05E-01	3.74E-01	6.18E-01	1.70E-03	1.044	1.50E+00	1.22E+00	8.09E-01	5.40E-03	1.223

Monteburns Transport History for material 8

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.539	4.32E+14	1.02E-02	1.10E-01	1.274E+02	0.000E+00	2.09E+00	1.56E-01	7.46E-02	2.15E-03	0.173	9.33E-01	4.97E-01	5.33E-01	6.51E-03	0.867
1	182.559	4.72E+14	1.30E-02	1.54E-01	1.793E+02	2.974E+00	1.67E+00	1.99E-01	1.20E-01	1.55E-03	0.272	9.78E-01	6.37E-01	6.52E-01	4.80E-03	1.003
2	183.631	5.48E+14	1.87E-02	2.59E-01	3.007E+02	7.961E+00	1.17E+00	2.86E-01	2.44E-01	1.93E-03	0.514	1.16E+00	9.18E-01	7.94E-01	6.00E-03	1.158
3	184.366	5.89E+14	2.62E-02	3.93E-01	4.566E+02	1.553E+01	6.31E-01	4.03E-01	6.39E-01	1.36E-03	1.037	1.41E+00	1.30E+00	9.23E-01	4.30E-03	1.276
4	185.054	5.82E+14	2.42E-02	3.59E-01	4.172E+02	2.245E+01	5.70E-01	3.72E-01	6.53E-01	1.69E-03	1.068	1.39E+00	1.21E+00	8.66E-01	5.34E-03	1.254
5	185.641	5.59E+14	2.35E-02	3.36E-01	3.903E+02	2.892E+01	6.11E-01	3.62E-01	5.92E-01	1.90E-03	1.017	1.53E+00	1.18E+00	7.72E-01	6.05E-03	1.192

Monteburns Transport History for material 9

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	185.221	1.23E+13	2.81E-02	5.87E-01	1.005E+01	0.000E+00	1.42E+00	1.07E+00	7.54E-01	5.24E-03	1.066	1.44E+00	1.09E+00	7.54E-01	5.30E-03	1.066
1	185.151	1.32E+13	2.86E-02	6.43E-01	1.102E+01	1.449E-01	1.41E+00	1.09E+00	7.77E-01	4.81E-03	1.108	1.42E+00	1.11E+00	7.81E-01	4.86E-03	1.112
2	185.131	1.24E+13	2.78E-02	5.93E-01	1.017E+01	2.785E-01	1.39E+00	1.06E+00	7.63E-01	5.47E-03	1.132	1.39E+00	1.08E+00	7.74E-01	5.54E-03	1.141
3	185.186	1.39E+13	2.85E-02	6.82E-01	1.168E+01	4.321E-01	1.42E+00	1.09E+00	7.70E-01	5.23E-03	1.158	1.42E+00	1.11E+00	7.81E-01	5.29E-03	1.167
4	185.213	1.56E+13	2.95E-02	7.94E-01	1.360E+01	6.109E-01	1.43E+00	1.13E+00	7.91E-01	6.23E-03	1.194	1.42E+00	1.14E+00	8.05E-01	6.30E-03	1.205
5	185.201	2.04E+13	3.09E-02	1.09E+00	1.874E+01	8.573E-01	1.47E+00	1.19E+00	8.08E-01	4.90E-03	1.222	1.46E+00	1.20E+00	8.24E-01	4.96E-03	1.234

Monteburns Transport History for material 10

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.198	1.42E+14	1.92E-02	1.55E+01	7.911E+01	0.000E+00	3.74E-01	2.81E-01	7.53E-01	1.41E-03	1.065	1.12E+00	8.44E-01	7.56E-01	4.23E-03	1.067
1	182.142	1.35E+14	1.99E-02	1.54E+01	7.873E+01	1.173E+00	4.03E-01	2.92E-01	7.26E-01	1.45E-03	1.067	1.15E+00	8.77E-01	7.60E-01	4.34E-03	1.095
2	183.394	1.27E+14	2.08E-02	1.52E+01	7.740E+01	2.326E+00	4.31E-01	3.04E-01	7.06E-01	1.52E-03	1.082	1.24E+00	9.15E-01	7.39E-01	4.57E-03	1.111
3	184.167	1.32E+14	2.14E-02	1.64E+01	8.346E+01	3.570E+00	4.49E-01	3.14E-01	7.00E-01	1.52E-03	1.096	1.29E+00	9.46E-01	7.32E-01	4.57E-03	1.125
4	184.760	1.43E+14	2.24E-02	1.86E+01	9.480E+01	4.983E+00	4.71E-01	3.28E-01	6.97E-01	1.55E-03	1.110	1.35E+00	9.88E-01	7.31E-01	4.66E-03	1.141
5	185.279	1.72E+14	2.34E-02	2.34E+01	1.194E+02	6.763E+00	4.99E-01	3.43E-01	6.88E-01	1.63E-03	1.115	1.41E+00	1.04E+00	7.34E-01	4.92E-03	1.157

Monteburns Transport History for material 11

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.175	3.98E+14	2.17E-02	7.14E+01	2.506E+02	0.000E+00	3.66E-01	3.18E-01	8.70E-01	1.44E-03	1.153	1.09E+00	9.55E-01	8.74E-01	4.33E-03	1.156
1	182.862	4.13E+14	2.22E-02	7.63E+01	2.679E+02	3.992E+00	4.19E-01	3.25E-01	7.76E-01	1.51E-03	1.108	1.19E+00	9.77E-01	8.23E-01	4.54E-03	1.145
2	184.625	4.36E+14	2.22E-02	8.10E+01	2.845E+02	8.232E+00	4.66E-01	3.26E-01	7.00E-01	1.56E-03	1.076	1.32E+00	9.83E-01	7.44E-01	4.72E-03	1.115
3	185.700	4.41E+14	2.20E-02	8.17E+01	2.870E+02	1.251E+01	5.11E-01	3.24E-01	6.34E-01	1.59E-03	1.033	1.41E+00	9.80E-01	6.94E-01	4.80E-03	1.090
4	186.422	4.50E+14	2.21E-02	8.40E+01	2.949E+02	1.691E+01	5.45E-01	3.25E-01	5.96E-01	1.63E-03	1.009	1.47E+00	9.88E-01	6.70E-01	4.95E-03	1.084
5	186.961	4.49E+14	2.21E-02	8.41E+01	2.953E+02	2.131E+01	5.71E-01	3.26E-01	5.70E-01	1.64E-03	0.993	1.53E+00	9.94E-01	6.48E-01	4.99E-03	1.075

Monteburns Transport History for material 12

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.155	4.44E+14	2.38E-02	4.37E+01	3.067E+02	0.000E+00	3.68E-01	3.48E-01	9.46E-01	1.50E-03	1.204	1.10E+00	1.04E+00	9.51E-01	4.49E-03	1.207
1	182.692	4.42E+14	2.39E-02	4.39E+01	3.081E+02	4.593E+00	4.20E-01	3.50E-01	8.32E-01	1.56E-03	1.152	1.19E+00	1.05E+00	8.86E-01	4.68E-03	1.191
2	184.414	4.34E+14	2.34E-02	4.26E+01	2.987E+02	9.045E+00	4.72E-01	3.44E-01	7.28E-01	1.57E-03	1.101	1.33E+00	1.04E+00	7.82E-01	4.73E-03	1.147
3	185.409	4.34E+14	2.30E-02	4.20E+01	2.950E+02	1.344E+01	5.14E-01	3.38E-01	6.58E-01	1.60E-03	1.056	1.41E+00	1.03E+00	7.27E-01	4.84E-03	1.120
4	186.133	4.34E+14	2.29E-02	4.21E+01	2.954E+02	1.784E+01	5.46E-01	3.37E-01	6.18E-01	1.60E-03	1.031	1.47E+00	1.03E+00	6.97E-01	4.86E-03	1.110
5	186.679	4.44E+14	2.29E-02	4.30E+01	3.018E+02	2.234E+01	5.70E-01	3.37E-01	5.91E-01	1.59E-03	1.016	1.53E+00	1.03E+00	6.74E-01	4.85E-03	1.101

Monteburns Transport History for material 13 total material for actinide

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	0.000	6.60E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.83E+00	0.00E+00	0.00E+00	8.20E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	7.07E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.25E+00	0.00E+00	0.00E+00	8.14E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	7.86E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	4.40E-01	0.00E+00	0.00E+00	7.99E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	8.20E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	4.65E-02	0.00E+00	0.00E+00	8.74E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	8.24E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.86E-02	0.00E+00	0.00E+00	9.56E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	8.07E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.82E-02	0.00E+00	0.00E+00	1.08E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

The MONTEBURNS Output File Chem Shim Peak #12 L-Carborane BPRAs

RESEARCH CRYSTAL RIVER 1/8 CORE WITH L-CARBORANE BPRA'S 4.66% ENRICH NO

Total Power (MW) = 3.18E+02 Days = 6.70E+02
outer steps = 5, # inner steps = 50, # predictor steps = 1
Importance Fraction = 0.0050

Monteburns MCNP k-eff Versus Time

	days	k-eff	rel err	nu	avQfis	eta
0m	0.00	0.99351	0.00056	2.470	181.133	0.742
1m	67.00	0.99903	0.00057	2.528	182.204	0.856
2m	201.00	1.00173	0.00050	2.604	183.515	1.019
3m	335.00	0.99925	0.00051	2.654	184.389	1.103
4m	469.00	0.99949	0.00063	2.692	185.078	1.096
4m	469.00	0.99949	0.00063	2.692	185.078	1.096

Monteburns Transport History

Monteburns Transport History for material 1 total material for actinide

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	0.000	1.07E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	8.65E-02	0.00E+00	0.00E+00	2.34E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	1.08E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	7.39E-02	0.00E+00	0.00E+00	4.31E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	1.09E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	6.62E-02	0.00E+00	0.00E+00	3.51E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	1.11E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	5.75E-02	0.00E+00	0.00E+00	4.37E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	1.12E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	4.51E-02	0.00E+00	0.00E+00	4.20E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	1.12E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	4.51E-02	0.00E+00	0.00E+00	4.20E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

Monteburns Transport History for material 2 total material for actinide

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	181.090	4.66E+14	3.44E-02	4.26E+01	4.655E+02	0.000E+00	3.77E-01	5.04E-01	1.34E+00	1.63E-03	1.417	1.12E+00	1.51E+00	1.34E+00	4.90E-03	1.420
1	181.879	5.00E+14	3.32E-02	4.44E+01	4.851E+02	7.229E+00	4.29E-01	4.86E-01	1.13E+00	1.62E-03	1.346	1.20E+00	1.46E+00	1.22E+00	4.86E-03	1.395
2	182.980	5.22E+14	3.20E-02	4.50E+01	4.919E+02	1.456E+01	4.86E-01	4.71E-01	9.68E-01	1.71E-03	1.285	1.32E+00	1.43E+00	1.08E+00	5.18E-03	1.357
3	183.844	5.30E+14	3.08E-02	4.41E+01	4.818E+02	2.174E+01	5.30E-01	4.53E-01	8.54E-01	1.74E-03	1.226	1.41E+00	1.38E+00	9.82E-01	5.30E-03	1.319
4	184.559	5.24E+14	2.98E-02	4.23E+01	4.623E+02	2.863E+01	5.67E-01	4.39E-01	7.74E-01	1.73E-03	1.178	1.49E+00	1.35E+00	9.06E-01	5.28E-03	1.284
4	184.559	5.24E+14	2.98E-02	4.23E+01	4.623E+02	2.863E+01	5.67E-01	4.39E-01	7.74E-01	1.73E-03	1.178	1.49E+00	1.35E+00	9.06E-01	5.28E-03	1.284

Monteburns Transport History for material 3 total material for actinide

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	181.092	4.96E+14	3.41E-02	2.24E+01	4.905E+02	0.000E+00	3.76E-01	4.99E-01	1.33E+00	1.61E-03	1.413	1.12E+00	1.50E+00	1.33E+00	4.84E-03	1.416
1	181.900	5.25E+14	3.34E-02	2.34E+01	5.116E+02	7.623E+00	4.29E-01	4.89E-01	1.14E+00	1.59E-03	1.349	1.19E+00	1.47E+00	1.23E+00	4.78E-03	1.398
2	183.033	5.42E+14	3.21E-02	2.34E+01	5.118E+02	1.525E+01	4.92E-01	4.72E-01	9.59E-01	1.70E-03	1.279	1.33E+00	1.43E+00	1.07E+00	5.13E-03	1.352
3	183.930	5.28E+14	3.06E-02	2.18E+01	4.768E+02	2.235E+01	5.34E-01	4.50E-01	8.43E-01	1.75E-03	1.218	1.41E+00	1.37E+00	9.71E-01	5.32E-03	1.311
4	184.623	5.14E+14	2.97E-02	2.07E+01	4.522E+02	2.909E+01	5.66E-01	4.37E-01	7.73E-01	1.74E-03	1.177	1.48E+00	1.34E+00	9.06E-01	5.31E-03	1.283
4	184.623	5.14E+14	2.97E-02	2.07E+01	4.522E+02	2.909E+01	5.66E-01	4.37E-01	7.73E-01	1.74E-03	1.177	1.48E+00	1.34E+00	9.06E-01	5.31E-03	1.283

Monteburns Transport History for material 4 total material for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta

	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.166	1.64E+13	2.45E-02	4.70E-01	1.167E+01	0.000E+00	3.69E-01	3.58E-01	9.72E-01	1.41E-03	1.221	1.10E+00	1.07E+00	9.77E-01	4.22E-03	1.224
1	181.247	1.93E+13	2.44E-02	5.54E-01	1.376E+01	2.050E-01	3.66E-01	3.58E-01	9.76E-01	1.41E-03	1.253	1.07E+00	1.07E+00	1.00E+00	4.22E-03	1.268
2	181.394	1.87E+13	2.55E-02	5.65E-01	1.403E+01	4.140E-01	3.90E-01	3.74E-01	9.59E-01	1.59E-03	1.279	1.14E+00	1.12E+00	9.84E-01	4.79E-03	1.296
3	181.541	2.18E+13	2.70E-02	7.01E-01	1.740E+01	6.733E-01	3.92E-01	3.96E-01	1.01E+00	1.53E-03	1.337	1.14E+00	1.19E+00	1.04E+00	4.60E-03	1.356
4	181.716	2.11E+13	2.69E-02	6.79E-01	1.686E+01	9.245E-01	3.86E-01	3.95E-01	1.02E+00	1.88E-03	1.366	1.12E+00	1.19E+00	1.05E+00	5.66E-03	1.387
4	181.716	2.11E+13	2.69E-02	6.79E-01	1.686E+01	9.245E-01	3.86E-01	3.95E-01	1.02E+00	1.88E-03	1.366	1.12E+00	1.19E+00	1.05E+00	5.66E-03	1.387

Monteburns Transport History for material 5 — total material / for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.088	4.24E+14	3.53E-02	1.20E+02	4.333E+02	0.000E+00	3.77E-01	5.16E-01	1.37E+00	1.62E-03	1.431	1.12E+00	1.55E+00	1.38E+00	4.87E-03	1.435
1	181.731	4.00E+14	3.41E-02	1.10E+02	3.981E+02	5.932E+00	4.22E-01	4.99E-01	1.18E+00	1.64E-03	1.374	1.18E+00	1.50E+00	1.28E+00	4.94E-03	1.422
2	182.647	3.98E+14	3.28E-02	1.06E+02	3.841E+02	1.166E+01	4.71E-01	4.82E-01	1.02E+00	1.70E-03	1.320	1.29E+00	1.46E+00	1.13E+00	5.13E-03	1.385
3	183.353	4.06E+14	3.19E-02	1.06E+02	3.827E+02	1.736E+01	5.08E-01	4.69E-01	9.23E-01	1.71E-03	1.277	1.37E+00	1.43E+00	1.04E+00	5.18E-03	1.358
4	183.960	4.06E+14	3.11E-02	1.04E+02	3.750E+02	2.295E+01	5.38E-01	4.58E-01	8.51E-01	1.68E-03	1.241	1.43E+00	1.40E+00	9.81E-01	5.11E-03	1.337
4	183.960	4.06E+14	3.11E-02	1.04E+02	3.750E+02	2.295E+01	5.38E-01	4.58E-01	8.51E-01	1.68E-03	1.241	1.43E+00	1.40E+00	9.81E-01	5.11E-03	1.337

Monteburns Transport History for material 6 — total material / for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.380	3.84E+14	1.37E-02	3.95E-01	1.530E+02	0.000E+00	1.77E+00	2.12E-01	1.20E-01	1.51E-03	0.265	9.03E-01	6.54E-01	7.24E-01	4.56E-03	1.043
1	182.011	3.56E+14	1.82E-02	4.88E-01	1.889E+02	3.056E+00	1.30E+00	2.81E-01	2.16E-01	1.55E-03	0.452	1.01E+00	8.69E-01	8.60E-01	4.73E-03	1.174
2	182.740	3.54E+14	2.57E-02	6.92E-01	2.678E+02	7.387E+00	7.71E-01	3.97E-01	5.15E-01	1.74E-03	0.889	1.23E+00	1.23E+00	9.99E-01	5.34E-03	1.306
3	183.373	3.62E+14	2.84E-02	7.85E-01	3.041E+02	1.231E+01	5.17E-01	4.39E-01	8.50E-01	1.69E-03	1.223	1.31E+00	1.37E+00	1.04E+00	5.21E-03	1.358
4	183.902	3.38E+14	2.74E-02	7.11E-01	2.751E+02	1.676E+01	5.52E-01	4.25E-01	7.69E-01	1.68E-03	1.174	1.43E+00	1.33E+00	9.34E-01	5.18E-03	1.304
4	183.902	3.38E+14	2.74E-02	7.11E-01	2.751E+02	1.676E+01	5.52E-01	4.25E-01	7.69E-01	1.68E-03	1.174	1.43E+00	1.33E+00	9.34E-01	5.18E-03	1.304

Monteburns Transport History for material 7 — total material / for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.540	3.87E+14	1.01E-02	1.07E+00	1.134E+02	0.000E+00	2.03E+00	1.55E-01	7.63E-02	1.59E-03	0.177	9.21E-01	4.94E-01	5.36E-01	4.85E-03	0.869
1	182.403	4.14E+14	1.24E-02	1.42E+00	1.495E+02	2.480E+00	1.75E+00	1.90E-01	1.09E-01	1.67E-03	0.249	9.62E-01	6.06E-01	6.30E-01	5.14E-03	0.983
2	183.502	4.46E+14	1.74E-02	2.16E+00	2.279E+02	6.259E+00	1.27E+00	2.67E-01	2.09E-01	1.62E-03	0.453	1.14E+00	8.54E-01	7.46E-01	5.04E-03	1.118
3	184.117	4.77E+14	2.42E-02	3.23E+00	3.406E+02	1.191E+01	7.29E-01	3.72E-01	5.10E-01	1.67E-03	0.899	1.32E+00	1.19E+00	9.02E-01	5.23E-03	1.262
4	184.704	4.91E+14	2.54E-02	3.49E+00	3.690E+02	1.803E+01	5.75E-01	3.90E-01	6.79E-01	1.57E-03	1.092	1.43E+00	1.26E+00	8.79E-01	4.95E-03	1.263
4	184.704	4.91E+14	2.54E-02	3.49E+00	3.690E+02	1.803E+01	5.75E-01	3.90E-01	6.79E-01	1.57E-03	1.092	1.43E+00	1.26E+00	8.79E-01	4.95E-03	1.263

Monteburns Transport History for material 8 — total material / for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.547	9.18E+14	9.90E-03	2.27E-01	2.635E+02	0.000E+00	2.02E+00	1.52E-01	7.51E-02	1.55E-03	0.174	9.07E-01	4.84E-01	5.33E-01	4.71E-03	0.866
1	183.208	1.03E+15	1.77E-02	4.59E-01	5.333E+02	8.845E+00	1.28E+00	2.71E-01	2.11E-01	1.59E-03	0.443	1.13E+00	8.67E-01	7.69E-01	4.94E-03	1.104
2	184.798	1.12E+15	2.59E-02	7.36E-01	8.545E+02	2.302E+01	6.32E-01	3.98E-01	6.30E-01	1.64E-03	1.010	1.44E+00	1.29E+00	8.96E-01	5.18E-03	1.234
3	186.065	1.10E+15	2.27E-02	6.34E-01	7.362E+02	3.523E+01	6.13E-01	3.50E-01	5.70E-01	1.61E-03	0.967	1.52E+00	1.14E+00	7.55E-01	5.14E-03	1.145
4	186.881	1.07E+15	2.13E-02	5.85E-01	6.790E+02	4.649E+01	6.49E-01	3.29E-01	5.07E-01	1.67E-03	0.909	1.58E+00	1.09E+00	6.88E-01	5.34E-03	1.101
4	186.881	1.07E+15	2.13E-02	5.85E-01	6.790E+02	4.649E+01	6.49E-01	3.29E-01	5.07E-01	1.67E-03	0.909	1.58E+00	1.09E+00	6.88E-01	5.34E-03	1.101

Monteburns Transport History for material 9 — total material / for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	185.125	1.23E+13	2.85E-02	5.92E-01	1.013E+01	0.000E+00	1.40E+00	1.09E+00	7.80E-01	4.91E-03	1.087	1.42E+00	1.10E+00	7.80E-01	4.97E-03	1.087
1	185.152	1.47E+13	2.87E-02	7.18E-01	1.229E+01	1.616E-01	1.42E+00	1.10E+00	7.72E-01	5.03E-03	1.105	1.43E+00	1.11E+00	7.77E-01	5.09E-03	1.110
2	185.171	1.31E+13	2.83E-02	6.38E-01	1.093E+01	3.052E-01	1.46E+00	1.08E+00	7.41E-01	5.92E-03	1.113	1.46E+00	1.10E+00	7.52E-01	5.99E-03	1.122
3	185.197	1.60E+13	2.91E-02	8.04E-01	1.378E+01	4.863E-01	1.42E+00	1.11E+00	7.87E-01	4.83E-03	1.173	1.41E+00	1.13E+00	8.00E-01	4.89E-03	1.183
4	185.195	1.53E+13	2.91E-02	7.70E-01	1.319E+01	6.596E-01	1.44E+00	1.12E+00	7.76E-01	5.51E-03	1.180	1.43E+00	1.13E+00	7.90E-01	5.57E-03	1.192
4	185.195	1.53E+13	2.91E-02	7.70E-01	1.319E+01	6.596E-01	1.44E+00	1.12E+00	7.76E-01	5.51E-03	1.180	1.43E+00	1.13E+00	7.90E-01	5.57E-03	1.192

Monteburns Transport History for material 10 — total material / for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.196	1.44E+14	1.92E-02	1.57E+01	8.020E+01	0.000E+00	3.74E-01	2.82E-01	7.53E-01	1.32E-03	1.065	1.12E+00	8.45E-01	7.56E-01	3.95E-03	1.067
1	182.137	1.33E+14	2.00E-02	1.53E+01	7.808E+01	1.164E+00	4.00E-01	2.94E-01	7.34E-01	1.45E-03	1.074	1.15E+00	8.81E-01	7.69E-01	4.35E-03	1.103

2	183.368	1.28E+14	2.07E-02	1.52E+01	7.763E+01	2.321E+00	4.30E-01	3.02E-01	7.03E-01	1.55E-03	1.079	1.23E+00	9.08E-01	7.36E-01	4.65E-03	1.108
3	184.163	1.34E+14	2.14E-02	1.66E+01	8.448E+01	3.580E+00	4.49E-01	3.13E-01	6.97E-01	1.48E-03	1.094	1.29E+00	9.43E-01	7.30E-01	4.46E-03	1.124
4	184.773	1.47E+14	2.23E-02	1.91E+01	9.750E+01	5.033E+00	4.71E-01	3.28E-01	6.96E-01	1.53E-03	1.108	1.35E+00	9.87E-01	7.29E-01	4.60E-03	1.139
4	184.773	1.47E+14	2.23E-02	1.91E+01	9.750E+01	5.033E+00	4.71E-01	3.28E-01	6.96E-01	1.53E-03	1.108	1.35E+00	9.87E-01	7.29E-01	4.60E-03	1.139

Monteburns Transport History for material 11 total material for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.175	3.97E+14	2.17E-02	7.12E+01	2.501E+02	0.000E+00	3.66E-01	3.18E-01	8.70E-01	1.40E-03	1.153	1.09E+00	9.54E-01	8.74E-01	4.20E-03	1.156
1	182.859	4.19E+14	2.22E-02	7.74E+01	2.719E+02	4.051E+00	4.17E-01	3.25E-01	7.80E-01	1.50E-03	1.112	1.18E+00	9.78E-01	8.27E-01	4.51E-03	1.149
2	184.647	4.30E+14	2.22E-02	8.00E+01	2.809E+02	8.237E+00	4.66E-01	3.26E-01	7.00E-01	1.55E-03	1.076	1.32E+00	9.85E-01	7.44E-01	4.66E-03	1.116
3	185.689	4.36E+14	2.20E-02	8.06E+01	2.830E+02	1.245E+01	5.10E-01	3.23E-01	6.33E-01	1.59E-03	1.032	1.41E+00	9.77E-01	6.93E-01	4.81E-03	1.090
4	186.410	4.50E+14	2.21E-02	8.40E+01	2.951E+02	1.685E+01	5.44E-01	3.25E-01	5.98E-01	1.62E-03	1.011	1.47E+00	9.88E-01	6.72E-01	4.92E-03	1.086
4	186.410	4.50E+14	2.21E-02	8.40E+01	2.951E+02	1.685E+01	5.44E-01	3.25E-01	5.98E-01	1.62E-03	1.011	1.47E+00	9.88E-01	6.72E-01	4.92E-03	1.086

Monteburns Transport History for material 12 total material for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.158	4.47E+14	2.37E-02	4.37E+01	3.069E+02	0.000E+00	3.67E-01	3.47E-01	9.46E-01	1.41E-03	1.205	1.09E+00	1.04E+00	9.50E-01	4.24E-03	1.208
1	182.698	4.41E+14	2.40E-02	4.39E+01	3.083E+02	4.595E+00	4.23E-01	3.51E-01	8.29E-01	1.50E-03	1.150	1.19E+00	1.05E+00	8.82E-01	4.51E-03	1.189
2	184.424	4.41E+14	2.34E-02	4.33E+01	3.037E+02	9.123E+00	4.72E-01	3.44E-01	7.28E-01	1.58E-03	1.101	1.33E+00	1.04E+00	7.81E-01	4.78E-03	1.146
3	185.438	4.40E+14	2.31E-02	4.28E+01	3.001E+02	1.360E+01	5.15E-01	3.39E-01	6.59E-01	1.61E-03	1.058	1.41E+00	1.03E+00	7.28E-01	4.88E-03	1.122
4	186.148	4.34E+14	2.28E-02	4.19E+01	2.938E+02	1.798E+01	5.45E-01	3.36E-01	6.16E-01	1.63E-03	1.030	1.47E+00	1.02E+00	6.96E-01	4.95E-03	1.109
4	186.148	4.34E+14	2.28E-02	4.19E+01	2.938E+02	1.798E+01	5.45E-01	3.36E-01	6.16E-01	1.63E-03	1.030	1.47E+00	1.02E+00	6.96E-01	4.95E-03	1.109

Monteburns Transport History for material 13 total material for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	6.58E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.83E+00	0.00E+00	0.00E+00	7.61E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	7.12E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.26E+00	0.00E+00	0.00E+00	8.17E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	7.82E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	4.33E-01	0.00E+00	0.00E+00	9.79E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	8.20E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	4.54E-02	0.00E+00	0.00E+00	1.00E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	8.21E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.86E-02	0.00E+00	0.00E+00	8.59E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	8.21E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.86E-02	0.00E+00	0.00E+00	8.59E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

The MONTEBURNS Output File Chem Shim Peak #4 J-Carborane BPRAs

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RESEARCH CRYSTAL RIVER 1/8 CORE WITH J-CARBORANE BPRA'S 4.66% ENRICH NO

Total Power (MW) =  3.18E+02   Days =  6.70E+02
# outer steps =  5,  # inner steps = 50,  # predictor steps = 1
Importance Fraction = 0.0050

Monteburns MCNP k-eff Versus Time
        days     k-eff      rel err      nu       avQfis      eta
  0m     0.00    0.99616    0.00062     2.466    181.133     0.733
  1m    67.00    0.99600    0.00066     2.529    182.197     0.817
  2m   201.00    0.99268    0.00066     2.605    183.521     0.962
  3m   335.00    0.99956    0.00058     2.653    184.396     1.096
  4m   469.00    1.00292    0.00062     2.692    185.066     1.106
  5m   603.00    1.00225    0.00055     2.721    185.623     1.082

Monteburns Transport History
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Monteburns Transport History for material 1 total material for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	1.07E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	8.10E-02	0.00E+00	0.00E+00	3.31E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	1.08E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	6.81E-02	0.00E+00	0.00E+00	3.37E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	1.10E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	6.00E-02	0.00E+00	0.00E+00	2.96E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	1.11E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	5.12E-02	0.00E+00	0.00E+00	3.73E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

4	0.000	1.12E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	4.32E-02	0.00E+00	0.00E+00	4.50E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	1.14E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	3.03E-02	0.00E+00	0.00E+00	4.12E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

Monteburns Transport History for material 2 — total material

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)	
0	181.094	4.57E+14	3.41E-02	5.16E+01	4.516E+02	0.000E+00	3.76E-01	4.99E-01	1.33E+00	1.67E-03	1.410
1	181.845	4.68E+14	3.29E-02	5.13E+01	4.487E+02	6.686E+00	4.22E-01	4.81E-01	1.14E+00	1.65E-03	1.351
2	182.889	4.92E+14	3.15E-02	5.20E+01	4.546E+02	1.346E+01	4.79E-01	4.62E-01	9.65E-01	1.67E-03	1.282
3	183.740	5.06E+14	3.08E-02	5.26E+01	4.604E+02	2.032E+01	5.23E-01	4.54E-01	8.67E-01	1.70E-03	1.235
4	184.422	5.32E+14	3.04E-02	5.47E+01	4.789E+02	2.746E+01	5.62E-01	4.47E-01	7.97E-01	1.74E-03	1.197
5	185.061	5.08E+14	2.89E-02	5.00E+01	4.373E+02	3.398E+01	5.94E-01	4.27E-01	7.20E-01	1.76E-03	1.142

for actinide

	n,gamma	n,fission	fis/cap	n2n	eta
	(barns)	(barns)		(barns)	
0	1.12E+00	1.50E+00	1.33E+00	5.00E-03	1.414
1	1.18E+00	1.45E+00	1.23E+00	4.98E-03	1.399
2	1.30E+00	1.40E+00	1.07E+00	5.04E-03	1.351
3	1.39E+00	1.38E+00	9.92E-01	5.15E-03	1.325
4	1.48E+00	1.37E+00	9.26E-01	5.30E-03	1.298
5	1.54E+00	1.32E+00	8.54E-01	5.39E-03	1.257

Monteburns Transport History for material 3 — total material

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)	
0	181.097	4.37E+14	3.40E-02	9.87E+00	4.316E+02	0.000E+00	3.72E-01	4.98E-01	1.34E+00	1.66E-03	1.417
1	181.846	4.65E+14	3.27E-02	1.01E+01	4.436E+02	6.610E+00	4.26E-01	4.79E-01	1.12E+00	1.67E-03	1.342
2	182.881	5.31E+14	3.15E-02	1.13E+01	4.921E+02	1.394E+01	4.80E-01	4.63E-01	9.64E-01	1.81E-03	1.283
3	183.818	5.26E+14	3.06E-02	1.09E+01	4.755E+02	2.103E+01	5.28E-01	4.50E-01	8.52E-01	1.71E-03	1.224
4	184.523	5.59E+14	2.99E-02	1.13E+01	4.958E+02	2.842E+01	5.63E-01	4.41E-01	7.85E-01	1.83E-03	1.187
5	185.190	5.55E+14	2.89E-02	1.09E+01	4.768E+02	3.553E+01	5.97E-01	4.27E-01	7.14E-01	1.67E-03	1.137

for actinide

	n,gamma	n,fission	fis/cap	n2n	eta
	(barns)	(barns)		(barns)	
0	1.11E+00	1.50E+00	1.35E+00	4.98E-03	1.420
1	1.19E+00	1.44E+00	1.21E+00	5.02E-03	1.389
2	1.31E+00	1.40E+00	1.07E+00	5.45E-03	1.352
3	1.40E+00	1.37E+00	9.77E-01	5.19E-03	1.315
4	1.48E+00	1.35E+00	9.13E-01	5.58E-03	1.289
5	1.55E+00	1.32E+00	8.50E-01	5.12E-03	1.254

Monteburns Transport History for material 4 — total material

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)	
0	181.147	1.63E+13	2.46E-02	4.68E-01	1.163E+01	0.000E+00	3.70E-01	3.61E-01	9.74E-01	2.22E-03	1.223
1	181.225	1.67E+13	2.49E-02	4.90E-01	1.216E+01	1.811E-01	3.91E-01	3.65E-01	9.34E-01	1.81E-03	1.226
2	181.390	1.95E+13	2.52E-02	5.82E-01	1.445E+01	3.964E-01	3.70E-01	3.70E-01	1.00E+00	1.97E-03	1.308
3	181.529	2.00E+13	2.65E-02	6.30E-01	1.564E+01	6.294E-01	3.87E-01	3.89E-01	1.01E+00	1.75E-03	1.335
4	181.676	2.58E+13	2.76E-02	8.50E-01	2.109E+01	9.437E-01	3.99E-01	4.05E-01	1.01E+00	1.72E-03	1.359
5	181.848	2.97E+13	2.91E-02	1.04E+00	2.570E+01	1.327E+00	4.09E-01	4.27E-01	1.04E+00	1.38E-03	1.393

for actinide

	n,gamma	n,fission	fis/cap	n2n	eta
	(barns)	(barns)		(barns)	
0	1.11E+00	1.08E+00	9.79E-01	6.66E-03	1.227
1	1.15E+00	1.10E+00	9.54E-01	5.43E-03	1.240
2	1.08E+00	1.11E+00	1.03E+00	5.92E-03	1.325
3	1.13E+00	1.17E+00	1.04E+00	5.26E-03	1.354
4	1.16E+00	1.21E+00	1.04E+00	5.17E-03	1.380
5	1.19E+00	1.28E+00	1.08E+00	4.14E-03	1.416

Monteburns Transport History for material 5 — total material

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)	
0	181.087	4.23E+14	3.53E-02	1.20E+02	4.334E+02	0.000E+00	3.76E-01	5.17E-01	1.37E+00	1.65E-03	1.432
1	181.740	4.17E+14	3.40E-02	1.15E+02	4.143E+02	6.174E+00	4.22E-01	4.99E-01	1.18E+00	1.69E-03	1.374
2	182.696	4.06E+14	3.25E-02	1.07E+02	3.874E+02	1.195E+01	4.71E-01	4.77E-01	1.01E+00	1.70E-03	1.314
3	183.397	4.07E+14	3.18E-02	1.06E+02	3.825E+02	1.765E+01	5.09E-01	4.67E-01	9.19E-01	1.68E-03	1.274
4	183.986	3.98E+14	3.12E-02	1.02E+02	3.678E+02	2.313E+01	5.41E-01	4.59E-01	8.49E-01	1.71E-03	1.240
5	184.487	4.03E+14	3.04E-02	1.01E+02	3.649E+02	2.857E+01	5.70E-01	4.49E-01	7.87E-01	1.75E-03	1.202

for actinide

	n,gamma	n,fission	fis/cap	n2n	eta
	(barns)	(barns)		(barns)	
0	1.12E+00	1.55E+00	1.38E+00	4.94E-03	1.435
1	1.18E+00	1.50E+00	1.28E+00	5.09E-03	1.421
2	1.29E+00	1.44E+00	1.12E+00	5.13E-03	1.379
3	1.37E+00	1.42E+00	1.04E+00	5.09E-03	1.356
4	1.43E+00	1.40E+00	9.79E-01	5.22E-03	1.336
5	1.50E+00	1.38E+00	9.20E-01	5.34E-03	1.308

Monteburns Transport History for material 6 — total material

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)	
0	181.384	3.91E+14	1.38E-02	4.04E-01	1.565E+02	0.000E+00	1.80E+00	2.13E-01	1.18E-01	1.74E-03	0.262
1	182.008	3.97E+14	1.87E-02	5.59E-01	2.164E+02	3.500E+00	1.28E+00	2.88E-01	2.25E-01	1.67E-03	0.467
2	182.898	3.91E+14	2.69E-02	7.99E-01	3.092E+02	8.501E+00	7.04E-01	4.15E-01	5.90E-01	1.53E-03	0.970
3	183.499	3.76E+14	2.79E-02	8.00E-01	3.097E+02	1.351E+01	5.19E-01	4.31E-01	8.30E-01	1.65E-03	1.207
4	184.061	3.42E+14	2.78E-02	7.29E-01	2.824E+02	1.808E+01	5.60E-01	4.31E-01	7.69E-01	1.70E-03	1.174
5	184.495	3.47E+14	2.72E-02	7.25E-01	2.808E+02	2.262E+01	5.78E-01	4.22E-01	7.30E-01	1.46E-03	1.151

for actinide

	n,gamma	n,fission	fis/cap	n2n	eta
	(barns)	(barns)		(barns)	
0	9.39E-01	6.58E-01	7.00E-01	5.26E-03	1.023
1	1.04E+00	8.91E-01	8.56E-01	5.09E-03	1.172
2	1.26E+00	1.29E+00	1.03E+00	4.72E-03	1.323
3	1.34E+00	1.35E+00	1.01E+00	5.08E-03	1.334
4	1.44E+00	1.35E+00	9.36E-01	5.26E-03	1.305
5	1.47E+00	1.33E+00	9.02E-01	4.54E-03	1.293

Monteburns Transport History for material 7 — total material

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)	
0	181.542	4.19E+14	1.01E-02	1.17E+00	1.230E+02	0.000E+00	2.02E+00	1.55E-01	7.67E-02	1.64E-03	0.177
1	182.435	4.38E+14	1.24E-02	1.51E+00	1.592E+02	2.641E+00	1.70E+00	1.90E-01	1.12E-01	1.62E-03	0.257
2	183.596	4.73E+14	1.77E-02	2.34E+00	2.469E+02	6.736E+00	1.23E+00	2.72E-01	2.21E-01	1.60E-03	0.473
3	184.240	5.09E+14	2.49E-02	3.54E+00	3.742E+02	1.294E+01	7.01E-01	3.82E-01	5.46E-01	1.60E-03	0.939
4	184.814	5.35E+14	2.54E-02	3.82E+00	4.034E+02	1.963E+01	5.84E-01	3.91E-01	6.70E-01	1.76E-03	1.084
5	185.439	5.23E+14	2.44E-02	3.59E+00	3.789E+02	2.591E+01	6.05E-01	3.76E-01	6.21E-01	1.59E-03	1.046

for actinide

	n,gamma	n,fission	fis/cap	n2n	eta
	(barns)	(barns)		(barns)	
0	8.95E-01	4.95E-01	5.53E-01	5.01E-03	0.886
1	9.71E-01	6.09E-01	6.27E-01	5.01E-03	0.981
2	1.18E+00	8.72E-01	7.42E-01	4.99E-03	1.114
3	1.34E+00	1.23E+00	9.17E-01	5.03E-03	1.273
4	1.45E+00	1.27E+00	8.71E-01	5.55E-03	1.258
5	1.51E+00	1.22E+00	8.09E-01	5.03E-03	1.221

Monteburns Transport History for material 8

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	total material n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	for actinide n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	181.523	4.08E+14	1.02E-02	1.04E-01	1.204E+02	0.000E+00	2.06E+00	1.56E-01	7.56E-02	1.30E-03	0.175	8.62E-01	4.97E-01	5.77E-01	3.95E-03	0.908
1	182.477	4.50E+14	1.28E-02	1.45E-01	1.685E+02	2.795E+00	1.71E+00	1.96E-01	1.15E-01	1.92E-03	0.262	9.38E-01	6.28E-01	6.70E-01	5.91E-03	1.022
2	183.580	5.30E+14	1.79E-02	2.40E-01	2.785E+02	7.415E+00	1.16E+00	2.74E-01	2.36E-01	1.77E-03	0.499	1.17E+00	8.79E-01	7.49E-01	5.50E-03	1.121
3	184.358	5.43E+14	2.45E-02	3.38E-01	3.928E+02	1.393E+01	6.76E-01	3.77E-01	5.58E-01	1.68E-03	0.953	1.38E+00	1.21E+00	8.76E-01	5.31E-03	1.242
4	185.000	5.82E+14	2.59E-02	3.84E-01	4.465E+02	2.134E+01	6.01E-01	3.98E-01	6.62E-01	1.74E-03	1.076	1.48E+00	1.29E+00	8.74E-01	5.48E-03	1.259
5	185.616	5.84E+14	2.49E-02	3.73E-01	4.329E+02	2.852E+01	6.12E-01	3.85E-01	6.28E-01	1.69E-03	1.053	1.52E+00	1.25E+00	8.28E-01	5.36E-03	1.236

Monteburns Transport History for material 9

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	total material n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	for actinide n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	185.157	1.24E+13	2.81E-02	5.88E-01	1.007E+01	0.000E+00	1.39E+00	1.08E+00	7.72E-01	4.92E-03	1.079	1.41E+00	1.09E+00	7.72E-01	4.98E-03	1.079
1	185.123	1.26E+13	2.89E-02	6.22E-01	1.066E+01	1.401E-01	1.40E+00	1.11E+00	7.88E-01	5.87E-03	1.120	1.41E+00	1.12E+00	7.94E-01	5.94E-03	1.124
2	185.165	1.51E+13	2.85E-02	7.36E-01	1.261E+01	3.059E-01	1.43E+00	1.09E+00	7.59E-01	5.17E-03	1.128	1.43E+00	1.10E+00	7.70E-01	5.23E-03	1.137
3	185.172	1.52E+13	2.86E-02	7.48E-01	1.281E+01	4.743E-01	1.41E+00	1.10E+00	7.77E-01	6.77E-03	1.165	1.40E+00	1.11E+00	7.90E-01	6.85E-03	1.176
4	185.192	1.82E+13	2.86E-02	8.99E-01	1.539E+01	6.766E-01	1.40E+00	1.10E+00	7.84E-01	4.62E-03	1.187	1.39E+00	1.11E+00	7.98E-01	4.67E-03	1.198
5	185.227	2.21E+13	3.07E-02	1.18E+00	2.016E+01	9.416E-01	1.45E+00	1.18E+00	8.13E-01	4.57E-03	1.224	1.43E+00	1.19E+00	8.30E-01	4.62E-03	1.238

Monteburns Transport History for material 10

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	total material n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	for actinide n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	181.190	1.56E+14	1.95E-02	1.74E+01	8.846E+01	0.000E+00	3.74E-01	2.86E-01	7.65E-01	1.40E-03	1.073	1.12E+00	8.58E-01	7.68E-01	4.20E-03	1.076
1	182.234	1.57E+14	2.05E-02	1.84E+01	9.402E+01	1.401E+00	4.07E-01	3.00E-01	7.37E-01	1.48E-03	1.077	1.16E+00	9.00E-01	7.74E-01	4.44E-03	1.108
2	183.608	1.51E+14	2.10E-02	1.83E+01	9.332E+01	2.792E+00	4.37E-01	3.07E-01	7.02E-01	1.51E-03	1.078	1.25E+00	9.22E-01	7.37E-01	4.53E-03	1.109
3	184.453	1.51E+14	2.20E-02	1.92E+01	9.800E+01	4.252E+00	4.61E-01	3.22E-01	6.99E-01	1.50E-03	1.095	1.32E+00	9.70E-01	7.33E-01	4.50E-03	1.126
4	185.050	1.45E+14	2.25E-02	1.90E+01	9.674E+01	5.694E+00	4.81E-01	3.31E-01	6.88E-01	1.59E-03	1.101	1.38E+00	9.96E-01	7.22E-01	4.79E-03	1.133
5	185.493	1.66E+14	2.34E-02	2.27E+01	1.155E+02	7.415E+00	5.08E-01	3.43E-01	6.76E-01	1.56E-03	1.101	1.44E+00	1.04E+00	7.21E-01	4.72E-03	1.144

Monteburns Transport History for material 11

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	total material n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	for actinide n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	181.172	3.98E+14	2.20E-02	7.23E+01	2.541E+02	0.000E+00	3.66E-01	3.22E-01	8.79E-01	1.44E-03	1.158	1.09E+00	9.66E-01	8.83E-01	4.31E-03	1.161
1	182.841	4.06E+14	2.25E-02	7.61E+01	2.673E+02	3.983E+00	4.20E-01	3.30E-01	7.85E-01	1.51E-03	1.116	1.19E+00	9.91E-01	8.33E-01	4.53E-03	1.154
2	184.598	4.30E+14	2.24E-02	8.07E+01	2.833E+02	8.205E+00	4.66E-01	3.29E-01	7.06E-01	1.63E-03	1.083	1.32E+00	9.93E-01	7.52E-01	4.91E-03	1.122
3	185.665	4.33E+14	2.22E-02	8.07E+01	2.835E+02	1.243E+01	5.11E-01	3.26E-01	6.37E-01	1.62E-03	1.036	1.41E+00	9.86E-01	6.98E-01	4.91E-03	1.095
4	186.393	4.49E+14	2.20E-02	8.34E+01	2.928E+02	1.679E+01	5.42E-01	3.24E-01	5.97E-01	1.64E-03	1.010	1.47E+00	9.84E-01	6.71E-01	4.98E-03	1.085
5	186.944	4.50E+14	2.21E-02	8.42E+01	2.957E+02	2.120E+01	5.72E-01	3.25E-01	5.68E-01	1.62E-03	0.989	1.54E+00	9.91E-01	6.45E-01	4.93E-03	1.071

Monteburns Transport History for material 12

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	total material n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	for actinide n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	181.154	4.40E+14	2.40E-02	4.38E+01	3.070E+02	0.000E+00	3.68E-01	3.52E-01	9.58E-01	1.48E-03	1.211	1.10E+00	1.06E+00	9.63E-01	4.44E-03	1.214
1	182.704	4.46E+14	2.42E-02	4.49E+01	3.150E+02	4.696E+00	4.23E-01	3.54E-01	8.37E-01	1.55E-03	1.156	1.19E+00	1.06E+00	8.91E-01	4.67E-03	1.196
2	184.436	4.46E+14	2.36E-02	4.41E+01	3.093E+02	9.307E+00	4.76E-01	3.46E-01	7.27E-01	1.53E-03	1.100	1.34E+00	1.04E+00	7.80E-01	4.62E-03	1.146
3	185.468	4.37E+14	2.31E-02	4.26E+01	2.987E+02	1.376E+01	5.15E-01	3.40E-01	6.60E-01	1.60E-03	1.058	1.41E+00	1.03E+00	7.30E-01	4.84E-03	1.124
4	186.168	4.30E+14	2.28E-02	4.15E+01	2.909E+02	1.810E+01	5.47E-01	3.36E-01	6.14E-01	1.66E-03	1.027	1.47E+00	1.02E+00	6.93E-01	5.04E-03	1.106
5	186.706	4.34E+14	2.28E-02	4.19E+01	2.942E+02	2.249E+01	5.74E-01	3.36E-01	5.85E-01	1.66E-03	1.008	1.54E+00	1.03E+00	6.67E-01	5.06E-03	1.092

Monteburns Transport History for material 13

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	total material n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	for actinide n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta
0	0.000	5.97E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.53E+00	0.00E+00	0.00E+00	6.80E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	6.27E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.17E+00	0.00E+00	0.00E+00	9.01E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	6.89E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.55E+00	0.00E+00	0.00E+00	9.05E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	7.48E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	7.64E-01	0.00E+00	0.00E+00	1.01E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	8.22E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.27E-01	0.00E+00	0.00E+00	9.57E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	8.15E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.10E-02	0.00E+00	0.00E+00	1.22E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

Monteburns Transport History for material 14

	Qfis (MeV)	Flux (n/cm^3)	SigmaF (1/cm)	Power (MW)	Pow.Den. (W/cc)	Burnup (GWd/MTU)	total material n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta	for actinide n,gamma (barns)	n,fission (barns)	fis/cap	n2n (barns)	eta

0	0.000	2.98E+13	0.00E+00	0.00E+00	0.000E+00	0.000E+00	9.94E-02	0.00E+00	0.00E+00	0.00E+00	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	7.52E+13	0.00E+00	0.00E+00	0.000E+00	0.000E+00	8.71E-02	0.00E+00	0.00E+00	0.00E+00	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	6.19E+13	0.00E+00	0.00E+00	0.000E+00	0.000E+00	9.67E-02	0.00E+00	0.00E+00	0.00E+00	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	6.16E+13	0.00E+00	0.00E+00	0.000E+00	0.000E+00	8.61E-02	0.00E+00	0.00E+00	0.00E+00	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
4	0.000	7.60E+13	0.00E+00	0.00E+00	0.000E+00	0.000E+00	7.64E-02	0.00E+00	0.00E+00	0.00E+00	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
5	0.000	1.13E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.11E-01	0.00E+00	0.00E+00	0.00E+00	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

The MONTEBURNS Output File Chem Shim #12 J-Carborane BPRAs

RESEARCH CRYSTAL RIVER 1/8 CORE WITH J-CARBORANE BPRA'S 4.66% ENRICH NO

Total Power (MW) = 3.18E+02 Days = 6.70E+02
outer steps = 5, # inner steps = 50, # predictor steps = 1
Importance Fraction = 0.0050

Monteburns MCNP k-eff Versus Time

	days	k-eff	rel err	nu	avQfis	eta
0m	0.00	0.98065	0.00056	2.468	181.136	0.744
1m	67.00	0.99504	0.00041	2.531	182.201	0.858
2m	201.00	0.99501	0.00064	2.605	183.524	1.026
3m	335.00	0.99817	0.00046	2.653	184.398	1.098
3m	335.00	0.99817	0.00046	2.653	184.398	1.098
3m	335.00	0.99817	0.00046	2.653	184.398	1.098

Monteburns Transport History

Monteburns Transport History for material 1

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	1.08E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	8.61E-02	0.00E+00	0.00E+00	2.80E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	1.08E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	6.90E-02	0.00E+00	0.00E+00	3.17E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	1.10E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	6.01E-02	0.00E+00	0.00E+00	3.19E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	1.11E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	5.13E-02	0.00E+00	0.00E+00	4.60E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	1.11E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	5.13E-02	0.00E+00	0.00E+00	4.60E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	1.11E+15	0.00E+00	0.00E+00	0.000E+00	0.000E+00	5.13E-02	0.00E+00	0.00E+00	4.60E-09	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

Monteburns Transport History for material 2

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.096	4.51E+14	3.37E-02	4.03E+01	4.404E+02	0.000E+00	3.73E-01	4.93E-01	1.32E+00	1.63E-03	1.409	1.11E+00	1.48E+00	1.33E+00	4.88E-03	1.412
1	181.845	4.59E+14	3.28E-02	4.01E+01	4.388E+02	6.539E+00	4.23E-01	4.80E-01	1.14E+00	1.65E-03	1.350	1.18E+00	1.45E+00	1.23E+00	4.98E-03	1.397
2	182.868	4.96E+14	3.15E-02	4.19E+01	4.586E+02	1.337E+01	4.77E-01	4.62E-01	9.69E-01	1.68E-03	1.285	1.30E+00	1.40E+00	1.08E+00	5.07E-03	1.354
3	183.727	5.07E+14	3.08E-02	4.22E+01	4.613E+02	2.024E+01	5.24E-01	4.53E-01	8.65E-01	1.72E-03	1.234	1.40E+00	1.38E+00	9.89E-01	5.22E-03	1.323
3	183.727	5.07E+14	3.08E-02	4.22E+01	4.613E+02	2.024E+01	5.24E-01	4.53E-01	8.65E-01	1.72E-03	1.234	1.40E+00	1.38E+00	9.89E-01	5.22E-03	1.323
3	183.727	5.07E+14	3.08E-02	4.22E+01	4.613E+02	2.024E+01	5.24E-01	4.53E-01	8.65E-01	1.72E-03	1.234	1.40E+00	1.38E+00	9.89E-01	5.22E-03	1.323

Monteburns Transport History for material 3

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.097	4.79E+14	3.35E-02	2.13E+01	4.661E+02	0.000E+00	3.74E-01	4.91E-01	1.31E+00	1.58E-03	1.404	1.12E+00	1.47E+00	1.32E+00	4.73E-03	1.407
1	181.871	4.77E+14	3.29E-02	2.09E+01	4.575E+02	6.817E+00	4.26E-01	4.81E-01	1.13E+00	1.65E-03	1.346	1.19E+00	1.45E+00	1.22E+00	4.97E-03	1.394
2	182.911	5.14E+14	3.16E-02	2.18E+01	4.777E+02	1.394E+01	4.82E-01	4.65E-01	9.64E-01	1.57E-03	1.282	1.31E+00	1.41E+00	1.07E+00	4.75E-03	1.351
3	183.812	5.12E+14	3.07E-02	2.13E+01	4.651E+02	2.087E+01	5.26E-01	4.52E-01	8.60E-01	1.72E-03	1.230	1.40E+00	1.38E+00	9.85E-01	5.22E-03	1.321
3	183.812	5.12E+14	3.07E-02	2.13E+01	4.651E+02	2.087E+01	5.26E-01	4.52E-01	8.60E-01	1.72E-03	1.230	1.40E+00	1.38E+00	9.85E-01	5.22E-03	1.321
3	183.812	5.12E+14	3.07E-02	2.13E+01	4.651E+02	2.087E+01	5.26E-01	4.52E-01	8.60E-01	1.72E-03	1.230	1.40E+00	1.38E+00	9.85E-01	5.22E-03	1.321

Monteburns Transport History for material 4

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	total material n,gamma	n,fission	fis/cap	n2n	eta	for actinide n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.153	1.84E+13	2.47E-02	5.30E-01	1.314E+01	0.000E+00	3.65E-01	3.61E-01	9.89E-01	1.39E-03	1.231	1.09E+00	1.08E+00	9.94E-01	4.17E-03	1.234

1	181.240	1.87E+13	2.51E-02	5.51E-01	1.368E+01	2.039E-01	3.77E-01	3.67E-01	9.75E-01	1.45E-03	1.253	1.11E+00	1.10E+00	9.96E-01	4.34E-03	1.267
2	181.389	2.08E+13	2.58E-02	6.35E-01	1.576E+01	4.388E-01	3.77E-01	3.77E-01	1.00E+00	1.37E-03	1.307	1.10E+00	1.13E+00	1.03E+00	4.12E-03	1.324
3	181.542	1.87E+13	2.67E-02	5.95E-01	1.477E+01	6.588E-01	3.78E-01	3.91E-01	1.04E+00	1.40E-03	1.353	1.10E+00	1.17E+00	1.07E+00	4.22E-03	1.374
3	181.542	1.87E+13	2.67E-02	5.95E-01	1.477E+01	6.588E-01	3.78E-01	3.91E-01	1.04E+00	1.40E-03	1.353	1.10E+00	1.17E+00	1.07E+00	4.22E-03	1.374
3	181.542	1.87E+13	2.67E-02	5.95E-01	1.477E+01	6.588E-01	3.78E-01	3.91E-01	1.04E+00	1.40E-03	1.353	1.10E+00	1.17E+00	1.07E+00	4.22E-03	1.374

Monteburns Transport History for material 5 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.090	4.35E+14	3.49E-02	1.22E+02	4.402E+02	0.000E+00	3.74E-01	5.11E-01	1.36E+00	1.66E-03	1.428	1.12E+00	1.53E+00	1.37E+00	4.98E-03	1.431
1	181.739	4.17E+14	3.40E-02	1.15E+02	4.138E+02	6.167E+00	4.23E-01	4.98E-01	1.18E+00	1.68E-03	1.372	1.18E+00	1.50E+00	1.27E+00	5.04E-03	1.420
2	182.700	4.03E+14	3.24E-02	1.06E+02	3.839E+02	1.189E+01	4.71E-01	4.76E-01	1.01E+00	1.71E-03	1.314	1.29E+00	1.44E+00	1.12E+00	5.15E-03	1.379
3	183.391	4.05E+14	3.18E-02	1.05E+02	3.803E+02	1.756E+01	5.08E-01	4.67E-01	9.19E-01	1.71E-03	1.274	1.37E+00	1.42E+00	1.04E+00	5.17E-03	1.356
3	183.391	4.05E+14	3.18E-02	1.05E+02	3.803E+02	1.756E+01	5.08E-01	4.67E-01	9.19E-01	1.71E-03	1.274	1.37E+00	1.42E+00	1.04E+00	5.17E-03	1.356
3	183.391	4.05E+14	3.18E-02	1.05E+02	3.803E+02	1.756E+01	5.08E-01	4.67E-01	9.19E-01	1.71E-03	1.274	1.37E+00	1.42E+00	1.04E+00	5.17E-03	1.356

Monteburns Transport History for material 6 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.380	4.19E+14	1.39E-02	4.37E-01	1.694E+02	0.000E+00	1.79E+00	2.15E-01	1.20E-01	1.77E-03	0.267	9.41E-01	6.65E-01	7.06E-01	5.33E-03	1.028
1	182.032	4.04E+14	1.93E-02	5.86E-01	2.269E+02	3.670E+00	1.27E+00	2.97E-01	2.35E-01	1.91E-03	0.483	1.02E+00	9.19E-01	9.05E-01	5.81E-03	1.208
2	182.869	4.02E+14	2.65E-02	8.10E-01	3.135E+02	8.740E+00	6.86E-01	4.09E-01	5.97E-01	1.64E-03	0.977	1.24E+00	1.27E+00	1.03E+00	5.04E-03	1.323
3	183.488	3.87E+14	2.82E-02	8.33E-01	3.227E+02	1.396E+01	5.31E-01	4.37E-01	8.23E-01	1.74E-03	1.201	1.35E+00	1.36E+00	1.01E+00	5.37E-03	1.338
3	183.488	3.87E+14	2.82E-02	8.33E-01	3.227E+02	1.396E+01	5.31E-01	4.37E-01	8.23E-01	1.74E-03	1.201	1.35E+00	1.36E+00	1.01E+00	5.37E-03	1.338
3	183.488	3.87E+14	2.82E-02	8.33E-01	3.227E+02	1.396E+01	5.31E-01	4.37E-01	8.23E-01	1.74E-03	1.201	1.35E+00	1.36E+00	1.01E+00	5.37E-03	1.338

Monteburns Transport History for material 7 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.551	3.79E+14	1.00E-02	1.05E+00	1.104E+02	0.000E+00	1.98E+00	1.54E-01	7.77E-02	1.60E-03	0.179	9.00E-01	4.91E-01	5.46E-01	4.86E-03	0.878
1	182.387	3.91E+14	1.23E-02	1.33E+00	1.404E+02	2.329E+00	1.74E+00	1.88E-01	1.08E-01	1.70E-03	0.249	9.62E-01	6.02E-01	6.26E-01	5.23E-03	0.981
2	183.457	4.25E+14	1.67E-02	1.98E+00	2.087E+02	5.791E+00	1.30E+00	2.56E-01	1.97E-01	1.62E-03	0.431	1.13E+00	8.21E-01	7.26E-01	5.05E-03	1.101
3	184.082	4.55E+14	2.34E-02	2.97E+00	3.139E+02	1.100E+01	7.91E-01	3.59E-01	4.54E-01	1.69E-03	0.832	1.31E+00	1.15E+00	8.81E-01	5.28E-03	1.247
3	184.082	4.55E+14	2.34E-02	2.97E+00	3.139E+02	1.100E+01	7.91E-01	3.59E-01	4.54E-01	1.69E-03	0.832	1.31E+00	1.15E+00	8.81E-01	5.28E-03	1.247
3	184.082	4.55E+14	2.34E-02	2.97E+00	3.139E+02	1.100E+01	7.91E-01	3.59E-01	4.54E-01	1.69E-03	0.832	1.31E+00	1.15E+00	8.81E-01	5.28E-03	1.247

Monteburns Transport History for material 8 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.551	8.94E+14	9.95E-03	2.22E-01	2.581E+02	0.000E+00	1.96E+00	1.53E-01	7.77E-02	1.49E-03	0.179	8.63E-01	4.87E-01	5.64E-01	4.58E-03	0.897
1	183.096	9.49E+14	1.69E-02	4.02E-01	4.668E+02	7.742E+00	1.32E+00	2.58E-01	1.94E-01	1.64E-03	0.414	1.10E+00	8.24E-01	7.49E-01	5.10E-03	1.089
2	184.611	1.07E+15	2.50E-02	6.79E-01	7.884E+02	2.082E+01	6.33E-01	3.85E-01	6.08E-01	1.51E-03	0.988	1.41E+00	1.24E+00	8.80E-01	4.76E-03	1.223
3	185.919	1.07E+15	2.39E-02	6.51E-01	7.560E+02	3.336E+01	6.22E-01	3.68E-01	5.92E-01	1.68E-03	0.990	1.53E+00	1.20E+00	7.84E-01	5.32E-03	1.170
3	185.919	1.07E+15	2.39E-02	6.51E-01	7.560E+02	3.336E+01	6.22E-01	3.68E-01	5.92E-01	1.68E-03	0.990	1.53E+00	1.20E+00	7.84E-01	5.32E-03	1.170
3	185.919	1.07E+15	2.39E-02	6.51E-01	7.560E+02	3.336E+01	6.22E-01	3.68E-01	5.92E-01	1.68E-03	0.990	1.53E+00	1.20E+00	7.84E-01	5.32E-03	1.170

Monteburns Transport History for material 9 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	185.153	1.32E+13	2.84E-02	6.35E-01	1.087E+01	0.000E+00	1.40E+00	1.09E+00	7.76E-01	4.49E-03	1.082	1.42E+00	1.10E+00	7.76E-01	4.54E-03	1.082
1	185.166	1.47E+13	2.97E-02	7.46E-01	1.277E+01	1.679E-01	1.46E+00	1.14E+00	7.80E-01	4.15E-03	1.112	1.46E+00	1.15E+00	7.85E-01	4.20E-03	1.116
2	185.166	1.52E+13	2.81E-02	7.34E-01	1.257E+01	3.331E-01	1.41E+00	1.07E+00	7.61E-01	5.59E-03	1.130	1.41E+00	1.09E+00	7.73E-01	5.66E-03	1.141
3	185.161	1.36E+13	2.89E-02	6.80E-01	1.165E+01	4.863E-01	1.42E+00	1.11E+00	7.82E-01	4.92E-03	1.169	1.41E+00	1.12E+00	7.96E-01	4.98E-03	1.180
3	185.161	1.36E+13	2.89E-02	6.80E-01	1.165E+01	4.863E-01	1.42E+00	1.11E+00	7.82E-01	4.92E-03	1.169	1.41E+00	1.12E+00	7.96E-01	4.98E-03	1.180
3	185.161	1.36E+13	2.89E-02	6.80E-01	1.165E+01	4.863E-01	1.42E+00	1.11E+00	7.82E-01	4.92E-03	1.169	1.41E+00	1.12E+00	7.96E-01	4.98E-03	1.180

Monteburns Transport History for material 10 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.198	1.57E+14	1.91E-02	1.70E+01	8.675E+01	0.000E+00	3.72E-01	2.80E-01	7.52E-01	1.44E-03	1.064	1.11E+00	8.39E-01	7.55E-01	4.33E-03	1.066
1	182.227	1.57E+14	2.03E-02	1.83E+01	9.314E+01	1.388E+00	4.06E-01	2.97E-01	7.32E-01	1.42E-03	1.073	1.16E+00	8.93E-01	7.68E-01	4.27E-03	1.103
2	183.612	1.52E+14	2.11E-02	1.85E+01	9.450E+01	2.796E+00	4.39E-01	3.09E-01	7.04E-01	1.60E-03	1.080	1.26E+00	9.29E-01	7.38E-01	4.81E-03	1.111
3	184.462	1.53E+14	2.19E-02	1.94E+01	9.901E+01	4.271E+00	4.60E-01	3.21E-01	6.99E-01	1.61E-03	1.095	1.32E+00	9.67E-01	7.33E-01	4.85E-03	1.127

3	184.462	1.53E+14	2.19E-02	1.94E+01	9.901E+01	4.271E+00	4.60E-01	3.21E-01	6.99E-01	1.61E-03	1.095	1.32E+00	9.67E-01	7.33E-01	4.85E-03	1.127
3	184.462	1.53E+14	2.19E-02	1.94E+01	9.901E+01	4.271E+00	4.60E-01	3.21E-01	6.99E-01	1.61E-03	1.095	1.32E+00	9.67E-01	7.33E-01	4.85E-03	1.127

Monteburns Transport History for material 11 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.177	3.93E+14	2.16E-02	7.03E+01	2.468E+02	0.000E+00	3.65E-01	3.17E-01	8.68E-01	1.44E-03	1.151	1.09E+00	9.50E-01	8.72E-01	4.31E-03	1.154
1	182.828	4.08E+14	2.25E-02	7.63E+01	2.681E+02	3.996E+00	4.19E-01	3.30E-01	7.87E-01	1.45E-03	1.119	1.19E+00	9.91E-01	8.36E-01	4.37E-03	1.156
2	184.602	4.27E+14	2.25E-02	8.02E+01	2.816E+02	8.193E+00	4.66E-01	3.30E-01	7.08E-01	1.56E-03	1.084	1.32E+00	9.95E-01	7.53E-01	4.70E-03	1.123
3	185.655	4.34E+14	2.22E-02	8.08E+01	2.839E+02	1.242E+01	5.11E-01	3.26E-01	6.37E-01	1.59E-03	1.036	1.41E+00	9.86E-01	6.98E-01	4.82E-03	1.095
3	185.655	4.34E+14	2.22E-02	8.08E+01	2.839E+02	1.242E+01	5.11E-01	3.26E-01	6.37E-01	1.59E-03	1.036	1.41E+00	9.86E-01	6.98E-01	4.82E-03	1.095
3	185.655	4.34E+14	2.22E-02	8.08E+01	2.839E+02	1.242E+01	5.11E-01	3.26E-01	6.37E-01	1.59E-03	1.036	1.41E+00	9.86E-01	6.98E-01	4.82E-03	1.095

Monteburns Transport History for material 12 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	181.158	4.52E+14	2.36E-02	4.41E+01	3.093E+02	0.000E+00	3.67E-01	3.45E-01	9.41E-01	1.44E-03	1.201	1.10E+00	1.04E+00	9.45E-01	4.33E-03	1.204
1	182.721	4.49E+14	2.42E-02	4.52E+01	3.169E+02	4.724E+00	4.22E-01	3.53E-01	8.38E-01	1.48E-03	1.157	1.19E+00	1.06E+00	8.92E-01	4.44E-03	1.197
2	184.444	4.48E+14	2.36E-02	4.42E+01	3.105E+02	9.353E+00	4.74E-01	3.46E-01	7.30E-01	1.58E-03	1.103	1.33E+00	1.04E+00	7.84E-01	4.76E-03	1.149
3	185.464	4.42E+14	2.31E-02	4.31E+01	3.023E+02	1.386E+01	5.16E-01	3.40E-01	6.59E-01	1.60E-03	1.058	1.41E+00	1.03E+00	7.30E-01	4.86E-03	1.123
3	185.464	4.42E+14	2.31E-02	4.31E+01	3.023E+02	1.386E+01	5.16E-01	3.40E-01	6.59E-01	1.60E-03	1.058	1.41E+00	1.03E+00	7.30E-01	4.86E-03	1.123
3	185.464	4.42E+14	2.31E-02	4.31E+01	3.023E+02	1.386E+01	5.16E-01	3.40E-01	6.59E-01	1.60E-03	1.058	1.41E+00	1.03E+00	7.30E-01	4.86E-03	1.123

Monteburns Transport History for material 13 — total material — for actinide

	Qfis	Flux	SigmaF	Power	Pow.Den.	Burnup	n,gamma	n,fission	fis/cap	n2n	eta	n,gamma	n,fission	fis/cap	n2n	eta
	(MeV)	(n/cm^3)	(1/cm)	(MW)	(W/cc)	(GWd/MTU)	(barns)	(barns)		(barns)		(barns)	(barns)		(barns)	
0	0.000	6.08E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.51E+00	0.00E+00	0.00E+00	6.35E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
1	0.000	6.26E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	2.20E+00	0.00E+00	0.00E+00	8.70E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
2	0.000	6.86E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	1.54E+00	0.00E+00	0.00E+00	8.94E-07	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	7.48E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	7.62E-01	0.00E+00	0.00E+00	1.01E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	7.48E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	7.62E-01	0.00E+00	0.00E+00	1.01E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000
3	0.000	7.48E+14	0.00E+00	0.00E+00	0.000E+00	0.000E+00	7.62E-01	0.00E+00	0.00E+00	1.01E-06	0.000	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.000

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BIOGRAPHICAL SKETCH

Kenneth Allen is a captain in the United States Army who attended high school in Goose Creek, SC. After high school, he was appointed as a cadet at the United States Military Academy at West Point, NY where he studied civil engineering. Upon graduation from USMA, in 1993 he was commissioned a second lieutenant in the Army Aviation Corps and he attended flight school at Fort Rucker Alabama where he became qualified to fly UH-1 Iroquois and UH-60 blackhawk helicopters. Ken served as a company commander of the U.S. Army's helicopter company in Japan before attending the University of Florida. At the University of Florida he pursued a master of engineering degree in nuclear engineering. Ken and his wife Stephanie have two sons, Zachary and Nicholas.