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Feasibility of a critical experiment utilizing uranium dioxide-beryllium oxide with neutron spectrum shifting capabilities

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FEASIBILITY OF A CRITICAL EXPERIMENT UTILIZING URANIUM DIOXIDE-BERYLLIUM OXIDE WITH NEUTRON SPECTRUM SHIFTING CAPABILITIES

by

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ABSTRACT

The goal of this project is to determine the feasibility of utilizing Annular Core Research Reactor (ACRR) fuel in core design with Sandia Pulse Reactor Facility's (SPRF) Seven Percent Critical Experiment (7uPCX) fuel rods as driver fuel for a critical experiment facility to support future critical and benchmark experiments for the International Criticality Safety Benchmark Evaluation Project (ICSBEP) handbook. This is part of the Critical Experiment Design (CED) process for future criticality experiments. These criticality experiment designs have the main goal of being performed in the same facility at different neutron energy ranges. To test the feasibility of this experiment facility design, analysis was performed on different configurations of the ACRR fuel with the well-characterized 7uPCX driver fuel. Metrics to determine the most suitable configuration included a critical reactor system with 35%-enriched ^{235}U ACRR fuel, ability to acquire beryllium and beryllium oxide cross section data through the critical experiment, and spectrum shifting beyond regular nuclear physics of criticality. The final results yielded a critical experiment design using fully built ACRR fuel elements with a neutron energy spectrum that is 78.15% thermal, 15.76% intermediate, and 5.73% fast. This final design of a critical experiment facility is for a thermal neutron energy experiment design. Many variations were performed on this thermal design and found to have difficulty shifting the neutron energy spectrum into higher energy ranges. With ongoing work, an intermediate neutron energy experiment design may be created in a way to fit in this facility.

ACKNOWLEDGMENTS

This work was performed in conjunction with the Nuclear Criticality Safety (NCS) team and Sandia Critical Experiments (SCX) team at Sandia National Laboratories (Sandia). I would like to thank everyone that has supported me from these groups during my time there.

At Sandia, I would like to thank James Cole, Krista Kaiser, Gary Harms, David Ames, and John Miller who all continued to drive this project forward and help me achieve the goals I had set for my models.

At Missouri University of Science and Technology, I would like to thank my advisor, Dr. Alajo, for allowing me to propose my ideas and refine them for developing these models.

Lastly, I would like to thank my family for their support in completing this thesis. Their science background allowed me to stay focused and foster ideas at home. This would not have been possible without their help.

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NOMENCLATURE

Symbol	Description
7uPCX	Seven Percent Critical Experiment
ACRR	Annular Core Research Reactor
BeO	Beryllium Oxide
BeO Fuel	Uranium Oxide - Beryllium Oxide Fuel
Cd	Cadmium
CED	Critical Experiment Design
F	Fast Energy Range
I	Intermediate Energy Range
ICSBEP	International Criticality Safety Benchmark Evaluation Project
PPS	Purpose-built pressure measurement and mapping sensor
Sandia	Sandia National Laboratories
T	Thermal Energy Range
Ta	Tantalum
UO_2	Uranium Oxide
UO_2-BeO	Uranium Oxide - Beryllium Oxide Fuel

1. INTRODUCTION

In the discipline of nuclear criticality safety, it is important to study critical systems for a better understanding of the behavior of the material within the system. These critical systems are known as “benchmarks”, and multiple experiments are performed on these systems to calculate and evaluate various aspects of the system. This data is then used to validate calculation tools and cross-section libraries by the nuclear criticality safety industry around the world. These benchmarks are compiled into a handbook known as the International Criticality Safety Benchmark Evaluation Project (ICSBEP) handbook.

The ICSBEP handbook contains over 800 cases of critical/subcritical experiment data using various fuels and systems. As the ICSBEP handbook currently stands, there are 37 benchmarks that provide data for critical systems containing beryllium reflectors. There are 14 benchmarks that contain data for systems with beryllium moderator. There is only one experiment set that contains beryllium oxide fuel, and that is HEU-COMP-THERM-010 [1]. More data utilizing beryllium within fuel is needed to assist in further validation of beryllium fuel types. Further benefit from this study includes the spectrum shifting capability of the design into the intermediate spectrum. Having more data within the intermediate spectrum is also important to the ICSBEP handbook for similar purposes as listed above, especially considering that HEU-COMP-THERM-010 is within the thermal range. This means that there are no current benchmarks utilizing beryllium within the fuel that are above the thermal neutron energy spectrum [1]. To increase this data, multiple models were developed to perform a feasibility study that would become the critical experiment setup for a potential benchmark incorporating beryllium within the fuel material with neutron energy spectrum shifting capabilities. This particular fuel material is uranium oxide-beryllium oxide (UO_2-BeO) from the Annular Core Research Reactor (ACRR) at Sandia National Laboratory (Sandia).

The ACRR at Sandia is a water-moderated pool-type research reactor capable of pulse and steady-state operations, which is shown in Figure 1.1 emitting Cherenkov radiation with pool lights on. The ACRR fuel elements consist of an outer stainless-steel cladding, trifluted end fittings, niobium insulation cups, and UO_2-BeO fuel pellets formed into disks. The UO_2-BeO material is 21.5 weight percent UO_2, with the uranium enriched to approximately 35 weight percent ^{235}U [2].

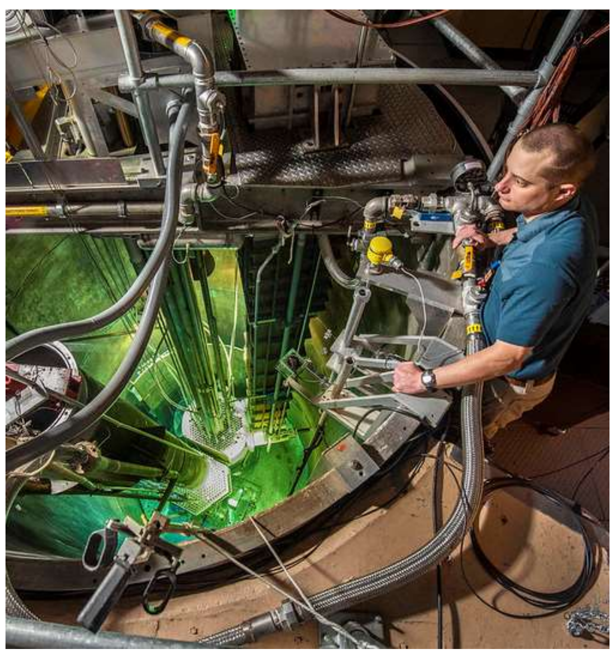


Figure 1.1: Sandia National Labs ACRR.

The Sandia Pulse Reactor Facility (SPRF) is a location designed for performing critical experiments of various designs and fuel types, which can be seen in Figure 1.2. The facility is designed to be able to do experiments by varying fuel pin pitch, core size, and moderator characteristics that provide a hands-on learning experience for nuclear criticality safety engineers in training. This is where the Seven Percent Critical Experiment (7uPCX) fuel rods are used [3].

Figure 1.2: 7uPCX Rods in SPRF.

The ACRR fuel elements would be brought to the SPRF and used in the reactor system that is available there. The flexible design of the system allows for larger fuel elements to be used in its setup. Because of the limited number of ACRR fuel elements available for use for this critical experiment, the 7uPCX fuel that is associated with the SPRF will be used as a driver fuel for this experiment.

This study involved generating models based on resources available at Sandia for the eventual creation of the critical system. The general idea of the model is to have a central test region containing the UO_2-BeO fuel surrounded by 7uPCX fuel to drive criticality for the experiments. The reactivity of the assembly will be controlled by varying the number of driver elements within the core and the amount of water within the core tank. Throughout this process, one model utilizing fully built ACRR fuel elements and one model utilizing layers of UO_2-BeO fuel pellets were analyzed. The goal for this project is to design a critical experiment facility for performing critical experiments of various neutron energy spectrums.

The major design parameters for this modeling process are as follows:

- 35%-enriched ^{235}U in the UO_2-BeO fuel
- ACRR fuel characterized
- 7uPCX fuel rods used as a driver fuel
- Critical system
- Beryllium cross section data is acquirable in the thermal neutron energy range (<0.625 eV)
- Beryllium cross section data is acquirable in the intermediate neutron energy range (0.625 eV – 100 keV)
- Beryllium oxide cross section data is acquirable in the thermal neutron energy range (<0.625 eV)
- Beryllium oxide cross section data is acquirable in the intermediate neutron energy range (0.625 eV – 100 keV)

The first model that was considered was the, “UO_2-BeO Pellet Configuration”. This model had individual UO_2-BeO pellets stacked centrally in the core in layers of 25 pellets each. These stacked layers were radially surrounded by 7uPCX fuel rods in a rectangular lattice. This lattice was enclosed by radial and axial reflectors.

The second model that was considered was the, “ACRR Fuel Element Configuration”. This model had the UO_2-BeO fuel contained in fuel element form as it is currently constructed. The central cavity of the core contained 7 full ACRR fuel elements. This central cavity was surrounded by 7uPCX fuel rods in a hexagonal lattice.

These two models were the main cornerstones for the calculations and decisions that were made during this feasibility study. These models will be discussed in detail in this document. Sensitivity analysis will be discussed and the process explained later in this document, as well as the process for minimizing uncertainty of the calculations.

This feasibility study is acting as a precursor to the CEdT process for critical experiments. The CEdT process directs critical experiments down the path to becoming future benchmarks in the ICSBEP handbook. In the future, it is intended for a critical experiment to be conducted using this UO_2-BeO fuel through this process.

This report will detail the process for how a parametric analysis was performed for selected design parameters that were used for consideration in the evolution of the experiment design. This will include the decisions that were made along the way that resulted in the two models’ current configurations. The final design of the critical experiment will also be discussed in this document.

2. FUEL DESIGN

2.1. BERYLLIUM AND BERYLLIUM OXIDE ANALYSIS

Beryllium has been used in multiple ICSBEP benchmarks for a variety of purposes. These purposes range from the reflector material to the moderator material. There is only one isotope of beryllium that is found in nature: ^{9}Be. The total, elastic, and capture cross sections for ^{9}Be are shown in Figure 2.1.

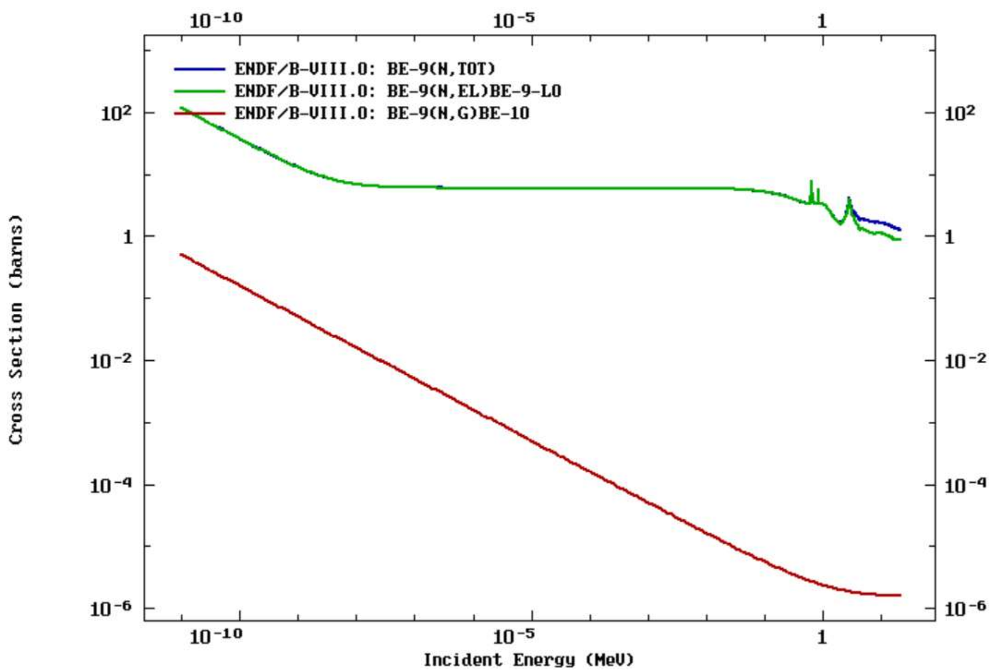


Figure 2.1: Beryllium Total, Elastic, and Capture Cross Sections [4].

The total cross section shows that it is very similar to the elastic cross section. With an elastic cross section on the order of 10^2 barns, this means that ^{9}Be has potential to act as a reflector depending on the reactor system. The capture cross section is much lower than the other cross sections shown. This shows that the rate at which beryllium absorbs is not as significant as the elastic cross section, although, it does have moderating capabilities.

Beryllium oxide (BeO) is a compound that is comprised of ^{9}Be and ^{16}O. BeO has also been used in benchmarks for a variety of purposes. These purposes range from the reflector material to the moderator. The total cross sections for these two isotopes are shown in Figure 2.2.

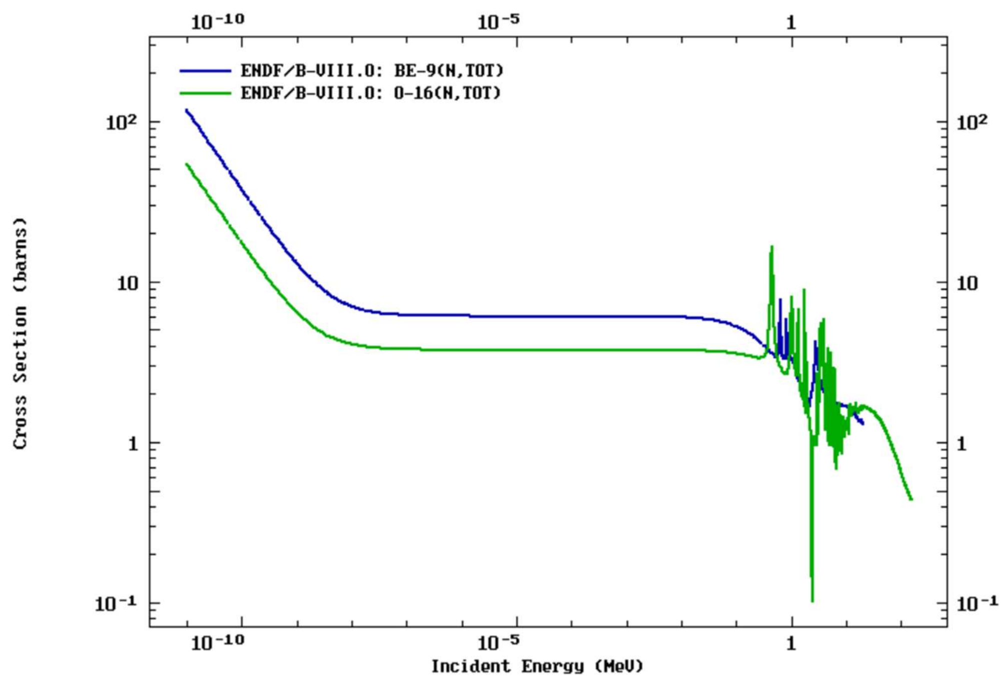


Figure 2.2: Beryllium and Oxygen Total Cross Sections [4].

The capture cross sections for ^{9}Be and ^{16}O are shown in Figure 2.3. The ^{16}O has a smaller capture cross section than the ^{9}Be for the thermal and intermediate energy ranges. The ^{16}O has a higher capture cross section in the fast energy region than the ^{9}Be.

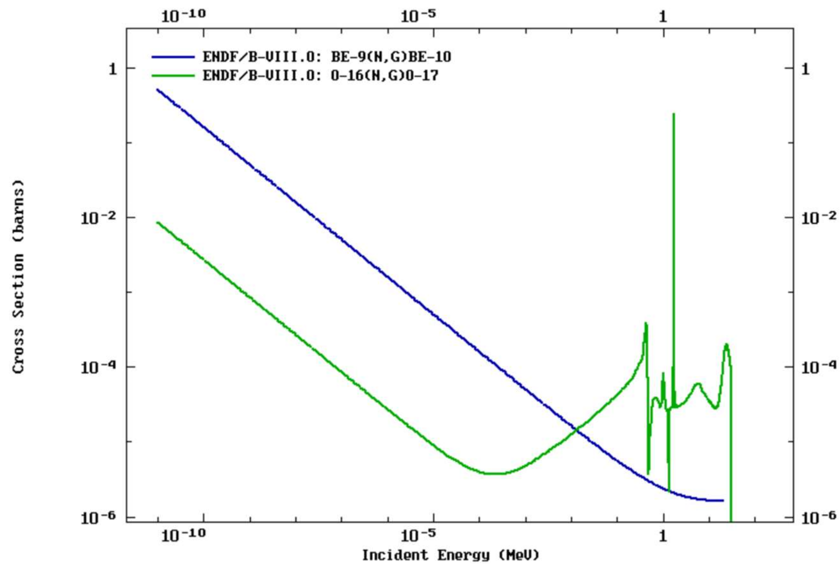


Figure 2.3: Beryllium and Oxygen Capture Cross Sections [4].

The elastic scattering cross sections for ^{9}Be and ^{16}O are shown in Figure 2.4. The ^{9}Be and ^{16}O have very similar cross section results for this scattering, but ^{9}Be has a larger elastic cross section than the ^{16}O.

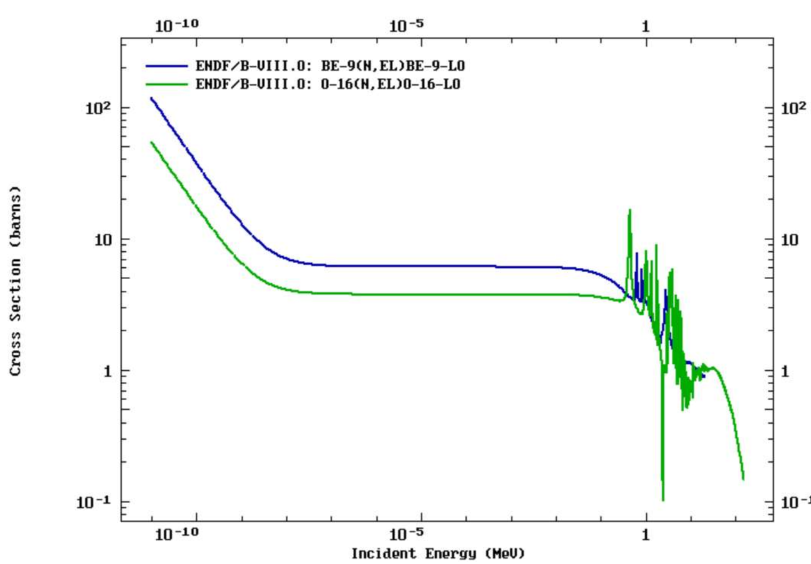


Figure 2.4: Beryllium and Oxygen Elastic Cross Sections [4].

The total, elastic, and capture cross sections for ^{9}Be and ^{16}O are all shown for easy comparison in Figure 2.5. The capture cross sections are shown to be much smaller for both ^{9}Be and ^{16}O as compared to the other cross sections by at least one order of magnitude. This means that beryllium and beryllium oxide would not be as good of an absorber material as it would be as a reflector material.

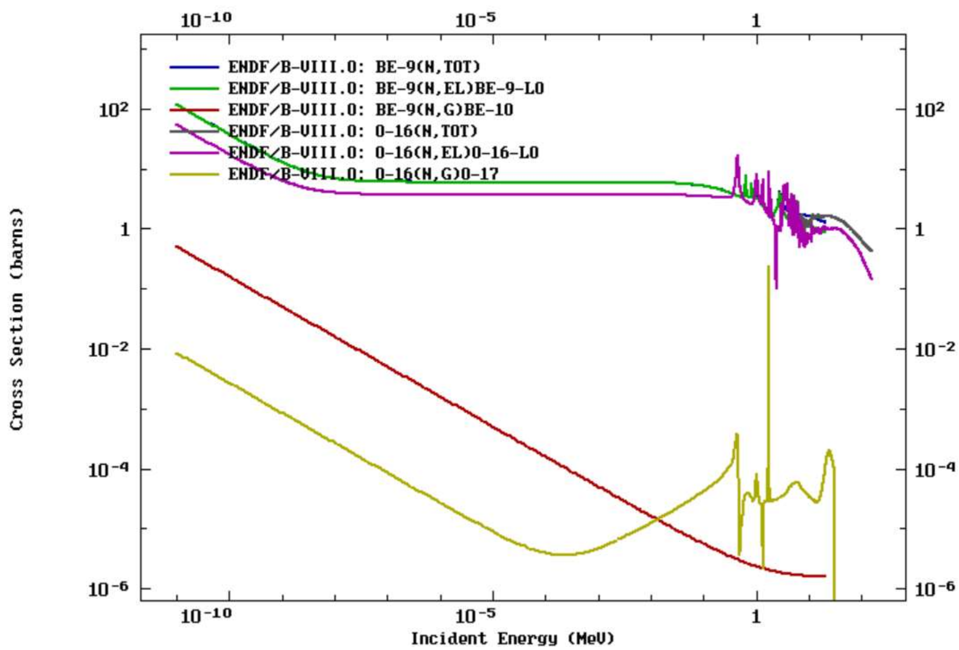


Figure 2.5: Beryllium and Oxygen Cross Sections of Interest [4].

2.2. BERYLLIUM OXIDE FUEL PELLETS

The ACRR UO2-BeO fuel meat for this first model configuration is in the form of fuel pellets comprised of four pieces. These four pieces include two inner half pieces and two outer half pieces. The fuel pellets can be seen in Figure 2.6.

Figure 2.6: ACRR Fuel Pellet Annuli [2].

Figure 2.7 shows a diagram of the fuel pellet radial cross section with all four annuli in position. The diameter of the fuel pellet is 3.368 cm with a gap between the inner and outer annuli.

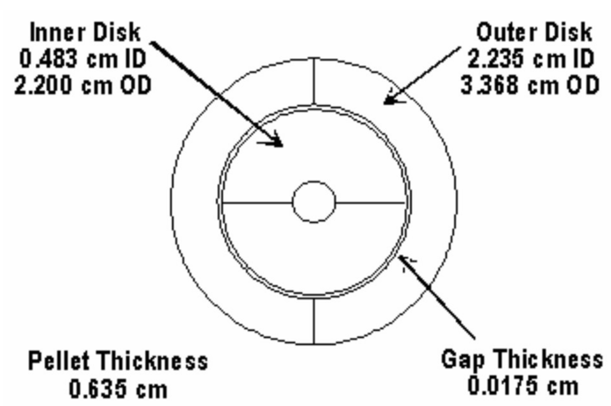


Figure 2.7: ACRR Fuel Pellet Description [2].

The ^{235}U enrichment of these fuel pellets is 35% with a fuel density of 3.4 g/cm^3. Table 2.1 contains some of the physical characteristics of the BeO fuel pellets extracted from §4.2.1.2 of the ACRR DSA and Sandia drawing T47230 [5].

Table 2.1: BeO Fuel Pellet Characteristics [5].

Property	Value
Fuel Material	UO_2-BeO
Weight Percent UO_2	21.5
^{235}U Enrichment (weight percent, w/o)	35
Fuel Density (g/cm^3)	3.4
Diameter of Inner Annulus (in)	0.190 +0.001/-0.005
Outer Diameter of Inner Pellet Pieces (in)	0.866 +0.000/-0.006
Inner Diameter of Outer Pellet Pieces (in)	0.880 +0.005/-0.003
Outer Diameter of Outer Pellet Piece (in)	1.326 +0.005/-0.003
Special Outer Piece Inner Radius (in)	0.880 +0.005/-0.003
Special Outer Piece Outer Radius (in)	1.262 +0.005/-0.003
Pellet Height (in)	0.250 +0.001/-0.004

From Table 2.1, several parameters were derived and are shown in Table 2.2. These parameters refer to the individual annuli pieces of the fuel pellet from the inner and outer disks [2].

Table 2.2: BeO Fuel Pellet Derived Characteristics [2].

Property	Value
Total Weight Percent ^{235}U	6.63
Volume of Half of Inner Pellet (cm^3)	1.149
Volume of Half of Outer Pellet (cm^3)	1.583
Volume of Full Pellet (cm^3)	5.464
^{235}U Mass of Half of Inner Pellet (g)	0.259
^{235}U Mass of Half of Outer Pellet (g)	0.357

2.3. ACRR FUEL ELEMENTS

The form that the BeO fuel took in this configuration was the form of a standard ACRR fuel element. The axial view of this fuel element can be seen in Figure 2.8.

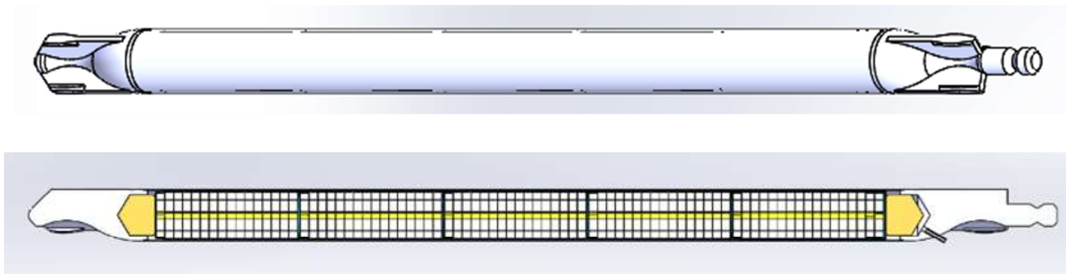


Figure 2.8: ACRR Fuel Element Schematics [6].

The fuel element dimensions are listed in Table 2.3 corresponding to Figure 2.8 above. The fuel element has a center gap in the middle of the fuel pellet. Moving outward, the inner shell of the four-piece fuel pellet meets a small gap, then the outer shell of the fuel pellet. This is enclosed in a niobium cup that is surrounded by stainless steel cladding.

Table 2.3: ACRR Fuel Element Dimensions [7].

Property	Dimension (cm)
Center Gap Radius	0.2415
Inner Shells Radius	1.1000
Outer Shells Radius	1.6840
Niobium Cup Radius	1.77038
Fuel Element Radius	1.87198
Fuel Element Length	75.1856

The ACRR fuel elements have sixteen fuel pellet disks (four pellet pieces shaped into a disk with inner diameter of 0.483 cm, outer diameter of 3.37 cm, and thickness of 0.635 cm) that are loaded into a niobium cup to a height of 10.16 cm. If the niobium cup is for the top of the fuel element, then it is filled with 17 stacked disks. These fuel pellet disks are the same kind of fuel pellets that were used in the first configuration. The niobium cup has a height of 10.846 cm and outer diameter of 3.5408 cm diameter with a wall thickness of 0.0381 cm. Five fuel-loaded niobium cups are stacked in an element to give an effective fuel height of 52.25 cm. Solid BeO plugs, about 2.5 cm thick, are positioned above and the fuel stack to act as reflectors. Stainless steel tubing with a length of 54.534 cm, outer diameter of 3.747 cm, and a wall thickness of 0.051 cm provides the outer cladding for the fuel element. The element end fittings are fluted for coolant flow purposes with the top fitting having an extended pin for handling purposes [7].

The fuel element was designed with fuel pellets this small to minimize fracturing of the fuel material in the rapid energy deposition of the pulse reactor system. The high energy pulse operations of the ACRR cause large thermal gradients and stresses that most fuel elements cannot normally sustain. This design was created with UO_2-BeO fuel in this capacity for the purpose of sustaining high thermal stress and thermal gradients [7].

2.4. 7UPCX FUEL RODS

The fuel responsible for driving the criticality of the system being investigated is 7uPCX fuel rods. This is a well-characterized fuel that appears in 6 experiment sets in the ICSBEP handbook: LEU-COMP-THERM-078, 080, 096, 097, 101, and 102 [1]. Figure 2.9 shows a schematic of these components in the fuel rod measured in inches with major components.

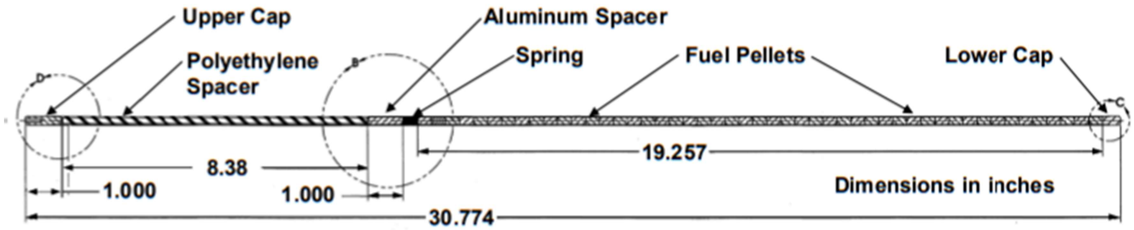


Figure 2.9: 7uPCX Fuel Rod Schematic [8].

The 7uPCX fuel rods were fabricated using unirradiated 6.90% enriched UO_2 fuel pellets from fuel elements designed to be used in the internal nuclear superheater section of the Pathfinder boiling water reactor operated in South Dakota by the Northern States Power Company in the 1960s. The nominal outside diameter of the fuel pellets is 0.52578 cm. The nominal outside diameter of the fuel rod cladding is 0.635 cm. The nominal fuel density is 10.265 g/cm^3 [8].

The cladding tubes are welded to the lower caps. The material stack in the fuel rods, starting at the bottom, is as follows: a 1.270 cm 3003 aluminum lower cap; a nominal 48.91278 cm stack of fuel pellets; a corrosion-resistant steel compression spring 0.4572 cm outside diameter, 0.35052 cm inside diameter, 2.2225 cm uncompressed length whose length adjusts according to the actual length of the fuel stack; a 2.540 cm 6061 aluminum spacer 0.52578 ± 0.02540 cm diameter, an 21.2852 ± 0.0508 cm long high-density polyethylene spacer also 0.52578 ± 0.02540 cm diameter, and a 2.540 cm 3003 aluminum top cap [8].

Figure 2.10 shows the model of the 7uPCX fuel rods in MCNP6.2 with major height markers and labeled components.

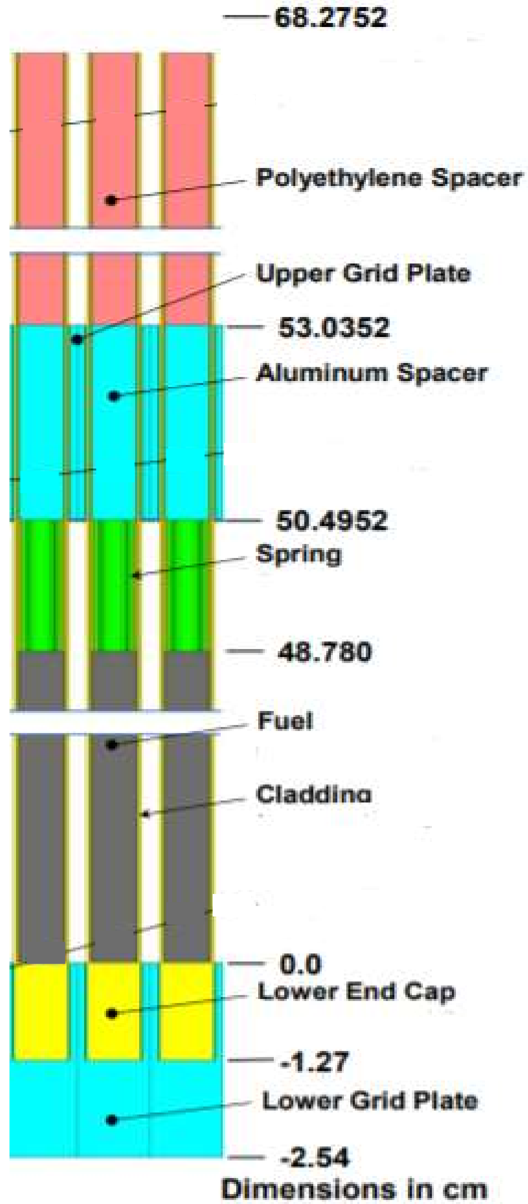


Figure 2.10: Model of 7uPCX Rods [8].

Major dimensions and uncertainties can be seen in Table 2.4. Some of the dimensions in this table have corresponding engineering tolerances included from previously performed benchmarks and drawings of these fuel rods.

Table 2.4: 7uPCX Fuel Rod Parameters [4].

Parameters	Dimensions (cm)
7uPCX Fuel Rod Height	68.2752
Polyethylene Spacer OD	0.52578 ± 0.02540
Polyethylene Spacer Height	15.24
Upper Grid Plate Height	2.54
Aluminum Spacer OD	0.52578 ± 0.02540
Aluminum Spacer Height	2.54
Spring OD	0.4572
Spring ID	0.35052
Spring Height	1.7152
Fuel Diameter	0.525628 ± 0.00048
Fuel Height	48.780 ± 0.13
Cladding Outer Diameter	0.634948 ± 0.000218
Cladding Inner Diameter	0.569038 ± 0.000164
Lower End Cap OD	0.634948
Lower End Cap Height	1.27
Lower Grid Plate Height	1.27

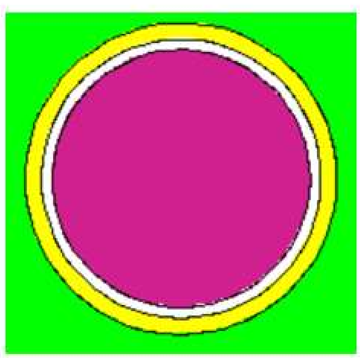
3. PRELIMINARY DESIGN

3.1. BERYLLIUM OXIDE FUEL PELLET MODEL

The first idea that was pursued involved using BeO fuel pellets stacked in a central cavity. This configuration was investigated as it requires the fewest alterations to the current tank and equipment arrangement, even though characterizing the isolated fuel pellets is not as preferred as characterizing the full fuel elements.

3.1.1. Fuel. The two fuels used in the BeO fuel pellet model were the 7uPCX driver fuel and the BeO fuel pellets.

3.1.1.1. 7uPCX fuel model. The 7uPCX driver fuel rods were modeled in MCNP6.2. The radial view of a single fuel rod can be seen in Figure 3.1. The 7uPCX fuel rod model has a cylinder of the UO_2 fuel meat surrounded by a gap modeled as void enclosed in a 3003 aluminum cladding.



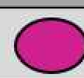
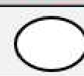
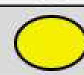
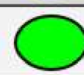
Color	Material
	UO_2
	Void
	3003 Aluminum
	Water

Figure 3.1: MCNP6.2 Model of the Radial View of the 7uPCX Fuel Rod.

The spring was modeled as a solid cylinder of steel. The aluminum and polyethylene spacers were also modeled as cylinders within the confines of the radius of the fuel region.

3.1.1.2. Beryllium oxide fuel pellet model. The second fuel that was used in the BeO fuel pellet design was the BeO fuel pellet. Figure 3.2 shows the radial view of a BeO fuel pellet modeled in MCNP6.2. The two HD portions of the inner disk are modeled as one inner ring, and the CM portions of the outer disk are modeled as one outer ring. The center gap and the gap between the inner and outer disks is filled with air.

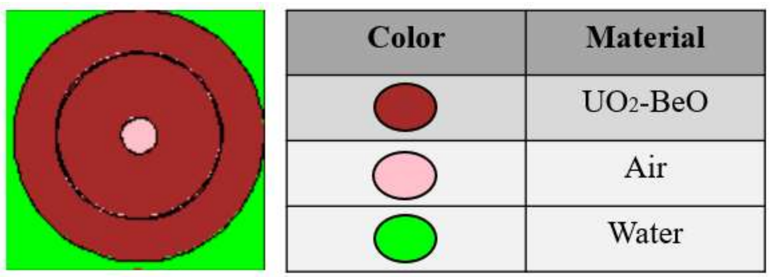


Figure 3.2: MCNP6.2 Model of the Radial View of the BeO Fuel Pellet.

The axial view of the BeO fuel pellet can be seen in Figure 3.3. The height of the fuel pellet is modeled to be 0.635 cm.

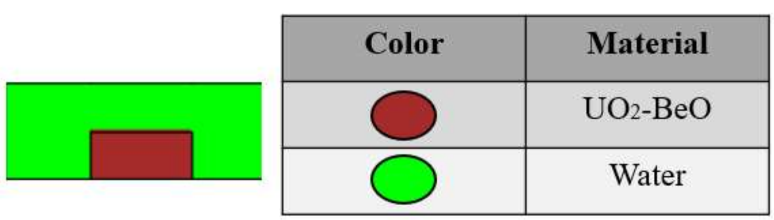


Figure 3.3: MCNP6.2 Model of the Axial View of the BeO Fuel Pellet.

The UO_2-BeO fuel material is 21.5 weight percent UO_2 with a ^{235}U enrichment of 35%. The rest of the uranium in the system was modeled to be the natural abundance of uranium excluding ^{235}U.

3.1.2. Critical Experiment Design. The first model design was based on the concept that the BeO fuel would be present in the form of pellets, rather than fully built fuel elements. These pellets could then be stacked up within the model to approach criticality using the 1/M approach. The main structure of this model would have a grid of these pellets stacked in the central cavity surrounded by a casing, and then driver fuel would surround that cavity to drive criticality.

The UO_2-BeO fuel pellet configuration contains 40 layers, each layer made up of a square grid of 25 individual ACRR fuel pellets. The radial model view of the pellet configuration concept can be seen in Figure 3.4. The central cavity is shown to contain the circular fuel pellets within a beryllium moderator. There are 540 7uPCX rods surrounding this central cavity radially and are shown to be submerged in water. The box containing the central cavity is modeled as 6061 aluminum.

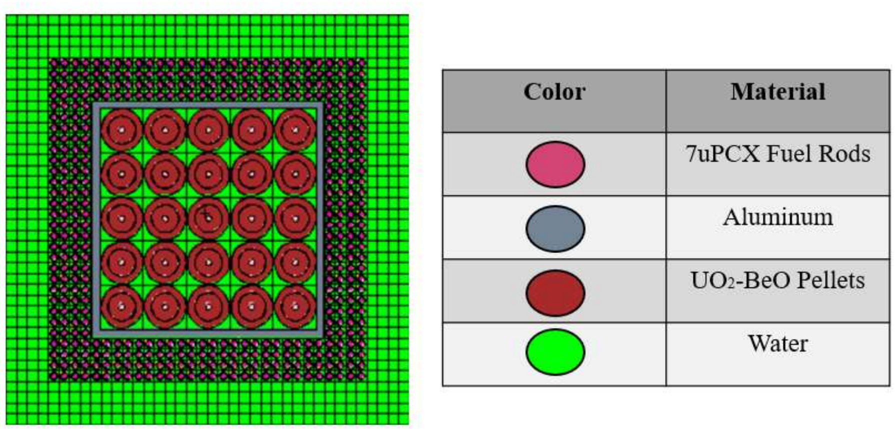


Figure 3.4: BeO Pellet Model Radial View.

Figure 3.5 shows the axial view of the pellet model. There are 40 layers of fuel pellets stacked up. Above and below this stack are axial water reflectors. The radial reflectors are made of water surrounding the 7uPCX grid.

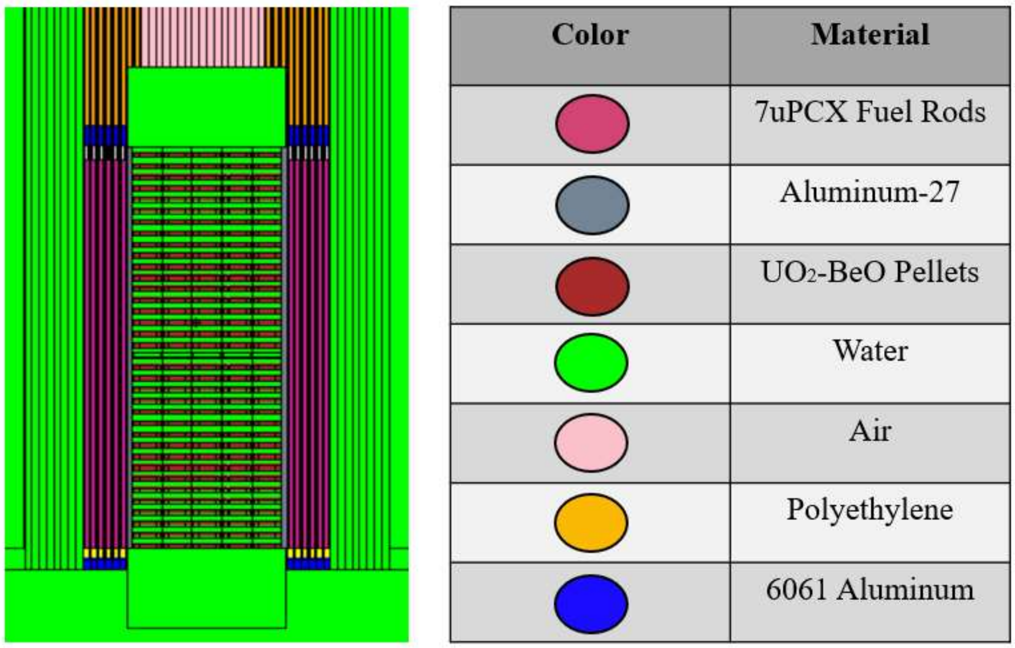


Figure 3.5: BeO Pellet Model Axial View.

The analysis for this critical experiment began with the first model. With Sandia's BeO fuel pellets available, these were what was considered as the first option for this project. The model was designed to have stackable fuel pellets to aid in using a 1/M approach to criticality. The following dimensions were provided for use for this theoretical facility shown in Table 3.1.

Table 3.1: BeO Pellet Model System Dimensions [7].

Property	Dimension (cm)
Water Level	68.2752
Axial Reflector Height	10
Radial Reflector Height	68.2752
7uPCX Pitch	0.854964
BeO Fuel Pellet Pitch	3.5
Central Cavity Height	50.40

3.1.3. Material Considerations. This model has multiple considerations that needed to be investigated in the design process. The feasibility of having a beryllium moderator surrounding these individual pellets is something that would be very difficult to manufacture. This model is also lacking the spacing between the beryllium moderator and BeO pellets that would tangibly be present. Considering that the goal of this study is to have a critical experiment design focusing on characterizing the BeO fuel, having a beryllium moderator present would make it difficult to see the sensitivity of the BeO fuel in future calculations.

To determine the best version of the fuel pellet model, the material composition of the driver fuel moderator, pellet moderator, radial reflectors, and axial reflectors were varied in different combinations using common moderator and reflector materials such as water, beryllium, and graphite. These models were analyzed to determine which ones would approach criticality within 40 layers of pellets, given that that was the amount of available space provided at the labs. Of these 81 material combinations, 23 of them were able to approach criticality at various points within 40 layers. Table 3.2 shows the 23 configurations that approached criticality, and at which point it occurred.

Table 3.2: BeO Pellet Model Critical Material Configurations.

Combination	Driver Fuel Mod	Pellet Mod	Radial Reflector	Axial Reflector	k_{eff} (upper layer)	σ	Layers where M=0
1311	Beryllium	Water	Beryllium	Beryllium	1.00887	0.00042	10/11
1312	Beryllium	Water	Beryllium	Graphite	1.00816	0.00041	11/12
1313	Beryllium	Water	Beryllium	Water	1.00555	0.00042	12/13
1321	Beryllium	Water	Graphite	Beryllium	1.00271	0.00045	16/17
1323	Beryllium	Water	Graphite	Water	1.00321	0.00047	18/19
1331	Beryllium	Water	Water	Beryllium	1.00257	0.00047	24/25
1332	Beryllium	Water	Water	Graphite	1.00071	0.00043	25/26
1333	Beryllium	Water	Water	Water	1.00507	0.00043	26/27
2311	Graphite	Water	Beryllium	Beryllium	1.00378	0.00043	13/14
2312	Graphite	Water	Beryllium	Graphite	1.00238	0.00041	14/15
2313	Graphite	Water	Beryllium	Water	1.00938	0.00041	16/17
2321	Graphite	Water	Graphite	Beryllium	1.00153	0.00045	20/21
2322	Graphite	Water	Graphite	Graphite	1.0069	0.00047	22/23
2323	Graphite	Water	Graphite	Water	1.00908	0.00046	23/24
2331	Graphite	Water	Water	Beryllium	1.00525	0.00045	31/32
2332	Graphite	Water	Water	Graphite	1.00125	0.00045	33/34
2333	Graphite	Water	Water	Water	1.00279	0.00044	34/35
3132	Water	Beryllium	Water	Graphite	1.00024	0.00041	4/5
3133	Water	Beryllium	Water	Water	1.00055	0.00042	6/7
3232	Water	Graphite	Water	Graphite	1.00003	0.00043	6/7
3233	Water	Graphite	Water	Water	1.00109	0.00041	10/11
3332	Water	Water	Water	Graphite	1.00248	0.00044	2/3
3333	Water	Water	Water	Water	1.00094	0.0004	3/4

After eliminating 58 of the 81 options through the 1/M approach, more elimination was still required. Because 7uPCX driver fuel is well-characterized within a water moderator, it was desirable to keep the driver fuel within water. This narrowed down the 23 options to 6 possible configurations. Because of the difficulty of implementing graphite or beryllium into a stackable pellet system, it was desirable to keep the pellet moderator water as well. This narrowed the options down to 2 possible configurations. From these two, 3333 was the best configuration to pursue because it took more layers for it to approach criticality.

3.1.4. Reducing Excess Reactivity. After this analysis was performed and 3333 was selected as the primary model configuration to pursue, it was determined that the amount of excess reactivity within the system was too high. Because this configuration was able to approach criticality by layer 4, this would make it less beneficial to students learning about the 1/M approach. The experiment would be too fast this way. Because of this, the amount of 7uPCX driver fuel was reduced in the system. Originally, there were 812 7uPCX driver fuel rods surrounding the central cavity of BeO fuel pellets. In Table 3.3, a 1/M approach was performed to see how much 7uPCX driver fuel could be removed to maintain criticality.

Table 3.3: Removal of 7uPCX Driver Fuel Effect on Criticality.

Rings of 7uPCX	k_{eff}
10	1.14022 ± 0.00073
8	1.10626 ± 0.00073
6	1.06716 ± 0.00071
4	1.01907 ± 0.00075
2	0.95876 ± 0.00072

Figure 3.6 shows the corresponding MCNP6.2 models for the amount of 7uPCX rings. Note that all other factors were held constant during these calculations.

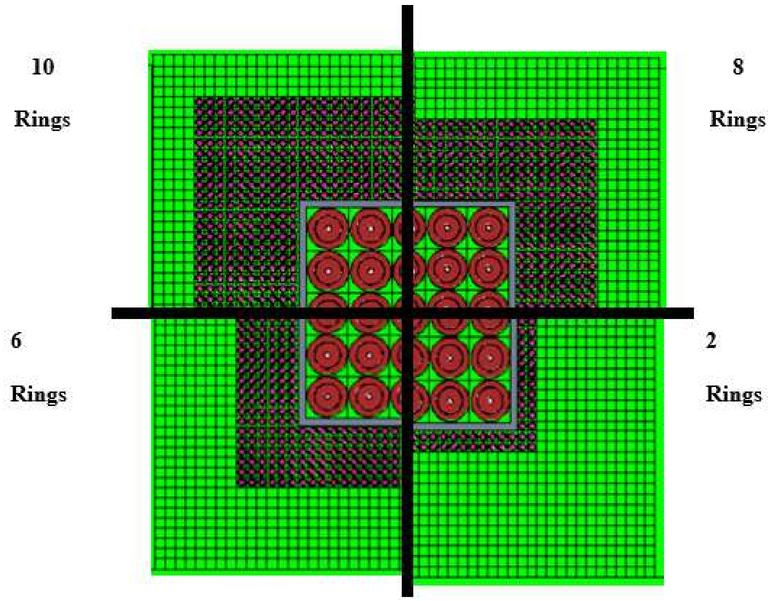


Figure 3.6: Removal of 7uPCX Driver Fuel.

These results indicate that maintaining 4 rings of 7uPCX surrounding the central cavity is necessary to achieve criticality. The final MCNP6.2 model is shown in Figure 3.7. Note that there are only 4 rings of 7uPCX fuel rods surrounding the central cavity of BeO fuel pellets.

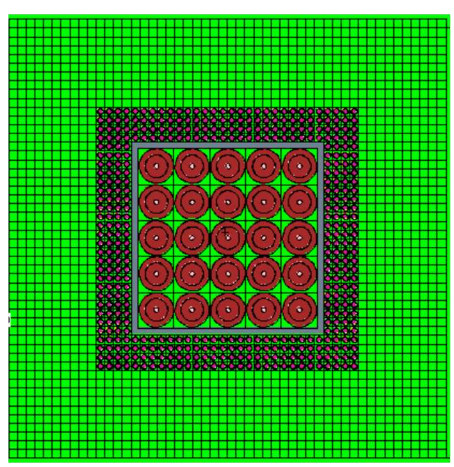


Figure 3.7: MCNP6.2 Model of BeO Pellet Model with Four Rings of 7uPCX.

To ensure that the 1/M approach still works by removing layers of BeO pellet fuel, the analysis was replicated for this new setup. The results are shown in Table 3.4.

Table 3.4: Effect of Layers of BeO Pellet Fuel on Criticality.

Layers	k_{eff}
40	1.01907 ± 0.00075
35	1.00644 ± 0.00080
34	1.00421 ± 0.00071
33	0.99991 ± 0.00072
32	0.99567 ± 0.00083
31	0.99199 ± 0.00076
30	0.98867 ± 0.00072

These results show that between layers 33 and 34, criticality occurs. This works for a 1/M experiment to be conducted by adding/removing layers of pellets.

3.1.5. Parametric Calculations. This section includes parametric calculations that were performed on the BeO fuel pellet model.

3.1.5.1. Reactivity effect of beryllium oxide. To understand the effect the presence the BeO fuel has in the system, the BeO pellets were replaced with a variety of other materials while the rest of the model was left in its baseline configuration. The BeO pellets was replaced with 7uPCX fuel, aluminum, water, and void. Table 3.5 shows the k_{eff} and reactivity worth associated with the BeO pellet replacements listed in the table.

Table 3.5: Reactivity Effect of Varying BeO Material in BeO Pellet Configuration.

Changes to Baseline Case	k_{eff}	**Reactivity Worth (%)**
34 Layers of BeO pellets - Baseline	1.00421 ± 0.00083	
Replace entire central cavity with 7uPCX fuel	1.08283 ± 0.00091	7.22 ± 0.11
Replace BeO pellets with aluminum	0.97207 ± 0.00083	-3.30 ± 0.12
Replace BeO pellets with water	0.98299 ± 0.00078	-2.16 ± 0.12
Replace BeO pellets with void	0.97682 ± 0.00079	-2.80 ± 0.12

Running multiple configurations changing driver fuel (7uPCX) moderation, pellet moderation, and reflecting material showed that 34 layers of 25 BeO pellets per layer, for a total of 850 pellets, surrounded by an aluminum casing and water as the 7uPCX driver fuel moderating material are sufficient to achieve criticality.

3.1.5.2. Fuel density. A sensitivity analysis was performed, looking at variations in the BeO pellet ^{235}U enrichment and BeO fuel density in the fuel. These analyses were done using the 34-layer configuration with water as the moderating material around the 7uPCX fuel rods. These 7uPCX fuel rods surrounded an aluminum sleeve containing the stacked loose pellets with interstitial water. The BeO fuel density was varied by ± 0.2 g/cc from the nominal density of 3.4 g/cc while leaving other material densities constant. Figure 3.8 shows the effects of variations in the density on k_{eff} of the system.

The data shows that there is an approximately linear trend in the increase in the systems multiplication factor with increasing BeO density. The R^2 value of this trend is 0.9929.

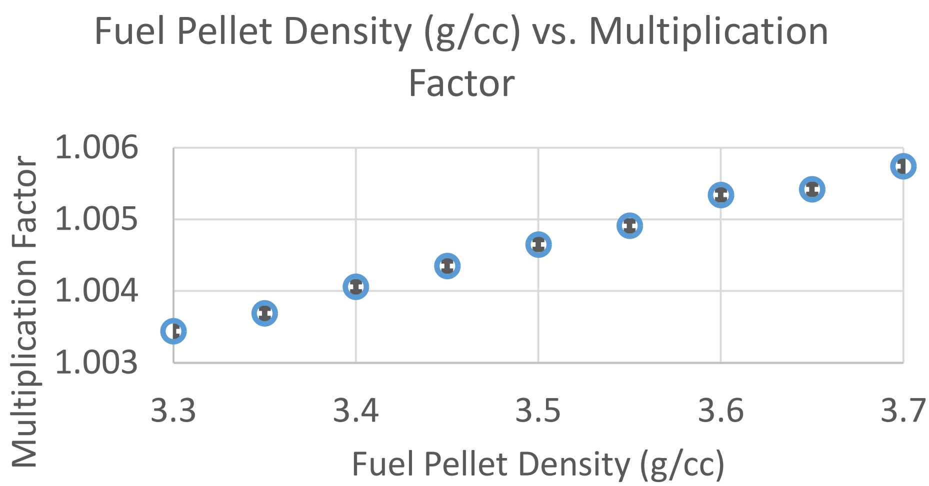


Figure 3.8: k_{eff} vs. BeO Material Density.

3.1.5.3. Fuel enrichment. The ^{235}U enrichment of the BeO pellet was varied by ± 1% from the nominal enrichment of 35%. Figure 3.9 shows the effects of the enrichment variations on k_{eff} of the system.

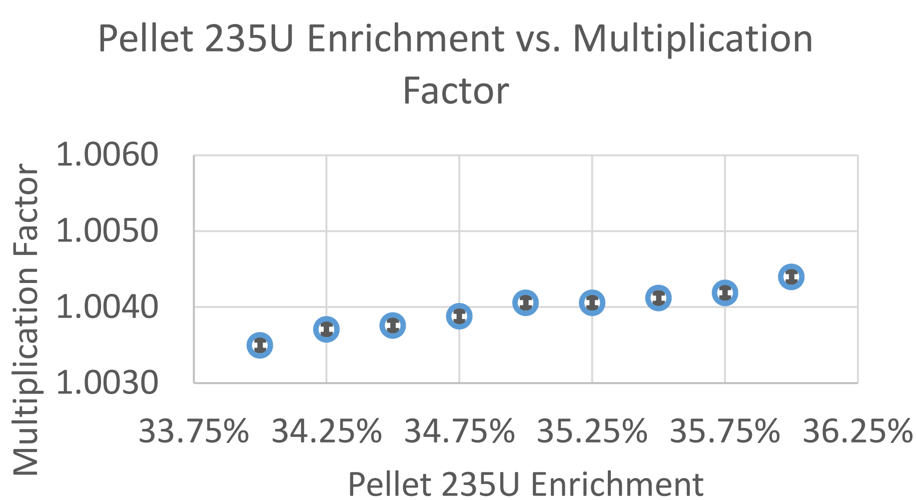


Figure 3.9: k_{eff} vs. BeO Pellet ^{235}U Enrichment.

This data shows that there is an approximately linear trend in the increase in k_{eff} for increasing ^{235}U enrichment. The R^2 value of this trend is 0.9602.

3.1.6. Neutron Energy Spectrum. The neutron energy spectrum was analyzed as part of investigating the design parameters for this model. This was analyzed in different areas of the model as shown in this section. The neutron energies are depicted by shaded regions cut off at 0.625 eV.

The neutron energy spectrum for the experiment layer in the BeO pellet model is shown in Figure 3.10. This spectrum shows a majority of thermal-energy neutrons below 0.625 eV. This is highlighted in the figure. The full width half maximum (FWHM) of this graph is on the order of 10^{-8} MeV, which means that the neutron energy spectrum in this particular configuration does not have a wide range of energies in which to shift.

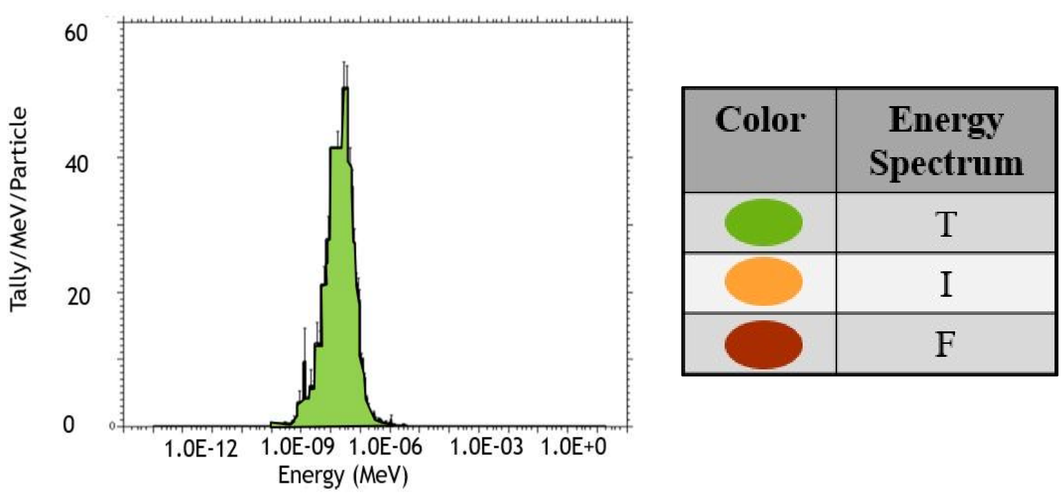


Figure 3.10: Beryllium Oxide Pellet Neutron Energy Spectrum in Central Cavity.

The neutron energy spectrum in a fuel rod adjacent to the aluminum box containing the central cavity is shown in Figure 3.11. This spectrum shows that, once again, the neutron energy spectrum is mostly thermalized in this region of the system, indicated by the colored portion. The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift.

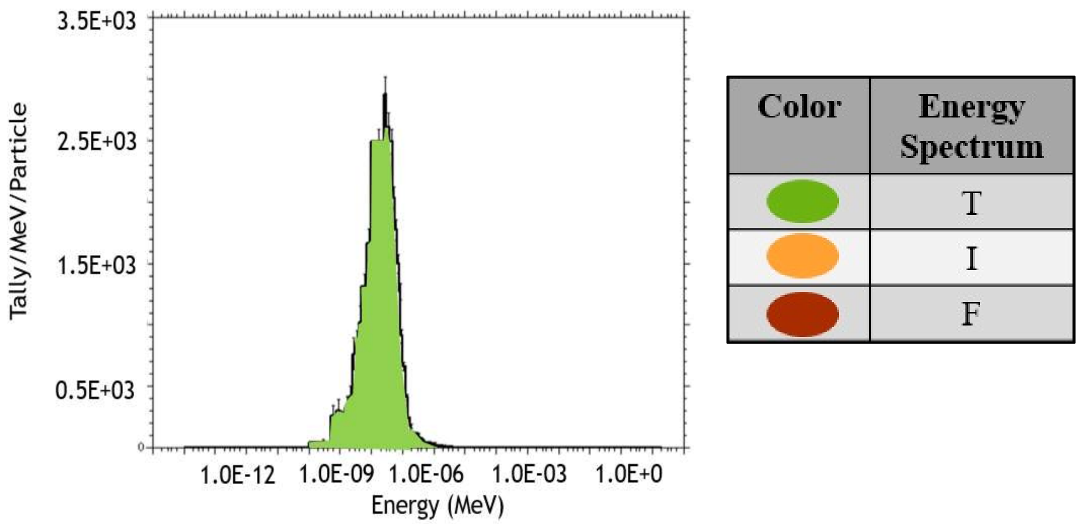


Figure 3.11: Beryllium Oxide Pellet Neutron Energy Spectrum in Experiment Layer.

The neutron energy spectrum in a fuel rod at the edge of the 7uPCX region is shown in Figure 3.12. This data shows that at the edge of the fuel region, it is still a very thermalized system. The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift.

The neutron energy spectrum in the central cavity of the fuel region is shown in Figure 3.13. This region is shown to have very thermalized neutrons with a small amount in higher energy regions. The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift.

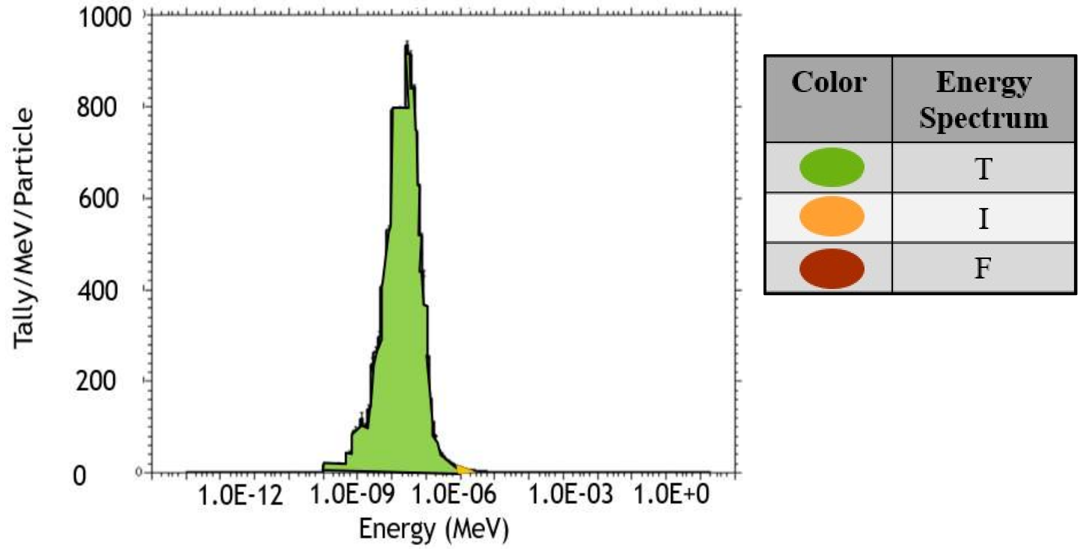


Figure 3.12: Beryllium Oxide Pellet Neutron Energy Spectrum Adjacent to Central Cavity.

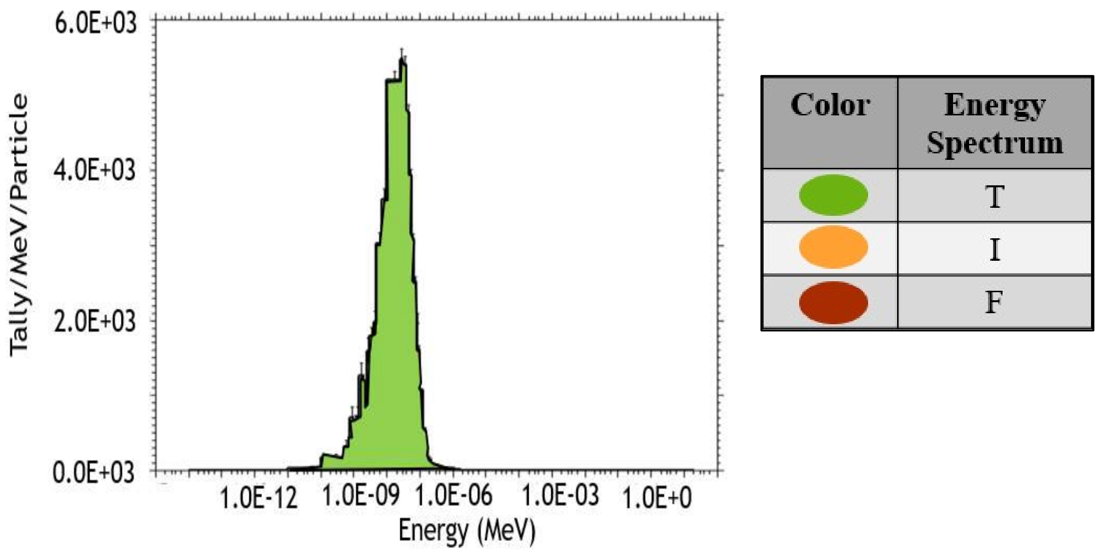


Figure 3.13: Beryllium Oxide Pellet Neutron Energy Spectrum at the Edge of Fuel Region.

3.1.7. Overall Assessment of the Beryllium Oxide Fuel Pellet Model. After the sensitivity calculations were performed, it was determined that the BeO fuel pellet model did not satisfy the design parameter of potentially achieving an intermediate neutron energy spectrum. It also did not characterize the ACRR fuel in the best way. Because of the use of the individual pellets, the exact fuel element that the current ACRR uses would not be characterized in the ICSBEP handbook. Because of this, a redesign of the model was necessary to achieve all of the goals of this critical experiment.

3.2. ACRR FUEL ELEMENT MODEL

The ACRR fuel element model was built around the idea that fully built and intact fuel elements originally meant for loading into the ACRR would be used in this critical experiment. In this way, the BeO fuel would be characterized as fuel elements that are currently being used in an operating reactor facility. This model would not have a direct 1/M learning application for students at the local university but would provide better data for characterizing the fuel. The design of this experiment builds off techniques and equipment utilized by other critical experiments performed (or designated for future execution) in SCX. For example, IER-441*, Epithermal HEX Lattices with Sandia 7uPCX Fuel for Testing Nuclear Data*, uses a hexagonal fuel lattice array with a central test region [9].

3.2.1. Fuel. There are two types of fuel used in the ACRR fuel element design: the 7uPCX driver fuel and the ACRR fuel element. These fuel types were modeled in MCNP6.2 [10]. This section will discuss the modeling of these fuels.

3.2.1.1. 7uPCX fuel model. The 7uPCX driver fuel rods were modeled in MCNP6.2. The radial view of a single fuel rod can be seen in Figure 3.14. The 7uPCX fuel rod model has a cylinder of the UO_2 fuel meat surrounded by a gap modeled as void enclosed in a 3003 aluminum cladding. The fuel region is divided into 4 midplane regions.

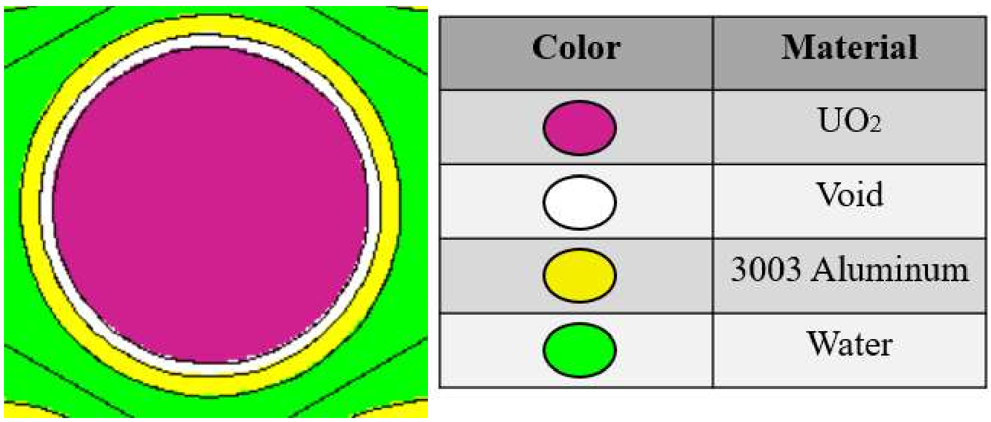


Figure 3.14: MCNP6.2 Model of 7uPCX Fuel Rod in ACRR Fuel Element Model.

The spring was modeled as a solid cylinder of steel with a voided center. The aluminum and polyethylene spacers were also modeled as cylinders within the confines of the radius of the fuel region. Voided gaps were placed between each of the spacers in the fuel rod. The 7uPCX fuel rods were modeled in an aluminum grid plate with BeO end caps and aluminum plugs holding it in place. Voided holes and gaps were also included in these to account for swelling.

3.2.1.2. ACRR fuel element model. The second fuel used in the ACRR fuel element model is the full ACRR fuel element. This was modeled using voided regions in the center gap of the fuel pellets within the fuel element, as well as voided gaps between the inner and outer sections of the BeO fuel pellet, and the outer fuel diameter, niobium cup, and stainless-steel cladding. The radial view of the fuel element can be seen in

Figure 3.15, and the axial view of the fuel element can be seen in Figure 3.16. The materials are labeled in Table 3.6.

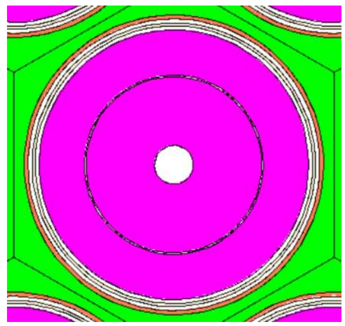


Figure 3.15: ACRR Fuel Element Radial View.

Figure 3.16: ACRR Fuel Element Axial View.

Table 3.6: ACRR Fuel Element Legend.

Color	Material
	UO_2-BeO Pellets
	Void
	Niobium
	Stainless Steel 304
	Water
	BeO Reflector
	Aluminum 6061

The end caps were modeled as BeO as can be seen in Figure 3.16. The stainless steel cladding surrounds these end caps and is what is used to hold the fuel element in place within the aluminum grid plate. The niobium cups are divided in the model into cylinders corresponding to each cup. There are five of these cylinders stacked in the model with voided gaps between each niobium cylinder.

3.2.2. Critical Experiment Design. The ACRR fuel element design was investigated as part of the CED feasibility study process. This concept includes ACRR fuel elements within a central test region of an assembly of 7uPCX rods. Figure 3.17 shows the MCNP6.2 model of this configuration in the radial view.

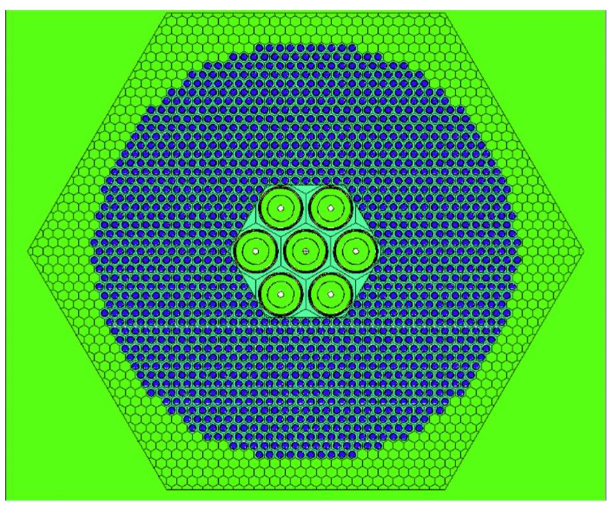


Figure 3.17: MCNP6.2 Radial View of the ACRR Fuel Element Design.

The ACRR fuel element design was given a hexagonal lattice for both the central cavity and the driver fuel regions because of the smaller pitch that can be achieved to help drive up the energy of neutrons being born in the system. This system is moderated and reflector by water. There are 1488 7uPCX fuel rods in this configuration with 7 ACRR fuel elements located in the central cavity.

The axial view of the ACRR fuel element design can be seen in Figure 3.18. The 7uPCX fuel rods are held in place by support arms. The entire model is fully submerged in a tank of water.

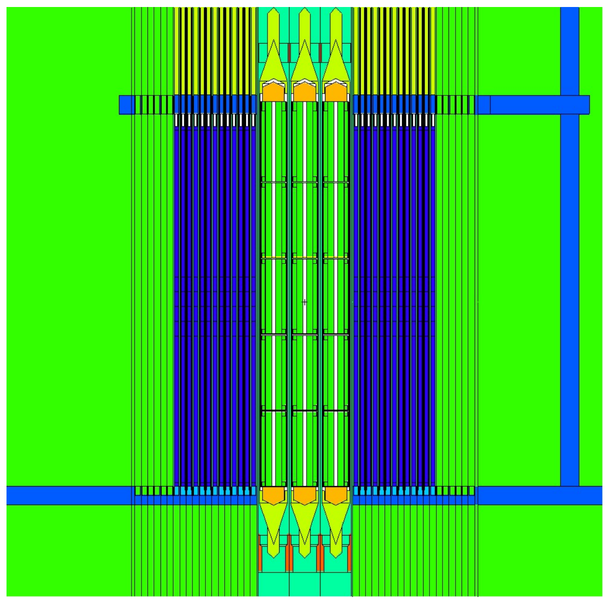


Figure 3.18: MCNP6.2 Axial View of the ACRR Fuel Element Design.

Up to seven ACRR fuel elements would potentially be available for the experiment at Sandia, and so, considering this restriction, seven elements were considered for beginning analysis [7].

3.2.3. Material Considerations. Certain material considerations were made, but the baseline case utilizing water moderator and reflector was the most feasible option for Sandia to begin analysis. This was a design choice made for the safety of the workers involved and due to restrictions from Sandia on this design choice [7].

ACRR fuel meat was held constant in the form of the fuel element. No changes were allowed to be made to this part of the design. The 7uPCX fuel rods were also held constant during this design process.

3.2.4. Reducing Excess Reactivity. Using these 7 ACRR fuel elements within a central hexagonal cavity, a 1/M approach to criticality was used to determine how many 7uPCX rods were necessary to drive criticality up to union. Considering the 7uPCX rods as rings, the following figures show each ring being added around the central cavity in numerical order: Figure 3.19, Figure 3.20, Figure 3.21, Figure 3.22, Figure 3.23, Figure 3.24, Figure 3.25, Figure 3.26, Figure 3.27, Figure 3.28, Figure 3.29, Figure 3.30, Figure 3.31, Figure 3.32, and Figure 3.33.

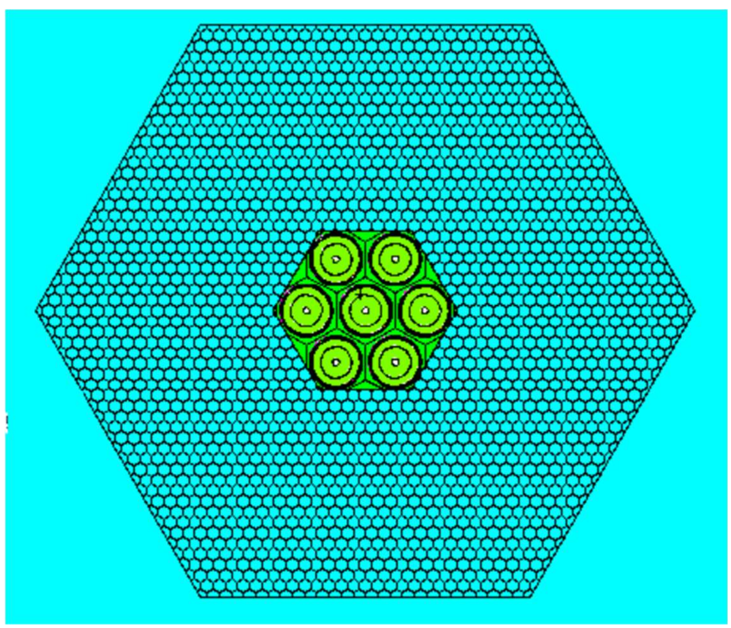


Figure 3.19: ACRR Fuel Element Model with No 7uPCX Fuel Rings.

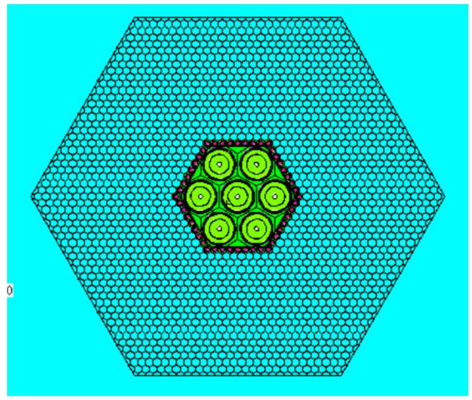


Figure 3.20: ACRR Fuel Element Model with 1 7uPCX Fuel Ring.

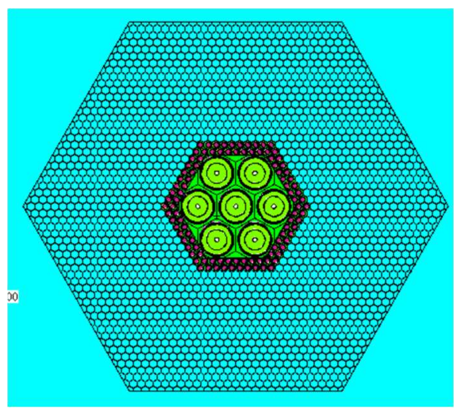


Figure 3.21: ACRR Fuel Element Model with 2 7uPCX Fuel Rings.

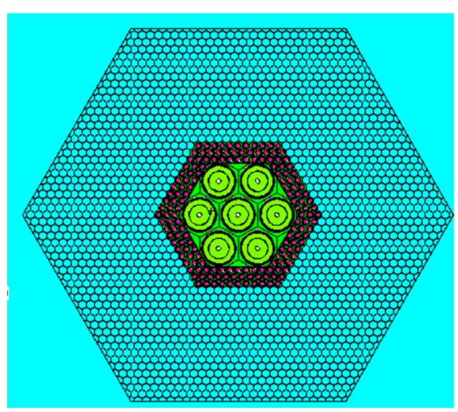


Figure 3.22: ACRR Fuel Element Model with 3 7uPCX Fuel Rings.

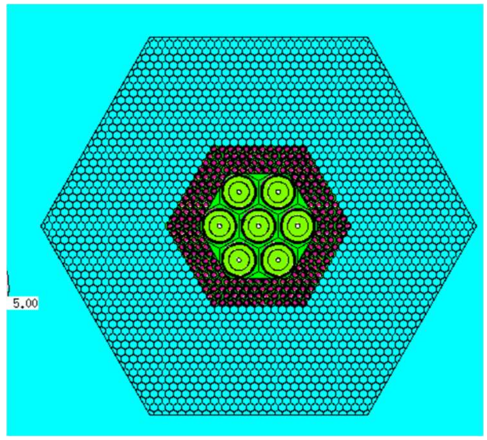


Figure 3.23: ACRR Fuel Element Model with 4 7uPCX Fuel Rings.

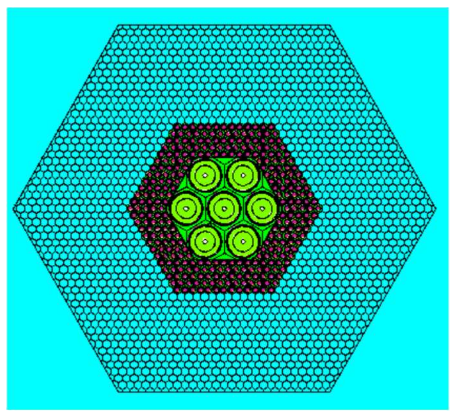


Figure 3.24: ACRR Fuel Element Model with 5 7uPCX Fuel Rings.

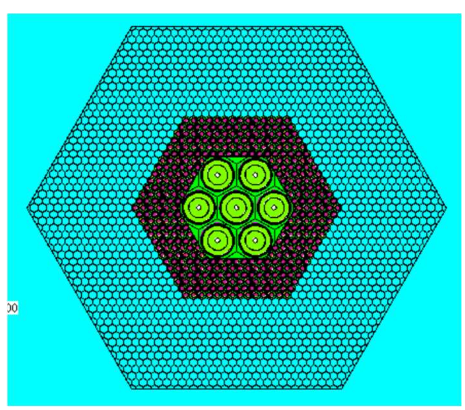


Figure 3.25: ACRR Fuel Element Model with 6 7uPCX Fuel Rings.

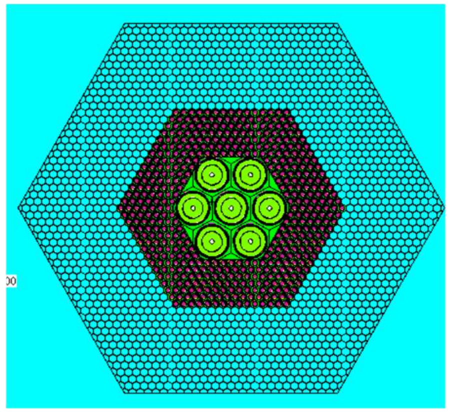


Figure 3.26: ACRR Fuel Element Model with 7 7uPCX Fuel Rings.

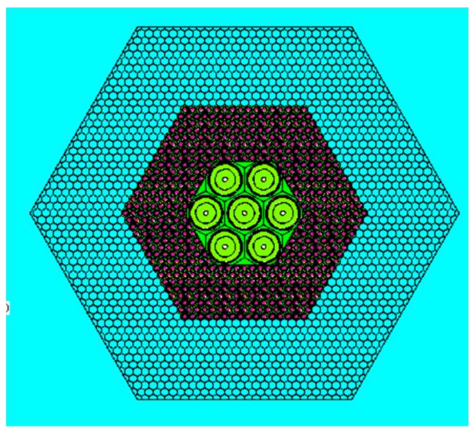


Figure 3.27: ACRR Fuel Element Model with 8 7uPCX Fuel Rings.

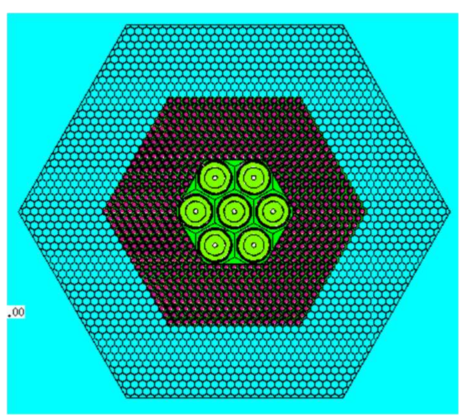


Figure 3.28: ACRR Fuel Element Model with 9 7uPCX Fuel Rings.

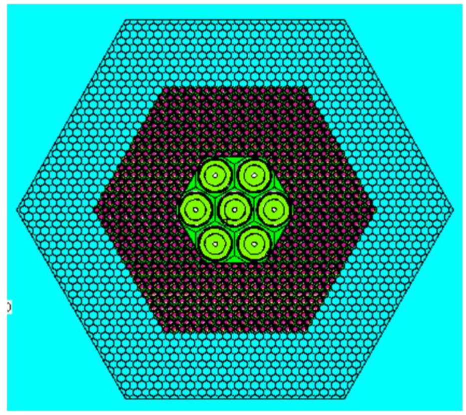


Figure 3.29: ACRR Fuel Element Model with 10 7uPCX Fuel Rings.

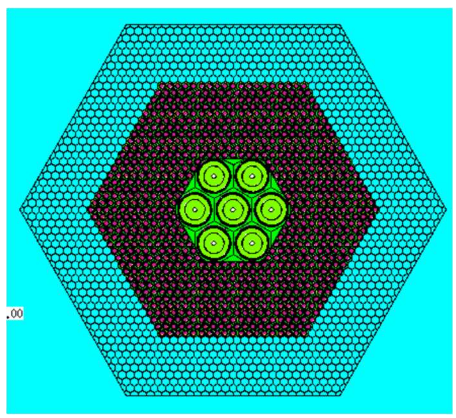


Figure 3.30: ACRR Fuel Element Model with 11 7uPCX Fuel Rings.

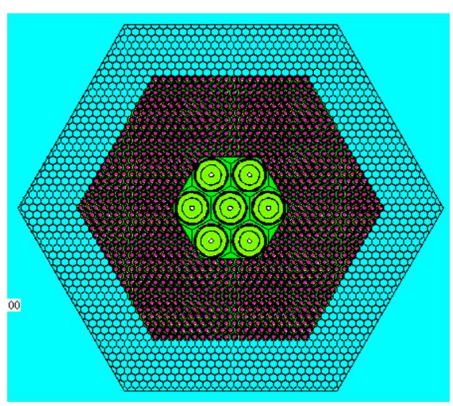


Figure 3.31: ACRR Fuel Element Model with 12 7uPCX Fuel Rings.

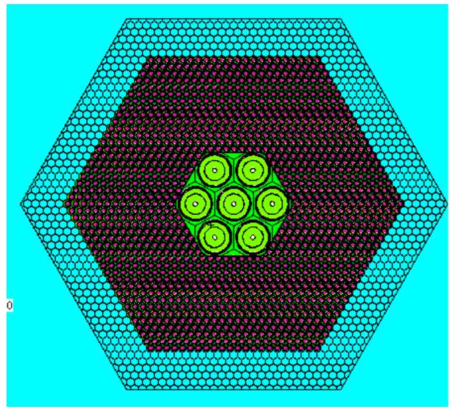


Figure 3.32: ACRR Fuel Element Model with 13 7uPCX Fuel Rings.

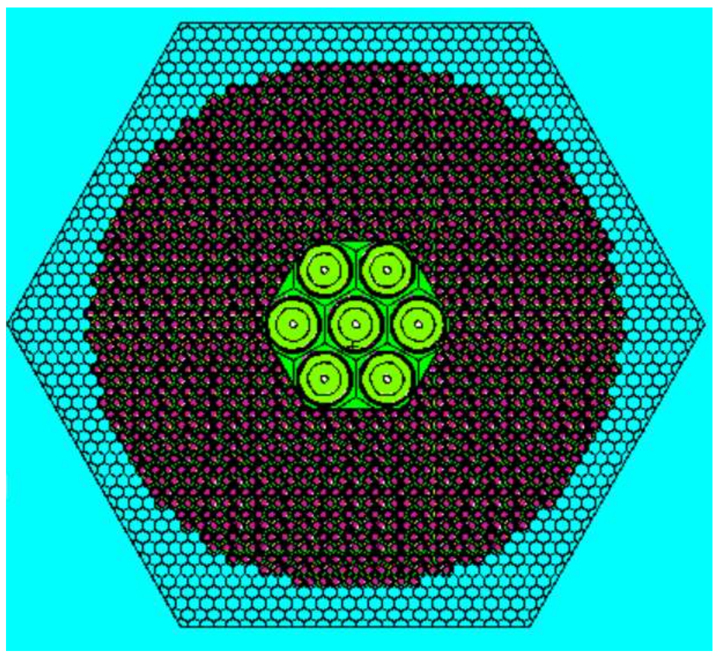


Figure 3.33: ACRR Fuel Element Model with 14 7uPCX Fuel Rings with Excess Reactivity.

The data for the criticality of the system for adding more and more rods can be seen in Table 3.7 from a 1/M approach series of calculations.

Table 3.7: 1/M Approach for 7uPCX Driver Fuel in the ACRR Fuel Element Model.

Added Rings	7uPCX Rods	k_{eff}
5	300	0.72453 ± 0.00003
6	378	0.76438 ± 0.00003
7	462	0.80047 ± 0.00003
8	552	0.83331 ± 0.00003
9	648	0.86318 ± 0.00003
10	750	0.89104 ± 0.00003
11	858	0.91664 ± 0.00003
12	972	0.94016 ± 0.00003
13	1092	0.96260 ± 0.00003
14	1218	1.00118 ± 0.00003
15	1362	1.02024 ± 0.00003

From this data, 1218 7uPCX fuel rods were sufficient to drive criticality to union. For future calculations, this model used 1362 7uPCX fuel rods for excess reactivity.

The neutron energy spectrum of the entire system with this base setup was modeled to have 85.63% of the neutrons in the thermal energy spectrum below 0.625 eV, 10.38% of the neutrons in the intermediate energy spectrum between 0.625 eV and 100 keV, and 3.98% of the neutrons in the fast energy spectrum above 100 keV.

3.2.5. Parametric Calculations. This section includes parametric calculations that were performed on the ACRR fuel element model.

3.2.5.1. Reactivity effects. Critical configurations with one and seven ACRR fuel elements were determined by varying the number of 7uPCX fuel rods. The fuel rods were added from the center toward the outside while maintaining a roughly cylindrical cross section of the array. Symmetrical arrays were generated by varying the 7upCX fuel rods in sets of six or twelve rods at a time. The analysis was performed for fuel rod arrays with a triangular pitch of 0.86 cm. The calculated critical configuration with one centrally located ACRR fuel element was 1488 7uPCX fuel rods. The calculated critical configuration with seven ACRR fuel element was 1362 7uPCX fuel rods. Reactivity effects were examined by altering the ACRR fuel element composition of the critical configurations. Table 3.8 provides the results from this study [7].

Table 3.8: Reactivity Effects for ACRR fuel element Configurations [7].

	1 ACRR fuel element	**7 ACRR fuel elements**
	0.86 cm pitch (1488 rods)	0.86 cm pitch (1362 rods)
Changes to Critical Configuration	**Reactivity Worth (%)**	**Reactivity Worth (%)**
Replace BeO fueled region with void	-0.478 ± 0.009	-4.506 ± 0.008
Replace ACRR fuel element(s) with void	-0.389 ± 0.009	-3.339 ± 0.008
Replace ACRR fuel element(s) with aluminum	-0.311 ± 0.009	-3.701 ± 0.008
Replace ACRR fuel element(s) with water	0.975 ± 0.009	-4.090 ± 0.008
Replace ACRR fuel element(s) with 7uPCX rods	0.375 ± 0.009	0.779 ± 0.007

Additionally, the effect of the grid spacing, or the pitch between 7uPCX fuel rods, was investigated. Table 3.9 provides results associated with increasing the 7uPCX fuel rod pitch from 0.86 to 1.55 cm for the case with seven ACRR fuel elements. The data from Table 3.9 indicates that the configuration with a 1.55 cm pitch is more sensitive to the presence of beryllium in the system [7] .

Table 3.9: Reactivity Effects for ACRR fuel element Configurations at Given 7uPCX Fuel Rod Pitches.

	7 ACRR fuel elements	**7 ACRR fuel elements**
	1.55 cm pitch (318 rods)	0.86 cm pitch (1366 rods)
Changes to Critical Configuration	**Reactivity Worth (%)**	**Reactivity Worth (%)**
Replace BeO fueled region with void	-12.208 ± 0.007	-4.506 ± 0.008
Replace ACRR fuel elements with void	-9.797 ± 0.007	-3.339 ± 0.008
Replace ACRR fuel elements with aluminum	-11.445 ± 0.007	-3.701 ± 0.008
Replace ACRR fuel elements with water	-14.120 ± 0.008	-4.090 ± 0.008
Replace ACRR fuel elements with 7uPCX rods	2.189 ± 0.010	0.779 ± 0.007

3.2.5.2. Fuel enrichment. A sensitivity analysis was performed looking at variations in the ^{235}U enrichment and weight percent of beryllium in the fuel. These analyses were for the seven ACRR fuel element configuration with water as the moderating material and 7uPCX fuel rods at a pitch of 0.86 cm surrounding the ACRR fuel elements. The ^{235}U enrichment of the system was investigated in increments of 0.25% above and below the nominal enrichment of 35%, which is much larger than the anticipated variation based on original documentation of the fuel elements. Figure 3.34 shows the effect of the variations in the enrichment have on k_{eff} of the system [7].

This data shows a linear trend from 33.75%-enriched ^{235}U to 36.25%-enriched ^{235}U with an R^2 value of 0.9899. The data spans a range of 1.01925 and 1.0205.

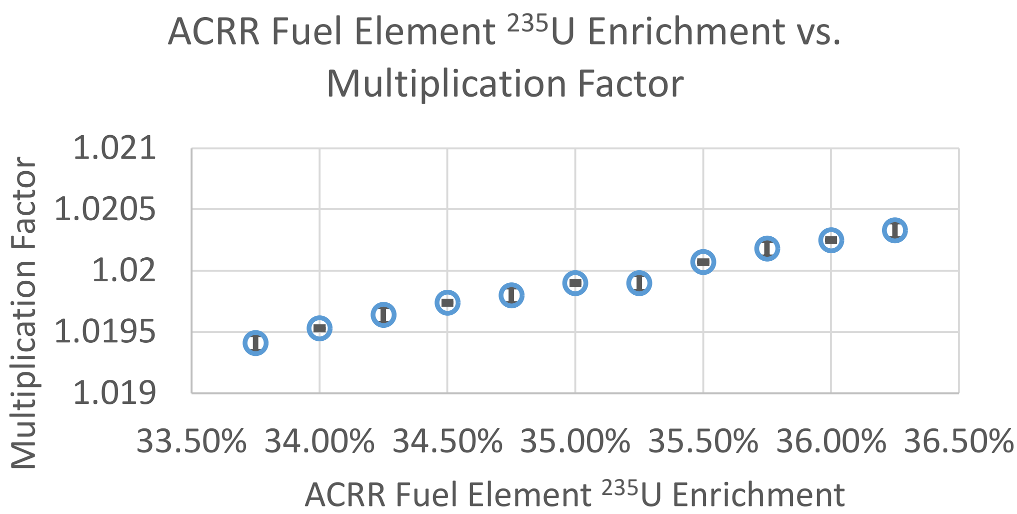


Figure 3.34: k_{eff} vs. ACRR fuel element ^{235}U Enrichment.

3.2.5.3. Beryllium oxide weight percent. The weight percent of BeO was investigated by ± 1% increments of 0.25% above and below the nominal weight percent of 28%. Figure 3.35 shows the effect changes of the BeO weight percent on the k_{eff} of the system [7].

The data trend of the effect of the BeO weight percent on the k_{eff} of the system is relatively linear. The data spans a range of 1.01925 and 1.02025 with 0.25% increments of change of the BeO weight percent between 26.5% and 29.25% BeO.

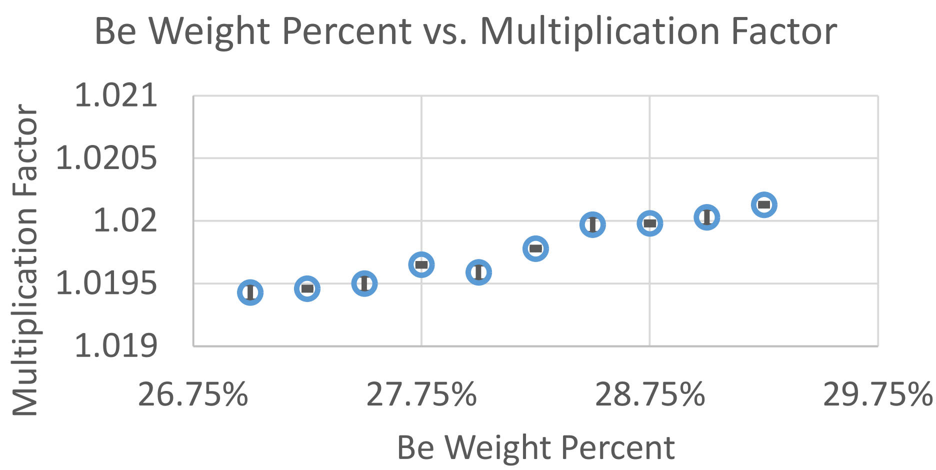


Figure 3.35: k_{eff} vs. BeO Weight Percent.

3.2.6. Neutron Energy Spectrum. The neutron energy spectrum for the ACRR fuel element model is analyzed in this section at different areas of the experiment. Major areas of interest include the central cavity, the 7uPCX fuel region, and the interfaces between the two. The neutron energies are depicted by shaded regions cut off at 0.625 eV.

The neutron energy spectrum for the ACRR fuel element region is shown in Figure 3.36. This spectrum shows a heavily thermal spectrum in this area. That means that the ACRR fuel element region is very thermalized in the center of this system. The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift.

The neutron energy spectrum in the center ACRR fuel element is shown in Figure 3.37. This is also a very thermal result, which is expected after seeing the thermal neutron energy spectrum from the central cavity in total. The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift.

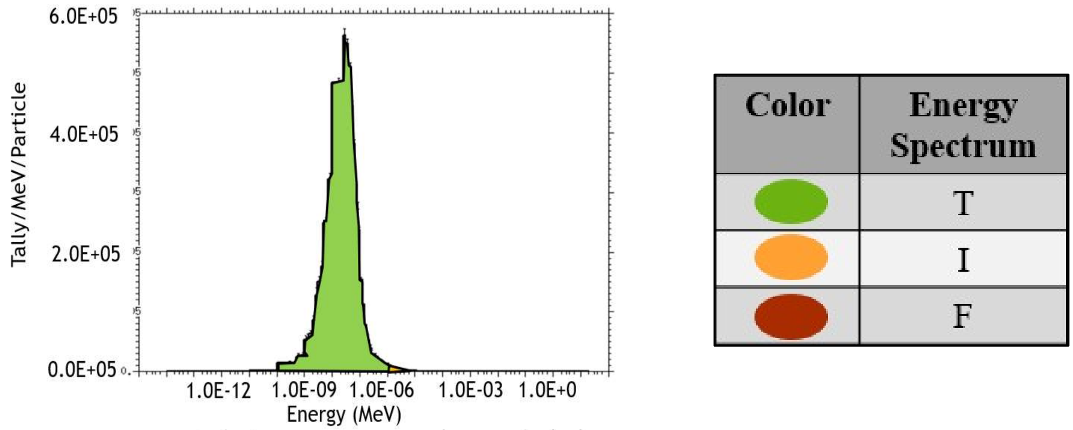


Figure 3.36: ACRR Fuel Element Neutron Energy Spectrum in Central Cavity.

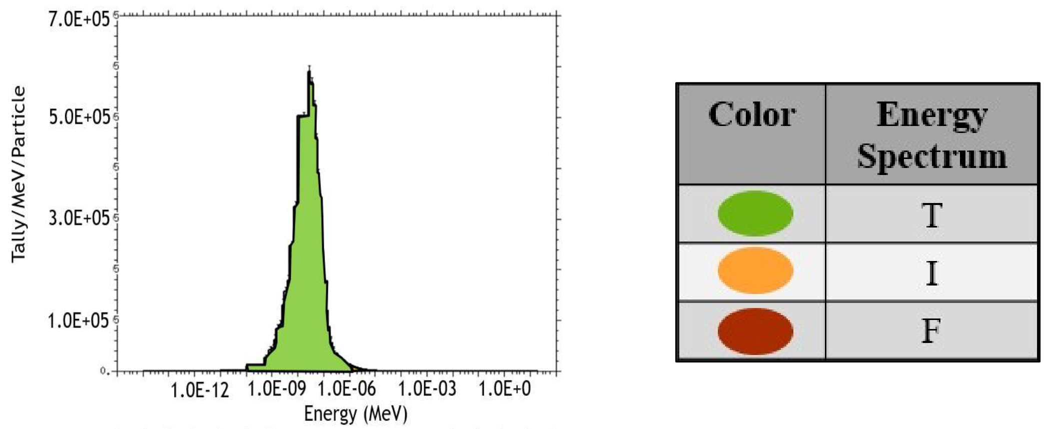


Figure 3.37: ACRR Fuel Element Neutron Energy Spectrum in Center.

The neutron energy spectrum at the edge of the central cavity is shown in Figure 3.38. This is very thermalized at the edge of the central cavity as well. The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift.

The neutron energy spectrum at the edge of the 7uPCX fuel region is shown in Figure 3.39. This is a different region of fuel, but still shows a very thermal spectrum.

The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift.

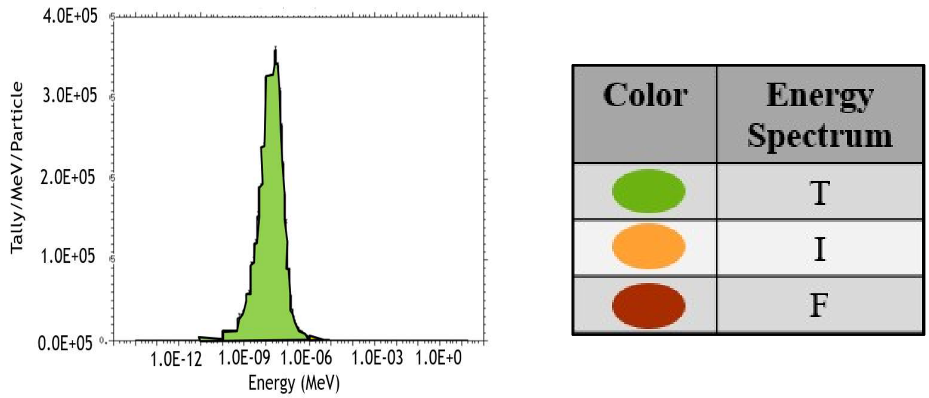


Figure 3.38: ACRR Fuel Element Neutron Energy Spectrum at Edge of Central Cavity.

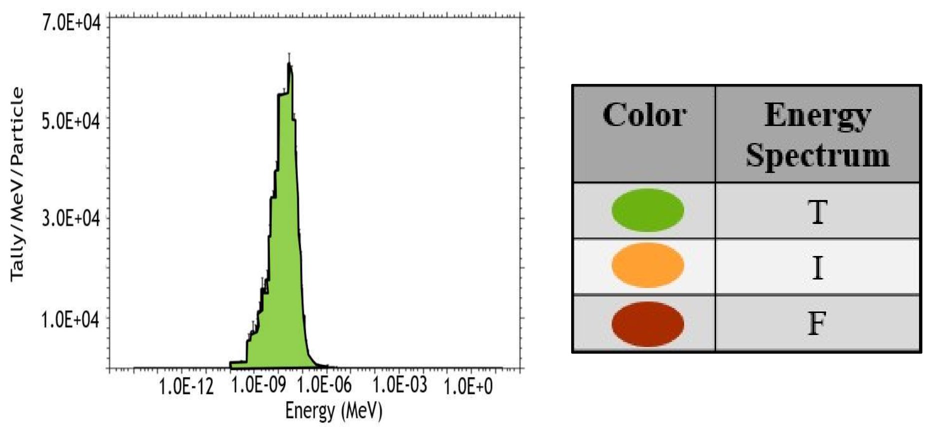


Figure 3.39: ACRR Fuel Element Neutron Energy Spectrum at Edge of Fuel Region.

3.2.7. Overall Assessment of the ACRR Fuel Element Model. The fuel element configuration was deemed the easiest and most straightforward setup because of the use of full ACRR fuel elements that were already constructed. This requires less interference with the fuel elements itself and more with the grid plate and tank arrangement. It is recognized that this configuration would likely be the easiest to accomplish and cost the least to execute. The neutron energy spectrum was less thermal than it was with the BeO pellet model, which makes it more feasible to achieve an intermediate neutron energy spectrum with a similar model design to this ACRR fuel element model.

3.3. SENSITIVITY ANALYSIS

A sensitivity analysis was performed on the two baseline feasibility models discussed in this report: the ACRR fuel element model, and the BeO fuel pellet model. Both models involve BeO fuels surrounded by 7uPCX driver fuels. Sensitivity data is produced using ksen cards in MCNP-6.2 with the same defaults as used in Whisper-1.1.

The sensitivity of the multiplication factor to changes (e.g., uncertainties) in the ^{235}U (92235.80c) fission data is provided for the fuel element and fuel pellet feasibility models along with existing ICSBEP handbook benchmark case models (from the Sandia NCS benchmark library) that also use beryllium in Figure 3.40. Because of the provided data, uncertainty bars were removed. From Figure 3.40, a strong sensitivity to ^{235}U fission data in the thermal region is observed for both feasibility cases. This is a result of a majority thermal neutron energy spectrum and significant moderation in the feasibility models. This moderation can be attributed to the water moderator, the beryllium oxide in the fuel meat, and the size of the fuel pellets [7].

Since one of the motivations for this critical experiment is to provide new benchmarking of systems containing beryllium, sensitivity data for the neutron reactions of beryllium (4009.80c) is presented in Figure 3.41 for both the fuel element and fuel pellet feasibility models. As can be seen from this data, the elastic scattering of beryllium does have a higher sensitivity to this cross-section. Additionally, the (n,2n) reaction contributes to higher energy flux and (n,α) reaction negatively contributes to neutron flux. The overall sensitivity to beryllium's neutron reactions is lower than the other compared benchmarks [7].

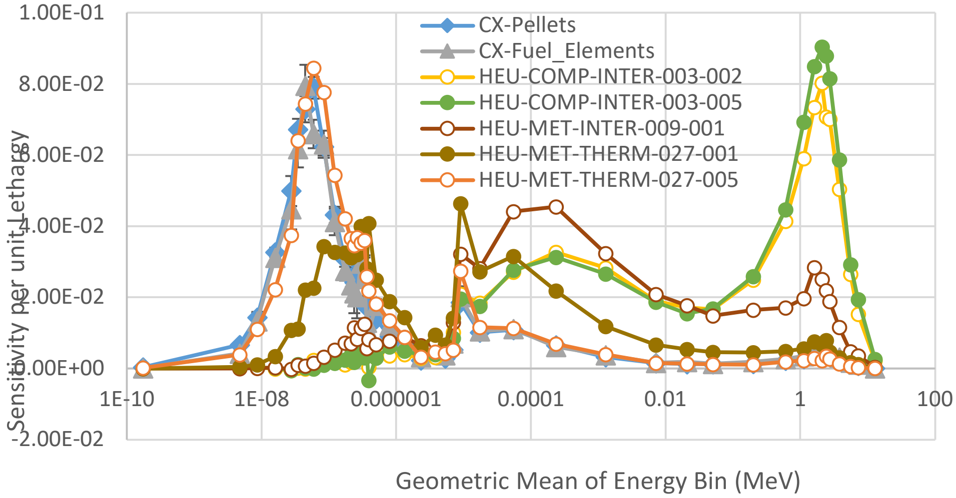


Figure 3.40: Sensitivity of Feasibility Models and Benchmarks to ^{235}U Fission Data.

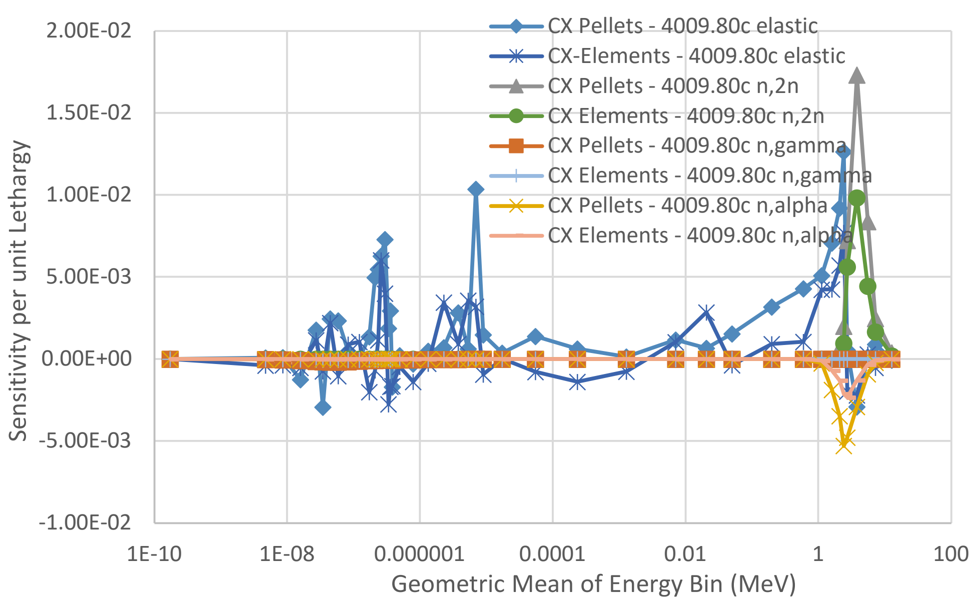


Figure 3.41: Sensitivity of Feasibility Models to Beryllium Reaction Data.

The individual beryllium reactions are summed to calculate the total sensitivity to beryllium (4009.80c) data in Figure 3.42. From Figure 3.42, the sensitivity of both feasibility models to beryllium reaction data is much less than several of the benchmark models. It is understood that the exact peaks and shapes of these other benchmarks may not be attained with the current configurations investigated. However, more beryllium worth would suit this experiment to better understand the behavior of beryllium in these discussed configurations [7].

While neither feasibility model shows as strong of a sensitivity to beryllium data as the benchmarks provided here, the feasibility models still offer other differences that may make them beneficial NCS benchmarks. As an example, the feasibility models have water moderator and are of lower uranium enrichment than the referenced benchmarks. The fuel type is also a composite fuel material rather than a metal fuel. These can contribute some differences that could benefit the ICSBEP handbook.

Figure 3.43 provides the sensitivity of both feasibility models and selected benchmarks to ^{238}U neutron capture (n,γ). As shown in Figure 3.43, neutron capture data is much more important to neutron multiplication in the feasibility models than the referenced benchmarks. To expand on this example, the importance of the ^{238}U capture cross-section resonance could have further implications to other sensitivities. The shifting of the neutron energy spectrum could have negative effects on the sensitivity of the beryllium data. This means that pursuing ongoing work to fine-tune these sensitivities with modification to the proposed experiment designs may prove useful to an intermediate neutron energy spectrum experiment design [7].

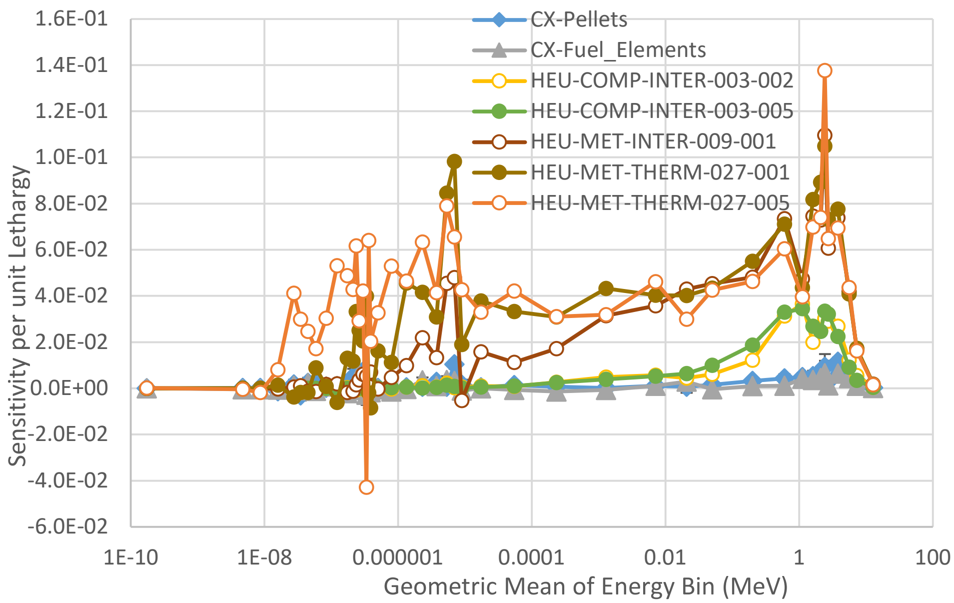


Figure 3.42: Sensitivity of Feasibility Models and Benchmarks to Beryllium Reaction Data.

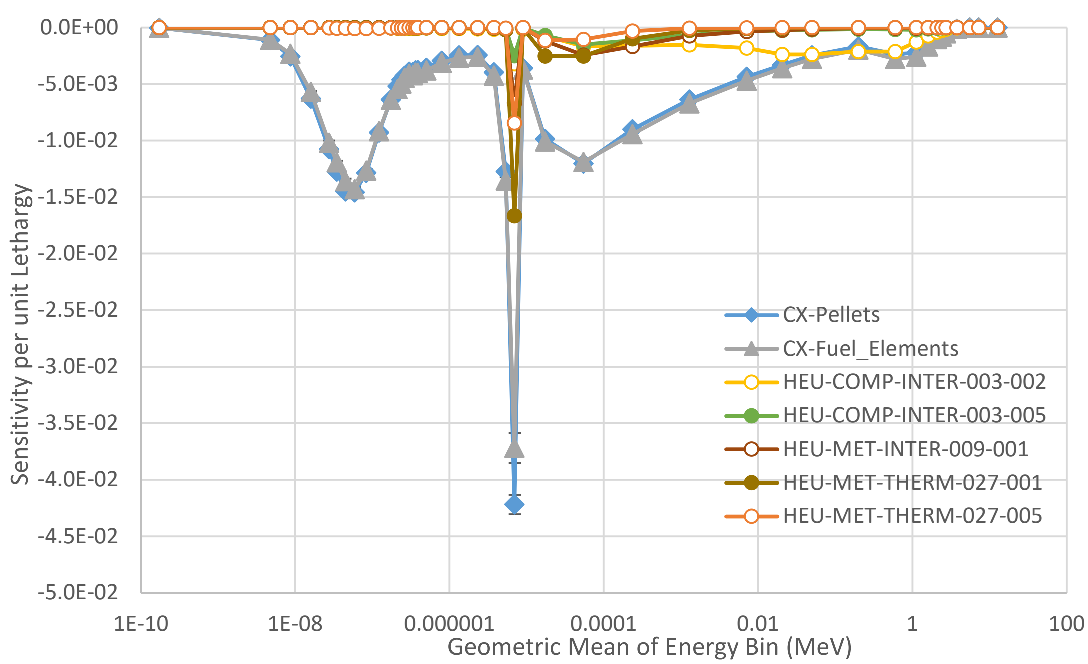


Figure 3.43: Sensitivity of Feasibility Models and Benchmarks to ^{238}U Neutron Capture Data.

4. FINAL DESIGN

This section will discuss the final design of the critical experiment design process as it was modeled in MCNP6.2.

4.1. FUEL

This section will discuss the fuel types and how they were modeled for the final design of the critical experiment. There were two fuels: the 7uPCX fuel rods and the ACRR fuel elements.

4.1.1. 7uPCX Fuel Model. The 7uPCX driver fuel rods were modeled in MCNP6.2. The radial view of a single fuel rod can be seen in Figure 4.1. The 7uPCX fuel rod model has a cylinder of the UO_2 fuel meat surrounded by a gap modeled as void enclosed in a 3003 aluminum cladding. The fuel region is divided into 4 midplane regions.

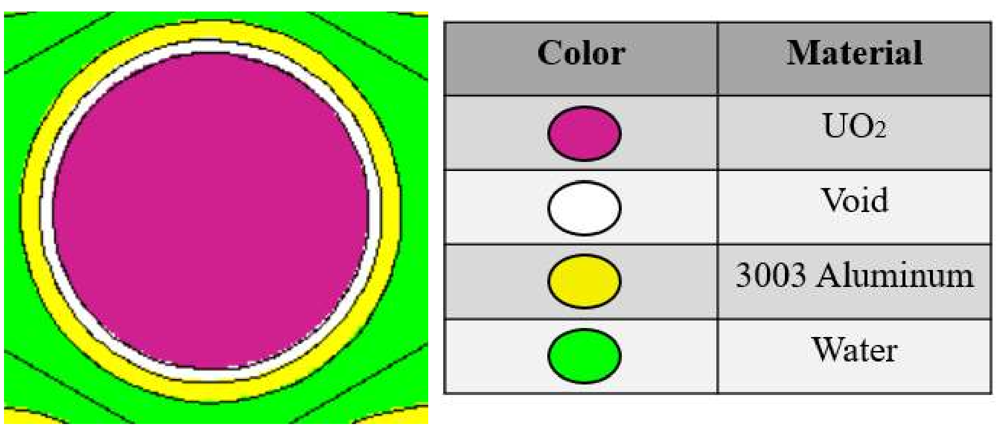


Figure 4.1: MCNP6.2 Model of the 7uPCX Fuel Rod in the ACRR Fuel Element Model.

The spring was modeled as a solid cylinder of steel with a voided center. The aluminum and polyethylene spacers were also modeled as cylinders within the confines of the radius of the fuel region. Voided gaps were placed between each of the spacers in the fuel rod. The 7uPCX fuel rods were modeled in an aluminum grid plate with BeO end caps and aluminum plugs holding it in place. Voided holes and gaps were also included in these to account for swelling.

4.1.2. ACRR Fuel Element Model. The second fuel used in the ACRR fuel element model is the full ACRR fuel element. This was modeled using voided regions in the center gap of the fuel pellets within the fuel element, as well as voided gaps between the inner and outer sections of the BeO fuel pellet, and the outer fuel diameter, niobium cup, and stainless steel cladding. The radial view of the fuel element can be seen in Figure 4.2, and the axial view of the fuel element can be seen in Figure 4.3. The materials are labeled in Table 4.1.

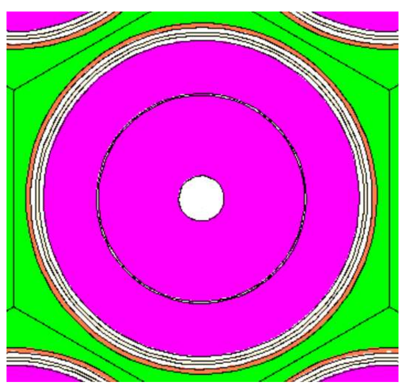


Figure 4.2: ACRR Fuel Element Radial View.

Figure 4.3: ACRR Fuel Element Axial View.

Table 4.1: ACRR Fuel Element Legend.

Color	Material
	UO_2-BeO Pellets
	Void
	Niobium
	Stainless Steel 304
	Water
	BeO Reflector
	Aluminum 6061

The end caps were modeled as BeO as can be seen in Figure 4.3. The stainless steel cladding surrounds these end caps and is what is used to hold the fuel element in place within the aluminum grid plate. The niobium cups are divided in the model into cylinders corresponding to each cup. There are five of these cylinders stacked in the model with voided gaps between each niobium cylinder.

4.2. CRITICAL EXPERIMENT DESIGN

The final design of this critical experiment reactor system was a modified version of the ACRR fuel element design. This can be seen in Figure 4.4. There are 7 ACRR fuel elements in the center of the water-moderated experiment with 1218 7uPCX fuel rods surrounding that central cavity. The ACRR fuel elements have a center-to-center pitch of 4.1871 cm and the 7uPCX fuel rods have a center-to-center pitch of 0.86 cm.

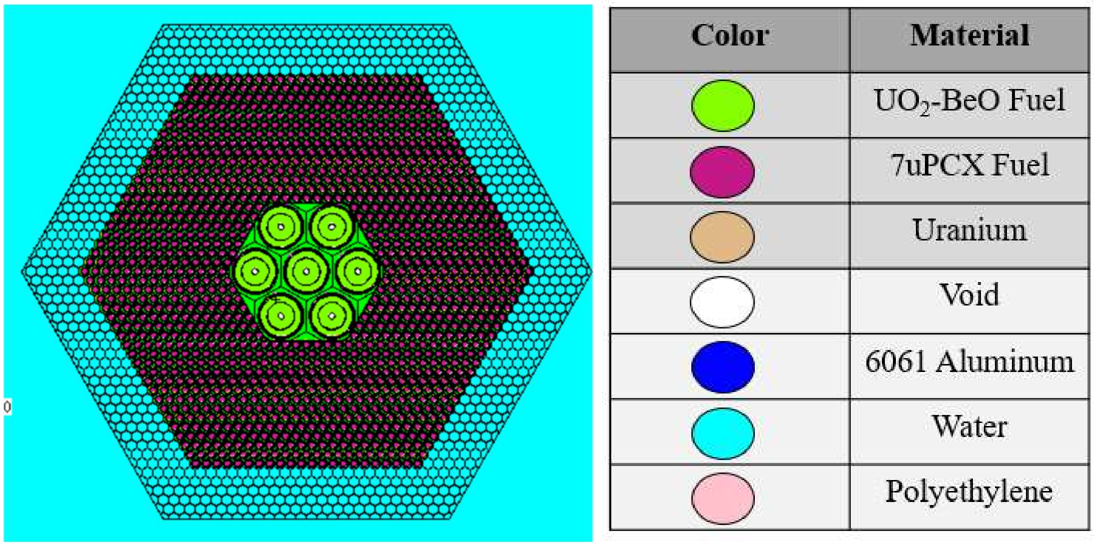
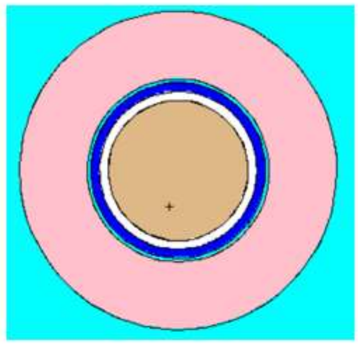


Figure 4.4: MCNP6.2 Model of Radial View of Final Design.

There are two detectors outside of this region also enclosed in the tank. These are purpose-built pressure measurement and mapping sensor (PPS) detectors. These PPS detectors have a 93%-enriched ^{235}U center with a thin uranium foil around it. A thin void region surrounds this uranium center to account for swelling. Surrounding the void is a 6061 aluminum shell. The water moderator sits in the thin space between the 6061 aluminum shell and the thicker polyethylene outer shell. This material breakdown is shown in Figure 4.5.

The dimensions from this radial view of the PPS detector can be found in Table 4.2.



Color	Material
	Uranium
	Void
	6061 Aluminum
	Water
	Polyethylene

Figure 4.5: MCNP6.2 Model of Radial View of PPS Detector.

Table 4.2: MCNP6.2 Model PPS Radial Dimensions.

Parameter	Dimension (cm)
Uranium Foil Thickness	0.00508
Uranium Outer Radius	2.54
Void Outer Radius	2.8575
6061 Aluminum Outer Radius	3.175
Water Outer Radius	3.30581
Polyethylene Outer Radius	5.75945

The axial view of one of these PPS detectors in the tank of water can be seen in Figure 4.6. There is the 93%-enriched ^{235}U core of the detector surrounded by the polyethylene outer shell. Above this uranium core is a large, voided region that extends beyond the water level of the tank and the tank height itself.

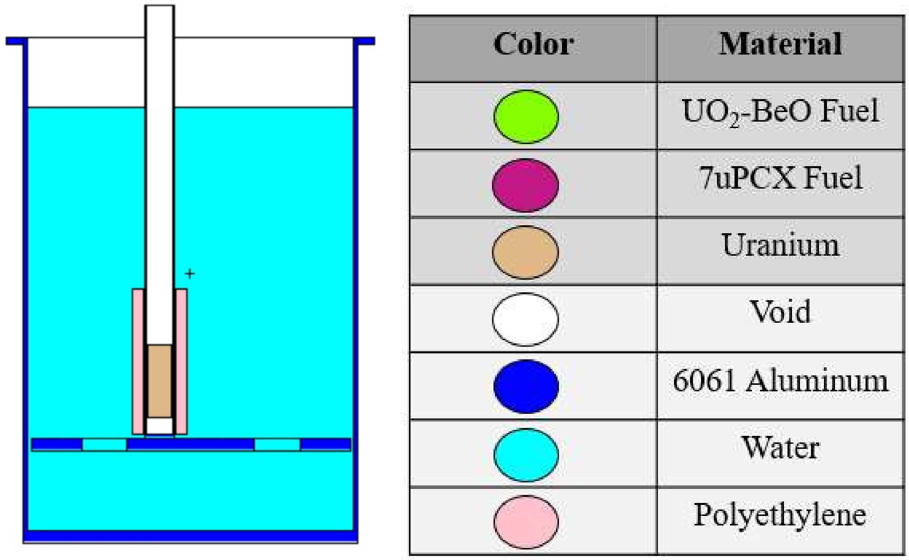


Figure 4.6: MCNP6.2 Model of Axial View of PPS Detector.

The axial dimensions of note for this detector are listed in Table 4.3. The void region represents the inside of a 6061 aluminum tube that contains the uranium center of the PPS detector.

Table 4.3: MCNP6.2 Model PPS Axial Dimensions.

Parameter	Dimension (cm)
Uranium Center Height	15.24
Void Height	88.4825
6061 Aluminum Height	89.1175
Water Height	87.3252
Polyethylene Height	29.98648
Tank Height	101.60

The center fuel region, which includes the central cavity of the 7 ACRR fuel elements and the surrounding 1218 7uPCX fuel rods, and the 2 PPS detectors can be seen in Figure 4.7. This shows the radial view of the entire tank of water. The other circles shown in this figure are 6061 aluminum support posts.

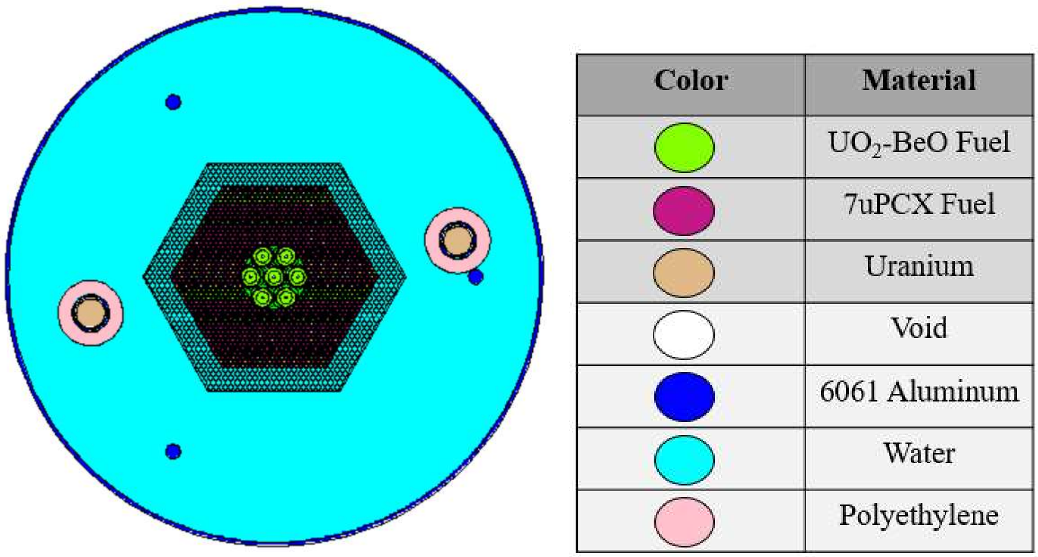


Figure 4.7: MCNP6.2 Model Radial View of Entire Final Design.

Table 4.4 shows the parameters of this experiment design. The parameters include the multiplication factor, uncertainty, and neutron energy spectrum breakdown.

Table 4.4: Final Design Parameters.

Parameter	**Value**
k_{eff}	1.00118 ± 0.00003
T (%)	78.51
I (%)	15.76
F (%)	5.73

This data shows that this is a critical system operating in the thermal neutron energy range.

4.3. NEUTRON ENERGY SPECTRUM

The neutron energy spectrum is analyzed in this section in different areas of the final design model. This is for understanding the energy of neutrons at different points of the fuel region to see if it satisfies the major design parameter of potential intermediate energy spectrums.

The neutron energy spectrum for the central cavity is shown in Figure 4.8. The neutron energies are depicted by shaded regions cut off at 0.625 eV. This shows a mostly thermalized neutron energy spectrum with a higher percentage of intermediate neutrons as compared to the preliminary models. The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift.

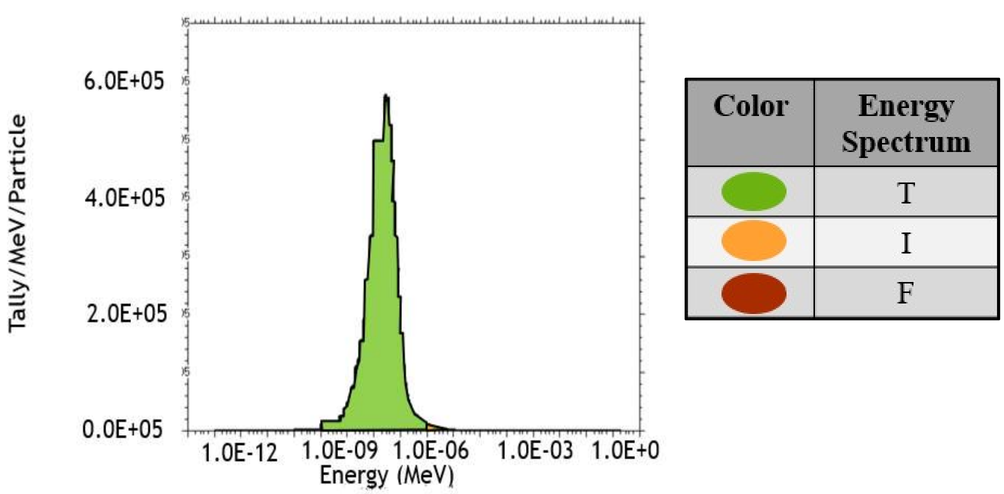
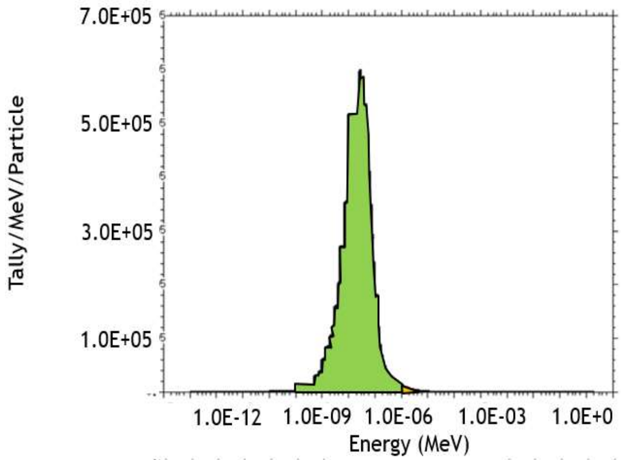


Figure 4.8: Final Design Neutron Energy Spectrum in Central Cavity.

The neutron energy spectrum for the ACRR fuel element located in the center of the central cavity is shown in Figure 4.9. This graph shows a slight increase in intermediate neutrons, up from the previous graph. The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift.



Color	Energy Spectrum
	T
	I
	F

Figure 4.9: Final Design Neutron Energy Spectrum in Center.

The neutron energy spectrum for an outer ACRR fuel element bordering the 7uPCX fuel region is shown in Figure 4.10. There is a slight increase in intermediate neutrons in the system at this point in the model, up from the previous graph. The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift.

The neutron energy spectrum in a fuel rod at the edge of the 7uPCX fuel region is shown in Figure 4.11. This graph shows a very thermal neutron energy spectrum for this area. The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift.

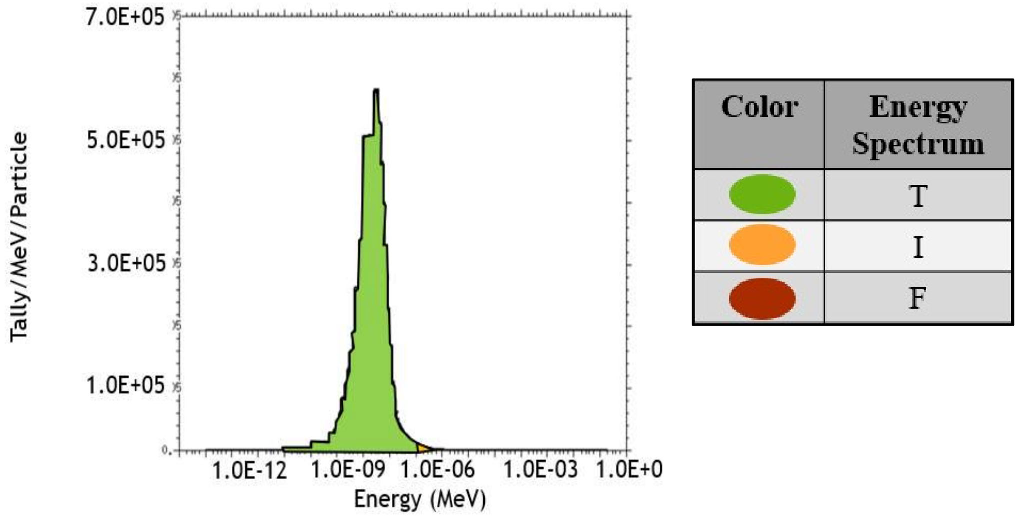


Figure 4.10: Final Design Neutron Energy Spectrum in Edge of Central Cavity.

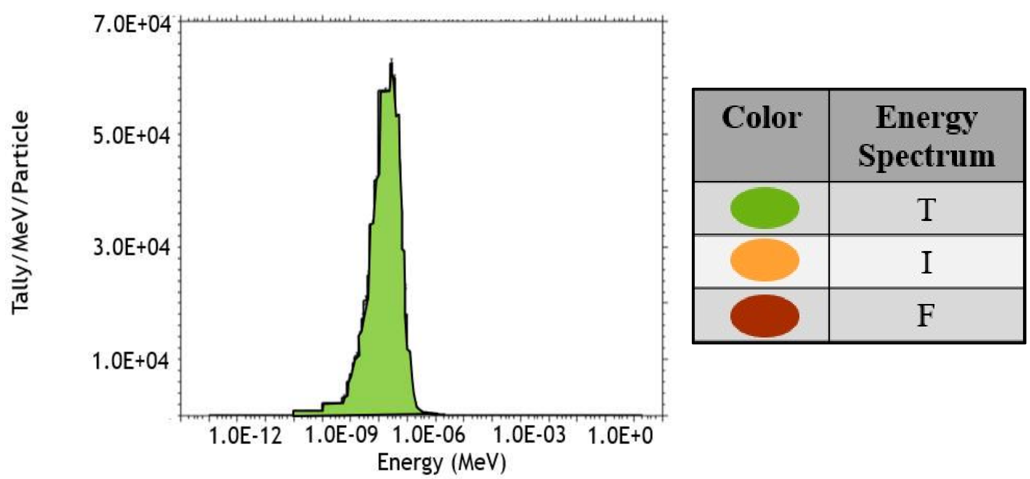


Figure 4.11: Final Design Neutron Energy Spectrum at Edge of Fuel Region.

4.4. OVERALL ASSESSMENT OF THE FINAL DESIGN

This critical experiment design utilizing 7 ACRR fuel elements and 1218 7uPCX fuel rods maintains its thermal neutron energy spectrum. This would make a thermal critical experiment. It did not achieve an intermediate spectrum, but the setup of the reactor system allows for modifications to be made to try to achieve this goal. The use of the full ACRR fuel element allows for the characterization of the exact fuel element the current ACRR uses in the ICSBEP handbook.

5. ONGOING WORK

Considering reactor physics principles, the changes that were investigated included moderator material, reflector material, additional rods, pitch of the 7uPCX driver fuel, pitch of the 7 ACRR fuel elements in the central cavity, the addition of a cadmium filter surrounding the central cavity, and the addition of absorber materials surrounding the entire fuel region.

The simulations run for these models were completed using the base model previously shown. The model with 1488 7uPCX rods was used for excess reactivity in changing certain parameters. The neutron energy spectrum that is discussed refers to the overall reactor system energy spectrum unless otherwise specified.

5.1. ABSORBER MATERIAL ANALYSIS

For spectrum analysis, the use of the baseline case for a thermal neutron energy spectrum benchmark experiment is feasible. To shift the spectrum into an intermediate neutron energy spectrum for a different experiment is one of the main goals. This requires materials that can absorb thermal neutrons at a high rate.

One of the major materials considered during analysis was tantalum. Tantalum is an absorber material that has previously been used as a spectrum shifting tool in IER-441 [8]. In Figure 5.1, the total cross section of tantalum's two naturally-occurring isotopes are shown. Tantalum-180 is shown to have the higher total cross section of the two in the thermal energy spectrum. This would aid in absorbing thermal neutrons to reduce their number in the reactor system.

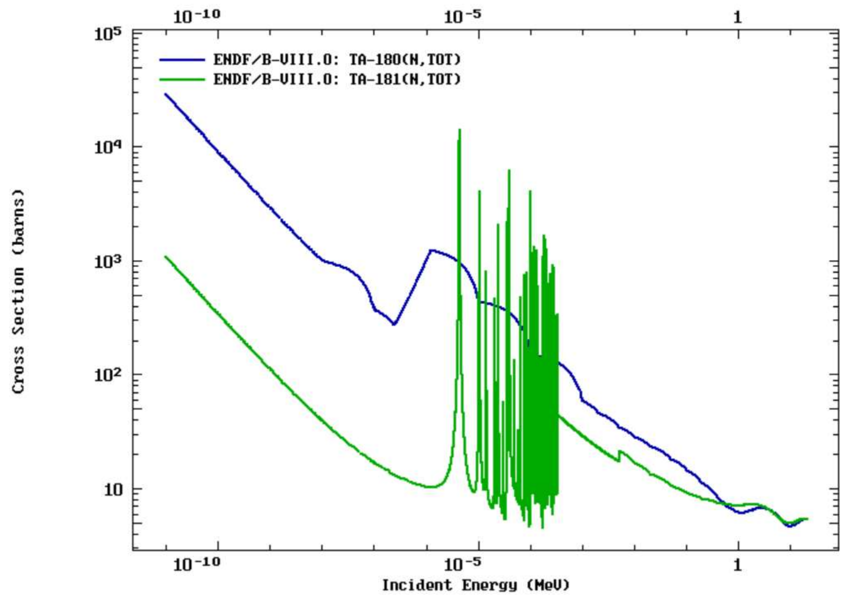


Figure 5.1: Total Cross Section Data for Naturally Occurring Ta Isotopes [10].

Since this is an absorber material, the capture cross section is the cross section of interest. In Figure 5.2, the capture cross section is isolated for tantalum's two naturally-occurring isotopes [11]. The contribution of the capture cross section of tantalum-180 is why the total cross section is high in the thermal energy spectrum. The capture cross section for tantalum-181 is also high in the thermal energy spectrum, albeit an order of magnitude lower than tantalum-180.

The fraction of appearance of each tantalum isotope in naturally-occurring samples is shown in Table 5.1. From this data, the appearance of tantalum-180 is only 0.012% in natural tantalum [11]. This is a very small amount in naturally-occurring tantalum. Tantalum-181, being the primary isotope in this case, would be the dominating tantalum capture cross section with the use of this material in a reactor system.

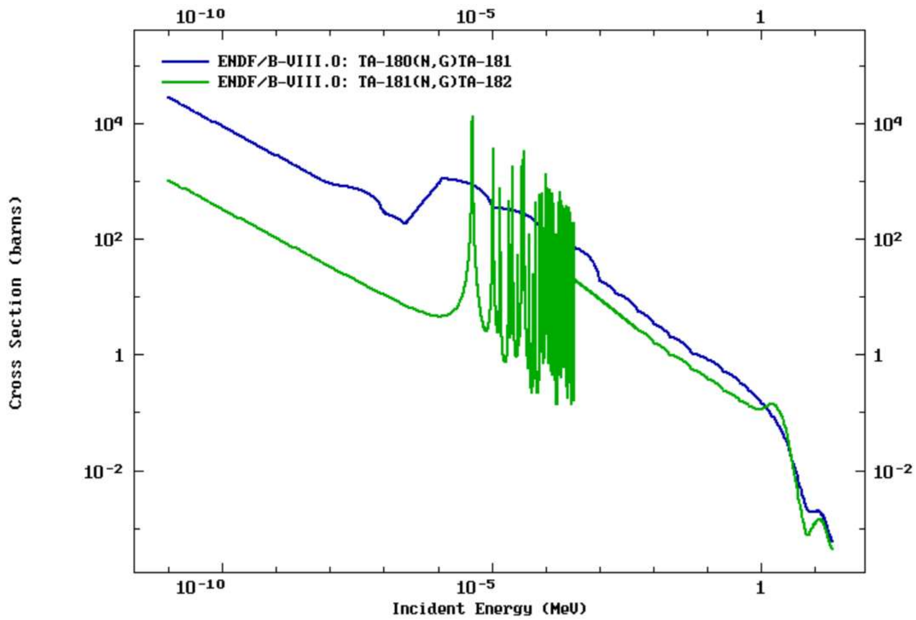


Figure 5.2: Capture Cross Section Data for Naturally Occurring Ta Isotopes [10].

Table 5.1: Natural Abundance of Tantalum Isotopes [11].

Tantalum Isotope	Natural Abundance
Ta-180	0.00012
Ta-181	0.99988

A major material that was considered during analysis was cadmium. Cadmium has many isotopes that appear naturally [11]. As can be seen from Figure 5.3, cadmium-113 has a high total cross section in the thermal energy range. For further investigation of its behavior as an absorber in a reactor system, the capture cross section was investigated as well.

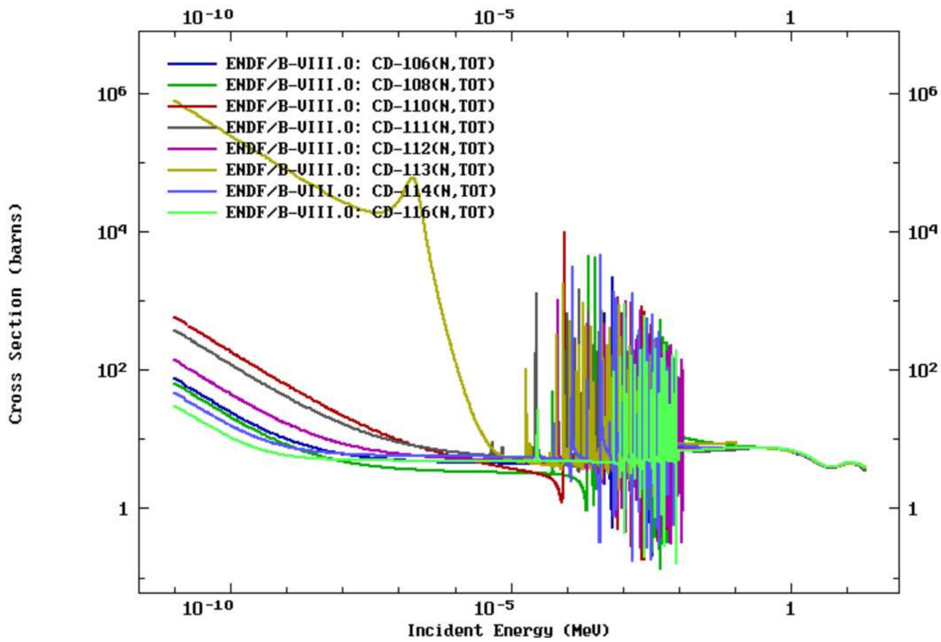


Figure 5.3: Total Cross Section Data for Naturally Occurring Cd Isotopes [10].

In Figure 5.4, the capture cross section of naturally occurring isotopes of cadmium were compared. Once again, cadmium-113 is shown to have the highest capture cross section out of other naturally occurring isotopes. The other isotopes of cadmium are also fairly high in capture, but cadmium-113 is the isotope of interest for a high capture cross section in the thermal energy range for neutrons.

The fraction of appearance of each cadmium isotope in naturally-occurring samples is shown in Table 5.2. From this data, the appearance of cadmium-113 is only 12.22% [11]. This shows that the high capture cross section of cadmium-113 may not be as strong in its natural state as it would in an enriched state.

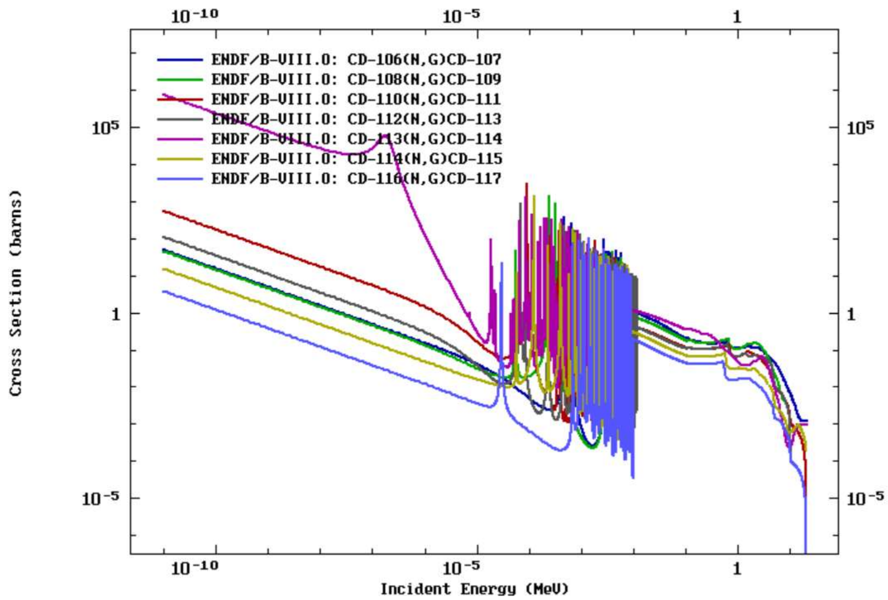


Figure 5.4: Capture Cross Section Data for Naturally Occurring Cd Isotopes [10].

Table 5.2: Natural Abundance of Cadmium Isotopes [11].

Cadmium Isotope	Natural Abundance
Cd-106	0.0125
Cd-108	0.0089
Cd-110	0.1249
Cd-111	0.128
Cd-112	0.2413
Cd-113	0.1222
Cd-114	0.2873
Cd-116	0.0749

To further design analysis, it was understood that certain absorber materials were necessary to add to the reactor system to absorb more thermal neutrons and reduce their number. This led to the first investigation of removing the inner rings of 7uPCX driver fuel surrounding the central cavity with assemblies of various pure absorber materials, as can be seen in Figure 5.5.

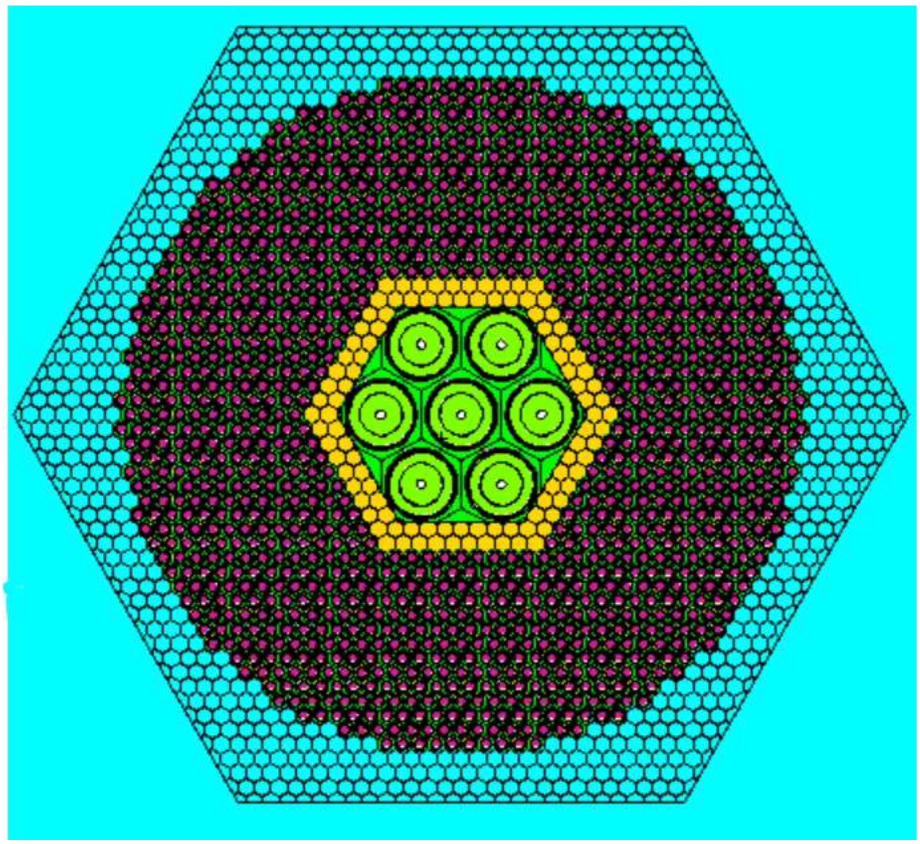


Figure 5.5: MCNP6.2 Model of 2 Rings of Absorber Rods Surrounding Central Cavity.

All the absorbers investigated were tantalum, samarium, gadolinium, europium, cadmium, dysprosium, boron, iridium, erbium, and hafnium. The results of the spectrum are shown in Table 5.3, where thermal (T), intermediate (I), and fast (F) energy spectrums are shown. Considering this data and the previous cross section analysis, tantalum and cadmium were the absorbing materials of choice for further investigation.

Table 5.3: Spectrum Analysis of Different Absorber Materials.

Material	k_{eff}	T (%)	I (%)	F (%)
Ta	0.83604 ± 0.00002	77.61	15.88	6.51
Sm	0.82894 ± 0.00002	77.33	16.02	6.65
Gd	0.83007 ± 0.00003	77.36	16.02	6.62
Eu	0.79756 ± 0.00002	77.56	15.54	6.90
Cd	0.88390 ± 0.00003	77.23	16.46	6.31
Dy	0.82708 ± 0.00002	77.33	16.03	6.64
B	0.78867 ± 0.00002	77.65	15.40	6.95
Ir	0.79922 ± 0.00002	77.62	15.63	6.75
Er	0.84312 ± 0.00002	77.30	16.18	6.52
Hf	0.82935 ± 0.00002	77.35	16.05	6.60

The overall effect of adding these two rings of 7uPCX was not great enough to stop the analysis at this point. The key takeaway from this was that cadmium had the greatest intermediate spectrum out of the absorber materials listed. This was expected considering its spectrum indicates a higher rate of absorption in the thermal energies over the other areas of the energy spectrum.

5.2. CONFIGURATION VARIATIONS OF FINAL DESIGN

Considering this data, the next pursuit included the addition of a cadmium sleeve to the reactor system. Since the goal is to reduce thermal energy neutrons, the cadmium sleeve was placed surrounding the 7uPCX fuel, where the 6.90% enrichment of ^{235}U causes more thermalized neutrons than the 35% enrich ^{235}U of the ACRR fuel. The data presented in Table 5.4 shows the data from a model with a cadmium sleeve surrounding the 7uPCX fuel. This analysis was investigating how the cadmium sleeve would impact the intermediate neutron energy spectrum, and if an increasing thickness of the sleeve would make a significant difference.

Table 5.4: Spectrum Analysis of Adding a Cadmium Sleeve.

Inner Radius	Outer Radius	k_{eff}	T (%)	I (%)	F (%)
20.11	22	0.96063 ± 0.00068	75.96	17.75	6.29
20.11	23	0.96407 ± 0.00069	76.07	17.64	6.29
20.11	24	0.96424 ± 0.00067	76.03	17.71	6.26
20.11	25	0.96471 ± 0.00068	75.99	17.73	6.28

From this data, the overall trend shows that increasing the thickness of the cadmium sleeve did increase the intermediate spectrum, but at such a small rate that other ideas needed to be pursued.

Another material was investigated in a similar way as the cadmium sleeve. From Table 5.3 previously, the data showed that erbium had the second greatest intermediate spectrum. To see the effect erbium would have in this setting, an erbium sleeve was placed surrounding the 7uPCX driver fuel region with varying thicknesses. The results are shown in Table 5.5.

Table 5.5: Spectrum Analysis of Adding an Erbium Sleeve.

Inner Radius	Outer Radius	k_{eff}	T (%)	I (%)	F (%)
20.11	21	0.95946 ± 0.00068	75.93	17.76	6.31
20.11	22	0.96367 ± 0.00069	76.02	17.70	6.28
20.11	23	0.96435 ± 0.00069	75.98	17.76	6.26
20.11	24	0.96515 ± 0.00068	76.05	17.68	6.27

This data showed similar results as the cadmium sleeve had shown. Because of the expense of erbium, this idea was not pursued further.

Following this, a combination of changes was made at each simulated iteration to see the change in the energy spectrum. In Table 5.6, each iteration is shown with the size of the internal cavity, amount of ACRR fuel elements used, a description of the variation that was implemented, the multiplication factor for the iteration, and the thermal, intermediate, and fast energy spectrum percentages. The variations that were made were from the baseline model unless otherwise specified. For the data in Table 5.6, the baseline case was used with the 7uPCX fuel rod pitch being 0.86 cm and the ACRR fuel element pitch being 4.1871 cm. Where it is stated that the variation is "same as above", this indicates to look at the preceding iterations' variation. That variation was maintained for the next iterations.

As can be seen in Table 5.6, the variations that were performed had different effects on the system that led to different changes in future iterations. For example, when the intermediate energy spectrum would increase, this usually led to a decrease in criticality, which ultimately required a change to increase the criticality back to union. Once there, another iteration could be performed to try to affect the intermediate spectrum again.

Because of these results, the central cavity was isolated and investigated separately from the rest of the reactor system. This excluded any 7uPCX driver fuel rods and only kept the internal ACRR fuel element cavity. This was a theoretical investigation to see how the 35%-enriched ACRR fuel elements alone could affect the neutron energy spectrum. The sensitivities would be more obviously for each variation performed, giving ideas as to how to shift the spectrum in the larger system. The base case central cavity was used to start off these simulations with a graphite moderator instead of a water moderator as can be seen in Table 5.7.

In the middle of the iterations, the 7uPCX was added back to the system and the intermediate energy spectrum drastically dropped. Because of the 6.90% enrichment of the 7uPCX and the need to drive criticality with this fuel, there are too many neutrons being thermalized in this system for any amount of absorbing material to handle. Because of this, more theoretical circumstances had to be investigated, such as adding more ACRR fuel elements when the inventory at Sandia does not allow for this possibility. The pitch was also modified for both fuel types in the system, which is also a theoretical change. These new iterations can be seen in Table 5.8.

As a result of these attempts to increase the percentage of intermediate-energy neutrons, it was determined that utilizing the 7uPCX fuel was too much of a burden on the neutron energy level. The 7uPCX fuel was no longer considered. Despite the resource limitations Sandia faces with only about 7 ACRR fuel elements available for this experiment, simulations were performed using more of these fuel elements to see if achieving the increased intermediate energy spectrum would be possible.

To do this, a combination of increasing the number of ACRR fuel elements, cadmium absorber rods, and decreasing the pitch was performed continuously until a satisfactory level of intermediate neutrons could be achieved.

Considering the results above, adding new cadmium rods into the array does increase the intermediate neutron energy spectrum, but lowers the criticality of the system. Since the criticality of the system is required and a high intermediate spectrum is preferred, more fuel was added to drive criticality back to union. Doing this lower the intermediate spectrum back to its original state, even though the fuel pitch is as low as possible. This back-and-forth interaction shows that, with the current setup of materials, fuel type, and pitch, an intermediate spectrum around 40% is about as much as can be expected without significant experiment design changes.

Table 5.6: Spectrum Analysis of Various Iterations of Base Model.

Iteration	ACRR			7uPCX			Moderator	Reflector	Absorber				k_{eff}	Neutron Spectrum		
	Amount	Location	Pitch (cm)	Amount	Enrichment	Pitch (cm)			Form	Material	Amount	Location		T (%)	I (%)	F (%)
1	7	Center	4.1871	1938	6.90%	0.86	Graphite	Water					0.78631 ± 0.00071	83.64	12.02	4.34
2	7	Center	4.1871	1938	6.90%	0.86	Graphite	Water					0.91519 ± 0.00066	79.85	14.89	5.26
3	7	Center	4.1871	1938	6.90%	0.86	Graphite	Water					0.96359 ± 0.00067	78.7	15.72	5.58
4	7	Center	4.1871	1938	6.90%	0.86	Graphite	Water					1.00123 ± 0.00068	77.93	16.27	5.8
5	7	Center	4.1871	1938	6.90%	0.86	Graphite	Water					1.02966 ± 0.00068	77.15	16.85	6
6	7	Center	4.1871	1938	6.90%	0.86	Graphite	Water	Rods	Ta	19	Around ACRR	0.90899 ± 0.00066	77.02	16.38	6.6
7	7	Center	4.1871	1938	6.90%	0.86	Graphite	Water	Rods	Cd	19	Around ACRR	0.95402 ± 0.00068	76.47	17.07	6.46
8	7	Center	4.1871	1938	6.90%	0.86	Graphite	Water	Rods	Cd	9	Around ACRR	0.97836 ± 0.00060	76.63	17.1	6.27
9	7	Center	4.1871	1938	6.90%	0.86	Graphite	Graphite					1.03153± 0.00058	76.9	17.05	6.05
10	7	Center	4.1871	1938	6.90%	0.86	Water	Water	Rods	Cd	14	Interspersed	1.00768 ± 0.00061	76.79	17.1	6.11
11	7	Center Ring	4.1871	1938	6.90%	0.86	Graphite	Water	Rods	Cd	14	Center	0.95413 ± 0.00061	77.41	16.49	6.1
12	7	Center Ring	4.1871	1938	6.90%	0.86	Graphite	Water	Rods	Cd	14	Center	0.94190 ± 0.00065	77.26	16.57	6.17
13	7	Center	4.1871	1938	15%	0.86	Graphite	Water	Rods	Gd	14	Interspersed	0.91350 ± 0.00071	60.31	33.82	5.87
14	7	Center	4.1871	1938	15%	0.86	Graphite	Water	Rods	Ta	14	Interspersed	0.96806 ± 0.00070	63.09	31.45	5.46
15	7	Center	4.1871	1938	15%	0.86	Graphite	Water	Rods	Ta+0.2B	14	Interspersed	0.80239 ± 0.00076	62.3	31.14	6.56
16	7	Center	4.1871	1938	15%	0.86	Graphite	Water	Rods	Cd	14	Interspersed	0.97575 ± 0.00073	60.47	34	5.53
17	7	Center	4.1871	1938	15%	0.86	Graphite	Void	Rods	Cd	14	Interspersed	0.97279 ± 0.00075	60.42	34.04	5.54
18	7	Center	4.1871	1938	15%	0.86	Graphite	Void	Rods	Cd	14	Interspersed	0.81037 ± 0.00081	50.63	42.17	7.2

Table 5.7: Spectrum Analysis of the Central Cavity.

Iteration	ACRR		7uPCX		Moderator	Reflector	Absorber				k_{eff}	Neutron Spectrum		
	Amount	Pitch (cm)	Amount	Pitch (cm)			Form	Material	Amount	Location		T (%)	I (%)	F (%)
1	19	4.1871	0	0.86	Water	Water					0.48905 ± 0.00060	81.95	14.35	3.7
2	37	4.1871	0	0.86	Water	Water					0.55872 ± 0.00059	74.38	21.58	4.04
3	7	4.1871	0	0.86	Graphite	Water					0.25599 ± 0.00042	72.24	21.54	6.22
4	7	4.1871	0	0.86	Graphite	Graphite					0.17653 ± 0.00034	63.04	27.9	9.06
5	7	4.1871	0	0.86	Graphite	Graphite	Rods	Cd	19	Around ACRR	0.10742 ± 0.00025	33.98	50.67	15.35
6	7	4.1871	1938	0.86	Graphite	Graphite	Rods	Cd	19	Around ACRR	0.65381 ± 0.00057	79.41	14.89	5.7
7	7	4.1871	1938	0.86	Graphite	Graphite	Rods	Ta+B	19	Around ACRR	0.45827 ± 0.00051	80.47	11.7	7.83
8	7	4.1871	1938	0.86	Graphite	MgO	Rods	MgO	19	Around ACRR	0.78319 ± 0.00062	82.21	13.02	4.77
9	7	4.1871	1938	0.86	Graphite	MgO	Rods	Mg	19	Around ACRR	0.78262 ± 0.00068	82.15	13.07	4.78
10		4.1871	1938	0.86	Graphite	Graphite					0.62071 ± 0.00065	68.69	27.28	4.03
11	7	4.1871	1938	0.86	Graphite	Graphite					0.79066 ± 0.00069	82.24	13.03	4.73
12	7	4.1871	1938	0.86	Graphite	Graphite	Rods	Ta	19	Around ACRR	0.67027 ± 0.00063	78.76	15.63	5.61
13	7	4.1871	1938	0.86	Graphite	Graphite	Rods	Ta	19	Around ACRR	0.63389 ± 0.00068	73.18	20.35	6.47
14	7	4.1871	1938	0.86	Graphite	Graphite	Rods	Pb	19	Around ACRR	0.79163 ± 0.00058	78.54	16.25	5.21
15	7	4.1871	1938	0.86	Graphite	Graphite	Rods	Pb	19	Around ACRR	0.78911 ± 0.00065	78.57	16.23	5.2

Table 5.8: Spectrum Analysis of Various Iterations of Pitch and Fuel.

Iteration	ACRR		7uPCX		Moderator	Reflector	Absorber				k_{eff}	Neutron Spectrum		
	Amount	Pitch (cm)	Amount	Pitch (cm)			Form	Material	Amount	Location		T (%)	I (%)	F (%)
1	7	4.1871	1488	0.82	Water	Water	[redacted]				0.90650 ± 0.00066	74.6	18.4	7
2	7	4.1871	1488	0.78	Water	Water	[redacted]				0.85897 ± 0.00064	72	20.05	7.95
3	7	4.1871	1488	0.74	Water	Water	[redacted]				0.80869 ± 0.00072	68.91	21.83	9.26
4	7	4.1871	1632	0.74	Water	Water	[redacted]				0.82335 ± 0.00057	68.43	22.23	9.34
5	7	4.1871	1782	0.74	Water	Water	[redacted]				0.83098 ± 0.00060	68.17	22.42	9.41
6	19	4.1871	1782	0.74	Water	Water	Filter	Cd	0.8 cm	Around ACRR	0.81484 ± 0.00067	72.56	20.36	7.08
7	19	4.1871	1782	0.74	Water	Water	Filter	Cd	0.18 cm	Around ACRR	0.80608 ± 0.00066	72.33	20.46	7.21
8	19	4.1871	1782	0.74	Water	Water	Filter	Cd	0.28 cm	Around ACRR	0.79769 ± 0.00064	72.06	20.68	7.26
9	19	4.1871	1782	0.74	Water	Water	Filter	Cd	0.38 cm	Around ACRR	0.79102 ± 0.00068	71.87	20.73	7.4
10	19	4.1871	1782	0.74	Water	Water	Filter	Cd	0.48 cm	Around ACRR	0.78747 ± 0.00070	71.68	20.83	7.49
11	19	4.1871	1938	0.74	Water	Water	Filter	Cd	0.48 cm	Around ACRR	0.79432 ± 0.00068	71.46	20.97	7.57
12	19	4	1938	0.74	Water	Water	Filter	Cd	0.48 cm	Around ACRR	0.77514 ± 0.00057	70.58	21.58	7.84
13	37	4	1938	0.74	Water	Water	Filter	Cd	0.48 cm	Around ACRR	0.80208 ± 0.00063	71.56	22.32	6.12
14	61	4	0	0.74	Water	Water	Filter	Cd	0.48 cm	Around ACRR	0.77431 ± 0.00066	70.87	25.36	3.77
15	61	4	0	0.74	Water	Water	Filter	Cd	0.48 cm	Around ACRR	0.70246 ± 0.00078	67.3	29.09	3.61

Table 5.8: Spectrum Analysis of Various Iterations of Pitch and Fuel (cont.).

Iteration	ACRR		7uPCX		Moderator	Reflector	Absorber				k_{eff}	Neutron Spectrum		
	Amount	Pitch (cm)	Amount	Pitch (cm)			Form	Material	Amount	Location		T (%)	I (%)	F (%)
16	61	4	0	0.74	Water	Water	Filter	Cd	0.48 cm	Around ACRR	1.12782 ± 0.00072	67.22	29.86	2.92
17	61	4	0	0.74	Water	Graphite	Filter	Cd	0.48 cm	Around ACRR	0.76633 ± 0.00073	67.55	29.1	3.35
18	61	4	0	0.74	Graphite	Graphite	Filter	Cd	0.48 cm	Around ACRR	0.81206 ± 0.00071	67.41	29.35	3.24
19	91	4	0	0.74	Water	Water	Filter	Cd	0.48 cm	Around ACRR	0.95079 ± 0.00082	69.6	27.41	2.99
20	91	4	0	0.74	Water	MgO	Filter	Cd	0.48 cm	Around ACRR	1.00750 ± 0.00081	69.81	27.34	2.85
21	91	3.8	0	0.74	Water	MgO	Filter	Cd	1.48 cm	Around ACRR	0.84394 ± 0.00075	56.78	39.14	4.08
22	84	3.8	0	0.74	Water	Water	Filter	Cd	1.48 cm	Around ACRR	0.89972 ± 0.00070	65.16	31.21	3.63
23	84	3.8	0	0.74	Water	MgO	Filter, Rods	Cd	1.48 cm, 7	Around ACRR	0.74232 ± 0.00066	54.45	40.94	4.61
24	84	3.8	0	0.74	Water	MgO	Filter, Rods	Cd	3.48 cm, 7	Around ACRR	0.81941 ± 0.00068	58.14	37.83	4.03
25	217	3.8	0	0.74	Water	MgO	Filter, Rods	Cd	3.48 cm, 7	Around ACRR	0.87661 ± 0.00071	56.27	39.69	4.04
26	271	3.8	0	0.74	Water	MgO	Filter, Rods	Cd	3.48 cm, 7	Around ACRR	0.93394 ± 0.00074	56.41	39.65	3.94
27	331	3.8	0	0.74	Water	MgO	Filter, Rods	Cd	3.48 cm, 7	Around ACRR	0.98023 ± 0.00073	56.32	39.81	3.87
28	397	3.8	0	0.74	Water	MgO	Filter, Rods	Cd	3.48 cm, 7	Around ACRR	1.01735 ± 0.00073	56.46	39.74	3.8
29	397	3.8	0	0.74	Water	MgO	Filter, Rods	Cd	3.48 cm, 19	Around ACRR, Center	0.96783 ± 0.00069	56.02	40.1	3.88
30	397	3.8	0	0.74	Water	MgO	Filter, Rods	Cd	5 cm, 7	Around ACRR, Center	1.00892 ± 0.00065	55.58	40.54	3.88
31	397	3.8	0	0.74	Water	Cd	Filter, Rods	Cd	5 cm, 7	Around ACRR, Center	1.00183 ± 0.00078	55.53	40.55	3.92
32	397	3.8	0	0.74	Water	Water	Filter, Rods	Cd	5 cm, 14	Around ACRR, Center	1.00118 ± 0.00003	51.83	43.55	4.62

5.3. BEST INTERMEDIATE DESIGN

The experiment design that contains the most intermediate energy neutrons is shown in Figure 5.6. The 7uPCX driver fuel was removed from this design because of its low enrichment impacting the neutron energy spectrum. The only fuel in this fuel region is the ACRR fuel element form of the UO_2-BeO fuel. This design contains water as the moderator. There are 54 cadmium rods interspersed within the fuel region with a 5 cm cadmium filter surrounding the fuel region. This design is inside a tank with a surrounding water reflector. There are two PPS detectors in this design similar to the final design.

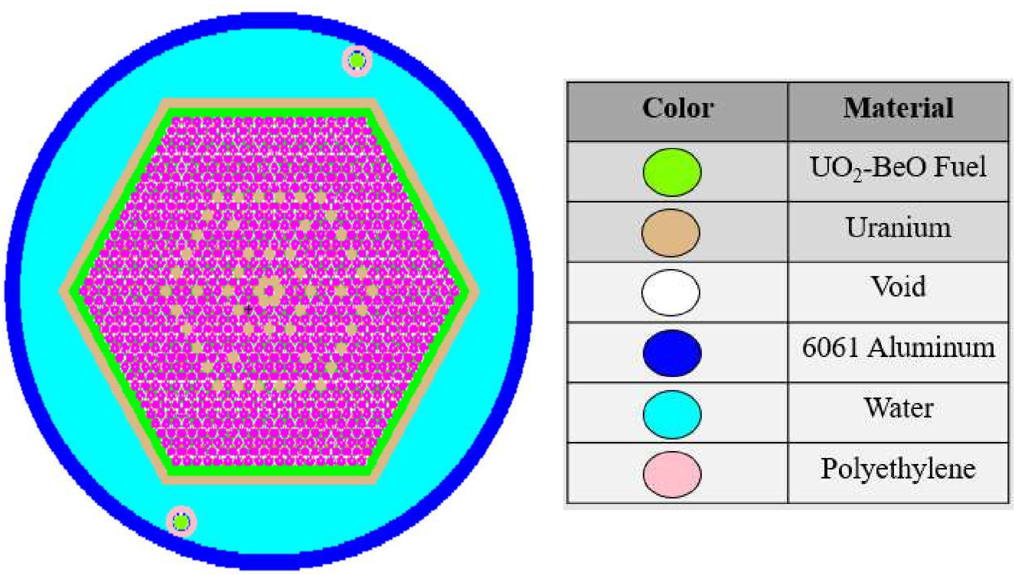


Figure 5.6: Best Intermediate Experiment Design.

This design has the following characteristics listed in Table 5.9. The pitch of the ACRR fuel is 3.8 cm with 972 total fuel elements in the design.

Table 5.9: Ongoing Work Best Design Parameters.

Parameter	Value
k_{eff}	1.00118 ± 0.00003
T (%)	51.83
I (%)	43.55
F (%)	4.62

The addition of cadmium absorber rods to the design in place of fuel elements resulted in a reduction in the criticality of the system. This resulted in adding more fuel elements to the design to drive up the criticality. This back-and-forth trend was performed until an asymptotic relationship was reached. This is the best configuration that could be created with the parameters and restrictions that were put into this design process.

The neutron energy spectrum for this approximately 40% intermediate energy model is shown in Figure 5.7, where the neutron energies are depicted by shaded regions cut off at 0.625 eV. This graph shows the neutron energy spectrum for the ACRR fuel elements in the system.

The neutron energy spectrum for the central ACRR fuel element in the system is shown in Figure 5.8. The energy spectrum in this area is shown to be leaning much further toward the intermediate energy range. The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift. Despite this, the intermediate neutron energy spectrum has more of a presence in the center of the fuel region than in previous configurations.

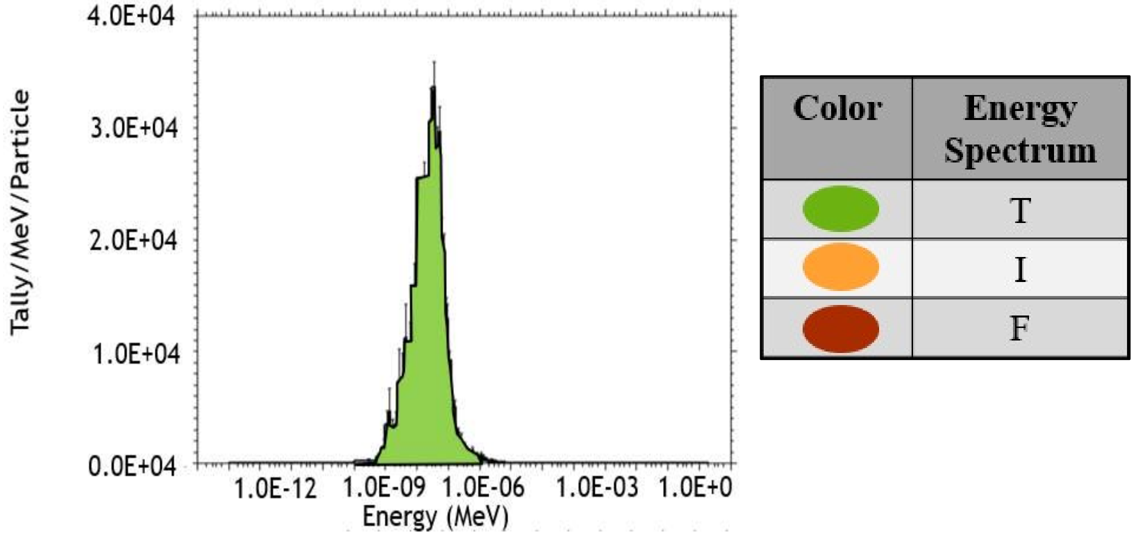


Figure 5.7: Ongoing Work Neutron Energy Spectrum in ACRR Fuel Elements.

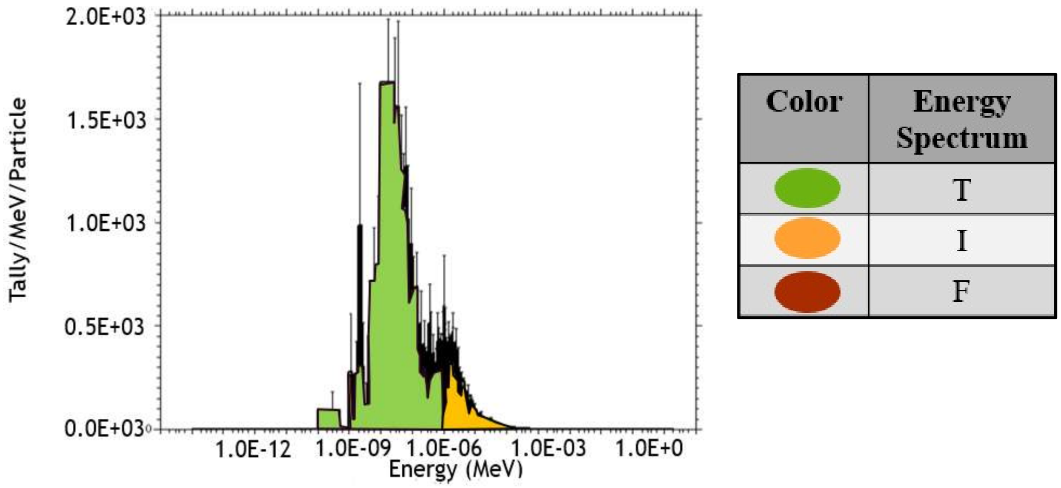


Figure 5.8: Ongoing Work Neutron Energy Spectrum in Center.

The neutron energy spectrum in the absorber rods in the system is shown in Figure 5.9. This graph shows that this is a very thermalized area, which is expected to occur within the absorber rods. The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift.

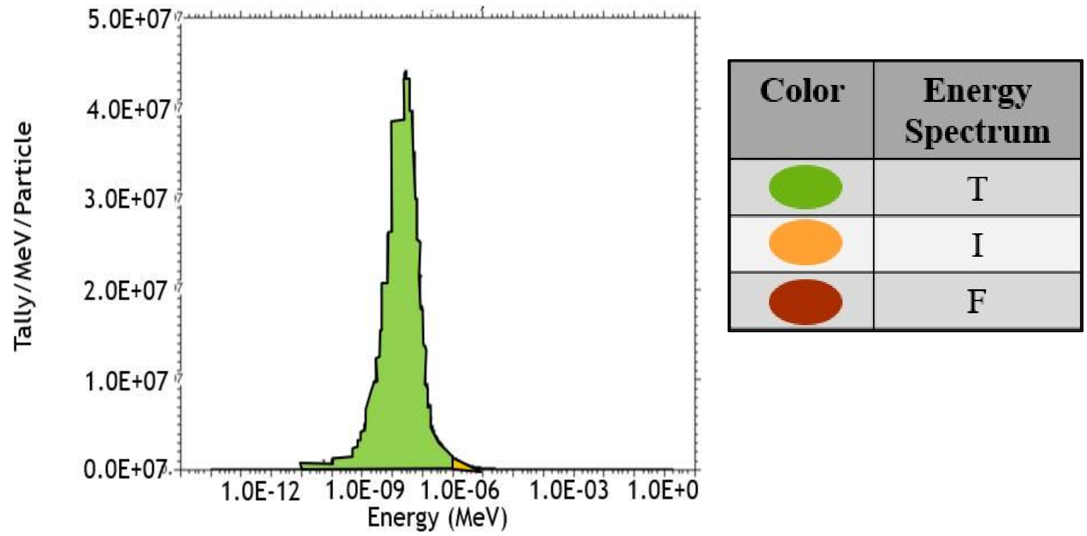


Figure 5.9: Ongoing Work Neutron Energy Spectrum in Cadmium Rods.

The neutron energy spectrum in the cadmium sleeve surrounding the fuel region is shown in Figure 5.10. This shows a much more intermediate energy range than the previous models. This is great for the entire model since this is a representation across the entire fuel region that there is a higher intermediate neutron population. The FWHM of this graph is on the order of 10^{-8} MeV, which is not a wide range of energies in which this configuration can shift to become a mostly intermediate neutron energy spectrum. The shape of this graph shows dips around 6 and 20 MeV, which are where ^{238}U has major resonance capture. This ^{238}U resonance reduces the neutron energy to still favor the thermal energy range.

For future intermediate neutron energy experiment designs, ongoing work would include making modifications to the ACRR fuel pellet design. Because of the 3.368 cm diameter of the fuel pellet, a lot of self-shielding may be impacting the results of the spectrum. Self-shielding analysis would be added to this ongoing work to investigate the impact this has on the spectrum.

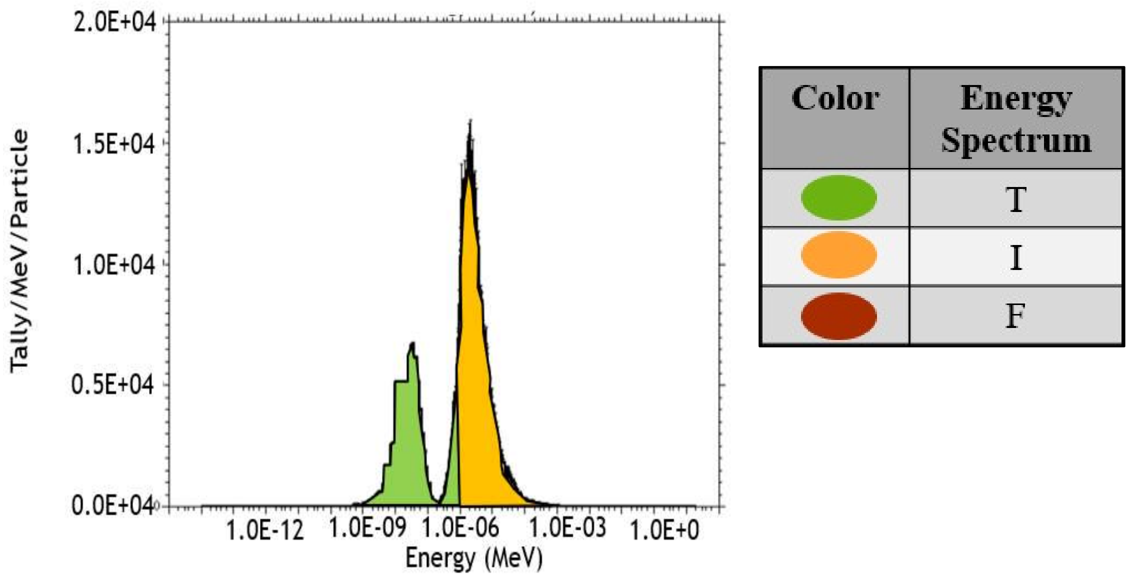


Figure 5.10: Ongoing Work Neutron Energy Spectrum at Edge of Fuel Region.

5.4. OVERALL SUMMARY OF ONGOING WORK

From the previous calculations, the current design with the ACRR fuel does not seem to be a feasible critical experiment for attaining the intermediate neutron energy spectrum. For further calculations into this intermediate design, the ACRR fuel element design may need adjustment in order to reduce the self-shielding and moderating effects of the fuel.

6. CONCLUSION

The goal of this project was to develop a critical experiment facility that would allow for multiple critical experiments to be conducted in different neutron energy ranges. The design of this facility had to meet the following requirements:

- 35%-enriched ^{235}U in the UO_2-BeO fuel
- ACRR fuel characterized
- 7uPCX fuel rods used as a driver fuel
- Critical system
- Beryllium cross section data is acquirable in the thermal neutron energy range (<0.625 eV)
- Beryllium cross section data is acquirable in the intermediate neutron energy range (0.625 eV – 100 keV)
- Beryllium oxide cross section data is acquirable in the thermal neutron energy range (<0.625 eV)
- Beryllium oxide cross section data is acquirable in the intermediate neutron energy range (0.625 eV – 100 keV)

The final design of this critical experiment used the fully built ACRR fuel elements as the method for inserting BeO fuel into the reactor system. This was surrounded by 7uPCX driver fuel rods to drive criticality and create a critical reactor system. The presence of the BeO fuel allows for the calculation and acquisition of beryllium and BeO cross section data. The current state of the final design is in a thermal neutron energy range, which allows for the acquisition of this cross-section data in the thermal range. With ongoing work, the intermediate neutron energy range may be achievable as a separate critical experiment design.

Considering the data presented previously for the pellet design and the fuel element design, the preferred method for pursuing thermal neutron energy spectrum experiments would be the fuel element design. Although, it does not satisfy the goal of achieving an intermediate neutron energy spectrum in its base configuration, it is the most capable of shifting the energy spectrum toward the intermediate neutron energy range. With the material available at Sandia currently, this model in its most viable form for the intermediate spectrum is not buildable at this time. More fuel elements would need to be manufactured, as well as a new grid plate for the array. Whereas the thermal energy spectrum experiments could be conducted in a much timelier manner, the intermediate spectrum would require more time and consideration before being completed within the next few years.

Therefore, the thermal neutron energy experiments are feasible with the final design previously discussed. The intermediate neutron energy experiments require more refinement but may be possible in the future.

APPENDIX A.

MCNP6.2 FUEL PELLET MODEL

Driver fuel

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c ********* worm ************
c driver fuel is a 14x14 array of 7UP Fuel. The driver fuel is reflected by water.
c
c   fuel rod with grid plates
c
 1    1  0.068772427  -1    12   -13       u=1 $ fuel vol= 10.5849
 2    0              -5    13   -14       u=1 $ inside spring
 3    5  1.8185E-02  -6     5    13   -14 u=1 $ spring
 4    2  5.9877E-02  -7    14   -15       u=1 $ Al spacer
 5    7  1.2236E-01  -7    15   -100      u=1 $ polyethylene spacer
 6    0              -2    12   -100         $ void in clad
                  (1 : 13)                  $ fuel
                  (6 : -13 : 14)             $ spring
                  (7 : -14 : 15)             $ Al spacer
                  (7 : -15 : 100)      u=1   $ poly spacer
 7    3  6.0366E-02  -3    11   -100         $ clad
                  (2 : -12)           u=1   $ void in rod
 8    4 -1  -4     3    11   -12        u=1 $  in lower GP
 9    2  5.9877E-02 10   -12                $ lower grid plate
                  (4 : -11)           u=1   $ hole
10     12  -1.848 -10                   u=1
11     12  -1.848   3    12   -14 -99      u=1 $  between GPs
```

```
15     4 -0.998  3    12   -14  99        u=1 $  between GPs
12     10  -1.0245e-3  -4    3    14   -15 u=1 $ air in upper GP
13     2  5.9877E-02  4    14   -15       u=1 $ upper grid plate
14     10  -1.0245e-3   3    15   -100     u=1 $ air above upper GP
c
c
*****************************************************************************
****************
c ************************* Axial Flux Fuel Assembly
***********************************
c
*****************************************************************************
****************
c
c 31     1  0.068772427  -1    12   -13   101       u=2 $ fuel vol= 10.5849
3001   1  0.068772427  -101  -1    12   -13       u=2 $ fuel segment 1 cm
3002   1  0.068772427   101  -102  -1    12   -13       u=2 $ fuel segment 2 cm
3003   1  0.068772427   102  -103  -1    12   -13       u=2 $ fuel segment 3 cm
3004   1  0.068772427   103  -104  -1    12   -13       u=2 $ fuel segment 4 cm
3005   1  0.068772427   104  -105  -1    12   -13       u=2 $ fuel segment 5 cm
3006   1  0.068772427   105  -106  -1    12   -13       u=2 $ fuel segment 6 cm
3007   1  0.068772427   106  -107  -1    12   -13       u=2 $ fuel segment 7 cm
3008   1  0.068772427   107  -108  -1    12   -13       u=2 $ fuel segment 8 cm
```

```
3009  1  0.068772427   108  -109  -1    12   -13      u=2 $ fuel segment 9 cm
3010  1  0.068772427   109  -110  -1    12   -13      u=2 $ fuel segment 10 cm
3011  1  0.068772427   110  -111  -1    12   -13      u=2 $ fuel segment 11 cm
3012  1  0.068772427   111  -112  -1    12   -13      u=2 $ fuel segment 12 cm
3013  1  0.068772427   112  -113  -1    12   -13      u=2 $ fuel segment 13 cm
3014  1  0.068772427   113  -114  -1    12   -13      u=2 $ fuel segment 14 cm
3015  1  0.068772427   114  -115  -1    12   -13      u=2 $ fuel segment 15 cm
3016  1  0.068772427   115  -116  -1    12   -13      u=2 $ fuel segment 16 cm
3017  1  0.068772427   116  -117  -1    12   -13      u=2 $ fuel segment 17 cm
3018  1  0.068772427   117  -118  -1    12   -13      u=2 $ fuel segment 18 cm
3019  1  0.068772427   118  -119  -1    12   -13      u=2 $ fuel segment 19 cm
3020  1  0.068772427   119  -120  -1    12   -13      u=2 $ fuel segment 20 cm
3021  1  0.068772427   120  -121  -1    12   -13      u=2 $ fuel segment 21 cm
3022  1  0.068772427   121  -122  -1    12   -13      u=2 $ fuel segment 22 cm
3023  1  0.068772427   122  -123  -1    12   -13      u=2 $ fuel segment 23 cm
3024  1  0.068772427   123  -124  -1    12   -13      u=2 $ fuel segment 24 cm
3025  1  0.068772427   124  -125  -1    12   -13      u=2 $ fuel segment 25 cm
3026  1  0.068772427   125  -126  -1    12   -13      u=2 $ fuel segment 26 cm
3027  1  0.068772427   126  -127  -1    12   -13      u=2 $ fuel segment 27 cm
3028  1  0.068772427   127  -128  -1    12   -13      u=2 $ fuel segment 28 cm
3029  1  0.068772427   128  -129  -1    12   -13      u=2 $ fuel segment 29 cm
3030  1  0.068772427   129  -130  -1    12   -13      u=2 $ fuel segment 30 cm
3031  1  0.068772427   130  -131  -1    12   -13      u=2 $ fuel segment 31 cm
```

```
3032   1  0.068772427   131  -132  -1    12   -13       u=2 $ fuel segment 32 cm
3033   1  0.068772427   132  -133  -1    12   -13       u=2 $ fuel segment 33 cm
3034   1  0.068772427   133  -134  -1    12   -13       u=2 $ fuel segment 34 cm
3035   1  0.068772427   134  -135  -1    12   -13       u=2 $ fuel segment 35 cm
3036   1  0.068772427   135  -136  -1    12   -13       u=2 $ fuel segment 36 cm
3037   1  0.068772427   136  -137  -1    12   -13       u=2 $ fuel segment 37 cm
3038   1  0.068772427   137  -138  -1    12   -13       u=2 $ fuel segment 38 cm
3039   1  0.068772427   138  -139  -1    12   -13       u=2 $ fuel segment 39 cm
3040   1  0.068772427   139  -140  -1    12   -13       u=2 $ fuel segment 40 cm
3041   1  0.068772427   140  -141  -1    12   -13       u=2 $ fuel segment 41 cm
3042   1  0.068772427   141  -142  -1    12   -13       u=2 $ fuel segment 42 cm
3043   1  0.068772427   142  -143  -1    12   -13       u=2 $ fuel segment 43 cm
3044   1  0.068772427   143  -144  -1    12   -13       u=2 $ fuel segment 44 cm
3045   1  0.068772427   144  -145  -1    12   -13       u=2 $ fuel segment 45 cm
3046   1  0.068772427   145  -146  -1    12   -13       u=2 $ fuel segment 46 cm
3047   1  0.068772427   146  -147  -1    12   -13       u=2 $ fuel segment 47 cm
3048   1  0.068772427   147  -148  -1    12   -13       u=2 $ fuel segment 48 cm
3049   1  0.068772427   148  -13   -1    12   -13      u=2 $ fuel segment 49 cm
32     0             -5    13   -14       u=2 $ inside spring
33     5  1.8185E-02  -6     5    13   -14 u=2 $ spring
34     2  5.9877E-02  -7    14   -15       u=2 $ Al spacer
35     7  1.2236E-01  -7    15   -100      u=2 $ polyethylene spacer
36     0             -2    12   -100         $ void in clad
```

```
                (1 : 13)            $ fuel
                (6 : -13 : 14)        $ spring
                (7 : -14 : 15)        $ Al spacer
                (7 : -15 : 100)    u=2   $ poly spacer
37    3  6.0366E-02  -3    11   -100        $ clad
                (2 : -12)          u=2   $ void in rod
38    4 -1  -4     3    11   -12        u=2 $  in lower GP
39    2  5.9877E-02 10   -12              $ lower grid plate
                (4 : -11)          u=2   $ hole
310    12  -1.848 -10                  u=2
311    12  -1.848   3    12   -14 -99     u=2 $  between GPs
315    4 -0.998  3    12   -14  99        u=2 $  between GPs
312    10  -1.0245e-3  -4    3    14   -15 u=2 $ air in upper GP
313    2  5.9877E-02  4    14   -15       u=2 $ upper grid plate
314    10  -1.0245e-3   3    15   -100    u=2 $ air above upper GP
c
c
*****************************************************************************
*****************
c *********************************** Air
*****************************************************
```

```
c
*********************************************************************
****************
c
16 10 -1.0245e-3 3 12 -14 99 #17          u=7 $ experiment region for 7up fuel
17 10 -1.0245e-3 -4 11 -15                u=7 $ 7up spectrum
18     10  -1.0245e-3   3    15   -100     u=7 $ air above upper GP
19     2  5.9877E-02  4    14   -15        u=7 $ upper grid plate
20     2  5.9877E-02 10   -12                $ lower grid plate
                (4 : -11)           u=7   $ hole
21     7  1.2236E-01  -3    15   -100      u=7 $ polyethylene spacer
c
c  a air cell
c
214    10 -1.0245e-3 -10 -100             u=8 $ air below grid plate
215    2  5.9877E-02  10  -11 :  4   11       $ bottom grid plate
                -12                 u=8
216    10  -1.0245e-3  -4   11  -12        u=8 $ air in lower grid plate
217    10  -1.0245e-3  12  -14 -99        u=8 $ air between grid plates
221    10  -1.0245e-3  12  -14 99 -100 #510 #9992  u=8 $ air between grid plates
C 218    10  -1.0245e-3  -4   14  -15 -100   u=8 $ air in upper grid plate
218    10  -1.0245e-3  -4   14  -15 -100   u=8 $ air in upper grid plate
219    2  5.9877E-02  4   14  -15        u=8 $ upper grid plate
```

```
C 220    10  -1.0245e-3  15 -100            u=8 $ air above grid plate
220    10  -1.0245e-3  15 -100            u=8 $ air above grid plate
c  the array
c
999   4 -1 901  -902   903  -904  lat=1  u=10
                fill -25:24 -25:24  0:0
      10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
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c
c
1000   10  -1.0245e-3  -100   913  -914   915  -916 911 #509 #511 #510 #9992  $ bounds
on upper array
        fill=10
1002  4 -1 10   -12  -932                   $ bottom grid plate
         (-921 : 912 : -913 : 914 : -915 : 916) #500 #501 #502 #503 #504 #1000 $ the
array
1003   2  5.9877E-02  961 -962  963 -964   14   -15     $ top grid plate
```

```
          (-921 : 912 : -913 : 914 : -915 : 916)     $ the array
1007   10  -1.0245e-3 921 -922 -923 -99              $ reflector
          (-921 : 912 : -913 : 914 : -915 : 916)     $ the array
               (-10 : 12 : 932)                $ bottom grid plate
          (-961 : 962 : -963 : 964 : -14 : 15) #502     $ top grid plate
1008   10  -1.0245e-3 921 -922 -923 99 -100             $ reflector
          (-921 : 912 : -913 : 914 : -915 : 916)     $ the array
               (-10 : 12 : 932)                $ bottom grid plate
          (-961 : 962 : -963 : 964 : -14 : 15) #500 #501 #502 #503 #504
          #509 #510 #9992
c 1030   0          -100   802 -805                 $ -x+y detector well
c 1031   2  5.9877E-02 -100   803 -804                $ -x+y detector tube
c                 (-802 : 805)                    $-x+y well
c 1032   7  1.2236E-01 -810   811 -812  814            $ -x+y detector poly
c 1033   0          -100   802 -807                 $ +x+y detector well
c 1034   2  5.9877E-02 -100   803 -806                $ +x+y detector tube
c                  (-802 : 807)                    $+x+y well
c 1035   7  1.2236E-01 -810   811 -813  815            $ +x+y detector poly
500 4 -1 -500 #1000 $ reflector top
501 4 -1 -501 #1000 $ reflector bottom
502 4 -1 -502 #509 $ reflector under
503 4 -1 -503  #1000 $ reflector left
504 4 -1 -504 #1000 $ reflector right
```

```
509 4 -1 -509 $ water base reflector
511 4 -1 -511 $ water base reflector
510 21 -2.69 -510  #511 #509 #9992  $ box to load BeO fuel into
c *******************************************************
c experiment disk
9200 4 -1  9200 u=5  $ shell around experiment
9211 4 -1 -9200 u=5 $ experiment
c beo fuel pellets
100 10 -0.0012045 -9100 u=3  $ inner pellet void
101 13 -3.3447 -9101 9100 u=3 $ inner pellet vol=2.29769
102 10 -0.0012045 -9102 9101 9100 u=3  $ gap
103 13 -3.3447 -9103 9102 9101 9100 u=3   $ outer pellet vol=3.16379
9012 4 -1 9103 U=3  $ moderator outside of pellet
9013 4 -1 -9104 lat=1 u=6 fill=0:4 0:4 0:39
     3 3 3 3 3  $ start layer 1
     3 3 3 3 3
     3 3 3 3 3
     3 3 3 3 3
     3 3 3 3 3
     3 3 3 3 3  $ start layer 2
     3 3 3 3 3
     3 3 3 3 3
     3 3 3 3 3
```

3 3 3 3 3

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5 5 5 5 5 $ start layer 18

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3 3 3 3 3 $ start layer 29

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3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3 $ start layer 30

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3 $ start layer 31

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3 $ start layer 32

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3 $ start layer 33

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3 $ start layer 34

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3 $ start layer 35

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3 $ start layer 36

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3 $ start layer 36

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3 $ start layer 36

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3

3 3 3 3 3 $ start layer 36

3 3 3 3 3

3 3 3 3 3

```
    3 3 3 3 3
    3 3 3 3 3
                  3 3 3 3 3  $ start layer 36
    3 3 3 3 3
    3 3 3 3 3
    3 3 3 3 3
    3 3 3 3 3
9992 0 -9105 fill=6
1100   0                                $ external void
              (-921 : 100 : 923)            $ water in upper tank

c fuel rod surfaces
c
1    cz    0.262814 $ fuel OD
2    cz    0.284519 $ clad ID
3    cz    0.317474 $ clad OD
4    cz    0.333375 $ ID of hole in grid plate at fuel
5    cz    0.17526  $ ID of spring
6    cz    0.22860  $ OD of spring
7    cz    0.26289  $ intermediate plug OD
8    cz    0.26289  $ poly OD
10   pz   -2.54     $ bottom of bottom grid plate
11   pz   -1.27     $ bottom of rod
```

```
12   pz    0.0      $ bottom of fuel
13   pz   48.780    $ top of fuel
14   pz   50.4952   $ bottom of upper grid plate
15   pz   53.0352   $ top of upper grid plate
c
c Axial Flux Fuel Assembly dividers
c
101  pz    1.0
102  pz    2.0
103  pz    3.0
104  pz    4.0
105  pz    5.0
106  pz    6.0
107  pz    7.0
108  pz    8.0
109  pz    9.0
110  pz   10.0
111  pz   11.0
112  pz   12.0
113  pz   13.0
114  pz   14.0
115  pz   15.0
116  pz   16.0
```

117 pz 17.0

118 pz 18.0

119 pz 19.0

120 pz 20.0

121 pz 21.0

122 pz 22.0

123 pz 23.0

124 pz 24.0

125 pz 25.0

126 pz 26.0

127 pz 27.0

128 pz 28.0

129 pz 29.0

130 pz 30.0

131 pz 31.0

132 pz 32.0

133 pz 33.0

134 pz 34.0

135 pz 35.0

136 pz 36.0

137 pz 37.0

138 pz 38.0

139 pz 39.0

```
140  pz   40.0
141  pz   41.0
142  pz   42.0
143  pz   43.0
144  pz   44.0
145  pz   45.0
146  pz   46.0
147  pz   47.0
148  pz   48.0
c
c     water level
c
100   pz    68.2752        $ top of the water
c
c   detector wells
c
802   pz    13.335     $ bottom inside of tube
803   pz    12.7       $ bottom of tube
804   c/z   25.4     -6.840   3.175  $ OD tube outside
805   c/z   25.4     -6.840   2.8575 $ ID of tube
806   c/z  -25.4     -6.840   3.175  $ OD tube
807   c/z  -25.4     -6.840   2.8575 $ ID of tube
810   pz    43.4848                  $ top of poly
```

```
811   pz    13.462                   $ bottom of poly
812   c/z   25.4     -6.840   5.75945 $ OD poly
813   c/z  -25.4     -6.840   5.75945 $ OD poly
814   c/z   25.4     -6.840   3.30581 $ ID poly
815   c/z  -25.4     -6.840   3.30581 $ ID poly
c
c cell boundaries
c
901  px   -0.427482
902  px    0.427482
903  py   -0.427482
904  py    0.427482
c
c array boundaries
c
911  pz  -2.54
912  pz  145.00001
913  px  -20.946618
914  px   21.801582
915  py  -20.946618
916  py   21.801582
c
c     the water
```

```
c
921   pz   -32.54     $ bottom of reflector
922   pz    82.55      $ top of reflector
923   cz    146.83125   $ outside of reflector
932   cz    50    $ outside curve of lower grid plate
c
c   upper grid plate
c
961   px   -20.955
962   px    20.955
963   py   -20.955
964   py    20.955
C
99   pz    -5
c reflector grahpite
500 RPP -50 50 20.955 50 0 68.2752   $ top
501 RPP -50 50 -50 -20.955 0 68.2752  $ bottom
502 RPP -50 50 -50 50 -32.54 -2.54  $ under
503 RPP -50 -20.955 -20.955 20.955 0 68.2752  $ left
504 RPP 20.955 50 -20.955 20.955 0 68.2752   $ right
c Be metal reflector base
509 RPP -8.9 9.73 -8.9 9.73 -10 0
511 RPP -8.9 9.73 -8.9 9.73 5.040e+01   6.040e+01
```

c area for BeO fuel to get stacked

510 RPP -8.95 9.82 -8.95 9.82 0 60.42

c

c

****

****

c BeO fuel stacking

9100 22 RCC 0 0 0 0 0 0.635 0.2413 $ inner pellet hole

9101 22 RCC 0 0 0 0 0 0.635 1.1 $ inner pellet

9102 22 RCC 0 0 0 0 0 0.635 1.118 $ gap

9103 22 RCC 0 0 0 0 0 0.635 1.6840 $ outter Fuel

9104 22 RPP -1.80 1.70 -1.80 1.70 0 1.275e+00 $ rectangle box for lattice holds moderator

9105 22 RPP -1.78 15.69 -1.78 15.69 0 5.040e+01 $ adjust this for changing size of lattice

c

****

****

c experiment locations

9200 22 RPP -1.7 1.6 -1.7 1.6 0.2 0.8 $ experiment disk

*tr22 -6.5 -6.5 0

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

```
c
c UO2 fuel
c
m1
     92234.80c 6.55390E-06
     92235.80c 1.60100E-03
     92236.80c 1.46320E-05
     92238.80c 2.12960E-02
      8016.80c 4.58370E-02
     47107.80c 4.78572E-09
     47109.80c 4.44618E-09
      5010.80c 4.74774E-08
      5011.80c 1.91103E-07
     48106.80c 1.54750E-10
     48108.80c 1.10182E-10
     48110.80c 1.54626E-09
     48111.80c 1.58464E-09
     48112.80c 2.98729E-09
     48113.80c 1.51284E-09
     48114.80c 3.55677E-09
     48116.80c 9.27262E-10
     27059.80c 2.16200E-08
     24050.80c 1.09060E-07
```

24052.80c 2.10310E-06

24053.80c 2.38475E-07

24054.80c 5.93615E-08

29063.80c 1.47443E-07

29065.80c 6.57172E-08

26054.80c 6.02678E-07

26056.80c 9.46075E-06

26057.80c 2.18490E-07

26058.80c 2.90770E-08

25055.80c 2.83720E-07

42092.80c 1.84654E-08

42094.80c 1.15098E-08

42095.80c 1.98093E-08

42096.80c 2.07549E-08

42097.80c 1.18831E-08

42098.80c 3.00250E-08

42100.80c 1.19826E-08

28058.80c 2.38194E-06

28060.80c 9.17520E-07

28061.80c 3.98840E-08

28062.80c 1.27168E-07

28064.80c 3.23858E-08

23000.70c 1.48130E-08

```
    74180.80c 4.31976E-12
    74182.80c 9.53947E-10
    74183.80c 5.15131E-10
    74184.80c 1.10298E-09
    74186.80c 1.02342E-09
C
c    6061 aluminum
c
m2   13027.80c  5.8376E-02
c     14000.xxx  4.1683E-04
    14028.80c 3.84441e-04
    14029.80c 1.95210e-05
    14030.80c 1.28684e-05
c     26000.xxx  1.8051E-04
    26054.80c 1.05508e-05
    26056.80c 1.65625e-04
    26057.80c 3.82501e-06
    26058.80c 5.09038e-07
c     29000.xxx  7.9320E-05
    29063.80c 5.48656e-05
    29065.80c 2.44544e-05
    25055.80c  2.6637E-05
c  Magnesium  6.9574E-04
```

12024.80c 5.49565e-04

12025.80c 6.9574e-05

12026.80c 7.6601e-05

c 24000.xxx 6.2542E-05

24050.80c 2.71745e-06

24052.80c 5.24033e-05

24053.80c 5.94212e-06

24054.80c 1.47912e-06

30000.70c 2.9839e-05

c Titanium 6.7918e-006

22046.80c 5.60324e-07

22047.80c 5.05310e-07

22048.80c 5.00691e-06

22049.80c 3.67436e-07

22050.80c 3.51815e-07

23000.70c 3.1918E-06

c

c 3003 aluminum

c

m3 13027.80c 5.9668E-02

c 14000.xxx 1.7561E-04

14028.80c 1.61965e-04

14029.80c 8.22417e-06

```
    14030.80c 5.42143e-06
c    26000.xxx  1.0303E-04
    26054.80c 6.02210e-06
    26056.80c 9.45341e-05
    26057.80c 2.18321e-06
    26058.80c 2.90545e-07
c    29000.xxx  3.2339E-05
    29063.80c 2.23689e-05
    29065.80c 9.97011e-06
    25055.80c  3.7407E-04
    30000.70c  1.2571e-05
c
c   water
c
m4   1001.80c  6.6659E-02
     8016.80c  3.3329E-02
mt4  lwtr.10t
c
c   stainless steel 304
c
m5
c  Iron 1.2527e-02
    26054.80c 7.32203e-04
```

```
    26056.80c 1.14940e-02
    26057.80c 2.65447e-04
    26058.80c 3.53261e-05
c  Chromium 3.6455E-03
    24050.80c 1.58397e-04
    24052.80c 3.05453e-03
    24053.80c 3.46359e-04
    24054.80c 8.62161e-05
c  Nickel 1.5724E-03
    28058.80c 1.07044e-03
    28060.80c 4.12332e-04
    28061.80c 1.79238e-05
    28062.80c 5.71489e-05
    28064.80c 1.45541e-05
    25055.80c  1.8160E-04  $Mn
     6000.80c  3.3225E-05  $C
    15031.80c  7.2471E-06  $P
c  Sulfur 4.6663e-006
    16032.80c 4.42972e-06
    16033.80c 3.54639e-08
    16034.80c 2.00184e-07
    16036.80c 9.33260e-10
c  Silicon 1.7761e-04
```

```
    14028.80c 1.63809e-04
    14029.80c 8.31783e-06
    14030.80c 5.48318e-06
c  Nitrogen 3.5613e-005
     7014.80c 3.54819e-05
     7015.80c 1.31056e-07
c
c    polyethylene (CH2)
c
m7
     1001.80c  8.2755E-02
     6000.80c  4.1377E-02
mt7   poly.10t
c
C Air
M10     7014.80c -0.752308   7015.80c -0.002960   8016.80c -0.231687
       8017.80c -0.000094   6000.80c -0.000124  18036.80c -0.000043
      18038.80c -0.000008  18040.80c -0.012776
M11 6000.80c 1 $ Graphite density = 2.1
mt11 grph.60t
M12 4009.80c 1 $ Be Metal density = 1.848
mt12 be.60t
c BeO fuel
```

```
M13    4009.80c  -0.2827602
       8016.80c  -0.5277690
               92235.80c -0.0662957
       92238.80c -0.1222844
               92234.80c -0.0004547
               92236.80c -0.0004358
mt13 beo.60t
m14 4009.80c 1 8016.80c 1 $ BeO density 3.02
m15 1001.80c 8 6000.80c 5 8016.80c 2 $ lucite density 1.18
m20 1001.80c 8 6000.80c 5 8016.80c 2 4009.80c 1 $ made up material density =
c
c Al density = 2.69
m21 13027.80c 1
c cadmium density= 8.69
m22  48106.80c   0.012500
     48108.80c   0.008900
     48110.80c   0.124900
     48111.80c   0.128000
     48112.80c   0.241300
     48113.80c   0.122200
     48114.80c   0.287300
     48116.80c   0.074900
c
```

```
c
c
imp:n    1 114r 0
mode   n p
kcode  10000  1  50  200
SDEF  x=d1 y=d2 z=d3
SI1    -6 5.7
SP1     0 1
SI2    -8 -6
SP2     0 1
SI3    20 28
SP3     0 1
c
KOPTS           KINETICS=YES
c tallies
f4:n 9211
e4 1e-9 49ilog 20
f14:n 17
e14 1e-9 49ilog 20
c peaking tallies
c peaking tallies
F104:n (1<999[-25:12 -25:24 0:0]<1000) T $ 7Up fuel grid (cell#<array cell # [fill values]< universe fill cell)
```

```
FM104 -5.333e-3 1 -4 1 T
F204:n (101<9013[0:4 0:4 0:35]<9992) T $ inner Beo pellets
FM204 -5.333e-3 1 -4 1 T
F304:n (103<9013[0:4 0:4 0:35]<9992) T $ outer Beo pellets
FM304 -5.333e-3 1 -4 1 T
SD104 1 1900r
SD204 1 900r
SD304 1 900r
c
F114:N (3001 3002 3003 3004 3005 3006 3007 3008 3009 3010 3011 3012 3013 &
        3014 3015 3016 3017 3018 3019 3020 3021 3022 3023 3024 3025 3026 &
                    3027 3028 3029 3030 3031 3032 3033 3034 3035 3036 3037
3038 3039 &
                    3040 3041 3042 3043 3044 3045 3046 3047 3048 3049<1000)
FM114 -1 1 -6 -8
c SD104 10.5849
SD114 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 &
   0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 &
        0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 &
        0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 &
        0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 0.21699 &
        0.21699 0.21699 0.21699 0.16925
```

APPENDIX B.

MCNP6.2 ACRR FUEL ELEMENT MODEL

```
1531 fuel rods in 1531 total positions
c
c  Core water (m4) and reflector water (m40) are separate
c  Reflector is at 25 deg C, density 0.99704 g/cc
c    note that this density is not exactly the 25 deg C density (0.99705 g/cc)
c    so the density can be changed separately from the core water density
c
c   fuel rod with grid plates
c
 1    1  -10.265   -1   40  -41       u=1  $ 1st midplane fuel
 2    1  -10.265   -1   41  -42       u=1  $ 2nd midplane fuel
 3    1  -10.265   -1   42  -43       u=1  $ 3rd midplane fuel
 4    1  -10.265   -1   43  -44       u=1  $ 4th midplane fuel
 5    1  -10.265   -1   12  -23       u=1  $ bottom fuel
 6    1  -10.265   -1   45 -100  -13  u=1  $ top fuel underwater
 7    1  -10.265   -1   23  -45 -100       $ rest of the fuel underwater
                    (1 : -40 : 44)    u=1    $ midplane fuel
 8    1  -10.265   -1  100  -13       u=1  $ fuel above water
15    0             1   -2   12  -13  u=1  $ gap at fuel
16    0            -5   13  -24       u=1  $ void inside spring
17    5  -1.6226    5   -6   13  -24  u=1  $ spring
18    0             6   -2   13  -24  u=1  $ gap at spring
19    2  -2.700    -7   24  -25       u=1  $ aluminum spacer
```

```
20    0           7   -2   24  -25  u=1  $ gap at aluminum spacer
21    7  -0.93     -8   25  -16      u=1  $ poly plug
22    0           8   -2   25  -16  u=1  $ gap at poly plug
23    3  -2.73     -3    2   17  -18  u=1  $ clad
24    3  -2.73     -3   11  -12          $ bottom plug
                (3 : -2 : -17 : 18) u=1   $ clad
25    3  -2.73     -3   16  -19          $ top plug
                (26 : -27 : 19)          $ hole at top
                (3 : -2 : -17 : 18) u=1   $ clad
26   40  -0.99704 -10 -100            u=1 $ water below grid plate
27    2  -2.700    10  -11 :  4   11      $ bottom grid plate
               -12               u=1
28    4  -0.99705  -4    3   11  -12   u=1 $ water in lower grid plate
29    4  -0.99705   3   12  -14 -100   u=1 $ water between grid plates
30    4  -0.99705   3   -4   14  -15      $ water in upper grid plate
              -100               u=1
31    2  -2.700     4   14  -15       u=1 $ upper grid plate
32   40  -0.99704  15 -100               $ water above grid plate
                (3 : -17 : 18)      $ clad
                (3 : -16 : 19)     u=1   $ top plug
33    0          -10  100           u=1 $ void below grid plate
34    0           3   12  -14  100   u=1 $ void between grid plates
35    0           3   -4   14  -15      $ void in upper grid plate
```

```
            100             u=1
36   0         15  100  -28         $ void between grid plate and guide plate
            (3 : -17 : 18)    u=1   $ clad
37   0        -26   27  -19      u=1 $ hole in top plug
38   9  -2.70     4   28  -29      u=1 $ guide plate (always above water)
39   0          3   -4   28  -29   u=1 $ hole in guide plate
40   0         29                $ void above guide plate
            (3 : -17 : 18)       $ clad
            (3 : -16 : 19)    u=1   $ top plug
c
c  cell with grid/guide plates
c
1301   40  -0.99704 -10 -100           u=3 $ water below grid plate
1302    2  -2.700    10  -12           u=3 $ bottom grid plate
1303   40  -0.99704  12  -14 -100      u=3 $ water between grid plates
1304    2  -2.700    14  -15           u=3 $ upper grid plate
1305   40  -0.99704  15 -100           u=3 $ water above grid plate
1306    0          -10  100           u=3 $ void below grid plate
1307    0           12  -14  100      u=3 $ void between grid plates
1308    0           14  -15  100      u=3 $ void in upper grid plate
1309    0           15  100  -28      u=3 $ void between grid plate and guide plate
1310    9  -2.70     28  -29           u=3 $ guide plate (always above water)
1311    0           29  100           u=3 $ void above guide plate
```

```
c
c  Experiment Rod - Tantalum
c
1901  11 -16.65     93  -94   -91  9001 u=9
1902  11 -16.65     93  -94 -9001  9002 u=9
1903  11 -16.65     93  -94 -9002  9003 u=9
1904  11 -16.65     93  -94 -9003  9004 u=9
1905  11 -16.65     93  -94 -9004  9005 u=9
1906  11 -16.65     93  -94 -9005  9006 u=9
1907  11 -16.65     93  -94 -9006  9007 u=9
1908  11 -16.65     93  -94 -9007  9008 u=9
1909  11 -16.65     93  -94 -9008  9009 u=9
1910  11 -16.65     93  -94 -9009  9010 u=9
1911  11 -16.65     93  -94 -9010       u=9
1920  11 -16.65    -91    11   -92
                (-93 : 94)          u=9
1926  40  -0.99704 -10 -100            u=9 $ water below grid plate
1927   2  -2.700    10  -11 :  4   11       $ bottom grid plate
                -12                 u=9
1928   0           -4   91   11  -12   u=9 $ void in lower grid plate
1929   0           91   12  -14 -100   u=9 $ void between grid plates
1930   0           91   -4   14  -15       $ void in upper grid plate
               -100                 u=9
```

```
1931   2  -2.700     4   14  -15        u=9 $ upper grid plate
1932   0           15 -100               $ void above grid plate
                ( 91 : -11 :  92)   u=9   $ experiment rod
1933   0          -10  100            u=9 $ void below grid plate
1934   0           91   12  -14  100   u=9 $ void between grid plates
1935   0           91   -4   14  -15       $ void in upper grid plate
               100                u=9
1936   0           15  100  -28           $ void between grid plate and guide plate
                ( 91 : -11 :  92)   u=9   $ experiment rod
1938   9  -2.70      4   28  -29        u=9 $ guide plate (always above water)
1939   0           91   -4   28  -29   u=9 $ hole in guide plate
1940   0           29                    $ void above guide plate
                ( 91 : -11 :  92)   u=9   $ experiment rod
c
c  a water cell in the core
c
114   40  -0.99704 -10 -100            u=7 $ water below grid plate
115    2  -2.700    10  -11 :  4   11       $ bottom grid plate
               -12                u=7
116    4  -0.99705  -4   11  -12        u=7 $ water in lower grid plate
117    4  -0.99705  12  -14 -100        u=7 $ water between grid plates
118    4  -0.99705  -4   14  -15 -100   u=7 $ water in upper grid plate
119    2  -2.700     4   14  -15        u=7 $ upper grid plate
```

```
120   40  -0.99704  15 -100           u=7 $ water above grid plate
122    0          -10  100            u=7 $ void below grid plate
123    0           12  -14  100       u=7 $ void between grid plates
124    0           -4   14  -15  100   u=7 $ void in upper grid plate
125    0           15  100  -28       u=7 $ void between grid plate and guide plate
126    9  -2.70      4   28  -29       u=7 $ guide plate (always above water)
127    0           -4   28  -29       u=7 $ hole in guide plate
128    0           29  100            u=7 $ void above guide plate
c
c  a water cell in the reflector
c
164   40  -0.99704 -10 -100           u=8 $ water below grid plate
165    2  -2.700    10  -11 :  4   11       $ bottom grid plate
                 -12                 u=8
166   40  -0.99704  -4   11  -12       u=8 $ water in lower grid plate
167   40  -0.99704  12  -14 -100       u=8 $ water between grid plates
168   40  -0.99704  -4   14  -15 -100   u=8 $ water in upper grid plate
169    2  -2.700     4   14  -15       u=8 $ upper grid plate
170   40  -0.99704  15 -100           u=8 $ water above grid plate
172    0          -10  100            u=8 $ void below grid plate
173    0           12  -14  100       u=8 $ void between grid plates
174    0           -4   14  -15  100   u=8 $ void in upper grid plate
175    0           15  100  -28       u=8 $ void between grid plate and guide plate
```

```
176    9  -2.70      4   28  -29        u=8 $ guide plate (always above water)
177    0             -4   28  -29        u=8 $ hole in guide plate
178    0             29  100             u=8 $ void above guide plate
c
c   Source
c
201   10  8.6463E-02 231 -232 -233      u=2 $ source (SS316L)
202    5  -7.9     232 -235 -236        u=2 $ screw
203    3  -2.73     -2  232 -234             $ stick end
               (-232 : 235 : 236)    u=2   $ screw
204    3  -2.73      2   -3  237  -29   u=2 $ stick tube
205    4  -0.99705  -2  234 -100  -29   u=2 $ water in stick
206    0             -2  234  100  -29   u=2 $ void in stick
214   40  -0.99704 -10 -100             u=2 $ water below grid plate
215    2  -2.700    10  -11 :  4   11        $ bottom grid plate
                -12                 u=2
216    4  -0.99705  -4   11  -12        u=2 $ water in lower grid plate
217    4  -0.99705  12  -14 -100            $ water between grid plates
                (-231 : 232 : 233)        $ source
                (2 : -232 : 234)          $ stick end
                (3 : -237 : 19)      u=2   $ stick tube
218    4  -0.99705  -4   14  -15 -100       $ water in upper grid plate
                (3 : -232 : 19)      u=2   $ stick
```

```
219   2  -2.700    4   14  -15       u=2 $ upper grid plate
220  40  -0.99704  15 -100               $ water between grid plate and guide plate
            (3 : -232 : 29)     u=2   $ stick
222   0        -10  100            u=2 $ void below grid plate
223   0         12  -14  100           $ void between grid plates
            (-231 : 232 : 233)       $ source
            (2 : -232 : 234)         $ stick end
            (3 : -237 : 19)     u=2   $ stick tube
224   0         -4   14  -15  100      $ void in upper grid plate
            (3 : -232 : 29)     u=2   $ stick
225   0         15  100  -28           $ void between grid plate and guide plate
            (3 : -232 : 29)     u=2   $ stick
226   9  -2.70     4   28  -29       u=2 $ guide plate
227   0          3   -4   28  -29   u=2 $ hole in guide plate
228   0         29  100                $ void above guide plate
            (238 : -29 : 239)   u=2   $ handle
229   2  -2.700  -238   29 -239       u=2 $ handle
c
c   Safety Element 1 with grid plates
c
451   1  -10.265   -1   40  -41 412 -413 u=4 $ 1st midplane fuel
452   1  -10.265   -1   41  -42 412 -413 u=4 $ 2nd midplane fuel
453   1  -10.265   -1   42  -43 412 -413 u=4 $ 3rd midplane fuel
```

```
454   1  -10.265   -1   43  -44 412 -413 u=4 $ 4th midplane fuel
455   1  -10.265   -1  412 -423         u=4 $ bottom fuel
456   1  -10.265   -1   45 -100 412 -413 u=4 $ top fuel underwater
457   1  -10.265   -1  423  -45 412 -413     $ rest of the fuel underwater
             (1 : -40 : 44)       u=4   $ midplane fuel
458   1  -10.265   -1  100 -413         u=4 $ fuel above water
405   0          401 -402  412 -413   u=4 $ gap at fuel
406   0         -405  413 -414       u=4 $ void inside spring
407   5 -2.3628   405 -406  413 -414   u=4 $ spring
408   0          406 -402  413 -414   u=4 $ gap at spring
409   3 -2.73    -403  450 -451           $ fuel clad + part of caps
            (402 : -412 : 414)         $ inside of fueled section
            (437 : -411 : 438)         $ bottom screw
            (437 : -439 : 440)    u=4   $ top screw
412   3 -2.73    -447  448 -449           $ fueled section ends
            (-450 : 451)               $ fuel clad + part of caps
            (437 : -411 : 438)         $ bottom screw
            (437 : -439 : 440)    u=4   $ top screw
413   3 -2.73    -447  453 -454           $ top plug
            (437 : -439 : 440)         $ screw
            (437 : -460 : 461)         $ screw in 2nd middle BP
            (-455 : 456)         u=4   $ clad
414   3 -2.73    -403  455 -456           $ poly section clad tube
```

```
             (402 : -415 : 436)        $ inside
             (437 : -460 : 461)        $ screw in 2nd middle BP
           (437 : -439 : 440)      u=4   $ screw
416   7 -0.93    -401  415 -424       u=4 $ poly plug
417   0          401 -402  415 -424   u=4 $ gap at poly plug
418   0         -402  424 -436       u=4 $ void above poly
419   3 -2.73    -403  458 -459          $ absorber section clad tube
             (437 : -460 : 461)        $ screw in 2nd middle BP
             (437 : -444 : 443)        $ top screw
             (402 : -425 : 427)   u=4   $ inside
420   8 -1.500   -402  425 -426       u=4 $ absorber
421   0         -402  426 -427       u=4 $ gap above absorber
422   2 -2.700    441 -442               $ grid at poly-absorber interface
             (404 : -441 : 456)        $ water @ full dia rod
             (452 : -456 : 454)        $ water @ ends
             (404 : -458 : 442)        $ water @ full dia rod
             (452 : -457 : 458)        $ water @ ends
             (437 : -460 : 461)   u=4   $ screw in 2nd middle BP
423   2 -2.700    437  428 -443          $ grid at top of absorber
           (445 : -446 : 443)          $ cap screw head
           (437 : -444 : 446)      u=4   $ top screw
424  40 -0.99704 -430 -100              $ water below grid plate
           (403 : -411 : 428)      u=4   $ the entire rod
```

```
425    2 -2.700    430 -432               $ bottom bundle plate
            (404 : -450 : 432)         $ water @ full dia rod
            (452 : -448 : 450)         $ water @ ends
            (437 : -411 : 438)    u=4   $ bottom screw
426    4 -0.99705 403 -404  450 -432         $ water in lower grid plate
           : 447 -452 448 -450     u=4
427    4 -0.99705  432 -434 -100           $ water between grid plates
          (403 : -411 : 428)       u=4   $ the entire rod
428    4 -0.99705 403 -404  434 -451        $ water in upper grid plate
            -100
           : 447 -452 451 -449
            -100
           : 403 -404  455 -435
            -100
           : 447 -452 453 -455
            -100                u=4
429    2 -2.700    434 -435               $ 1st middle bundle plate
            (404 : -434 : 451)         $ water @ full dia rod
            (452 : -451 : 449)         $ water @ ends
            (404 : -455 : 435)         $ water @ full dia rod
            (452 : -453 : 455)         $ water @ ends
          (437 : -439 : 440)       u=4   $ top screw
430   40 -0.99704  435 -100               $ water above grid plate
```

```
          (-441 : 442)              $ grid at poly-absorber
          (-428 : 443)              $ grid at top of absorber
          (403 : -411 : 428)     u=4   $ the entire rod
432   0        -430  100             $ void below grid plate
          (403 : -411 : 428)     u=4   $ the entire rod
433   0         432 -434  100          $ void between grid plates
          (403 : -411 : 428)     u=4   $ the entire rod
434   0        403 -404  434 -451      $ void in upper grid plate
             100
           : 447 -452 451 -449
             100
           : 403 -404  455 -435
             100
           : 447 -452 453 -455
             100              u=4
435   0         435  100             $ void above grid plate
          (-441 : 442)              $ grid at poly-absorber
          (-428 : 443)              $ grid at top of absorber
          (447 : -459 : 428)          $ top end of absorber rod
          (403 : -411 : 459)     u=4   $ the entire rod
436   5 -7.9     -437 462 -438    u=4 $ bottom screw
437   5 -7.9     -437 439 -440       u=4 $ top screw
438   5 -7.9     -437 444 -446       u=4 $ screw body above absorber
```

```
439    5 -7.9     -445 446 -443         u=4 $ cap screw head
440    3 -2.73    -447 457 -428              $ fueled section ends
                (437 : -460 : 461)          $ screw in 2nd middle BP
             (437 : -444 : 443)             $ top screw
               (-458 : 459)          u=4    $ fuel clad + part of caps
441    4 -0.99705 403 -404 441 -456         $ water in 2nd middle bundle plate
                -100
              : 447 -452 456 -454
                -100
              : 403 -404 458 -442
                -100
              : 447 -452 457 -458
                -100                 u=4
442    0          403 -404 441 -456         $ void in 2nd middle bundle plate
                 100
              : 447 -452 456 -454
                 100
              : 403 -404 458 -442
                 100
              : 447 -452 457 -458
                 100                 u=4
443    5 -7.9     -437 460 -461         u=4   $ screw in 2nd middle BP
444    4 -0.99705 -437 411 -462         u=4 $ bottom screw
```

```
c
c   Safety Element 1 with and grid plates NO FUEL
c
801    4 -0.99705 -402  412 -414 -100  u=14 $ fuel volume under water
802    0          -402  412 -414  100  u=14 $ fuel volume above water
809    3 -2.73    -403  450 -451            $ fuel clad + part of caps
             (402 : -412 : 414)          $ inside of fueled section
             (437 : -411 : 438)          $ bottom screw
             (437 : -439 : 440)   u=14   $ top screw
812    3 -2.73    -447  448 -449            $ fueled section ends
             (-450 : 451)               $ fuel clad + part of caps
             (437 : -411 : 438)          $ bottom screw
             (437 : -439 : 440)   u=14   $ top screw
813    3 -2.73    -447  453 -454            $ top plug
             (437 : -439 : 440)          $ screw
             (437 : -460 : 461)          $ screw in 2nd middle BP
             (-455 : 456)        u=14   $ clad
814    3 -2.73    -403  455 -456            $ poly section clad tube
             (402 : -415 : 436)          $ inside
             (437 : -460 : 461)          $ screw in 2nd middle BP
          (437 : -439 : 440)      u=14   $ screw
816    7 -0.93    -401  415 -424       u=14 $ poly plug
817    0          401 -402  415 -424  u=14 $ gap at poly plug
```

```
818    0          -402  424 -436       u=14 $ void above poly
819    3 -2.73    -403  458 -459            $ absorber section clad tube
               (437 : -460 : 461)          $ screw in 2nd middle BP
               (437 : -444 : 443)          $ top screw
               (402 : -425 : 427)   u=14   $ inside
820    8 -1.500   -402  425 -426       u=14 $ absorber
821    0          -402  426 -427       u=14 $ gap above absorber
822    2 -2.700    441 -442                 $ grid at poly-absorber interface
               (404 : -441 : 456)          $ water @ full dia rod
               (452 : -456 : 454)          $ water @ ends
               (404 : -458 : 442)          $ water @ full dia rod
               (452 : -457 : 458)          $ water @ ends
               (437 : -460 : 461)   u=14   $ screw in 2nd middle BP
823    2 -2.700    437  428 -443            $ grid at top of absorber
             (445 : -446 : 443)            $ cap screw head
             (437 : -444 : 446)     u=14   $ top screw
824   40 -0.99704 -430 -100                 $ water below grid plate
             (403 : -411 : 428)     u=14   $ the entire rod
825    2 -2.700    430 -432                 $ bottom bundle plate
               (404 : -450 : 432)          $ water @ full dia rod
               (452 : -448 : 450)          $ water @ ends
               (437 : -411 : 438)   u=14   $ bottom screw
826    4 -0.99705 403 -404  450 -432        $ water in lower grid plate
```

```
            : 447 -452 448 -450    u=14
827    4 -0.99705  432 -434 -100           $ water between grid plates
           (403 : -411 : 428)      u=14   $ the entire rod
828    4 -0.99705 403 -404  434 -451       $ water in upper grid plate
              -100
            : 447 -452 451 -449
              -100
            : 403 -404  455 -435
              -100
            : 447 -452 453 -455
              -100                u=14
829    2 -2.700    434 -435                $ 1st middle bundle plate
              (404 : -434 : 451)         $ water @ full dia rod
              (452 : -451 : 449)         $ water @ ends
              (404 : -455 : 435)         $ water @ full dia rod
              (452 : -453 : 455)         $ water @ ends
           (437 : -439 : 440)      u=14   $ top screw
830   40 -0.99704  435 -100                $ water above grid plate
           (-441 : 442)                  $ grid at poly-absorber
           (-428 : 443)                  $ grid at top of absorber
           (403 : -411 : 428)      u=14   $ the entire rod
832    0         -430  100                 $ void below grid plate
           (403 : -411 : 428)      u=14   $ the entire rod
```

```
833    0          432 -434  100           $ void between grid plates
          (403 : -411 : 428)      u=14   $ the entire rod
834    0          403 -404  434 -451      $ void in upper grid plate
            100
           : 447 -452 451 -449
            100
           : 403 -404  455 -435
            100
           : 447 -452 453 -455
            100               u=14
835    0          435  100                $ void above grid plate
          (-441 : 442)                  $ grid at poly-absorber
          (-428 : 443)                  $ grid at top of absorber
          (447 : -459 : 428)              $ top end of absorber rod
          (403 : -411 : 459)      u=14   $ the entire rod
836    5 -7.9     -437 462 -438       u=14 $ bottom screw
837    5 -7.9     -437 439 -440       u=14 $ top screw
838    5 -7.9     -437 444 -446       u=14 $ screw body above absorber
839    5 -7.9     -445 446 -443       u=14 $ cap screw head
840    3 -2.73    -447 457 -428           $ fueled section ends
             (437 : -460 : 461)         $ screw in 2nd middle BP
           (437 : -444 : 443)           $ top screw
            (-458 : 459)         u=14   $ fuel clad + part of caps
```

```
841   40 -0.99704 403 -404 441 -456          $ water in 2nd middle bundle plate
               -100
             : 447 -452 456 -454
               -100
             : 403 -404 458 -442
               -100
             : 447 -452 457 -458
               -100                u=14
842    0          403 -404 441 -456          $ void in 2nd middle bundle plate
                100
             : 447 -452 456 -454
                100
             : 403 -404 458 -442
                100
             : 447 -452 457 -458
                100                u=14
843    5 -7.9     -437 460 -461        u=14   $ screw in 2nd middle BP
844    4 -0.99705 -437 411 -462        u=14 $ bottom screw
c
c   Safety Element 2 with grid plates
c
551    1  -10.265   -1   40  -41 512 -513 u=5 $ 1st midplane fuel
552    1  -10.265   -1   41  -42 512 -513 u=5 $ 2nd midplane fuel
```

```
553    1  -10.265   -1   42  -43 512 -513 u=5 $ 3rd midplane fuel
554    1  -10.265   -1   43  -44 512 -513 u=5 $ 4th midplane fuel
555    1  -10.265   -1  512 -523          u=5 $ bottom fuel
556    1  -10.265   -1   45 -100 512 -513 u=5 $ top fuel underwater
557    1  -10.265   -1  523  -45 512 -513     $ rest of the fuel underwater
                 (1 : -40 : 44)        u=5   $ midplane fuel
558    1  -10.265   -1  100 -513          u=5 $ fuel above water
505    0           501 -502  512 -513   u=5 $ gap at fuel
506    0          -505  513 -514       u=5 $ void inside spring
507    5 -2.3628   505 -506  513 -514   u=5 $ spring
508    0           506 -502  513 -514   u=5 $ gap at spring
509    3 -2.73    -503  550 -551           $ fuel clad + part of caps
               (502 : -512 : 514)         $ inside of fueled section
               (537 : -511 : 538)         $ bottom screw
               (537 : -539 : 540)    u=5   $ top screw
512    3 -2.73    -547  548 -549           $ fueled section ends
               (-550 : 551)               $ fuel clad + part of caps
               (537 : -511 : 538)         $ bottom screw
               (537 : -539 : 540)    u=5   $ top screw
513    3 -2.73    -547  553 -554           $ top plug
               (537 : -539 : 540)         $ screw
               (537 : -560 : 561)         $ screw in 2nd middle BP
               (-555 : 556)         u=5   $ clad
```

```
514   3 -2.73    -503  555 -556          $ poly section clad tube
               (502 : -515 : 536)         $ inside
               (537 : -560 : 561)         $ screw in 2nd middle BP
             (537 : -539 : 540)      u=5   $ screw
516   7 -0.93    -501  515 -524       u=5 $ poly plug
517   0           501 -502  515 -524   u=5 $ gap at poly plug
518   0          -502  524 -536       u=5 $ void above poly
519   3 -2.73    -503  558 -559          $ absorber section clad tube
               (537 : -560 : 561)         $ screw in 2nd middle BP
               (537 : -544 : 543)         $ top screw
               (502 : -525 : 527)    u=5   $ inside
520   8 -1.500   -502  525 -526       u=5 $ absorber
521   0          -502  526 -527       u=5 $ gap above absorber
522   2 -2.700    541 -542                $ grid at poly-absorber interface
               (504 : -541 : 556)         $ water @ full dia rod
               (552 : -556 : 554)         $ water @ ends
               (504 : -558 : 542)         $ water @ full dia rod
               (552 : -557 : 558)         $ water @ ends
               (537 : -560 : 561)    u=5   $ screw in 2nd middle BP
523   2 -2.700    537  528 -543          $ grid at top of absorber
             (545 : -546 : 543)           $ cap screw head
             (537 : -544 : 546)      u=5   $ top screw
524   40 -0.99704 -530 -100              $ water below grid plate
```

```
        (503 : -511 : 528)       u=5   $ the entire rod
525   2 -2.700    530 -532                $ bottom bundle plate
          (504 : -550 : 532)         $ water @ full dia rod
          (552 : -548 : 550)         $ water @ ends
          (537 : -511 : 538)    u=5   $ bottom screw
526   4 -0.99705 503 -504  550 -532          $ water in lower grid plate
         : 547 -552 548 -550     u=5
527   4 -0.99705  532 -534 -100            $ water between grid plates
        (503 : -511 : 528)       u=5   $ the entire rod
528   4 -0.99705 503 -504  534 -551        $ water in upper grid plate
          -100
         : 547 -552 551 -549
          -100
         : 503 -504  555 -535
          -100
         : 547 -552 553 -555
          -100                 u=5
529   2 -2.700    534 -535                $ 1st middle bundle plate
          (504 : -534 : 551)         $ water @ full dia rod
          (552 : -551 : 549)         $ water @ ends
          (504 : -555 : 535)         $ water @ full dia rod
          (552 : -553 : 555)         $ water @ ends
        (537 : -539 : 540)       u=5   $ top screw
```

```
530   40 -0.99704  535 -100              $ water above grid plate
           (-541 : 542)                  $ grid at poly-absorber
           (-528 : 543)                  $ grid at top of absorber
           (503 : -511 : 528)       u=5   $ the entire rod
532    0         -530  100               $ void below grid plate
           (503 : -511 : 528)       u=5   $ the entire rod
533    0          532 -534  100           $ void between grid plates
           (503 : -511 : 528)       u=5   $ the entire rod
534    0         503 -504  534 -551       $ void in upper grid plate
              100
            : 547 -552 551 -549
              100
            : 503 -504  555 -535
              100
            : 547 -552 553 -555
              100              u=5
535    0          535  100               $ void above grid plate
           (-541 : 542)                  $ grid at poly-absorber
           (-528 : 543)                  $ grid at top of absorber
           (547 : -559 : 528)             $ top end of absorber rod
           (503 : -511 : 559)       u=5   $ the entire rod
536    5 -7.9     -537 562 -538        u=5 $ bottom screw
537    5 -7.9     -537 539 -540        u=5 $ top screw
```

```
538    5 -7.9     -537 544 -546         u=5 $ screw body above absorber
539    5 -7.9     -545 546 -543         u=5 $ cap screw head
540    3 -2.73    -547 557 -528               $ fueled section ends
                (537 : -560 : 561)          $ screw in 2nd middle BP
              (537 : -544 : 543)            $ top screw
               (-558 : 559)         u=5    $ fuel clad + part of caps
541   40 -0.99704 503 -504 541 -556         $ water in 2nd middle bundle plate
                -100
              : 547 -552 556 -554
                -100
              : 503 -504 558 -542
                -100
              : 547 -552 557 -558
                -100                u=5
542    0          503 -504 541 -556         $ void in 2nd middle bundle plate
                 100
              : 547 -552 556 -554
                 100
              : 503 -504 558 -542
                 100
              : 547 -552 557 -558
                 100                u=5
543    5 -7.9     -537 560 -561         u=5   $ screw in 2nd middle BP
```

```
544    4 -0.99705 -537 511 -562        u=5 $ bottom screw
c
c   Safety Element 2 with grid plates NO fuel
c
901    4 -0.99705 -502  512 -514 -100  u=15 $ fuel volume under water
902    0          -502  512 -514  100  u=15 $ fuel volume above water
909    3 -2.73    -503  550 -551           $ fuel clad + part of caps
                (502 : -512 : 514)         $ inside of fueled section
                (537 : -511 : 538)         $ bottom screw
                (537 : -539 : 540)   u=15   $ top screw
912    3 -2.73    -547  548 -549           $ fueled section ends
                (-550 : 551)              $ fuel clad + part of caps
                (537 : -511 : 538)         $ bottom screw
                (537 : -539 : 540)   u=15   $ top screw
913    3 -2.73    -547  553 -554           $ top plug
                (537 : -539 : 540)         $ screw
                (537 : -560 : 561)         $ screw in 2nd middle BP
                (-555 : 556)        u=15   $ clad
914    3 -2.73    -503  555 -556           $ poly section clad tube
                (502 : -515 : 536)         $ inside
                (537 : -560 : 561)         $ screw in 2nd middle BP
             (537 : -539 : 540)      u=15   $ screw
916    7 -0.93    -501  515 -524       u=15 $ poly plug
```

```
917   0          501 -502  515 -524  u=15 $ gap at poly plug
918   0         -502  524 -536      u=15 $ void above poly
919   3 -2.73    -503  558 -559           $ absorber section clad tube
                (537 : -560 : 561)         $ screw in 2nd middle BP
                (537 : -544 : 543)         $ top screw
                (502 : -525 : 527)   u=15   $ inside
920   8 -1.500   -502  525 -526      u=15 $ absorber
921   0         -502  526 -527      u=15 $ gap above absorber
922   2 -2.700    541 -542               $ grid at poly-absorber interface
                (504 : -541 : 556)         $ water @ full dia rod
                (552 : -556 : 554)         $ water @ ends
                (504 : -558 : 542)         $ water @ full dia rod
                (552 : -557 : 558)         $ water @ ends
                (537 : -560 : 561)   u=15   $ screw in 2nd middle BP
923   2 -2.700    537  528 -543           $ grid at top of absorber
            (545 : -546 : 543)            $ cap screw head
            (537 : -544 : 546)      u=15   $ top screw
924   40 -0.99704 -530 -100               $ water below grid plate
            (503 : -511 : 528)      u=15   $ the entire rod
925   2 -2.700    530 -532               $ bottom bundle plate
                (504 : -550 : 532)         $ water @ full dia rod
                (552 : -548 : 550)         $ water @ ends
                (537 : -511 : 538)   u=15   $ bottom screw
```

```
926    4 -0.99705 503 -504  550 -532          $ water in lower grid plate
            : 547 -552 548 -550    u=15
927    4 -0.99705  532 -534 -100           $ water between grid plates
           (503 : -511 : 528)       u=15   $ the entire rod
928    4 -0.99705 503 -504  534 -551        $ water in upper grid plate
             -100
            : 547 -552 551 -549
             -100
            : 503 -504  555 -535
             -100
            : 547 -552 553 -555
             -100               u=15
929    2 -2.700    534 -535                 $ 1st middle bundle plate
             (504 : -534 : 551)         $ water @ full dia rod
             (552 : -551 : 549)         $ water @ ends
             (504 : -555 : 535)         $ water @ full dia rod
             (552 : -553 : 555)         $ water @ ends
           (537 : -539 : 540)       u=15   $ top screw
930   40 -0.99704  535 -100                $ water above grid plate
           (-541 : 542)                  $ grid at poly-absorber
           (-528 : 543)                  $ grid at top of absorber
           (503 : -511 : 528)       u=15   $ the entire rod
932    0          -530  100                $ void below grid plate
```

```
          (503 : -511 : 528)      u=15   $ the entire rod
933   0         532 -534  100          $ void between grid plates
          (503 : -511 : 528)      u=15   $ the entire rod
934   0         503 -504  534 -551      $ void in upper grid plate
             100
           : 547 -552 551 -549
             100
           : 503 -504  555 -535
             100
           : 547 -552 553 -555
             100              u=15
935   0         535  100               $ void above grid plate
          (-541 : 542)                 $ grid at poly-absorber
          (-528 : 543)                 $ grid at top of absorber
          (547 : -559 : 528)            $ top end of absorber rod
          (503 : -511 : 559)      u=15   $ the entire rod
936   5 -7.9     -537 562 -538       u=15 $ bottom screw
937   5 -7.9     -537 539 -540       u=15 $ top screw
938   5 -7.9     -537 544 -546       u=15 $ screw body above absorber
939   5 -7.9     -545 546 -543       u=15 $ cap screw head
940   3 -2.73    -547 557 -528            $ fueled section ends
            (537 : -560 : 561)         $ screw in 2nd middle BP
           (537 : -544 : 543)          $ top screw
```

```
          (-558 : 559)        u=15   $ fuel clad + part of caps
941   40 -0.99704 503 -504 541 -556        $ water in 2nd middle bundle plate
           -100
          : 547 -552 556 -554
           -100
          : 503 -504 558 -542
           -100
          : 547 -552 557 -558
           -100              u=15
942    0          503 -504 541 -556        $ void in 2nd middle bundle plate
            100
          : 547 -552 556 -554
            100
          : 503 -504 558 -542
            100
          : 547 -552 557 -558
            100              u=15
943    5 -7.9     -537 560 -561        u=15   $ screw in 2nd middle BP
944    4 -0.99705 -537 511 -562        u=15 $ bottom screw
c
c   Control Element with grid plates
c
651    1  -10.265   -1   40  -41 612 -613 u=6 $ 1st midplane fuel
```

```
652   1  -10.265   -1   41  -42 612 -613 u=6 $ 2nd midplane fuel
653   1  -10.265   -1   42  -43 612 -613 u=6 $ 3rd midplane fuel
654   1  -10.265   -1   43  -44 612 -613 u=6 $ 4th midplane fuel
655   1  -10.265   -1  612 -623          u=6 $ bottom fuel
656   1  -10.265   -1   45 -100 612 -613 u=6 $ top fuel underwater
657   1  -10.265   -1  623  -45 612 -613     $ rest of the fuel underwater
                 (1 : -40 : 44)       u=6   $ midplane fuel
658   1  -10.265   -1  100 -613          u=6 $ fuel above water
605   0            601 -602  612 -613   u=6 $ gap at fuel
606   0           -605  613 -614        u=6 $ void inside spring
607   5 -2.3628   605 -606  613 -614   u=6 $ spring
608   0            606 -602  613 -614   u=6 $ gap at spring
609   3 -2.73    -603  650 -651            $ fuel clad + part of caps
               (602 : -612 : 614)          $ inside of fueled section
               (637 : -611 : 638)          $ bottom screw
               (637 : -639 : 640)    u=6   $ top screw
612   3 -2.73    -647  648 -649            $ fueled section ends
               (-650 : 651)                $ fuel clad + part of caps
               (637 : -611 : 638)          $ bottom screw
               (637 : -639 : 640)    u=6   $ top screw
613   3 -2.73    -647  653 -654            $ top plug
               (637 : -639 : 640)          $ screw
               (637 : -660 : 661)          $ screw in 2nd middle BP
```

```
          (-655 : 656)        u=6   $ clad
614   3 -2.73    -603  655 -656          $ poly section clad tube
          (602 : -615 : 636)        $ inside
          (637 : -660 : 661)        $ screw in 2nd middle BP
        (637 : -639 : 640)      u=6   $ screw
616   7 -0.93    -601  615 -624       u=6 $ poly plug
617   0          601 -602  615 -624   u=6 $ gap at poly plug
618   0         -602  624 -636       u=6 $ void above poly
619   3 -2.73    -603  658 -659          $ absorber section clad tube
          (637 : -660 : 661)        $ screw in 2nd middle BP
          (637 : -644 : 643)        $ top screw
          (602 : -625 : 627)   u=6   $ inside
620   8 -1.500   -602  625 -626       u=6 $ absorber
621   0         -602  626 -627       u=6 $ gap above absorber
622   2 -2.700    641 -642                $ grid at poly-absorber interface
          (604 : -641 : 656)        $ water @ full dia rod
          (652 : -656 : 654)        $ water @ ends
          (604 : -658 : 642)        $ water @ full dia rod
          (652 : -657 : 658)        $ water @ ends
          (637 : -660 : 661)   u=6   $ screw in 2nd middle BP
623   2 -2.700    637  628 -643          $ grid at top of absorber
        (645 : -646 : 643)           $ cap screw head
        (637 : -644 : 646)      u=6   $ top screw
```

```
624   40 -0.99704 -630 -100                  $ water below grid plate
             (603 : -611 : 628)        u=6   $ the entire rod
625    2 -2.700    630 -632                  $ bottom bundle plate
                 (604 : -650 : 632)          $ water @ full dia rod
                 (652 : -648 : 650)          $ water @ ends
                 (637 : -611 : 638)    u=6   $ bottom screw
626    4 -0.99705 603 -604  650 -632         $ water in lower grid plate
               : 647 -652 648 -650     u=6
627    4 -0.99705  632 -634 -100             $ water between grid plates
             (603 : -611 : 628)        u=6   $ the entire rod
628    4 -0.99705 603 -604  634 -651         $ water in upper grid plate
                 -100
               : 647 -652 651 -649
                 -100
               : 603 -604  655 -635
                 -100
               : 647 -652 653 -655
                 -100               u=6
629    2 -2.700    634 -635                  $ 1st middle bundle plate
                 (604 : -634 : 651)          $ water @ full dia rod
                 (652 : -651 : 649)          $ water @ ends
                 (604 : -655 : 635)          $ water @ full dia rod
                 (652 : -653 : 655)          $ water @ ends
```

```
          (637 : -639 : 640)       u=6   $ top screw
630   40 -0.99704  635 -100               $ water above grid plate
          (-641 : 642)                  $ grid at poly-absorber
          (-628 : 643)                  $ grid at top of absorber
          (603 : -611 : 628)       u=6   $ the entire rod
632    0         -630  100                $ void below grid plate
          (603 : -611 : 628)       u=6   $ the entire rod
633    0          632 -634  100           $ void between grid plates
          (603 : -611 : 628)       u=6   $ the entire rod
634    0         603 -604  634 -651       $ void in upper grid plate
             100
           : 647 -652 651 -649
             100
           : 603 -604  655 -635
             100
           : 647 -652 653 -655
             100                 u=6
635    0          635  100                $ void above grid plate
          (-641 : 642)                  $ grid at poly-absorber
          (-628 : 643)                  $ grid at top of absorber
          (647 : -659 : 628)              $ top end of absorber rod
          (603 : -611 : 659)       u=6   $ the entire rod
636    5 -7.9     -637 662 -638        u=6 $ bottom screw
```

```
637    5 -7.9     -637 639 -640         u=6 $ top screw
638    5 -7.9     -637 644 -646         u=6 $ screw body above absorber
639    5 -7.9     -645 646 -643         u=6 $ cap screw head
640    3 -2.73    -647 657 -628             $ fueled section ends
              (637 : -660 : 661)          $ screw in 2nd middle BP
            (637 : -644 : 643)            $ top screw
             (-658 : 659)         u=6    $ fuel clad + part of caps
641   40 -0.99704 603 -604 641 -656         $ water in 2nd middle bundle plate
              -100
            : 647 -652 656 -654
              -100
            : 603 -604 658 -642
              -100
            : 647 -652 657 -658
              -100                  u=6
642    0          603 -604 641 -656         $ void in 2nd middle bundle plate
              100
            : 647 -652 656 -654
              100
            : 603 -604 658 -642
              100
            : 647 -652 657 -658
              100                  u=6
```

```
643    5 -7.9     -637 660 -661         u=6   $ screw in 2nd middle BP
644    4 -0.99705 -637 611 -662         u=6 $ bottom screw
c
c   Control Element with grid plates NO FUEL
c
301    4 -0.99705 -602  612 -614 -100  u=16 $ fuel volume under water
302    0          -602  612 -614  100  u=16 $ fuel volume above water
309    3 -2.73    -603  650 -651           $ fuel clad + part of caps
            (602 : -612 : 614)         $ inside of fueled section
            (637 : -611 : 638)         $ bottom screw
            (637 : -639 : 640)   u=16   $ top screw
312    3 -2.73    -647  648 -649           $ fueled section ends
            (-650 : 651)               $ fuel clad + part of caps
            (637 : -611 : 638)         $ bottom screw
            (637 : -639 : 640)   u=16   $ top screw
313    3 -2.73    -647  653 -654           $ top plug
            (637 : -639 : 640)         $ screw
            (637 : -660 : 661)         $ screw in 2nd middle BP
            (-655 : 656)        u=16   $ clad
314    3 -2.73    -603  655 -656           $ poly section clad tube
            (602 : -615 : 636)         $ inside
            (637 : -660 : 661)         $ screw in 2nd middle BP
          (637 : -639 : 640)      u=16   $ screw
```

```
316   7 -0.93    -601  615 -624      u=16 $ poly plug
317   0          601 -602  615 -624  u=16 $ gap at poly plug
318   0         -602  624 -636       u=16 $ void above poly
319   3 -2.73    -603  658 -659            $ absorber section clad tube
              (637 : -660 : 661)          $ screw in 2nd middle BP
              (637 : -644 : 643)          $ top screw
              (602 : -625 : 627)   u=16   $ inside
320   8 -1.500   -602  625 -626      u=16 $ absorber
321   0         -602  626 -627       u=16 $ gap above absorber
322   2 -2.700    641 -642                $ grid at poly-absorber interface
              (604 : -641 : 656)          $ water @ full dia rod
              (652 : -656 : 654)          $ water @ ends
              (604 : -658 : 642)          $ water @ full dia rod
              (652 : -657 : 658)          $ water @ ends
              (637 : -660 : 661)   u=16   $ screw in 2nd middle BP
323   2 -2.700    637  628 -643           $ grid at top of absorber
          (645 : -646 : 643)              $ cap screw head
          (637 : -644 : 646)       u=16   $ top screw
324  40 -0.99704 -630 -100                $ water below grid plate
          (603 : -611 : 628)       u=16   $ the entire rod
325   2 -2.700    630 -632                $ bottom bundle plate
              (604 : -650 : 632)          $ water @ full dia rod
              (652 : -648 : 650)          $ water @ ends
```

```
           (637 : -611 : 638)   u=16   $ bottom screw
326    4 -0.99705 603 -604  650 -632          $ water in lower grid plate
          : 647 -652 648 -650    u=16
327    4 -0.99705  632 -634 -100           $ water between grid plates
         (603 : -611 : 628)       u=16   $ the entire rod
328    4 -0.99705 603 -604  634 -651        $ water in upper grid plate
           -100
          : 647 -652 651 -649
           -100
          : 603 -604  655 -635
           -100
          : 647 -652 653 -655
           -100                 u=16
329    2 -2.700    634 -635                 $ 1st middle bundle plate
           (604 : -634 : 651)          $ water @ full dia rod
           (652 : -651 : 649)          $ water @ ends
           (604 : -655 : 635)          $ water @ full dia rod
           (652 : -653 : 655)          $ water @ ends
         (637 : -639 : 640)       u=16   $ top screw
330   40 -0.99704  635 -100                $ water above grid plate
         (-641 : 642)                    $ grid at poly-absorber
         (-628 : 643)                    $ grid at top of absorber
         (603 : -611 : 628)       u=16   $ the entire rod
```

```
332    0         -630  100               $ void below grid plate
            (603 : -611 : 628)       u=16   $ the entire rod
333    0          632 -634  100           $ void between grid plates
            (603 : -611 : 628)       u=16   $ the entire rod
334    0          603 -604  634 -651       $ void in upper grid plate
                100
              : 647 -652 651 -649
                100
              : 603 -604  655 -635
                100
              : 647 -652 653 -655
                100                u=16
335    0          635  100                $ void above grid plate
            (-641 : 642)                  $ grid at poly-absorber
            (-628 : 643)                  $ grid at top of absorber
            (647 : -659 : 628)             $ top end of absorber rod
            (603 : -611 : 659)       u=16   $ the entire rod
336    5 -7.9     -637 662 -638        u=16 $ bottom screw
337    5 -7.9     -637 639 -640        u=16 $ top screw
338    5 -7.9     -637 644 -646        u=16 $ screw body above absorber
339    5 -7.9     -645 646 -643        u=16 $ cap screw head
340    3 -2.73    -647 657 -628             $ fueled section ends
                (637 : -660 : 661)          $ screw in 2nd middle BP
```

```
          (637 : -644 : 643)          $ top screw
           (-658 : 659)        u=16   $ fuel clad + part of caps
341   40 -0.99704 603 -604 641 -656        $ water in 2nd middle bundle plate
            -100
          : 647 -652 656 -654
            -100
          : 603 -604 658 -642
            -100
          : 647 -652 657 -658
            -100              u=16
342    0        603 -604 641 -656        $ void in 2nd middle bundle plate
             100
          : 647 -652 656 -654
             100
          : 603 -604 658 -642
             100
          : 647 -652 657 -658
             100              u=16
343    5 -7.9     -637 660 -661       u=16   $ screw in 2nd middle BP
344    4 -0.99705 -637 611 -662       u=16 $ bottom screw
c
c  Volume above the wall
c
```

c 989   0   -1951 1952 -1953 1954 -1955 1956 1958 -918 $ bounds on the inner upper array

c   (1911 : -1912 : 1913 : -1914 : 1915 : -1916 : -1917) $ the inner array

c

c Water in the projection

c

c 990 40 -0.99704   -1951 1952 -1953 1954 -1955 1956 -921 924 $ bounds on the inner upper array

c

c Water below grid plate

c

c 991 40 -0.99704   -1951 1952 -1953 1954 -1955 1956 -1957 921 $ bounds on the inner upper array

c

c Outer wall of experiment container

c

c 992   2 -2.70   -1951 1952 -1953 1954 -1955 1956 1957 -1958 $ bounds on the inner upper array

c   (1941 : -1942 : 1943 : -1944 : 1945 : -1946 : -1947) $ the inner array

c

c Gap between absorber and outer wall

c

```
c 993    0           -1941 1942 -1943 1944 -1945 1946 1947 -1958 $ bounds on the inner
upper array
c                (1931 : -1932 : 1933 : -1934 : 1935 : -1936 : -1937)   $ the inner array
c
c  Absorber layer in experiment container
c
c 994   0         -1931 1932 -1933 1934 -1935 1936 1937 -1958 $ bounds on the inner
upper array
c                (1921 : -1922 : 1923 : -1924 : 1925 : -1926 : -1927)   $ the inner array
c
c  First wall of experiment container
c
c 995   2  -2.70      -1921 1922 -1923 1924 -1925 1926 1927 -1958 $ bounds on the inner
upper array
c                (1911 : -1912 : 1913 : -1914 : 1915 : -1916 : -1917)   $ the inner array
c
c  the inner array
c
996    0           -1901  1902 -1903  1904 -1905  1906  lat=2  u=20
                fill  -2:2  -2:2   0:0
     32 32 32 32 32
     32 32 31 31 32
     32 31 31 31 32
```

```
     32 31 31 32 32
     32 32 32 32 32
997   0            -1911 1912 -1913 1914 -1915 1916  924 -918 $ bounds on the inner upper
array
         fill=20
c 998   40  -0.99704   -921  924 -925                    $ bounds of the inner lower array
c                    -1911 1912 -1913 1914 -1915 1916
c                     fill=20
c
c  the outer array
c
999    4  -0.99705  -901  902 -903  904 -905  906  lat=2  u=10
                fill -27:28 -27:27  0:0
c  1531 fuel rods 1531 total positions
     3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
     3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
     3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 8
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     3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 8 8
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     3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 8 8 8
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     3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 8 8 8 8
```

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1 1 8 8 8 8 8 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3

3 8 8 8 8 8 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

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3 8 8 8 8 8 8 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 8

8 8 8 8 8 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3

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8 8 8 8 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3

3 8 8 8 8 8 8 8 8 8 8 1 1 1 1 1 1 1 1 1 1 8 8 8 8 8 8 8

```
     8 8 8 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
     3 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
     8 8 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
     3 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
     8 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
     3 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
     3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
     3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
     3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
c
c
1000  40  -0.99704   -911  912 -913  914 -915  916  921 -918 $ bounds on the upper array
            (1911 : -1912 : 1913 : -1914 : 1915 : -1916)   $ the inner array
      fill=10
c            (1911 : -1912 : 1913 : -1914 : 1915 : -1916)   $ the inner array
1001  40  -0.99704   -921  924 -925                         $ bounds of the lower array
              -941  942 -943  944 -945  946  917
            (1911 : -1912 : 1913 : -1914 : 1915 : -1916)   $ the inner array
c            (1911 : -1912 : 1913 : -1914 : 1915 : -1916)   $ the outside of the experiment
c            (1951 : -1952 : 1953 : -1954 : 1955 : -1956)   $ the outside of the experiment
              fill=10
c            (1911 : -1912 : 1913 : -1914 : 1915 : -1916)   $ the inner array
1002   2   -2.700    10   -12  -932                   $ bottom grid plate
```

```
          (911 : -912 : 913 : -914 : 915 : -916 : -921 : 918)  $ the array
           970  971  972  973  974  975             $ the holes
1003   2   -2.700   -961  962 -963  964 -965  966   14   -15     $ top grid plate
          (911 : -912 : 913 : -914 : 915 : -916 : -921 : 918)  $ the array
1004   9   -2.70    -961  962 -963  964 -965  966   28   -29     $ guide plate (always above
water)
          (911 : -912 : 913 : -914 : 915 : -916 : -921 : 918)  $ the array
1007  40  -0.99704   921 -922 -923 -100               $ reflector
          (911 : -912 : 913 : -914 : 915 : -916 : -921 : 918)  $ the array
              (-10 : 12 : 932)                 $ bottom grid plate
         (961 : -962 : 963 : -964 : 965 : -966 : -14 : 15) $ top grid plate
         (981 : 982 : -983 : 966 : -14 : 15)        $ +x arm of top grid plate
         (982 : -966 : -963 : -14 : 15)             $ +x arm of top grid plate
         (-984 : 985 : -986 : 962 : -14 : 15)        $ -x-y arm of top grid plate
         (985 : -962 : 964 : -14 : 15)              $ -x-y arm of top grid plate
         (-987 : 988 : -989 : -965 :  -14 : 15)      $ -x+y arm of top grid plate
         (988 : -961 : 965 : -14 : 15)              $ -x+y arm of top grid plate
          (-12 : 14 : 990)                  $ support post
          (-12 : 14 : 991)                  $ support post
          (-12 : 14 : 992)                  $ support post
          (-15 : 28 : 990)                  $ support post
          (-15 : 28 : 991)                  $ support post
          (-15 : 28 : 992)                  $ support post
```

```
         (801 : -803 : 804)                    $-x+y detector tube
         (801 : -803 : 806)                    $+x+y detector tube
         (810 : -811 : 812 : -814)               $-x+y detector poly
         (810 : -811 : 813 : -815)               $+x+y detector poly
1008  40  -0.99704  -921  924 -925 -100              $ water in the projection
           (941 : -942 : 943 : -944 : 945 : -946 : -917)   $ the lower array
1009   0             921 -922 -923  100             $ voided reflector (above water level)
         (911 : -912 : 913 : -914 : 915 : -916 : -921 : 918)  $ the array
              (-10 : 12 : 932)                  $ bottom grid plate
         (961 : -962 : 963 : -964 : 965 : -966 : -14 : 15) $ top grid plate
        (981 : 982 : -983 : 966 : -14 : 15)         $ +x arm of top grid plate
        (982 : -966 : -963 : -14 : 15)              $ +x arm of top grid plate
        (-984 : 985 : -986 : 962 : -14 : 15)        $ -x-y arm of top grid plate
        (985 : -962 : 964 : -14 : 15)               $ -x-y arm of top grid plate
        (-987 : 988 : -989 : -965 :  -14 : 15)       $ -x+y arm of top grid plate
        (988 : -961 : 965 : -14 : 15)               $ -x+y arm of top grid plate
        (961 : -962 : 963 : -964 : 965 : -966 : -28 : 29) $ guide plate
        (981 : 982 : -983 : 966 : -28 : 29)         $ +x arm of the guide plate
        (982 : -966 : -963 : -28 : 29)              $ +x arm of the guide plate
        (-984 : 985 : -986 : 962 : -28 : 29)        $ -x-y arm of the guide plate
        (985 : -962 : 964 : -28 : 29)               $ -x-y arm of the guide plate
        (-987 : 988 : -989 : -965 :  -28 : 29)       $ -x+y arm of the guide plate
        (988 : -961 : 965 : -28 : 29)               $ -x+y arm of the guide plate
```

```
         (-12 : 14 : 990)            $ support post
         (-12 : 14 : 991)            $ support post
         (-12 : 14 : 992)            $ support post
         (-15 : 28 : 990)            $ support post
         (-15 : 28 : 991)            $ support post
         (-15 : 28 : 992)            $ support post
         (801 : -803 : 804)          $-x+y detector tube
         (801 : -803 : 806)          $+x+y detector tube
         (810 : -811 : 812 : -814)   $-x+y detector poly
         (810 : -811 : 813 : -815)   $+x+y detector poly
1010  40  -0.99704  -921  924 -925  100      $ void in the projection
1011   2  -2.700    926 -922 -929  925       $ upper tank wall
             (-921 : 922 : 923)         $ water in upper tank
1012   2  -2.700    927 -922 -928  929       $ upper flange
1013   2  -2.700   -926  930 -931            $ projection wall
             (921 : -924 : 925)         $ projection
1014  40  -0.99704  10  -12  -970            $ lower grid plate hole 1
1015  40  -0.99704  10  -12  -971            $ lower grid plate hole 2
1016  40  -0.99704  10  -12  -972            $ lower grid plate hole 3
1017  40  -0.99704  10  -12  -973            $ lower grid plate hole 4
1018  40  -0.99704  10  -12  -974            $ lower grid plate hole 5
1019  40  -0.99704  10  -12  -975            $ lower grid plate hole 6
1020   2  -2.700   -981 -982  983 -966  14 -15  :   $ +x arm of top grid plate
```

```
              -982  966  963  14  -15
1021   2   -2.700     984 -985  986 -962  14 -15  :    $ -x-y arm of top grid plate
              -985  962 -964  14 -15
1022   2   -2.700     987 -988  989  965  14 -15  :    $ +x-y arm of top grid plate
              -988  961 -965  14 -15
1023   2   -2.700    12   -14   -990              $ support post
1024   2   -2.700    12   -14   -991              $ support post
1025   2   -2.700    12   -14   -992              $ support post
1030   0            -801   802 -805                  $ -x+y detector well
             (820 : -821 : 822)                 $-x+y detector
1031   2   -2.700   -801   803 -804                  $ -x+y detector tube
             (-802 : 805)                      $-x+y well
1032   7   -0.93    -810   811 -812  814               $ -x+y detector poly
1033   0            -801   802 -807                  $ +x+y detector well
             (820 : -821 : 824)                 $+x+y detector
1034   2   -2.700   -801   803 -806                  $ +x+y detector tube
             (-802 : 807)                      $+x+y well
1035   7   -0.93    -810   811 -813  815               $ +x+y detector poly
1040  19  -10.0e-20 -820   821 -822  823                $ -x+y thin detector
1041  19   -1.e-30  -820   821 -823                   $ -x+y volume detector
1042  19  -10.0e-20 -820   821 -824  825                $ +x+y thin detector
1043  19   -1.e-30  -820   821 -825                   $ +x+y volume detector
1050   9   -2.700    -981 -982  983 -966  28 -29  :    $ +x arm of the guide plate
```

```
               -982  966  963  28 -29
1051   9   -2.700     984 -985  986 -962  28 -29  :    $ -x-y arm of the guide plate
               -985  962 -964  28 -29
1052   9   -2.700     987 -988  989  965  28 -29  :    $ +x-y arm of the guide plate
               -988  961 -965  28 -29
1053   2   -2.700    15   -28   -990               $ support post
1054   2   -2.700    15   -28   -991               $ support post
1055   2   -2.700    15   -28   -992               $ support post
c
c  ACRR fuel element from void05b.inp in D:\ng\smallNG\excalc\foils
c
c
c  Fuel Element
c
1101   4 -0.99705 -1101                u=31 $ water below bottom grid plate
1102  38  -2.70    1101  -1102              $ bottom grid plate
            (-1101 : 1109 : 1105)        $ bottom part of bottom GP hole
            (-1109 : 1110 : 1108)        $ conical part of bottom GP hole
            (-1110 : 1104 : 1106)  u=31   $ top part of bottom GP hole
1103   4 -0.99705  1102  -1103              $ water between grid plates
         (-1111:1112:1106:-1123:1122:-1118:-1121) $ +y bottom fin
         (-1114:1113:1106:-1123:1122:1118:-1121) $ -y+x bottom fin
         (-1116:1115:1106:-1123:1122:1118:-1121) $ -y-x bottom fin
```

```
          (-1111:1112:-1118:1120:-1133) $ +y top fin
          (-1114:1113:1118:1120:-1133) $ -y+x top fin
          (-1116:1115:1118:1120:-1133) $ -y-x top fin
             (1108 : -1123 : 1121)        $ stick on the bottom
             (1123 : 1122 : 1120)         $ conical part
             (-1122 : 1124 : 1120)        $ cylindrical part on top
             (-1131 : 1132 : 1120)        $ cylincrical part
             (-1132 : 1133 : 1120)        $ conical part
             (-1133 : 1135 : 1121)        $ stick
             (1120 : -1124 : 1131)  u=31   $ cladding
1104  38  -2.70    1103  -1104              $ top grid plate
               1107                u=31   $ hole in top grid plate
1105   4 -0.99705  1104  -100               $ water above grid plate
          (-1111:1112:-1118:1120:1138:-1121) $ +y top fin
          (-1114:1113:1118:1120:1138:-1121) $ -y+x top fin
          (-1116:1115:1118:1120:1138:-1121) $ -y-x top fin
             (-1131 : 1132 : 1120)        $ cylincrical part
             (-1132 : 1133 : 1120)        $ conical part
             (-1133 : 1135 : 1121)  u=31   $ stick
1106   4 -0.99705  1101  -1109  -1105        $ bottom part of bottom GP hole
          (-1111:1112:1108:1106:1122:-1118:-1121) $ +y bottom fin
          (-1114:1113:1108:1106:1122:1118:-1121) $ -y+x bottom fin
          (-1116:1115:1108:1106:1122:1118:-1121) $ -y-x bottom fin
```

```
          (1108 : -1123 : 1121)        $ stick on the bottom
          (1123 : 1122 : 1120)         $ conical part
          (-1122 : 1124 : 1120)  u=31   $ cylindrical part on top
1107   4 -0.99705  1109  -1110  -1108       $ conical part of bottom GP hole
        (-1111:1112:1108:1106:1122:-1118:-1121) $ +y bottom fin
        (-1114:1113:1108:1106:1122:1118:-1121) $ -y+x bottom fin
        (-1116:1115:1108:1106:1122:1118:-1121) $ -y-x bottom fin
          (1108 : -1123 : 1121)        $ stick on the bottom
          (1123 : 1122 : 1120)         $ conical part
          (-1122 : 1124 : 1120)  u=31   $ cylindrical part on top
1108   4 -0.99705  1110  -1102  -1106       $ top part of bottom GP hole
        (-1111:1112:1106:1122:-1118:-1121) $ +y bottom fin
        (-1114:1113:1106:1122:1118:-1121) $ -y+x bottom fin
        (-1116:1115:1106:1122:1118:-1121) $ -y-x bottom fin
          (1108 : -1123 : 1121)        $ stick on the bottom
          (1123 : 1122 : 1120)         $ conical part
          (-1122 : 1124 : 1120)  u=31   $ cylindrical part on top
1109   4 -0.99705  1103  -1104  -1107       $ hole in top grid plate
        (-1111:1112:-1118:1120:-1133:-1121) $ +y top fin
        (-1114:1113:1118:1120:-1133:-1121) $ -y+x top fin
        (-1116:1115:1118:1120:-1133:-1121) $ -y-x top fin
          (-1131 : 1132 : 1120)        $ cylincrical part
          (-1132 : 1133 : 1120)        $ conical part
```

```
            (-1133 : 1135 : 1121)  u=31   $ stick
1110   0         100              u=31   $ void above the water line
c
c  bottom end fixture
c
1111  33  -8.03   -1108   1123  -1121   u=31 $ stick on the bottom
1112  33  -8.03   -1123  -1122  -1120        $ conical part
            (1127 : 1126 : 1125)   u=31   $ conical part of hole
1113  33  -8.03    1122  -1124  -1120        $ cylindrical part on top
            (-1126 : 1124 : 1125)         $ cylindrical part of hole
            (1127 : 1126 : 1125)   u=31   $ conical part of hole
1114   0         1126  -1124  -1125       $ cylindrical part of hole
            (1142 : 1127 : 1141)   u=31   $ bottom BeO reflector
1115   0        -1127  -1126  -1125       $ conical part of hole
            (1142 : 1127 : 1141)   u=31   $ bottom BeO reflector
1116  33  -8.03    1111  -1112  -1108  -1106 $ +y bottom fin
              1123  -1122   1118   1121 u=31
1117  33  -8.03    1114  -1113  -1108  -1106 $ -y+x bottom fin
              1123  -1122  -1118   1121 u=31
1118  33  -8.03    1116  -1115  -1108  -1106 $ -y-x bottom fin
              1123  -1122  -1118   1121 u=31
c
c  top end fixture
```

```
c
1121  33  -8.03    1131  -1132  -1120        $ cylindrical part
               (-1131 : 1136 : 1125)        $ cylindrical part of hole
               (-1136 : 1137 : 1125)  u=31   $ conical part of hole
1122  33  -8.03    1132  -1133  -1120        $ conical part
               (-1136 : 1137 : 1125)  u=31   $ conical part of hole
1123  33  -8.03    1133  -1135  -1121   u=31 $ stick
1124   0          1131  -1136  -1125        $ cylindrical part of hole
               (-1162 : 1143 : 1142)  u=31   $ top BeO reflector
1125   0          1136  -1137  -1125        $ conical part of hole
               (-1162 : 1143 : 1142)  u=31   $ top BeO reflector
1126  33  -8.03    1111  -1112   1118  -1120 $ +y top fin
                 1133  -1138   1121   u=31
1127  33  -8.03    1114  -1113  -1118  -1120 $ -y+x top fin
                 1133  -1138   1121   u=31
1128  33  -8.03    1116  -1115  -1118  -1120 $ -y-x top fin
                1133  -1138   1121   u=31
c
c  clad tube
c
1129  33  -8.03    1119  -1120   1124  -1131 $ cladding
                                   u=31
1130   0         -1119   1124  -1131        $ inside of cladding
```

```
               (1142 : 1127 : 1141)         $ bottom BeO reflector
               (1150 : -1141 : 1162)        $ Nb cans
               (-1162 : 1143 : 1142)  u=31   $ top BeO reflector
c
c  BeO reflectors
c
1131  37  -2.80   -1142  -1127  -1141   u=31 $ bottom BeO reflector
1132  37  -2.80    1162  -1143  -1142   u=31 $ top BeO reflector
c
c  niobium cups
c
1140  34  -8.40    1151  -1150   1141  -1162 $ walls of Nb cans
                                    u=31
1141  34  -8.40    1141  -1152  -1151   u=31 $ floor of can 1
1142  34  -8.40    1153  -1154  -1151   u=31 $ floor of can 2
1143  34  -8.40    1155  -1156  -1151   u=31 $ floor of can 3
1144  34  -8.40    1157  -1158  -1151   u=31 $ floor of can 4
1145  34  -8.40    1159  -1160  -1151   u=31 $ floor of can 5
1146  34  -8.40    1161  -1162  -1151   u=31 $ lid
1147   0          1152  -1153  -1151        $ inside can 1
               (-1152 : 1177 : 1173)  u=31   $ fuel can 1
1148   0          1154  -1155  -1151        $ inside can 2
               (-1154 : 1180 : 1173)  u=31   $ fuel can 2
```

```
1149   0          1156  -1157  -1151       $ inside can 3
               (-1156 : 1183 : 1173)  u=31   $ fuel can 3
1150   0          1158  -1159  -1151       $ inside can 4
               (-1158 : 1186 : 1173)  u=31   $ fuel can 4
1151   0          1160  -1161  -1151       $ inside can 5
               (-1160 : 1189 : 1173)  u=31   $ fuel can 5
c
c  fuel
c
1160  31  -3.524   1152  -1177   1170  -1171 u=31 $ inner fuel        can 1
1161  31  -3.524   1152  -1175   1172  -1174 u=31 $ bottom pellet     can 1
1162  31  -3.524   1175  -1176   1172  -1173 u=31 $ 14 pellets        can 1
1163  31  -3.524   1176  -1177   1172  -1174 u=31 $ top pellet        can 1
1164   0          1152  -1177  -1170       u=31 $ hole              can 1
1165   0          1152  -1177   1171  -1172 u=31 $ gap               can 1
1166   0          1152  -1175   1174  -1173 u=31 $ outside bot pellet can 1
1167   0          1176  -1177   1174  -1173 u=31 $ outside top pellet can 1
1168  31  -3.524   1154  -1180   1170  -1171 u=31 $ inner fuel        can 2
1169  31  -3.524   1154  -1178   1172  -1174 u=31 $ bottom pellet     can 2
1170  31  -3.524   1178  -1179   1172  -1173 u=31 $ 14 pellets        can 2
1171  31  -3.524   1179  -1180   1172  -1174 u=31 $ top pellet        can 2
1172   0          1154  -1180  -1170       u=31 $ hole              can 2
1173   0          1154  -1180   1171  -1172 u=31 $ gap               can 2
```

```
1174   0          1154  -1178   1174  -1173 u=31 $ outside bot pellet can 2
1175   0          1179  -1180   1174  -1173 u=31 $ outside top pellet can 2
1176  31  -3.524   1156  -1183   1170  -1171 u=31 $ inner fuel        can 3
1177  31  -3.524   1156  -1181   1172  -1174 u=31 $ bottom pellet     can 3
1178  31  -3.524   1181  -1182   1172  -1173 u=31 $ 14 pellets        can 3
1179  31  -3.524   1182  -1183   1172  -1174 u=31 $ top pellet        can 3
1180   0          1156  -1183  -1170       u=31 $ hole             can 3
1181   0          1156  -1183   1171  -1172 u=31 $ gap              can 3
1182   0          1156  -1181   1174  -1173 u=31 $ outside bot pellet can 3
1183   0          1182  -1183   1174  -1173 u=31 $ outside top pellet can 3
1184  31  -3.524   1158  -1186   1170  -1171 u=31 $ inner fuel        can 4
1185  31  -3.524   1158  -1184   1172  -1174 u=31 $ bottom pellet     can 4
1186  31  -3.524   1184  -1185   1172  -1173 u=31 $ 14 pellets        can 4
1187  31  -3.524   1185  -1186   1172  -1174 u=31 $ top pellet        can 4
1188   0          1158  -1186  -1170       u=31 $ hole             can 4
1189   0          1158  -1186   1171  -1172 u=31 $ gap              can 4
1190   0          1158  -1184   1174  -1173 u=31 $ outside bot pellet can 4
1191   0          1185  -1186   1174  -1173 u=31 $ outside top pellet can 4
1192  31  -3.524   1160  -1189   1170  -1171 u=31 $ inner fuel        can 5
1193  31  -3.524   1160  -1187   1172  -1174 u=31 $ bottom pellet     can 5
1194  31  -3.524   1187  -1188   1172  -1173 u=31 $ 14 pellets        can 5
1195  31  -3.524   1188  -1189   1172  -1174 u=31 $ top pellet        can 5
1196   0          1160  -1189  -1170       u=31 $ hole             can 5
```

```
1197   0          1160  -1189   1171  -1172 u=31 $ gap              can 5

1198   0          1160  -1187   1174  -1173 u=31 $ outside bot pellet can 5

1199   0          1188  -1189   1174  -1173 u=31 $ outside top pellet can 5

c

1201   4 -0.99705   -100                  u=32 $ empty below waterline

1202   0            100                 u=32 $ empty above waterline

c

1100   0                                    $ external void (imp=0)

               (-926 : 922 : 929)                $ tank wall

               (-927 : 922 : 928)                $ flange

               (926 : -930 : 931)                $ projection wall

          (911 : -912 : 913 : -914 : 915 : -916 : -921 : 918)  $ the array

          (801 : -803 : 804)                     $-x+y detector tube

          (801 : -803 : 806)                     $+x+y detector tube


c

c fuel rod surfaces

c

1    cz    0.26289  $ fuel OD (0.207")

2    cz    0.284519 $ clad ID (0.01297" wall from measured mass)

3    cz    0.317475 $ clad OD (0.249980")

4    cz    0.333375 $ ID of hole in grid plate at fuel (0.260")

5    cz    0.17526  $ ID of spring
```

```
6    cz    0.22860  $ OD of spring
7    cz    0.26289  $ intermediate plug OD (0.207")
8    cz    0.26289  $ poly OD (0.207")
10   pz   -2.54     $ bottom of bottom grid plate
11   pz   -1.27     $ bottom of rod (.5" plug)
12   pz    0.0      $ bottom of fuel (47 pellets, 0.414" long)
13   pz   48.780    $ top of fuel (48.77954 cm fuel column)
14   pz   50.4952   $ bottom of upper grid plate
15   pz   53.0352   $ top of upper grid plate
16   pz   74.35596  $ bottom of top plug
17   pz   -0.4826   $ bottom of clad tube
18   pz   75.0824   $ top of clad tube
19   pz   76.89596  $ top of top plug
20   pz   23.39     $ bottom of midplane fuel
21   pz   25.39     $ top of midplane fuel
22   pz   48.280    $ bottom of upper fuel detector
23   pz    0.5      $ top of lower fuel detector
24   pz   50.53076  $ bottom of aluminum spacer
25   pz   53.07076  $ top of aluminum spacer
26   cz    0.17526  $ OD of hole in top plug
27   pz   75.81     $ bottom of hole in top plug
28   pz   70.8152   $ bottom of guide plate
29   pz   71.7677   $ top of guide plate
```

```
c
c Source surfaces
c
231   pz    24.31796    $ bottom of source
232   pz    25.51938   $ top of source
233   cz     0.29972   $ OD of source
234   pz    27.65552   $ top of plug in stick
235   pz    26.10358   $ top of screw
236   cz     0.12573   $ 3-48 screw
237   pz    26.2382    $ bottom of tube in stick
238   cz     0.4000    $ handle - wants to be 0.4064
239   pz    81.9277    $ top of handle
c
c Experiment Rod Surfaces
c
91    cz     0.3175    $ OD of experiment rod
92    pz    78.1812    $ top of experiment rod
93    pz    22.39      $ bottom of central detector zone
94    pz    26.39      $ top of central detector zone
9001  cz     0.309461  $ radial boundaries of central zone
9002  cz     0.301207
9003  cz     0.283981
9004  cz     0.265640
```

```
9005  cz    0.245934

9006  cz    0.224506

9007  cz    0.200805

9008  cz    0.173902

9009  cz    0.141990

9010  cz    0.100402

c

c Safety Element 1 surfaces

c

401 4 cz    0.26289  $ fuel OD (0.207")

402 4 cz    0.284519 $ clad ID (0.01297" wall from measured mass)

403 4 cz    0.317475 $ clad OD (0.249980")

404 4 cz    0.333375 $ ID of hole in grid plate at fuel (0.2522")

405 4 cz    0.17526  $ ID of spring

406 4 cz    0.22860  $ OD of spring

411 4 pz   -2.54     $ bottom of rod (1" plug)

412 4 pz    0.25908  $ bottom of fuel (47 pellets, 0.414" long)

413 4 pz   48.97608  $ top of fuel (48.77954 cm fuel column)

414 4 pz   50.2412   $ bottom of upper plug

415 4 pz   53.29936  $ bottom of poly

416 4 pz   -0.635    $ bottom of bottom groove

417 4 pz   -0.3175   $ top of bottom groove

418 4 pz   51.01082  $ bottom of top groove
```

```
419 4 pz    51.32832  $ top of top groove
420 4 pz    23.39     $ bottom of midplane fuel
421 4 pz    25.39     $ top of midplane fuel
422 4 pz    48.47608  $ bottom of upper fuel detector
423 4 pz     0.75908  $ top of lower fuel detector
424 4 pz    65.49136  $ top of poly plug
425 4 pz    68.84924  $ bottom of absorber
426 4 pz   140.07376  $ top of absorber
427 4 pz   140.57376  $ gap above absorber (0.5 cm)
428 4 pz   141.94536  $ plug above absorber (8")
430 4 pz    -2.54     $ bottom of lower grid plate
432 4 pz     0.0      $ top of lower grid plate
434 4 pz    50.50028  $ bottom of mid bundle plate 1
435 4 pz    53.04028  $ top of mid bundle plate 1
436 4 pz    65.79108  $ gap above poly
437 4 cz     0.1811   $ screws
438 4 pz    -0.3175   $ bottom screw top
439 4 pz    50.81778  $ bottom of screw
440 4 pz    52.72278  $ top of screw
441 4 pz    66.05016  $ bottom of the 2nd mid bundle plate
442 4 pz    68.59016  $ top of the 2nd mid bundle plate
443 4 pz   143.21536  $ top of the top bundle plate
444 4 pz   141.11224  $ bottom of top screw
```

```
445 4 cz     0.254    $ top cap screw head
446 4 pz   142.79372  $ countersink for cap screw
447 4 cz     0.2794   $ end cap ends
448 4 pz    -1.11252  $ bottom of fueled section
449 4 pz    51.6128   $ top of fueled section
450 4 pz    -0.50546  $ bottom of full diameter fueled rod
451 4 pz    51.00574  $ top of full diameter fueled rod
452 4 cz     0.28353  $ hole in bundle plate at ends
453 4 pz    51.92776  $ bottom of the poly section
454 4 pz    67.16268  $ top of the poly section
455 4 pz    52.53482  $ bottom of the full diameter poly section
456 4 pz    66.55562  $ top of the full diameter poly section
457 4 pz    67.47764  $ bottom of absorber rod
458 4 pz    68.0847   $ bottom of full diameter absorber rod
459 4 pz   141.3383   $ top of full diameter absorber rod
460 4 pz    66.36766  $ bottom of set screw in 2nd middle BP
461 4 pz    68.27266  $ top of set screw in 2nd middle BP
462 4 pz    -2.2225   $ bottom of set screw in lower bundle plate
c
c Safety Element 2 surfaces
c
501 5 cz     0.26289  $ fuel OD (0.207")
502 5 cz     0.284519 $ clad ID (0.01297" wall from measured mass)
```

```
503 5 cz     0.317475 $ clad OD (0.249980")
504 5 cz     0.333375 $ ID of hole in grid plate at fuel (0.2522")
505 5 cz     0.17526  $ ID of spring
506 5 cz     0.22860  $ OD of spring
511 5 pz    -2.54     $ bottom of rod (1" plug)
512 5 pz     0.25908  $ bottom of fuel (47 pellets, 0.414" long)
513 5 pz    48.97608  $ top of fuel (48.77954 cm fuel column)
514 5 pz    50.2412   $ bottom of upper plug
515 5 pz    53.29936  $ bottom of poly
516 5 pz    -0.635    $ bottom of bottom groove
517 5 pz    -0.3175   $ top of bottom groove
518 5 pz    51.01082  $ bottom of top groove
519 5 pz    51.32832  $ top of top groove
520 5 pz    23.39     $ bottom of midplane fuel
521 5 pz    25.39     $ top of midplane fuel
522 5 pz    48.47608  $ bottom of upper fuel detector
523 5 pz     0.75908  $ top of lower fuel detector
524 5 pz    65.49136  $ top of poly plug
525 5 pz    68.84924  $ bottom of absorber
526 5 pz   140.07376  $ top of absorber
527 5 pz   140.57376  $ gap above absorber (0.5 cm)
528 5 pz   141.94536  $ plug above absorber (8")
530 5 pz    -2.54     $ bottom of lower grid plate
```

532 5 pz 0.0 $ top of lower grid plate

534 5 pz 50.50028 $ bottom of mid bundle plate 1

535 5 pz 53.04028 $ top of mid bundle plate 1

536 5 pz 65.79108 $ gap above poly

537 5 cz 0.1811 $ screws

538 5 pz -0.3175 $ bottom screw top

539 5 pz 50.81778 $ bottom of screw

540 5 pz 52.72278 $ top of screw

541 5 pz 66.05016 $ bottom of the 2nd mid bundle plate

542 5 pz 68.59016 $ top of the 2nd mid bundle plate

543 5 pz 143.21536 $ top of the top bundle plate

544 5 pz 141.11224 $ bottom of top screw

545 5 cz 0.254 $ top cap screw head

546 5 pz 142.79372 $ countersink for cap screw

547 5 cz 0.2794 $ end cap ends

548 5 pz -1.11252 $ bottom of fueled section

549 5 pz 51.6128 $ top of fueled section

550 5 pz -0.50546 $ bottom of full diameter fueled rod

551 5 pz 51.00574 $ top of full diameter fueled rod

552 5 cz 0.28353 $ hole in bundle plate at ends

553 5 pz 51.92776 $ bottom of the poly section

554 5 pz 67.16268 $ top of the poly section

555 5 pz 52.53482 $ bottom of the full diameter poly section

```
556 5 pz    66.55562  $ top of the full diameter poly section
557 5 pz    67.47764  $ bottom of absorber rod
558 5 pz    68.0847   $ bottom of full diameter absorber rod
559 5 pz   141.3383   $ top of full diameter absorber rod
560 5 pz    66.36766  $ bottom of set screw in 2nd middle BP
561 5 pz    68.27266  $ top of set screw in 2nd middle BP
562 5 pz    -2.2225   $ bottom of set screw in lower bundle plate
c
c Control Element surfaces
c
601 6 cz     0.26289  $ fuel OD (0.207")
602 6 cz     0.284519 $ clad ID (0.01297" wall from measured mass)
603 6 cz     0.317475 $ clad OD (0.249980")
604 6 cz     0.333375 $ ID of hole in grid plate at fuel (0.2522")
605 6 cz     0.17526  $ ID of spring
606 6 cz     0.22860  $ OD of spring
611 6 pz    -2.54     $ bottom of rod (1" plug)
612 6 pz     0.25908  $ bottom of fuel (47 pellets, 0.414" long)
613 6 pz    48.97608  $ top of fuel (48.77954 cm fuel column)
614 6 pz    50.2412   $ bottom of upper plug
615 6 pz    53.29936  $ bottom of poly
616 6 pz    -0.635    $ bottom of bottom groove
617 6 pz    -0.3175   $ top of bottom groove
```

```
618 6 pz    51.01082  $ bottom of top groove
619 6 pz    51.32832  $ top of top groove
620 6 pz    23.39     $ bottom of midplane fuel
621 6 pz    25.39     $ top of midplane fuel
622 6 pz    48.47608  $ bottom of upper fuel detector
623 6 pz     0.75908  $ top of lower fuel detector
624 6 pz    65.49136  $ top of poly plug
625 6 pz    68.84924  $ bottom of absorber
626 6 pz   140.07376  $ top of absorber
627 6 pz   140.57376  $ gap above absorber (0.5 cm)
628 6 pz   141.94536  $ plug above absorber (8")
630 6 pz    -2.54     $ bottom of lower grid plate
632 6 pz     0.0      $ top of lower grid plate
634 6 pz    50.50028  $ bottom of mid bundle plate 1
635 6 pz    53.04028  $ top of mid bundle plate 1
636 6 pz    65.79108  $ gap above poly
637 6 cz     0.1811   $ screws
638 6 pz    -0.3175   $ bottom screw top
639 6 pz    50.81778  $ bottom of screw
640 6 pz    52.72278  $ top of screw
641 6 pz    66.05016  $ bottom of the 2nd mid bundle plate
642 6 pz    68.59016  $ top of the 2nd mid bundle plate
643 6 pz   143.21536  $ top of the top bundle plate
```

```
644 6 pz   141.11224  $ bottom of top screw
645 6 cz     0.254    $ top cap screw head
646 6 pz   142.79372  $ countersink for cap screw
647 6 cz     0.2794   $ end cap ends
648 6 pz    -1.11252  $ bottom of fueled section
649 6 pz    51.6128   $ top of fueled section
650 6 pz    -0.50546  $ bottom of full diameter fueled rod
651 6 pz    51.00574  $ top of full diameter fueled rod
652 6 cz     0.28353  $ hole in bundle plate at ends
653 6 pz    51.92776  $ bottom of the poly section
654 6 pz    67.16268  $ top of the poly section
655 6 pz    52.53482  $ bottom of the full diameter poly section
656 6 pz    66.55562  $ top of the full diameter poly section
657 6 pz    67.47764  $ bottom of absorber rod
658 6 pz    68.0847   $ bottom of full diameter absorber rod
659 6 pz   141.3383   $ top of full diameter absorber rod
660 6 pz    66.36766  $ bottom of set screw in 2nd middle BP
661 6 pz    68.27266  $ top of set screw in 2nd middle BP
662 6 pz    -2.2225   $ bottom of set screw in lower bundle plate
c
c   detector wells
c
801   pz    89.2175    $ top of tube
```

```
802   pz    0.735     $ this is 0.25" above the bottom of the tube - bottom inside of tube
803   pz    0.1       $ this is 0.1 cm above the bottom grid plate - bottom of tube
804   c/z   32.385    6.400   3.175  $ 2.5" OD tube outside
805   c/z   32.385    6.400   2.8575 $ 2.25" ID of tube
806   c/z  -32.385   -6.400   3.175  $ 2.5" OD tube
807   c/z  -32.385   -6.400   2.8575 $ 2.25" ID of tube
810   pz    30.84848                 $ 11.82" above bottom of poly
811   pz    0.862                    $ bottom of poly - 0.3" bottom of the tube
812   c/z   32.385    6.400   5.75945 $ OD poly
813   c/z  -32.385   -6.400   5.75945 $ OD poly
814   c/z   32.385    6.400   3.30581 $ ID poly
815   c/z  -32.385   -6.400   3.30581 $ ID poly
c
c   PPS detectors
c
820   pz    19.41                    $ top
821   pz    4.17                     $ bottom
822   c/z   32.385    6.400   2.54    $ 2" OD detector volume
823   c/z   32.385    6.400   2.53492 $ 1.996" ID detector foil
824   c/z  -32.385   -6.400   2.54    $ 2" OD detector volume
825   c/z  -32.385   -6.400   2.53492 $ 1.996" ID detector foil
c
c cell boundaries
```

```
c
901  px    0.43000                         $ 0.860 cm pitch
902  px   -0.43000
903   p      1   1.7320508076  0  0.8600   $ 0.860 cm pitch
904   p      1   1.7320508076  0 -0.8600
905   p     -1   1.7320508076  0  0.8600
906   p     -1   1.7320508076  0 -0.8600
c
c  the outer array boundaries
c    the first number is 27 x pitch * cos(30)
c    the other one is twice that
c
911   py     20.10911
912   py    -20.10911
913   p     1.7320508076   1  0  40.21822
914   p     1.7320508076   1  0 -40.21822
915   p    -1.7320508076   1  0  40.21822
916   p    -1.7320508076   1  0 -40.21822
917   pz   -75
918   pz   140
c
c  the inner array boundaries
c    the first number is 4.5 x pitch * cos(30)
```

```
c    the other one is twice that
c
1911   py      5.58586
1912   py     -5.58586
1913   p     1.7320508076   1  0   11.17173
1914   p     1.7320508076   1  0  -11.17173
1915   p    -1.7320508076   1  0   11.17173
1916   p    -1.7320508076   1  0  -11.17173
1917   pz   -1.27
c 1911   py      1.86195
c 1912   py     -1.86195
c 1913   p     1.7320508076   1  0   3.72391
c 1914   p     1.7320508076   1  0  -3.72391
c 1915   p    -1.7320508076   1  0   3.72391
c 1916   p    -1.7320508076   1  0  -3.72391
c 1917   pz   -1.27
c
c  outside of the inner 0.0625" wall
c    the first number is 3.5 x pitch * cos(30) + 0.065"
c    the other one is twice that
c
1921   py      2.76549
1922   py     -2.76549
```

```
1923   p     1.7320508076   1  0   5.53097
1924   p     1.7320508076   1  0  -5.53097
1925   p    -1.7320508076   1  0   5.53097
1926   p    -1.7320508076   1  0  -5.53097
1927   pz   -1.42875
c
c  outside of the inner 0.040" thick Cd liner
c    the first number is 3.5 x pitch * cos(30) + 0.065" + 0.040"
c    the other one is twice that
c
1931   py      2.86709
1932   py     -2.86709
1933   p     1.7320508076   1  0   5.73417
1934   p     1.7320508076   1  0  -5.73417
1935   p    -1.7320508076   1  0   5.73417
1936   p    -1.7320508076   1  0  -5.73417
1937   pz   -1.53035
c
c  the inside of the 0.125" thick experiment can
c    the first number is 4.5 x pitch * cos(30) - 0.125 "
c    the other one is twice that
c
1941   py      3.03402
```

```
1942   py     -3.03402
1943   p     1.7320508076   1  0   6.06804
1944   p     1.7320508076   1  0  -6.06804
1945   p    -1.7320508076   1  0   6.06804
1946   p    -1.7320508076   1  0  -6.06804
1947   pz   -1.5304
c
c  the outside of the experiment can
c    the first number is 4.5 x pitch * cos(30)
c    the other one is twice that
c
1951   py      3.35152
1952   py     -3.35152
1953   p     1.7320508076   1  0   6.70304
1954   p     1.7320508076   1  0  -6.70304
1955   p    -1.7320508076   1  0   6.70304
1956   p    -1.7320508076   1  0  -6.70304
1957   pz   -2.54
1958   pz   76.0
c
c    the part of the array in the projection
c
941   py     16.45
```

```
942   py    -16.45
943   p     1.7320508076   1  0  32.9
944   p     1.7320508076   1  0 -32.9
945   p    -1.7320508076   1  0  32.9
946   p    -1.7320508076   1  0 -32.9
c
c     water level
c
100   pz    68.2752     $ top of the water - 68.2752 gives 6" above grid plate
c
c                  $ in the following "water" = water level (surface 100) if < 48.78
c                  $                         = 48.78 if water level is above top of fuel
40    pz    20.39   $ bottom of the first middle detector: water/2 - 6
41    pz    22.39   $ top of first detector: water/2 - 4
42    pz    24.39   $ top of second detector: water/2 - 2
43    pz    26.39   $ half of the water height, top of third detector: water/2
44    pz    28.39   $ top of fourth detector: water/2 + 2
45    pz    48.28   $ upper 1/2 cm of fuel under water: water - 0.5 OR 48.78 - 0.5
c
c     the tank
c
921   pz   -19.05      $ bottom inside of tank - 7.5" below top of bottom GP
922   pz    82.55      $ top of tank - 40" above bottom of tank water
```

```
923   cz    46.83125   $ inside of tank - 36.875" diameter
924   pz   -74.295     $ bottom inside of projection - 21.75" below bottom of tank water
925   cz    19.05      $ inside of projection - 15" diameter
926   pz   -21.59      $ bottom outside of tank - 1" thick
927   pz    81.28      $ top flange on tank - 1/2" thick
928   cz    50.00625   $ outside of top flange - 1" overhang
929   cz    47.46625   $ outside of tank - 1/4" wall
930   pz   -74.93      $ bottom outside of projection - 1/4" wall
931   cz    19.685     $ outside of projection - 1/4" wall
932   cz    46.355     $ outside curve of lower grid plate (36.5" OD)
933   cz    46.355     $ outside curve of upper grid plate (36.5" OD)
c
c    the upper grid plate - 16" hex
c
961   py     21.59
962   py    -21.59
963   p     1.7320508076   1  0  43.18
964   p     1.7320508076   1  0 -43.18
965   p    -1.7320508076   1  0  43.18
966   p    -1.7320508076   1  0 -43.18
c
c   lower grid plate holes
c
```

```
970   c/z   30.7959  17.78    5.08
971   c/z    0.0     35.56    5.08
972   c/z  -30.7959  17.78    5.08
973   c/z  -30.7959 -17.78    5.08
974   c/z    0.0    -35.56    5.08
975   c/z   30.7959 -17.78    5.08
c
c    arms on the upper grid plate
c
981   px    38.1762
982   py     2.54
983   py    -2.54
984   p     1   1.7320508076  0 -76.3524
985   p    -1.7320508076   1  0   5.08
986   p    -1.7320508076   1  0  -5.08
987   p     1  -1.7320508076  0 -76.3524
988   p     1.7320508076   1  0   5.08
989   p     1.7320508076   1  0  -5.08
990   c/z   35.56       0  1.27
991   c/z  -17.78  30.7959  1.27
992   c/z  -17.78 -30.7959  1.27
c
c surfaces for ACRR fuel element
```

```
c
c
c  the grid plates
c
1101 9 pz  11.33       $ bottom of bottom grid plate
1102 9 pz  16.41       $ top of bottom grid plate
1103 9 pz  80.55       $ bottom of top grid plate
1104 9 pz  83.09       $ top of top grid plate
1105 9 cz  1.5875      $ 1.25" dia through hole in bottom grid plate
1106 9 cz  1.8542      $ 1.46" dia cylindrical part of countersink
1107 9 cz  1.94945     $ 1.535" dia through hole in top grid plate
1108 9 z   15.14 1.8542  13.2858 0.0  $ cone of countersink
1109 9 pz  14.8733     $ plane where bottom cylinder meets cone
1110 9 pz  15.14       $ plane where top cylinder meets cone
c
c  fins on end fixtures
c
1111 9 px  -0.17526    $ fin plane (0.138" thick)
1112 9 px   0.17526    $ fin plane
1113 9  p   1 1.7320508076 0  0.35052
1114 9  p   1 1.7320508076 0 -0.35052
1115 9  p  -1 1.7320508076 0  0.35052
1116 9  p  -1 1.7320508076 0 -0.35052
```

```
1117 9 px   0.0

1118 9 py   0.0

c

c  bottom fixture

c

1119 9 cz  1.82118     $ ID of the cladding (1.455")

1120 9 cz  1.87198     $ OD of the fuel element 1.475" OD

1121 9 cz  0.7874      $ stick on the bottom

1122 9 pz  20.78388    $ plane where cone meets cylinder

1123 9 z   20.78388 1.87325  15.11714  0.0  $ cone

1124 9 pz  22.4425     $ top of fixture

1125 9 cz  1.48717     $ hole in fixture

1126 9 pz  21.1725     $ plane that separates cylinder from cone in hole

1127 9 z   21.1725 1.48717  20.4395 0.0  $ cone of hole

c

c  top fixture

c

1131 9 pz  76.3413     $ bottom of top fixture

1132 9 pz  77.99992    $ plane where cone meets cylinder

1133 9 z   77.99992 1.87325  83.63936 0.0 $ cone

1134 9 pz  87.18456    $ plane at top

1135 9 z   87.18456 0.7874  87.97196 0.0 $ cone at top

1136 9 pz  77.6113     $ plane that separates cylinder from cone in hole
```

```
1137 9 z   77.6113 1.48717  78.3443 0.0  $ cone in hole
1138 9 pz  84.0375     $ top of top fins
c
c  BeO reflectors
c
1141 9 pz  22.9886     $ top of bottom reflector
1142 9 cz  1.46177     $ OD of reflector
1143 9 z   77.1414 1.46177  77.8744 0.0  $ cone on top reflector
c
c  niobium cups
c
1150 9 cz  1.77038     $ OR of niobium cups (0.697")
1151 9 cz  1.73228     $ IR of niobium cups (0.015" wall)
1152 9 pz  23.0394     $ top floor 1
1153 9 pz  33.3264     $ bottom floor 2
1154 9 pz  33.3772     $ top floor 2
1155 9 pz  43.6642     $ bottom floor 3
1156 9 pz  43.7150     $ top floor 3
1157 9 pz  54.0020     $ bottom floor 4
1158 9 pz  54.0528     $ top floor 4
1159 9 pz  64.3398     $ bottom floor 5
1160 9 pz  64.3906     $ top floor 5
1161 9 pz  75.1856     $ lid bottom
```

```
1162 9 pz  75.2364     $ lid top
c
c  the fuel
c
1170 9 cz  0.2415      $ IR of inner pellet
1171 9 cz  1.1000      $ OR of inner pellet
1172 9 cz  1.1175      $ IR of outer pellet
1173 9 cz  1.684       $ OR of outer pellet
1174 9 cz  1.57986     $ OR of smaller outer pellet (0.041" smaller)
1175 9 pz  23.6744     $ fuel 1   can 1
1176 9 pz  32.5644     $ fuel 2   can 1
1177 9 pz  33.1994     $ fuel top can 1
1178 9 pz  34.0122     $ fuel 1   can 2
1179 9 pz  42.9022     $ fuel 2   can 2
1180 9 pz  43.5372     $ fuel top can 2
1181 9 pz  44.3500     $ fuel 1   can 3
1182 9 pz  53.2400     $ fuel 2   can 3
1183 9 pz  53.8750     $ fuel top can 3
1184 9 pz  54.6878     $ fuel 1   can 4
1185 9 pz  63.5778     $ fuel 2   can 4
1186 9 pz  64.2128     $ fuel top can 4
1187 9 pz  65.0256     $ fuel 1   can 5
1188 9 pz  73.9156     $ fuel 2   can 5
```

```
1189 9 pz  75.1856     $ fuel top can 5
c
c
c ACRR cell boundaries
c
1901  px    2.0855                        $ 4.1871 cm pitch
1902  px   -2.0855
1903   p      1   1.7320508076  0  4.1871   $ 4.1871 cm pitch
1904   p      1   1.7320508076  0 -4.1871
1905   p     -1   1.7320508076  0  4.1871
1906   p     -1   1.7320508076  0 -4.1871

c
c UO2 fuel
c Fuel density 10.2650 g/cc (derived from assembly records)
c average fuel column mass 108.7165 g (averaged from assembly records)
c given fuel pellet diameter 0.207"
c derived fuel column length 48.77954 cm
c
c 0.999845 UO2, the rest is impurities
c
c 0.02814% U-234 in uranium (ORNL measurement)
c 6.90339% U-235 in uranium (ORNL measurement)
```

```
c 0.06336% U-236 in uranium (ORNL measurement)
c
m1
     92234.80c  6.55010E-6
     92235.80c  1.60003E-3
     92236.80c  1.46230E-5
     92238.80c  2.12840E-2
      8016.80c  4.58104E-2
c now the impurities that were measured
c     47000.xxc  8.4242E-9  $Ag
c  Silver
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        107          51.839 %
c        109          48.161 %
      47107.80c 4.36702e-009
      47109.80c 4.05718e-009
c      5000.xxc  2.1614E-7  $B
c  Boron
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        10          19.9 %
c        11          80.1 %
```

```
     5010.80c 4.30119e-008
     5011.80c 1.73128e-007
c    48000.xxc  6.8189E-9  $Cd
c  Cadmium
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        106           1.25 %
c        108           0.89 %
c        110          12.49 %
c        111          12.8 %
c        112          24.13 %
c        113          12.22 %
c        114          28.73 %
c        116           7.49 %
     48106.80c 8.52363e-011
     48108.80c 6.06882e-011
     48110.80c 8.51681e-010
     48111.80c 8.72819e-010
     48112.80c 1.6454e-009
     48113.80c 8.3327e-010
     48114.80c 1.95907e-009
     48116.80c 5.10736e-010
    27059.80c  2.1608E-8  $Co
```

```
c    24000.xxc  2.5085E-6  $Cr
c  Chromium
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        50            4.345 %
c        52           83.789 %
c        53            9.501 %
c        54            2.365 %
     24050.80c 1.08994e-007
     24052.80c 2.10185e-006
     24053.80c 2.38333e-007
     24054.80c 5.9326e-008
c    29000.xxc  1.9358E-7  $Cu
c  Copper
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        63           69.17 %
c        65           30.83 %
     29063.80c 1.33899e-007
     29065.80c 5.96807e-008
c    26000.xxc  1.0305E-5  $Fe
c  Iron
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
```

```
c  Isotopic Mass    Atom Fraction
c        54            5.845 %
c        56           91.754 %
c        57            2.119 %
c        58            0.282 %
      26054.80c 6.02327e-007
      26056.80c 9.45525e-006
      26057.80c 2.18363e-007
      26058.80c 2.90601e-008
     25055.80c  2.8355E-7  $Mn
c  Molybdenum 1.2435e-007
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        92           14.84 %
c        94            9.25 %
c        95           15.92 %
c        96           16.68 %
c        97            9.55 %
c        98           24.13 %
c        100            9.63 %
      42092.80c 1.84535e-008
      42094.80c 1.15024e-008
      42095.80c 1.97965e-008
```

```
     42096.80c 2.07416e-008
     42097.80c 1.18754e-008
     42098.80c 3.00057e-008
     42100.80c 1.19749e-008
c    28000.xxc  3.4966E-6  $Ni
c  Nickel
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        58          68.0769 %
c        60          26.2231 %
c        61           1.1399 %
c        62           3.6345 %
c        64           0.9256 %
     28058.80c 2.38038e-006
     28060.80c 9.16917e-007
     28061.80c 3.98577e-008
     28062.80c 1.27084e-007
     28064.80c 3.23645e-008
c  Vanadium 1.4804E-08
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        50           0.25 %
c        51          99.75 %
```

```
     23050.80c 3.701E-11
     23051.80c 1.4767E-08
c    74000.xxc  3.5979E-9  $W
c  Tungsten
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        180           0.12 %
c        182          26.5 %
c        183          14.31 %
c        184          30.64 %
c        186          28.43 %
c     74180.66c 4.31748e-012 $ no MCNP XS for W-180
     74182.80c 9.53444e-010
     74183.80c 5.14859e-010
     74184.80c 1.1024e-009
     74186.80c 1.02288e-009
c impurities that were below the detection limit at half the limit
c    66000.xxc  4.2796E-10 $Dy - no Dy in MCNP cross sections
c    63000.xxc  4.5763E-10 $Eu
c  Europium
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        151          47.81 %
```

c 153 52.19 %

63151.80c 2.18793e-010

63153.80c 2.38837e-010

c 64000.xxc 4.4225E-10 $Gd

c Gadolinium

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Atom Fraction

c 152 0.2 %

c 154 2.18 %

c 155 14.8 %

c 156 20.47 %

c 157 15.65 %

c 158 24.84 %

c 160 21.86 %

64152.80c 8.845e-013

64154.80c 9.64105e-012

64155.80c 6.5453e-011

64156.80c 9.05286e-011

64157.80c 6.92121e-011

64158.80c 1.09855e-010

64160.80c 9.66759e-011

c 62000.xxc 5.2624E-10 $Sm

c Samarium

```
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        144           3.07 %
c        147          14.99 %
c        148          11.24 %
c        149          13.82 %
c        150           7.38 %
c        152          26.75 %
c        154          22.75 %
c      62144.49c 1.61556e-011 $ no MCNP XS for Sm-144
     62147.80c 7.88834e-011
c      62148.49c 5.91494e-011 $ no MCNP XS for Sm-148
     62149.80c 7.27264e-011
     62150.80c 3.88365e-011
     62152.80c 1.40769e-010
c      62154.49c 1.1972e-010 $ no MCNP XS for Sm-154
c
c    6061 aluminum
c    composition from Kaiser certified test report
c    density 2.700
c
m2   13027.80c  -0.9606
c     14000.xxx  -0.0072
```

```
     14028.80c  -0.006615 14029.80c  -0.000348 14030.80c  -0.000237
c    26000.xxx  -0.0062
     26054.80c  -0.000350 26056.80c  -0.005698 26057.80c  -0.000134
     26058.80c  -0.000018
c    29000.xxx  -0.0031
     29063.80c  -0.002123 29065.80c  -0.000977
     25055.80c  -0.009
c  Magnesium
c     1.04 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        24           77.95 %
c        25           10.28 %
c        26           11.77 %
      12024.80c -0.0081068
      12025.80c -0.00106913
      12026.80c -0.00122407
c    24000.xxx  -0.002
     24050.80c  -0.000083 24052.80c  -0.001674 24053.80c  -0.000193
     24054.80c  -0.000049
c  Tin
c     0.12 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
```

```
c  Isotopic Mass    Mass Fraction
c        112           0.91439 %
c        114           0.63327 %
c        115           0.3291 %
c        116          14.196 %
c        117           7.5631 %
c        118          24.055 %
c        119           8.604 %
c        120          32.907 %
c        122           4.7545 %
c        124           6.0434 %
      50112.80c -1.09727e-005
      50114.80c -7.59927e-006
      50115.80c -3.94916e-006
      50116.80c -0.000170352
      50117.80c -9.0757e-005
      50118.80c -0.000288661
      50119.80c -0.000103248
      50120.80c -0.000394886
      50122.80c -5.70546e-005
      50124.80c -7.25207e-005
c  Titanium
c     0.02 wt %
```

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass   Mass Fraction

c   46   7.9201 %

c   47   7.2978 %

c   48   73.845 %

c   49   5.5322 %

c   50   5.4049 %

22046.80c -1.58402e-005

22047.80c -1.45956e-005

22048.80c -0.00014769

22049.80c -1.10644e-005

22050.80c -1.08098e-005

c Vanadium

c   0.01 wt %

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass   Mass Fraction

c   50   0.24512 %

c   51   99.755 %

23050.80c -2.4512e-007

23051.80c -9.97549e-005

c

c   3003 aluminum

c   average values where a range is specified

```
c    half of max values where only a maximum is specified
c    density 2.73 g/cc
c
m3   13027.80c  -0.97925
c     29000.xxx  -0.00125
     29063.80c  -0.000856 29065.80c  -0.000394
c     26000.xxx  -0.0035
     26054.80c  -0.000198 26056.80c  -0.003217 26057.80c  -0.000076
     26058.80c  -0.000010
     25055.80c  -0.0125
c     14000.xxx  -0.003
     14028.80c  -0.002756 14029.80c  -0.000145 14030.80c  -0.000099
c  Tin
c      0.05 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        112           0.91439 %
c        114           0.63327 %
c        115           0.3291 %
c        116          14.196 %
c        117           7.5631 %
c        118          24.055 %
c        119           8.604 %
```

```
c        120          32.907 %
c        122           4.7545 %
c        124           6.0434 %
     50112.80c -4.57196e-006
     50114.80c -3.16636e-006
     50115.80c -1.64548e-006
     50116.80c -7.09801e-005
     50117.80c -3.78154e-005
     50118.80c -0.000120275
     50119.80c -4.30199e-005
     50120.80c -0.000164536
     50122.80c -2.37727e-005
     50124.80c -3.0217e-005
c
c    water
c      Temperature: 25 C
c      rho: 0.99705
c
m4    1001.80c  6.6659E-2
     8016.80c  3.3329E-2
c mt4   hh2o.25t
c
c    water for reflector
```

```
c      Temperature: 25 deg C
c      rho: 0.99704
c
m40   1001.80c  6.6659E-2
      8016.80c  3.3329E-2
c mt40  hh2o.25t
c
c    stainless steel 304
c    0.19 Cr, 0.0925 Ni, 0.02 Mn, 0.01 Si, balance (0.6875) Fe
c    density 7.9
c
m5   14028.80c  -0.009187 14029.80c  -0.000483 14030.80c  -0.000329
     24050.80c  -0.00794  24052.80c  -0.15903  24053.80c  -0.01838
     24054.80c  -0.00465
     25055.80c  -0.02
     26054.80c  -0.03851  26056.80c  -0.63213  26057.80c  -0.01472
     26058.80c  -0.00214
     28058.80c  -0.06237  28060.80c  -0.02465  28061.80c  -0.00106
     28062.80c  -0.00351  28064.80c  -0.00091
c
c    polyethylene (CH2)
c      density 0.93
c
```

```
m7    6000.80c  1          1001.80c  2
mt7   poly.20t
c
c    Boron Carbide (B4C)
c      crystal density 2.52 g/cc (Hdbk Chem/Phys, 64th ed, p. B-76)
c      max packing density (1.7 per Jim Fisk)
c      the pellets supplied by Framatome ANP will be 70-76% of theoretical
c        density - 1.764 - 1.9152 g/cc
c      these atom densities give a mass density of 1.5 g/cc
c
m8    5010.80c  1.2968E-2  5011.80c  5.2197E-2
      6000.80c  1.6320E-2
c     26000.xxx  1.6175E-5
c  Iron
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        54            5.845 %
c        56           91.754 %
c        57            2.119 %
c        58            0.282 %
      26054.80c 9.45429e-007
      26056.80c 1.48412e-005
      26057.80c 3.42748e-007
```

```
     26058.80c 4.56135e-008
c     14000.xxx  3.2163E-6
c  Silicon
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        28           92.2297 %
c        29            4.6832 %
c        30            3.0872 %
     14028.80c 2.96638e-006
     14029.80c 1.50626e-007
     14030.80c 9.92936e-008
    15031.80c  5.8328E-6
    16032.80c  5.6341E-6
     7014.80c  3.8695E-5
     8016.80c  5.6460E-5
c
c
c    aluminum tooling plate
c    composition from certified test report
c    density 2.70
c
m9   13027.80c  -0.9229
c  Silicon
```

```
c     0.5 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        28          91.873 %
c        29           4.8318 %
c        30           3.2948 %
      14028.80c -0.00459367
      14029.80c -0.000241589
      14030.80c -0.000164739
c  Iron
c     0.6 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        54           5.6456 %
c        56          91.902 %
c        57           2.1604 %
c        58           0.29254 %
      26054.80c -0.000338733
      26056.80c -0.00551409
      26057.80c -0.000129622
      26058.80c -1.75527e-005
c  Copper
c     1.2 wt %
```

```
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        63           68.499 %
c        65           31.501 %
     29063.80c -0.00821993
     29065.80c -0.00378007
     25055.80c -0.0075
c  Magnesium
c     1.6 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        24           77.95 %
c        25           10.28 %
c        26           11.77 %
     12024.80c -0.012472
     12025.80c -0.00164482
     12026.80c -0.00188319
c  Chromium
c     0.06 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        50            4.1737 %
c        52           83.699 %
```

c 53 9.6736 %

c 54 2.4534 %

24050.80c -2.50421e-005

24052.80c -0.000502196

24053.80c -5.80415e-005

24054.80c -1.47202e-005

c Zinc

c 3 wt %

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Mass Fraction

c 64 47.54 %

c 66 28.126 %

c 67 4.196 %

c 68 19.475 %

c 70 0.66295 %

30064.80c -0.0142619

30066.80c -0.0084379

30067.80c -0.00125881

30068.80c -0.00584256

30070.80c -0.000198884

c

c stainless steel 316L

c 0.17 Cr, 0.12 Ni, 0.01 Mn, 0.00015 C, 0.000225 P, 0.00015 S

```
c   0.005 Si, 0.0025 Mo, balance (0.669475) Fe
c   density 8.0
c
m10
c  Iron 0.057754
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        54            5.845 %
c        56           91.754 %
c        57            2.119 %
c        58            0.282 %
     26054.80c 0.00337572
     26056.80c 0.0529916
     26057.80c 0.00122381
     26058.80c 0.000162866
c  Chromium 0.015751
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        50            4.345 %
c        52           83.789 %
c        53            9.501 %
c        54            2.365 %
     24050.80c 0.000684381
```

```
     24052.80c 0.0131976
     24053.80c 0.0014965
     24054.80c 0.000372511
c  Nickel 0.0098498
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        58           68.0769 %
c        60           26.2231 %
c        61            1.1399 %
c        62            3.6345 %
c        64            0.9256 %
     28058.80c 0.00670544
     28060.80c 0.00258292
     28061.80c 0.000112278
     28062.80c 0.000357991
     28064.80c 9.11697e-005
c  Manganese 0.00087692
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        55           100 %
     25055.80c 0.00087692
c  Carbon 6.0167e-005
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
```

c Isotopic Mass Atom Fraction

c 12 98.93 %

c 13 1.07 %

6000.80c 6.0167e-005

c Phosphorus 6.0167e-005

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Atom Fraction

c 31 100 %

15031.80c 6.0167e-005

c Sulfur 2.2536e-005

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Atom Fraction

c 32 94.93 %

c 33 0.76 %

c 34 4.29 %

c 36 0.02 %

16032.80c 2.13934e-005

16033.80c 1.71274e-007

16034.80c 9.66794e-007

16036.80c 4.5072e-009

c Silicon 2.2536e-005

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Atom Fraction

c 28 92.2297 %

c 29 4.6832 %

c 30 3.0872 %

14028.80c 2.07849e-005

14029.80c 1.05541e-006

14030.80c 6.95731e-007

c Molybdenum 0.0012554

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Atom Fraction

c 92 14.84 %

c 94 9.25 %

c 95 15.92 %

c 96 16.68 %

c 97 9.55 %

c 98 24.13 %

c 100 9.63 %

42092.80c 0.000186301

42094.80c 0.000116125

42095.80c 0.00019986

42096.80c 0.000209401

42097.80c 0.000119891

42098.80c 0.000302928

42100.80c 0.000120895

```
c
c    Tantalum  16.65 g/cc
c
c  Tantalum 5.5413E-02
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        180           0.012 %
c        181          99.988 %
m11
     73180.80c 6.64956E-06
     73181.80c 5.54064E-02
c
c   6061 aluminum
c   composition from Kaiser certified test report
c   density 2.700
c
m12
     13027.80c  -0.9770
c  Silicon
c     0.62 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        28          91.873 %
```

c 29 4.8318 %

c 30 3.2948 %

14028.80c -0.00569615

14029.80c -0.000299571

14030.80c -0.000204276

c Iron

c 0.17 wt %

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Mass Fraction

c 54 5.6456 %

c 56 91.902 %

c 57 2.1604 %

c 58 0.29254 %

26054.80c -9.59745e-005

26056.80c -0.00156233

26057.80c -3.67263e-005

26058.80c -4.97325e-006

c Copper

c 0.23 wt %

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Mass Fraction

c 63 68.499 %

c 65 31.501 %

29063.80c -0.00157549

29065.80c -0.000724513

c Manganese

25055.80c -0.0002

c Magnesium

c 1.2 wt %

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Mass Fraction

c 24 77.95 %

c 25 10.28 %

c 26 11.77 %

12024.80c -0.009354

12025.80c -0.00123361

12026.80c -0.00141239

c Chromium

c 0.06 wt %

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Mass Fraction

c 50 4.1737 %

c 52 83.699 %

c 53 9.6736 %

c 54 2.4534 %

24050.80c -2.50421e-005

```
     24052.80c -0.000502196
     24053.80c -5.80415e-005
     24054.80c -1.47202e-005
c
c  Cadmium
c    Density 8.64 g/cc (matweb.com)
c
m13
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        106            1.25 %
c        108            0.89 %
c        110           12.49 %
c        111           12.8 %
c        112           24.13 %
c        113           12.22 %
c        114           28.73 %
c        116            7.49 %
     48106.80c 1.25E-02
     48108.80c 8.9E-03
     48110.80c 1.249E-01
     48111.80c 1.28E-01
     48112.80c 2.413E-01
```

```
     48113.80c 1.222E-01
     48114.80c 2.873E-01
     48116.80c 7.49E-02
c
c     fully enriched uranium for PPS detectors
m19    92235.80c -0.93      92238.80c -0.07
c
c  ACRR materials - added 30 to material number
c
c      original fuel in code short on U-235 by 3.6 gm (97.536 gm should be 101.1211 gm)
c         c     uo2-beo fuel (3.276 g/cc)
c       m1      4009.50c -0.27958     8016.50c -0.52162    92235.50c -6.3958e-2
c             92238.50c -1.2238e-1  92234.50c -4.5605e-4  92236.50c -4.3631e-4
c             41093.50c -0.01157
c      uo2-beo fuel (3.276 g/cc with no hole)
m31      4009.80c -0.282817
       8016.80c -0.527675
                  92235.80c -6.6309e-2
       92238.80c -1.22309e-1
                  92234.80c -4.5482e-4
                  92236.80c -4.3587e-4
mt31 beo.60t
c       no nb mixed in       41093.50c -0.01157
```

```
c    water (1 g/cc)
m32     1001.80c  2          8016.80c  1
c    ss 304 (7.95 g/cc)
m33
c  Silicon
c     0.59 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        28          91.873 %
c        29           4.8318 %
c        30           3.2948 %
      14028.80c -0.00542053
      14029.80c -0.000285075
      14030.80c -0.000194392
       24050.80c -0.00806  24052.80c -0.15526
       24053.80c -0.01760  24054.80c -0.00437
       25055.80c -0.017  26054.80c -0.03993  26056.80c -0.63126
       26057.80c -0.01473  26058.80c -0.00213
       28058.80c -0.07062  28060.80c -0.026987 28061.80c -0.00114
       28062.80c -0.00372  28064.80c -0.00093
c    niobium (8.4 g/cc)
m34    41093.80c  1
c    beo (2.8 g/cc)
```

```
m37     4009.80c  0.5         8016.80c  0.5

mt37 beo.60t

c    al 6061 (2.7 g/cc)

m38

c  Magnesium

c     1 wt %

c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.

c  Isotopic Mass    Mass Fraction

c        24          77.95 %

c        25          10.28 %

c        26          11.77 %

     12024.80c -0.007795

     12025.80c -0.00102801

     12026.80c -0.00117699

      13027.80c -0.968

c  Silicon

c     0.6 wt %

c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.

c  Isotopic Mass    Mass Fraction

c        28          91.873 %

c        29           4.8318 %

c        30           3.2948 %

     14028.80c -0.00551241
```

```
     14029.80c -0.000289907
     14030.80c -0.000197686
c  Chromium
c     0.35 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        50           4.1737 %
c        52          83.699 %
c        53           9.6736 %
c        54           2.4534 %
     24050.80c -0.000146079
     24052.80c -0.00292948
     24053.80c -0.000338576
     24054.80c -8.58677e-005
      25055.80c -0.0015
c  Iron
c     0.7 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        54           5.6456 %
c        56          91.902 %
c        57           2.1604 %
c        58           0.29254 %
```

```
     26054.80c -0.000395189
     26056.80c -0.00643311
     26057.80c -0.000151226
     26058.80c -2.04781e-005
c  Copper
c     0.4 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        63          68.499 %
c        65          31.501 %
     29063.80c -0.00273998
     29065.80c -0.00126002
c
c  END of ACRR fuel materials
c
f1014:n     (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179
          1184 1185 1186 1187 1192 1193 1194 1195< (996 [-2 -2 0]))
f1024:n     (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179
          1184 1185 1186 1187 1192 1193 1194 1195< (996 [-2 -1 0]))
f1034:n     (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179
          1184 1185 1186 1187 1192 1193 1194 1195< (996 [-2 0 0]))
f1044:n     (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179
          1184 1185 1186 1187 1192 1193 1194 1195< (996 [-2 1 0]))
```

f1054:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [-2 2 0]))

f1064:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [-1 -2 0]))

f1074:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [-1 -1 0]))

f1084:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [-1 0 0]))

f1094:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [-1 1 0]))

f1104:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [-1 2 0]))

f1114:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [0 -2 0]))

f1124:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [0 -1 0]))

f1134:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [0 0 0]))

f1144:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [0 1 0]))

f1154:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [0 2 0]))

f1164:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179

1184 1185 1186 1187 1192 1193 1194 1195< (996 [1 -2 0]))

f1174:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179

1184 1185 1186 1187 1192 1193 1194 1195< (996 [1 -1 0]))

f1184:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179

1184 1185 1186 1187 1192 1193 1194 1195< (996 [1 0 0]))

f1194:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179

1184 1185 1186 1187 1192 1193 1194 1195< (996 [1 1 0]))

f1204:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179

1184 1185 1186 1187 1192 1193 1194 1195< (996 [1 2 0]))

f1214:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179

1184 1185 1186 1187 1192 1193 1194 1195< (996 [2 -2 0]))

f1224:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179

1184 1185 1186 1187 1192 1193 1194 1195< (996 [2 -1 0]))

f1234:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179

1184 1185 1186 1187 1192 1193 1194 1195< (996 [2 0 0]))

f1244:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179

1184 1185 1186 1187 1192 1193 1194 1195< (996 [2 1 0]))

f1254:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179

1184 1185 1186 1187 1192 1193 1194 1195< (996 [2 2 0]))

f1004:n (1 < (999 [-7:7 -7:7 0])) (2 < (999 [-7:7 -7:7 0]))

(3 < (999 [-7:7 -7:7 0])) (4 < (999 [-7:7 -7:7 0]))

(5 < (999 [-7:7 -7:7 0])) (6 < (999 [-7:7 -7:7 0]))

(7 < (999 [-7:7 -7:7 0]))

```
     t
c
f4:n    (1 < (999 [-7:7 -7:7 0])) (2 < (999 [-7:7 -7:7 0]))
     (3 < (999 [-7:7 -7:7 0])) (4 < (999 [-7:7 -7:7 0]))
     (5 < (999 [-7:7 -7:7 0])) (6 < (999 [-7:7 -7:7 0]))
     (7 < (999 [-7:7 -7:7 0]))
     t
fc4  Neutron Flux in the Fuel Underwater in the Central Assembly
c    238-group SCALE structure
e4        1e-011     1e-010     5e-010   7.5e-010     1e-009
       1.2e-009   1.5e-009     2e-009   2.5e-009     3e-009
         4e-009     5e-009   7.5e-009     1e-008  2.53e-008
         3e-008     4e-008     5e-008     6e-008     7e-008
         8e-008     9e-008     1e-007  1.25e-007    1.5e-007
      1.75e-007     2e-007  2.25e-007    2.5e-007  2.75e-007
         3e-007  3.25e-007    3.5e-007  3.75e-007     4e-007
       4.5e-007     5e-007    5.5e-007    6e-007  6.25e-007
       6.5e-007     7e-007    7.5e-007    8e-007   8.5e-007
         9e-007  9.25e-007    9.5e-007  9.75e-007     1e-006
      1.01e-006  1.02e-006  1.03e-006  1.04e-006  1.05e-006
      1.06e-006  1.07e-006  1.08e-006  1.09e-006   1.1e-006
      1.11e-006  1.12e-006  1.13e-006  1.14e-006  1.15e-006
     1.175e-006   1.2e-006 1.225e-006  1.25e-006   1.3e-006
```

1.35e-006	1.4e-006	1.45e-006	1.5e-006	1.59e-006
1.68e-006	1.77e-006	1.86e-006	1.94e-006	2e-006
2.12e-006	2.21e-006	2.3e-006	2.38e-006	2.47e-006
2.57e-006	2.67e-006	2.77e-006	2.87e-006	2.97e-006
3e-006	3.05e-006	3.15e-006	3.5e-006	3.73e-006
4e-006	4.75e-006	5e-006	5.4e-006	6e-006
6.25e-006	6.5e-006	6.75e-006	7e-006	7.15e-006
8.1e-006	9.1e-006	1e-005	1.15e-005	1.19e-005
1.29e-005	1.375e-005	1.44e-005	1.51e-005	1.6e-005
1.7e-005	1.85e-005	1.9e-005	2e-005	2.1e-005
2.25e-005	2.5e-005	2.75e-005	3e-005	3.125e-005
3.175e-005	3.325e-005	3.375e-005	3.46e-005	3.55e-005
3.7e-005	3.8e-005	3.91e-005	3.96e-005	4.1e-005
4.24e-005	4.4e-005	4.52e-005	4.7e-005	4.83e-005
4.92e-005	5.06e-005	5.2e-005	5.34e-005	5.9e-005
6.1e-005	6.5e-005	6.75e-005	7.2e-005	7.6e-005
8e-005	8.2e-005	9e-005	0.0001	0.000108
0.000115	0.000119	0.000122	0.000186	0.0001925
0.0002075	0.00021	0.00024	0.000285	0.000305
0.00055	0.00067	0.000683	0.00095	0.00115
0.0015	0.00155	0.0018	0.0022	0.00229
0.00258	0.003	0.00374	0.0039	0.006
0.00803	0.0095	0.013	0.017	0.025

```
        0.03    0.045    0.05    0.052    0.06
        0.073    0.075    0.082    0.085    0.1
        0.1283    0.15    0.2    0.27    0.33
        0.4    0.42    0.44    0.47    0.4995
        0.55    0.573    0.6    0.67    0.679
        0.75    0.82    0.8611    0.875    0.9
        0.92    1.01    1.1    1.2    1.25
        1.317    1.356    1.4    1.5    1.85
        2.354    2.479    3    4.304    4.8
        6.434    8.187    10    12.84    13.84
        14.55    15.68    17.33    20
c
f14:n   1   2   3   4   5   6   7
     451 452 453 454 455 456 457
     551 552 553 554 555 556 557
     651 652 653 654 655 656 657  t
fc14   Neutron Flux in the Fuel Underwater Everywhere
c    238-group SCALE structure
e14       1e-011    1e-010    5e-010    7.5e-010    1e-009
        1.2e-009    1.5e-009    2e-009    2.5e-009    3e-009
        4e-009    5e-009    7.5e-009    1e-008    2.53e-008
        3e-008    4e-008    5e-008    6e-008    7e-008
        8e-008    9e-008    1e-007    1.25e-007    1.5e-007
```

1.75e-007	2e-007	2.25e-007	2.5e-007	2.75e-007
3e-007	3.25e-007	3.5e-007	3.75e-007	4e-007
4.5e-007	5e-007	5.5e-007	6e-007	6.25e-007
6.5e-007	7e-007	7.5e-007	8e-007	8.5e-007
9e-007	9.25e-007	9.5e-007	9.75e-007	1e-006
1.01e-006	1.02e-006	1.03e-006	1.04e-006	1.05e-006
1.06e-006	1.07e-006	1.08e-006	1.09e-006	1.1e-006
1.11e-006	1.12e-006	1.13e-006	1.14e-006	1.15e-006
1.175e-006	1.2e-006	1.225e-006	1.25e-006	1.3e-006
1.35e-006	1.4e-006	1.45e-006	1.5e-006	1.59e-006
1.68e-006	1.77e-006	1.86e-006	1.94e-006	2e-006
2.12e-006	2.21e-006	2.3e-006	2.38e-006	2.47e-006
2.57e-006	2.67e-006	2.77e-006	2.87e-006	2.97e-006
3e-006	3.05e-006	3.15e-006	3.5e-006	3.73e-006
4e-006	4.75e-006	5e-006	5.4e-006	6e-006
6.25e-006	6.5e-006	6.75e-006	7e-006	7.15e-006
8.1e-006	9.1e-006	1e-005	1.15e-005	1.19e-005
1.29e-005	1.375e-005	1.44e-005	1.51e-005	1.6e-005
1.7e-005	1.85e-005	1.9e-005	2e-005	2.1e-005
2.25e-005	2.5e-005	2.75e-005	3e-005	3.125e-005
3.175e-005	3.325e-005	3.375e-005	3.46e-005	3.55e-005
3.7e-005	3.8e-005	3.91e-005	3.96e-005	4.1e-005
4.24e-005	4.4e-005	4.52e-005	4.7e-005	4.83e-005

```
4.92e-005   5.06e-005   5.2e-005   5.34e-005   5.9e-005
6.1e-005   6.5e-005   6.75e-005   7.2e-005   7.6e-005
8e-005   8.2e-005   9e-005   0.0001   0.000108
0.000115   0.000119   0.000122   0.000186   0.0001925
0.0002075   0.00021   0.00024   0.000285   0.000305
0.00055   0.00067   0.000683   0.00095   0.00115
0.0015   0.00155   0.0018   0.0022   0.00229
0.00258   0.003   0.00374   0.0039   0.006
0.00803   0.0095   0.013   0.017   0.025
0.03   0.045   0.05   0.052   0.06
0.073   0.075   0.082   0.085   0.1
0.1283   0.15   0.2   0.27   0.33
0.4   0.42   0.44   0.47   0.4995
0.55   0.573   0.6   0.67   0.679
0.75   0.82   0.8611   0.875   0.9
0.92   1.01   1.1   1.2   1.25
1.317   1.356   1.4   1.5   1.85
2.354   2.479   3   4.304   4.8
6.434   8.187   10   12.84   13.84
14.55   15.68   17.33   20
c
*f7:n   1  2  3  4  5  6  7  t
fc7 Fission Dep in all ordinary fuel underwater - not normalized as others
```

```
c
*f17:n    451 452 453 454 455 456 457
          551 552 553 554 555 556 557
          651 652 653 654 655 656 657 t
fc17 Fission Dep in all CE/SE fuel underwater - not normalized as others
c
        t
c
c  the PPS detectors
c
*f687:n    1040
*f697:n    1042
*f787:n    1041
*f797:n    1043
c
c  Neutron spectrum in the experiment rod detectors
c
fc914 Neutron spectrum in central 4 cm of the experiment rods
f914:n    1901 1902 1903 1904 1905 1906 1907 1908 1909
          1910  t
c
c     238-group SCALE structure
e914          1e-011      1e-010      5e-010    7.5e-010      1e-009
```

1.2e-009	1.5e-009	2e-009	2.5e-009	3e-009
4e-009	5e-009	7.5e-009	1e-008	2.53e-008
3e-008	4e-008	5e-008	6e-008	7e-008
8e-008	9e-008	1e-007	1.25e-007	1.5e-007
1.75e-007	2e-007	2.25e-007	2.5e-007	2.75e-007
3e-007	3.25e-007	3.5e-007	3.75e-007	4e-007
4.5e-007	5e-007	5.5e-007	6e-007	6.25e-007
6.5e-007	7e-007	7.5e-007	8e-007	8.5e-007
9e-007	9.25e-007	9.5e-007	9.75e-007	1e-006
1.01e-006	1.02e-006	1.03e-006	1.04e-006	1.05e-006
1.06e-006	1.07e-006	1.08e-006	1.09e-006	1.1e-006
1.11e-006	1.12e-006	1.13e-006	1.14e-006	1.15e-006
1.175e-006	1.2e-006	1.225e-006	1.25e-006	1.3e-006
1.35e-006	1.4e-006	1.45e-006	1.5e-006	1.59e-006
1.68e-006	1.77e-006	1.86e-006	1.94e-006	2e-006
2.12e-006	2.21e-006	2.3e-006	2.38e-006	2.47e-006
2.57e-006	2.67e-006	2.77e-006	2.87e-006	2.97e-006
3e-006	3.05e-006	3.15e-006	3.5e-006	3.73e-006
4e-006	4.75e-006	5e-006	5.4e-006	6e-006
6.25e-006	6.5e-006	6.75e-006	7e-006	7.15e-006
8.1e-006	9.1e-006	1e-005	1.15e-005	1.19e-005
1.29e-005	1.375e-005	1.44e-005	1.51e-005	1.6e-005
1.7e-005	1.85e-005	1.9e-005	2e-005	2.1e-005

2.25e-005	2.5e-005	2.75e-005	3e-005	3.125e-005
3.175e-005	3.325e-005	3.375e-005	3.46e-005	3.55e-005
3.7e-005	3.8e-005	3.91e-005	3.96e-005	4.1e-005
4.24e-005	4.4e-005	4.52e-005	4.7e-005	4.83e-005
4.92e-005	5.06e-005	5.2e-005	5.34e-005	5.9e-005
6.1e-005	6.5e-005	6.75e-005	7.2e-005	7.6e-005
8e-005	8.2e-005	9e-005	0.0001	0.000108
0.000115	0.000119	0.000122	0.000186	0.0001925
0.0002075	0.00021	0.00024	0.000285	0.000305
0.00055	0.00067	0.000683	0.00095	0.00115
0.0015	0.00155	0.0018	0.0022	0.00229
0.00258	0.003	0.00374	0.0039	0.006
0.00803	0.0095	0.013	0.017	0.025
0.03	0.045	0.05	0.052	0.06
0.073	0.075	0.082	0.085	0.1
0.1283	0.15	0.2	0.27	0.33
0.4	0.42	0.44	0.47	0.4995
0.55	0.573	0.6	0.67	0.679
0.75	0.82	0.8611	0.875	0.9
0.92	1.01	1.1	1.2	1.25
1.317	1.356	1.4	1.5	1.85
2.354	2.479	3	4.304	4.8
6.434	8.187	10	12.84	13.84

```
         14.55       15.68       17.33         20
c
c  experiment rod detectors
c
fc924 Captures in the central 4 cm of the experiment rods
f924:n    1901 1902 1903 1904 1905 1906 1907 1908 1909
          1910  t
fm924   (1 11 102) $ experiment rod captures
c
c     238-group SCALE structure
e924          1e-011      1e-010      5e-010    7.5e-010      1e-009
          1.2e-009    1.5e-009      2e-009    2.5e-009      3e-009
            4e-009      5e-009    7.5e-009      1e-008   2.53e-008
            3e-008      4e-008      5e-008      6e-008      7e-008
            8e-008      9e-008      1e-007   1.25e-007    1.5e-007
         1.75e-007      2e-007   2.25e-007    2.5e-007   2.75e-007
            3e-007   3.25e-007    3.5e-007   3.75e-007      4e-007
          4.5e-007      5e-007    5.5e-007      6e-007   6.25e-007
          6.5e-007      7e-007    7.5e-007      8e-007    8.5e-007
            9e-007   9.25e-007    9.5e-007   9.75e-007      1e-006
         1.01e-006   1.02e-006   1.03e-006   1.04e-006   1.05e-006
         1.06e-006   1.07e-006   1.08e-006   1.09e-006    1.1e-006
         1.11e-006   1.12e-006   1.13e-006   1.14e-006   1.15e-006
```

1.175e-006	1.2e-006	1.225e-006	1.25e-006	1.3e-006
1.35e-006	1.4e-006	1.45e-006	1.5e-006	1.59e-006
1.68e-006	1.77e-006	1.86e-006	1.94e-006	2e-006
2.12e-006	2.21e-006	2.3e-006	2.38e-006	2.47e-006
2.57e-006	2.67e-006	2.77e-006	2.87e-006	2.97e-006
3e-006	3.05e-006	3.15e-006	3.5e-006	3.73e-006
4e-006	4.75e-006	5e-006	5.4e-006	6e-006
6.25e-006	6.5e-006	6.75e-006	7e-006	7.15e-006
8.1e-006	9.1e-006	1e-005	1.15e-005	1.19e-005
1.29e-005	1.375e-005	1.44e-005	1.51e-005	1.6e-005
1.7e-005	1.85e-005	1.9e-005	2e-005	2.1e-005
2.25e-005	2.5e-005	2.75e-005	3e-005	3.125e-005
3.175e-005	3.325e-005	3.375e-005	3.46e-005	3.55e-005
3.7e-005	3.8e-005	3.91e-005	3.96e-005	4.1e-005
4.24e-005	4.4e-005	4.52e-005	4.7e-005	4.83e-005
4.92e-005	5.06e-005	5.2e-005	5.34e-005	5.9e-005
6.1e-005	6.5e-005	6.75e-005	7.2e-005	7.6e-005
8e-005	8.2e-005	9e-005	0.0001	0.000108
0.000115	0.000119	0.000122	0.000186	0.0001925
0.0002075	0.00021	0.00024	0.000285	0.000305
0.00055	0.00067	0.000683	0.00095	0.00115
0.0015	0.00155	0.0018	0.0022	0.00229
0.00258	0.003	0.00374	0.0039	0.006

```
          0.00803    0.0095    0.013    0.017    0.025
          0.03    0.045    0.05    0.052    0.06
          0.073    0.075    0.082    0.085    0.1
          0.1283    0.15    0.2    0.27    0.33
          0.4    0.42    0.44    0.47    0.4995
          0.55    0.573    0.6    0.67    0.679
          0.75    0.82    0.8611    0.875    0.9
          0.92    1.01    1.1    1.2    1.25
          1.317    1.356    1.4    1.5    1.85
          2.354    2.479    3    4.304    4.8
          6.434    8.187    10    12.84    13.84
          14.55    15.68    17.33    20
c
c  experiment rod detectors
c
fc904 Captures in the central 4 cm of the experiment rods
f904:n    1901 1902 1903 1904 1905 1906 1907 1908 1909
      1910  t
fm904   (1 11 102) $ experiment rod captures
c
c
c
imp:n    1 480r 0
```

```
mode   n

kcode  10000  1  50  200

ksrc   10 10 17.55

ksen1 xs iso=92235.80c 92238.80c 4009.80c MT=2 18 -2

prdmp    0  0  0  1

print    -128

lost   1000 10

tr4   0.   0.   0.  $ SE1 0=up  -68.57746=down

tr5   0.   0.   0.  $ SE2 0=up  -68.57746=down

tr6   0.   0.   0.  $ CE  0=up  -68.57746=down

tr9   0.   0. -23.0394 $ ACRR fuel element

kopts  kinetics=yes

c ctme   125
```

APPENDIX C.

MCNP6.2 FINAL DESIGN MODEL

```
1531 fuel rods in 1531 total positions
c
c  Core water (m4) and reflector water (m40) are separate
c  Reflector is at 25 deg C, density 0.99704 g/cc
c    note that this density is not exactly the 25 deg C density (0.99705 g/cc)
c    so the density can be changed separately from the core water density
c
c   fuel rod with grid plates
c
 1     1  -10.265   -1   40  -41       u=1  $ 1st midplane fuel
 2     1  -10.265   -1   41  -42       u=1  $ 2nd midplane fuel
 3     1  -10.265   -1   42  -43       u=1  $ 3rd midplane fuel
 4     1  -10.265   -1   43  -44       u=1  $ 4th midplane fuel
 5     1  -10.265   -1   12  -23       u=1  $ bottom fuel
 6     1  -10.265   -1   45 -100  -13  u=1  $ top fuel underwater
 7     1  -10.265   -1   23  -45 -100       $ rest of the fuel underwater
                  (1 : -40 : 44)     u=1    $ midplane fuel
 8     1  -10.265   -1  100  -13       u=1  $ fuel above water
15     0             1   -2   12  -13  u=1  $ gap at fuel
16     0            -5   13  -24       u=1  $ void inside spring
17     5  -1.6226    5   -6   13  -24  u=1  $ spring
18     0             6   -2   13  -24  u=1  $ gap at spring
19     2  -2.700    -7   24  -25       u=1  $ aluminum spacer
```

```
20    0           7   -2   24  -25  u=1  $ gap at aluminum spacer
21    7  -0.93     -8   25  -16      u=1  $ poly plug
22    0           8   -2   25  -16  u=1  $ gap at poly plug
23    3  -2.73     -3    2   17  -18  u=1  $ clad
24    3  -2.73     -3   11  -12          $ bottom plug
                (3 : -2 : -17 : 18) u=1   $ clad
25    3  -2.73     -3   16  -19          $ top plug
                (26 : -27 : 19)         $ hole at top
                (3 : -2 : -17 : 18) u=1   $ clad
26   40  -0.99704 -10 -100           u=1 $ water below grid plate
27    2  -2.700    10  -11 :  4   11      $ bottom grid plate
               -12               u=1
28    4  -0.99705  -4    3   11  -12   u=1 $ water in lower grid plate
29    4  -0.99705   3   12  -14 -100   u=1 $ water between grid plates
30    4  -0.99705   3   -4   14  -15      $ water in upper grid plate
              -100               u=1
31    2  -2.700     4   14  -15       u=1 $ upper grid plate
32   40  -0.99704  15 -100               $ water above grid plate
                (3 : -17 : 18)      $ clad
                (3 : -16 : 19)     u=1   $ top plug
33    0          -10  100           u=1 $ void below grid plate
34    0            3   12  -14  100   u=1 $ void between grid plates
35    0            3   -4   14  -15      $ void in upper grid plate
```

```
                 100              u=1
36    0          15  100  -28          $ void between grid plate and guide plate
                 (3 : -17 : 18)     u=1   $ clad
37    0         -26   27  -19       u=1 $ hole in top plug
38    9  -2.70      4   28  -29       u=1 $ guide plate (always above water)
39    0           3   -4   28  -29   u=1 $ hole in guide plate
40    0          29                   $ void above guide plate
                 (3 : -17 : 18)         $ clad
                 (3 : -16 : 19)     u=1   $ top plug
c
c  cell with grid/guide plates
c
1301   40  -0.99704 -10 -100            u=3 $ water below grid plate
1302    2  -2.700    10  -12            u=3 $ bottom grid plate
1303   40  -0.99704  12  -14 -100       u=3 $ water between grid plates
1304    2  -2.700    14  -15            u=3 $ upper grid plate
1305   40  -0.99704  15 -100            u=3 $ water above grid plate
1306    0          -10  100            u=3 $ void below grid plate
1307    0           12  -14  100       u=3 $ void between grid plates
1308    0           14  -15  100       u=3 $ void in upper grid plate
1309    0           15  100  -28       u=3 $ void between grid plate and guide plate
1310    9  -2.70     28  -29            u=3 $ guide plate (always above water)
1311    0           29  100            u=3 $ void above guide plate
```

```
c
c  Experiment Rod - Tantalum
c
1901  11 -16.65     93  -94   -91  9001 u=9
1902  11 -16.65     93  -94 -9001  9002 u=9
1903  11 -16.65     93  -94 -9002  9003 u=9
1904  11 -16.65     93  -94 -9003  9004 u=9
1905  11 -16.65     93  -94 -9004  9005 u=9
1906  11 -16.65     93  -94 -9005  9006 u=9
1907  11 -16.65     93  -94 -9006  9007 u=9
1908  11 -16.65     93  -94 -9007  9008 u=9
1909  11 -16.65     93  -94 -9008  9009 u=9
1910  11 -16.65     93  -94 -9009  9010 u=9
1911  11 -16.65     93  -94 -9010       u=9
1920  11 -16.65    -91    11   -92
                (-93 : 94)          u=9
1926  40  -0.99704 -10 -100            u=9 $ water below grid plate
1927   2  -2.700    10  -11 :  4   11       $ bottom grid plate
                -12                 u=9
1928   0           -4   91   11  -12   u=9 $ void in lower grid plate
1929   0            91   12  -14 -100   u=9 $ void between grid plates
1930   0            91   -4   14  -15       $ void in upper grid plate
               -100                 u=9
```

```
1931   2  -2.700     4   14  -15        u=9 $ upper grid plate
1932   0           15 -100               $ void above grid plate
                ( 91 : -11 :  92)   u=9   $ experiment rod
1933   0          -10  100            u=9 $ void below grid plate
1934   0           91   12  -14  100   u=9 $ void between grid plates
1935   0           91   -4   14  -15       $ void in upper grid plate
               100                u=9
1936   0           15  100  -28           $ void between grid plate and guide plate
                ( 91 : -11 :  92)   u=9   $ experiment rod
1938   9  -2.70      4   28  -29        u=9 $ guide plate (always above water)
1939   0           91   -4   28  -29   u=9 $ hole in guide plate
1940   0           29                    $ void above guide plate
                ( 91 : -11 :  92)   u=9   $ experiment rod
c
c  a water cell in the core
c
114   40  -0.99704 -10 -100            u=7 $ water below grid plate
115    2  -2.700    10  -11 :  4   11       $ bottom grid plate
               -12                u=7
116    4  -0.99705  -4   11  -12        u=7 $ water in lower grid plate
117    4  -0.99705  12  -14 -100        u=7 $ water between grid plates
118    4  -0.99705  -4   14  -15 -100   u=7 $ water in upper grid plate
119    2  -2.700     4   14  -15        u=7 $ upper grid plate
```

```
120   40  -0.99704  15 -100           u=7 $ water above grid plate
122    0          -10  100            u=7 $ void below grid plate
123    0           12  -14  100       u=7 $ void between grid plates
124    0           -4   14  -15  100   u=7 $ void in upper grid plate
125    0           15  100  -28       u=7 $ void between grid plate and guide plate
126    9  -2.70      4   28  -29       u=7 $ guide plate (always above water)
127    0           -4   28  -29       u=7 $ hole in guide plate
128    0           29  100            u=7 $ void above guide plate
c
c  a water cell in the reflector
c
164   40  -0.99704 -10 -100           u=8 $ water below grid plate
165    2  -2.700    10  -11 :  4   11       $ bottom grid plate
                -12                 u=8
166   40  -0.99704  -4   11  -12       u=8 $ water in lower grid plate
167   40  -0.99704  12  -14 -100       u=8 $ water between grid plates
168   40  -0.99704  -4   14  -15 -100   u=8 $ water in upper grid plate
169    2  -2.700     4   14  -15       u=8 $ upper grid plate
170   40  -0.99704  15 -100           u=8 $ water above grid plate
172    0          -10  100            u=8 $ void below grid plate
173    0           12  -14  100       u=8 $ void between grid plates
174    0           -4   14  -15  100   u=8 $ void in upper grid plate
175    0           15  100  -28       u=8 $ void between grid plate and guide plate
```

```
176    9  -2.70      4   28  -29        u=8 $ guide plate (always above water)
177    0            -4   28  -29        u=8 $ hole in guide plate
178    0            29  100             u=8 $ void above guide plate
c
c   Source
c
201   10  8.6463E-02 231 -232 -233      u=2 $ source (SS316L)
202    5  -7.9      232 -235 -236       u=2 $ screw
203    3  -2.73     -2  232 -234            $ stick end
                (-232 : 235 : 236)    u=2   $ screw
204    3  -2.73      2   -3  237  -29   u=2 $ stick tube
205    4  -0.99705  -2  234 -100  -29   u=2 $ water in stick
206    0            -2  234  100  -29   u=2 $ void in stick
214   40  -0.99704 -10 -100             u=2 $ water below grid plate
215    2  -2.700    10  -11 :  4   11       $ bottom grid plate
                 -12                  u=2
216    4  -0.99705  -4   11  -12        u=2 $ water in lower grid plate
217    4  -0.99705  12  -14 -100            $ water between grid plates
                 (-231 : 232 : 233)         $ source
                 (2 : -232 : 234)           $ stick end
                 (3 : -237 : 19)      u=2   $ stick tube
218    4  -0.99705  -4   14  -15 -100       $ water in upper grid plate
                 (3 : -232 : 19)      u=2   $ stick
```

```
219   2  -2.700    4   14  -15       u=2 $ upper grid plate
220  40  -0.99704  15 -100              $ water between grid plate and guide plate
              (3 : -232 : 29)     u=2   $ stick
222   0         -10  100           u=2 $ void below grid plate
223   0          12  -14  100          $ void between grid plates
              (-231 : 232 : 233)       $ source
              (2 : -232 : 234)         $ stick end
              (3 : -237 : 19)     u=2   $ stick tube
224   0          -4   14  -15  100     $ void in upper grid plate
              (3 : -232 : 29)     u=2   $ stick
225   0          15  100  -28          $ void between grid plate and guide plate
              (3 : -232 : 29)     u=2   $ stick
226   9  -2.70     4   28  -29      u=2 $ guide plate
227   0           3   -4   28  -29   u=2 $ hole in guide plate
228   0          29  100               $ void above guide plate
              (238 : -29 : 239)   u=2   $ handle
229   2  -2.700  -238   29 -239       u=2 $ handle
c
c   Safety Element 1 with grid plates
c
451    1  -10.265   -1   40  -41 412 -413 u=4 $ 1st midplane fuel
452    1  -10.265   -1   41  -42 412 -413 u=4 $ 2nd midplane fuel
453    1  -10.265   -1   42  -43 412 -413 u=4 $ 3rd midplane fuel
```

```
454   1  -10.265   -1   43  -44 412 -413 u=4 $ 4th midplane fuel
455   1  -10.265   -1  412 -423         u=4 $ bottom fuel
456   1  -10.265   -1   45 -100 412 -413 u=4 $ top fuel underwater
457   1  -10.265   -1  423  -45 412 -413     $ rest of the fuel underwater
                  (1 : -40 : 44)       u=4   $ midplane fuel
458   1  -10.265   -1  100 -413         u=4 $ fuel above water
405   0          401 -402  412 -413   u=4 $ gap at fuel
406   0         -405  413 -414       u=4 $ void inside spring
407   5 -2.3628   405 -406  413 -414   u=4 $ spring
408   0          406 -402  413 -414   u=4 $ gap at spring
409   3 -2.73    -403  450 -451          $ fuel clad + part of caps
                (402 : -412 : 414)         $ inside of fueled section
                (437 : -411 : 438)         $ bottom screw
                (437 : -439 : 440)    u=4   $ top screw
412   3 -2.73    -447  448 -449          $ fueled section ends
                (-450 : 451)              $ fuel clad + part of caps
                (437 : -411 : 438)         $ bottom screw
                (437 : -439 : 440)    u=4   $ top screw
413   3 -2.73    -447  453 -454          $ top plug
                (437 : -439 : 440)         $ screw
                (437 : -460 : 461)         $ screw in 2nd middle BP
                (-455 : 456)          u=4   $ clad
414   3 -2.73    -403  455 -456          $ poly section clad tube
```

```
              (402 : -415 : 436)        $ inside
              (437 : -460 : 461)        $ screw in 2nd middle BP
           (437 : -439 : 440)      u=4   $ screw
416   7 -0.93    -401  415 -424      u=4 $ poly plug
417   0          401 -402  415 -424   u=4 $ gap at poly plug
418   0         -402  424 -436       u=4 $ void above poly
419   3 -2.73    -403  458 -459           $ absorber section clad tube
              (437 : -460 : 461)        $ screw in 2nd middle BP
              (437 : -444 : 443)        $ top screw
              (402 : -425 : 427)   u=4   $ inside
420   8 -1.500   -402  425 -426       u=4 $ absorber
421   0         -402  426 -427       u=4 $ gap above absorber
422   2 -2.700    441 -442                $ grid at poly-absorber interface
              (404 : -441 : 456)        $ water @ full dia rod
              (452 : -456 : 454)        $ water @ ends
              (404 : -458 : 442)        $ water @ full dia rod
              (452 : -457 : 458)        $ water @ ends
              (437 : -460 : 461)   u=4   $ screw in 2nd middle BP
423   2 -2.700    437  428 -443           $ grid at top of absorber
           (445 : -446 : 443)           $ cap screw head
           (437 : -444 : 446)      u=4   $ top screw
424  40 -0.99704 -430 -100               $ water below grid plate
           (403 : -411 : 428)      u=4   $ the entire rod
```

```
425    2 -2.700    430 -432                $ bottom bundle plate
            (404 : -450 : 432)         $ water @ full dia rod
            (452 : -448 : 450)         $ water @ ends
            (437 : -411 : 438)    u=4   $ bottom screw
426    4 -0.99705 403 -404  450 -432         $ water in lower grid plate
           : 447 -452 448 -450     u=4
427    4 -0.99705  432 -434 -100           $ water between grid plates
          (403 : -411 : 428)       u=4   $ the entire rod
428    4 -0.99705 403 -404  434 -451        $ water in upper grid plate
            -100
           : 447 -452 451 -449
            -100
           : 403 -404  455 -435
            -100
           : 447 -452 453 -455
            -100                u=4
429    2 -2.700    434 -435                $ 1st middle bundle plate
            (404 : -434 : 451)         $ water @ full dia rod
            (452 : -451 : 449)         $ water @ ends
            (404 : -455 : 435)         $ water @ full dia rod
            (452 : -453 : 455)         $ water @ ends
          (437 : -439 : 440)       u=4   $ top screw
430   40 -0.99704  435 -100               $ water above grid plate
```

```
          (-441 : 442)               $ grid at poly-absorber
          (-428 : 443)               $ grid at top of absorber
          (403 : -411 : 428)      u=4   $ the entire rod
432    0        -430  100              $ void below grid plate
          (403 : -411 : 428)      u=4   $ the entire rod
433    0         432 -434  100          $ void between grid plates
          (403 : -411 : 428)      u=4   $ the entire rod
434    0        403 -404  434 -451      $ void in upper grid plate
             100
           : 447 -452 451 -449
             100
           : 403 -404  455 -435
             100
           : 447 -452 453 -455
             100               u=4
435    0         435  100              $ void above grid plate
          (-441 : 442)               $ grid at poly-absorber
          (-428 : 443)               $ grid at top of absorber
          (447 : -459 : 428)           $ top end of absorber rod
          (403 : -411 : 459)      u=4   $ the entire rod
436    5 -7.9     -437 462 -438    u=4 $ bottom screw
437    5 -7.9     -437 439 -440       u=4 $ top screw
438    5 -7.9     -437 444 -446       u=4 $ screw body above absorber
```

```
439   5 -7.9     -445 446 -443         u=4 $ cap screw head
440   3 -2.73    -447 457 -428             $ fueled section ends
              (437 : -460 : 461)          $ screw in 2nd middle BP
            (437 : -444 : 443)            $ top screw
             (-458 : 459)         u=4    $ fuel clad + part of caps
441   4 -0.99705 403 -404 441 -456         $ water in 2nd middle bundle plate
              -100
            : 447 -452 456 -454
              -100
            : 403 -404 458 -442
              -100
            : 447 -452 457 -458
              -100               u=4
442   0          403 -404 441 -456         $ void in 2nd middle bundle plate
               100
            : 447 -452 456 -454
               100
            : 403 -404 458 -442
               100
            : 447 -452 457 -458
               100               u=4
443   5 -7.9     -437 460 -461         u=4   $ screw in 2nd middle BP
444   4 -0.99705 -437 411 -462         u=4 $ bottom screw
```

```
c
c   Safety Element 1 with and grid plates NO FUEL
c
801    4 -0.99705 -402  412 -414 -100  u=14 $ fuel volume under water
802    0          -402  412 -414  100  u=14 $ fuel volume above water
809    3 -2.73    -403  450 -451           $ fuel clad + part of caps
               (402 : -412 : 414)          $ inside of fueled section
               (437 : -411 : 438)          $ bottom screw
               (437 : -439 : 440)   u=14   $ top screw
812    3 -2.73    -447  448 -449           $ fueled section ends
               (-450 : 451)                $ fuel clad + part of caps
               (437 : -411 : 438)          $ bottom screw
               (437 : -439 : 440)   u=14   $ top screw
813    3 -2.73    -447  453 -454           $ top plug
               (437 : -439 : 440)          $ screw
               (437 : -460 : 461)          $ screw in 2nd middle BP
               (-455 : 456)         u=14   $ clad
814    3 -2.73    -403  455 -456           $ poly section clad tube
               (402 : -415 : 436)          $ inside
               (437 : -460 : 461)          $ screw in 2nd middle BP
             (437 : -439 : 440)     u=14   $ screw
816    7 -0.93    -401  415 -424      u=14 $ poly plug
817    0           401 -402  415 -424  u=14 $ gap at poly plug
```

```
818    0          -402  424 -436       u=14 $ void above poly
819    3 -2.73    -403  458 -459             $ absorber section clad tube
               (437 : -460 : 461)          $ screw in 2nd middle BP
               (437 : -444 : 443)          $ top screw
               (402 : -425 : 427)   u=14   $ inside
820    8 -1.500   -402  425 -426       u=14 $ absorber
821    0          -402  426 -427       u=14 $ gap above absorber
822    2 -2.700    441 -442                  $ grid at poly-absorber interface
               (404 : -441 : 456)          $ water @ full dia rod
               (452 : -456 : 454)          $ water @ ends
               (404 : -458 : 442)          $ water @ full dia rod
               (452 : -457 : 458)          $ water @ ends
               (437 : -460 : 461)   u=14   $ screw in 2nd middle BP
823    2 -2.700    437  428 -443             $ grid at top of absorber
            (445 : -446 : 443)             $ cap screw head
            (437 : -444 : 446)      u=14   $ top screw
824   40 -0.99704 -430 -100                  $ water below grid plate
            (403 : -411 : 428)      u=14   $ the entire rod
825    2 -2.700    430 -432                  $ bottom bundle plate
               (404 : -450 : 432)          $ water @ full dia rod
               (452 : -448 : 450)          $ water @ ends
               (437 : -411 : 438)   u=14   $ bottom screw
826    4 -0.99705 403 -404  450 -432          $ water in lower grid plate
```

```
        : 447 -452 448 -450    u=14
827    4 -0.99705  432 -434 -100           $ water between grid plates
        (403 : -411 : 428)      u=14   $ the entire rod
828    4 -0.99705 403 -404  434 -451        $ water in upper grid plate
          -100
        : 447 -452 451 -449
          -100
        : 403 -404  455 -435
          -100
        : 447 -452 453 -455
          -100                u=14
829    2 -2.700    434 -435                $ 1st middle bundle plate
          (404 : -434 : 451)         $ water @ full dia rod
          (452 : -451 : 449)         $ water @ ends
          (404 : -455 : 435)         $ water @ full dia rod
          (452 : -453 : 455)         $ water @ ends
        (437 : -439 : 440)      u=14   $ top screw
830   40 -0.99704  435 -100                $ water above grid plate
        (-441 : 442)                 $ grid at poly-absorber
        (-428 : 443)                 $ grid at top of absorber
        (403 : -411 : 428)      u=14   $ the entire rod
832    0         -430  100                $ void below grid plate
        (403 : -411 : 428)      u=14   $ the entire rod
```

```
833    0          432 -434  100           $ void between grid plates
          (403 : -411 : 428)       u=14   $ the entire rod
834    0          403 -404  434 -451       $ void in upper grid plate
            100
           : 447 -452 451 -449
            100
           : 403 -404  455 -435
            100
           : 447 -452 453 -455
            100                u=14
835    0          435  100                 $ void above grid plate
          (-441 : 442)                  $ grid at poly-absorber
          (-428 : 443)                  $ grid at top of absorber
          (447 : -459 : 428)              $ top end of absorber rod
          (403 : -411 : 459)       u=14   $ the entire rod
836    5 -7.9     -437 462 -438        u=14 $ bottom screw
837    5 -7.9     -437 439 -440        u=14 $ top screw
838    5 -7.9     -437 444 -446        u=14 $ screw body above absorber
839    5 -7.9     -445 446 -443        u=14 $ cap screw head
840    3 -2.73    -447 457 -428            $ fueled section ends
             (437 : -460 : 461)          $ screw in 2nd middle BP
           (437 : -444 : 443)            $ top screw
            (-458 : 459)          u=14   $ fuel clad + part of caps
```

```
841   40 -0.99704 403 -404 441 -456         $ water in 2nd middle bundle plate
           -100
          : 447 -452 456 -454
           -100
          : 403 -404 458 -442
           -100
          : 447 -452 457 -458
           -100              u=14
842    0          403 -404 441 -456         $ void in 2nd middle bundle plate
            100
          : 447 -452 456 -454
            100
          : 403 -404 458 -442
            100
          : 447 -452 457 -458
            100              u=14
843    5 -7.9     -437 460 -461        u=14   $ screw in 2nd middle BP
844    4 -0.99705 -437 411 -462        u=14 $ bottom screw
c
c   Safety Element 2 with grid plates
c
551    1  -10.265   -1   40  -41 512 -513 u=5 $ 1st midplane fuel
552    1  -10.265   -1   41  -42 512 -513 u=5 $ 2nd midplane fuel
```

```
553    1  -10.265   -1   42  -43 512 -513 u=5 $ 3rd midplane fuel
554    1  -10.265   -1   43  -44 512 -513 u=5 $ 4th midplane fuel
555    1  -10.265   -1  512 -523         u=5 $ bottom fuel
556    1  -10.265   -1   45 -100 512 -513 u=5 $ top fuel underwater
557    1  -10.265   -1  523  -45 512 -513     $ rest of the fuel underwater
                (1 : -40 : 44)       u=5   $ midplane fuel
558    1  -10.265   -1  100 -513         u=5 $ fuel above water
505    0           501 -502  512 -513   u=5 $ gap at fuel
506    0          -505  513 -514       u=5 $ void inside spring
507    5 -2.3628   505 -506  513 -514   u=5 $ spring
508    0           506 -502  513 -514   u=5 $ gap at spring
509    3 -2.73    -503  550 -551           $ fuel clad + part of caps
              (502 : -512 : 514)         $ inside of fueled section
              (537 : -511 : 538)         $ bottom screw
              (537 : -539 : 540)    u=5   $ top screw
512    3 -2.73    -547  548 -549           $ fueled section ends
              (-550 : 551)               $ fuel clad + part of caps
              (537 : -511 : 538)         $ bottom screw
              (537 : -539 : 540)    u=5   $ top screw
513    3 -2.73    -547  553 -554           $ top plug
              (537 : -539 : 540)         $ screw
              (537 : -560 : 561)         $ screw in 2nd middle BP
              (-555 : 556)        u=5   $ clad
```

```
514    3 -2.73    -503  555 -556           $ poly section clad tube
            (502 : -515 : 536)         $ inside
            (537 : -560 : 561)         $ screw in 2nd middle BP
         (537 : -539 : 540)       u=5   $ screw
516    7 -0.93    -501  515 -524       u=5 $ poly plug
517    0           501 -502  515 -524   u=5 $ gap at poly plug
518    0          -502  524 -536       u=5 $ void above poly
519    3 -2.73    -503  558 -559           $ absorber section clad tube
            (537 : -560 : 561)         $ screw in 2nd middle BP
            (537 : -544 : 543)         $ top screw
            (502 : -525 : 527)    u=5   $ inside
520    8 -1.500   -502  525 -526       u=5 $ absorber
521    0          -502  526 -527       u=5 $ gap above absorber
522    2 -2.700    541 -542                $ grid at poly-absorber interface
            (504 : -541 : 556)         $ water @ full dia rod
            (552 : -556 : 554)         $ water @ ends
            (504 : -558 : 542)         $ water @ full dia rod
            (552 : -557 : 558)         $ water @ ends
            (537 : -560 : 561)    u=5   $ screw in 2nd middle BP
523    2 -2.700    537  528 -543           $ grid at top of absorber
         (545 : -546 : 543)            $ cap screw head
         (537 : -544 : 546)       u=5   $ top screw
524   40 -0.99704 -530 -100                $ water below grid plate
```

```
          (503 : -511 : 528)       u=5   $ the entire rod
525    2 -2.700    530 -532                $ bottom bundle plate
              (504 : -550 : 532)         $ water @ full dia rod
              (552 : -548 : 550)         $ water @ ends
              (537 : -511 : 538)    u=5   $ bottom screw
526    4 -0.99705 503 -504  550 -532          $ water in lower grid plate
            : 547 -552 548 -550     u=5
527    4 -0.99705  532 -534 -100           $ water between grid plates
          (503 : -511 : 528)       u=5   $ the entire rod
528    4 -0.99705 503 -504  534 -551        $ water in upper grid plate
              -100
            : 547 -552 551 -549
              -100
            : 503 -504  555 -535
              -100
            : 547 -552 553 -555
              -100                u=5
529    2 -2.700    534 -535                $ 1st middle bundle plate
              (504 : -534 : 551)         $ water @ full dia rod
              (552 : -551 : 549)         $ water @ ends
              (504 : -555 : 535)         $ water @ full dia rod
              (552 : -553 : 555)         $ water @ ends
          (537 : -539 : 540)       u=5   $ top screw
```

```
530   40 -0.99704  535 -100              $ water above grid plate
          (-541 : 542)                   $ grid at poly-absorber
          (-528 : 543)                   $ grid at top of absorber
          (503 : -511 : 528)       u=5   $ the entire rod
532    0        -530  100                $ void below grid plate
          (503 : -511 : 528)       u=5   $ the entire rod
533    0         532 -534  100           $ void between grid plates
          (503 : -511 : 528)       u=5   $ the entire rod
534    0        503 -504  534 -551       $ void in upper grid plate
              100
            : 547 -552 551 -549
              100
            : 503 -504  555 -535
              100
            : 547 -552 553 -555
              100              u=5
535    0         535  100                $ void above grid plate
          (-541 : 542)                   $ grid at poly-absorber
          (-528 : 543)                   $ grid at top of absorber
          (547 : -559 : 528)             $ top end of absorber rod
          (503 : -511 : 559)       u=5   $ the entire rod
536    5 -7.9     -537 562 -538        u=5 $ bottom screw
537    5 -7.9     -537 539 -540        u=5 $ top screw
```

```
538    5 -7.9     -537 544 -546         u=5 $ screw body above absorber
539    5 -7.9     -545 546 -543         u=5 $ cap screw head
540    3 -2.73    -547 557 -528              $ fueled section ends
              (537 : -560 : 561)        $ screw in 2nd middle BP
            (537 : -544 : 543)          $ top screw
             (-558 : 559)        u=5    $ fuel clad + part of caps
541   40 -0.99704 503 -504 541 -556          $ water in 2nd middle bundle plate
              -100
            : 547 -552 556 -554
              -100
            : 503 -504 558 -542
              -100
            : 547 -552 557 -558
              -100              u=5
542    0          503 -504 541 -556         $ void in 2nd middle bundle plate
               100
            : 547 -552 556 -554
               100
            : 503 -504 558 -542
               100
            : 547 -552 557 -558
               100              u=5
543    5 -7.9     -537 560 -561         u=5   $ screw in 2nd middle BP
```

```
544    4 -0.99705 -537 511 -562        u=5 $ bottom screw
c
c   Safety Element 2 with grid plates NO fuel
c
901    4 -0.99705 -502  512 -514 -100  u=15 $ fuel volume under water
902    0          -502  512 -514  100  u=15 $ fuel volume above water
909    3 -2.73    -503  550 -551           $ fuel clad + part of caps
                (502 : -512 : 514)         $ inside of fueled section
                (537 : -511 : 538)         $ bottom screw
                (537 : -539 : 540)   u=15   $ top screw
912    3 -2.73    -547  548 -549           $ fueled section ends
                (-550 : 551)               $ fuel clad + part of caps
                (537 : -511 : 538)         $ bottom screw
                (537 : -539 : 540)   u=15   $ top screw
913    3 -2.73    -547  553 -554           $ top plug
                (537 : -539 : 540)         $ screw
                (537 : -560 : 561)         $ screw in 2nd middle BP
                (-555 : 556)        u=15   $ clad
914    3 -2.73    -503  555 -556           $ poly section clad tube
                (502 : -515 : 536)         $ inside
                (537 : -560 : 561)         $ screw in 2nd middle BP
             (537 : -539 : 540)      u=15   $ screw
916    7 -0.93    -501  515 -524      u=15 $ poly plug
```

```
917    0           501 -502  515 -524  u=15 $ gap at poly plug
918    0          -502  524 -536       u=15 $ void above poly
919    3 -2.73    -503  558 -559            $ absorber section clad tube
                (537 : -560 : 561)          $ screw in 2nd middle BP
                (537 : -544 : 543)          $ top screw
                (502 : -525 : 527)   u=15   $ inside
920    8 -1.500   -502  525 -526       u=15 $ absorber
921    0          -502  526 -527       u=15 $ gap above absorber
922    2 -2.700    541 -542                 $ grid at poly-absorber interface
                (504 : -541 : 556)          $ water @ full dia rod
                (552 : -556 : 554)          $ water @ ends
                (504 : -558 : 542)          $ water @ full dia rod
                (552 : -557 : 558)          $ water @ ends
                (537 : -560 : 561)   u=15   $ screw in 2nd middle BP
923    2 -2.700    537  528 -543            $ grid at top of absorber
             (545 : -546 : 543)             $ cap screw head
             (537 : -544 : 546)      u=15   $ top screw
924   40 -0.99704 -530 -100                 $ water below grid plate
             (503 : -511 : 528)      u=15   $ the entire rod
925    2 -2.700    530 -532                 $ bottom bundle plate
                (504 : -550 : 532)          $ water @ full dia rod
                (552 : -548 : 550)          $ water @ ends
                (537 : -511 : 538)   u=15   $ bottom screw
```

```
926    4 -0.99705 503 -504  550 -532          $ water in lower grid plate
             : 547 -552 548 -550    u=15
927    4 -0.99705  532 -534 -100            $ water between grid plates
           (503 : -511 : 528)       u=15   $ the entire rod
928    4 -0.99705 503 -504  534 -551        $ water in upper grid plate
              -100
             : 547 -552 551 -549
              -100
             : 503 -504  555 -535
              -100
             : 547 -552 553 -555
              -100                u=15
929    2 -2.700    534 -535                 $ 1st middle bundle plate
              (504 : -534 : 551)         $ water @ full dia rod
              (552 : -551 : 549)         $ water @ ends
              (504 : -555 : 535)         $ water @ full dia rod
              (552 : -553 : 555)         $ water @ ends
           (537 : -539 : 540)       u=15   $ top screw
930   40 -0.99704  535 -100                 $ water above grid plate
           (-541 : 542)                  $ grid at poly-absorber
           (-528 : 543)                  $ grid at top of absorber
           (503 : -511 : 528)       u=15   $ the entire rod
932    0          -530  100                 $ void below grid plate
```

```
          (503 : -511 : 528)      u=15   $ the entire rod
933    0         532 -534  100           $ void between grid plates
          (503 : -511 : 528)      u=15   $ the entire rod
934    0         503 -504  534 -551       $ void in upper grid plate
             100
           : 547 -552 551 -549
             100
           : 503 -504  555 -535
             100
           : 547 -552 553 -555
             100               u=15
935    0         535  100                $ void above grid plate
          (-541 : 542)                  $ grid at poly-absorber
          (-528 : 543)                  $ grid at top of absorber
          (547 : -559 : 528)             $ top end of absorber rod
          (503 : -511 : 559)      u=15   $ the entire rod
936    5 -7.9     -537 562 -538        u=15 $ bottom screw
937    5 -7.9     -537 539 -540        u=15 $ top screw
938    5 -7.9     -537 544 -546        u=15 $ screw body above absorber
939    5 -7.9     -545 546 -543        u=15 $ cap screw head
940    3 -2.73    -547 557 -528            $ fueled section ends
             (537 : -560 : 561)         $ screw in 2nd middle BP
           (537 : -544 : 543)           $ top screw
```

```
            (-558 : 559)        u=15   $ fuel clad + part of caps
941   40 -0.99704 503 -504 541 -556         $ water in 2nd middle bundle plate
             -100
            : 547 -552 556 -554
             -100
            : 503 -504 558 -542
             -100
            : 547 -552 557 -558
             -100               u=15
942    0          503 -504 541 -556         $ void in 2nd middle bundle plate
              100
            : 547 -552 556 -554
              100
            : 503 -504 558 -542
              100
            : 547 -552 557 -558
              100               u=15
943    5 -7.9     -537 560 -561        u=15   $ screw in 2nd middle BP
944    4 -0.99705 -537 511 -562        u=15 $ bottom screw
c
c   Control Element with grid plates
c
651    1  -10.265   -1   40  -41 612 -613 u=6 $ 1st midplane fuel
```

```
652   1  -10.265   -1   41  -42 612 -613 u=6 $ 2nd midplane fuel
653   1  -10.265   -1   42  -43 612 -613 u=6 $ 3rd midplane fuel
654   1  -10.265   -1   43  -44 612 -613 u=6 $ 4th midplane fuel
655   1  -10.265   -1  612 -623          u=6 $ bottom fuel
656   1  -10.265   -1   45 -100 612 -613 u=6 $ top fuel underwater
657   1  -10.265   -1  623  -45 612 -613     $ rest of the fuel underwater
                (1 : -40 : 44)       u=6   $ midplane fuel
658   1  -10.265   -1  100 -613          u=6 $ fuel above water
605   0          601 -602  612 -613   u=6 $ gap at fuel
606   0         -605  613 -614       u=6 $ void inside spring
607   5 -2.3628   605 -606  613 -614   u=6 $ spring
608   0          606 -602  613 -614   u=6 $ gap at spring
609   3 -2.73    -603  650 -651           $ fuel clad + part of caps
              (602 : -612 : 614)         $ inside of fueled section
              (637 : -611 : 638)         $ bottom screw
              (637 : -639 : 640)    u=6   $ top screw
612   3 -2.73    -647  648 -649           $ fueled section ends
              (-650 : 651)               $ fuel clad + part of caps
              (637 : -611 : 638)         $ bottom screw
              (637 : -639 : 640)    u=6   $ top screw
613   3 -2.73    -647  653 -654           $ top plug
              (637 : -639 : 640)         $ screw
              (637 : -660 : 661)         $ screw in 2nd middle BP
```

```
            (-655 : 656)          u=6   $ clad
614    3 -2.73    -603  655 -656           $ poly section clad tube
            (602 : -615 : 636)          $ inside
            (637 : -660 : 661)          $ screw in 2nd middle BP
          (637 : -639 : 640)        u=6   $ screw
616    7 -0.93    -601  615 -624        u=6 $ poly plug
617    0           601 -602  615 -624   u=6 $ gap at poly plug
618    0          -602  624 -636        u=6 $ void above poly
619    3 -2.73    -603  658 -659           $ absorber section clad tube
            (637 : -660 : 661)          $ screw in 2nd middle BP
            (637 : -644 : 643)          $ top screw
            (602 : -625 : 627)    u=6   $ inside
620    8 -1.500   -602  625 -626        u=6 $ absorber
621    0          -602  626 -627        u=6 $ gap above absorber
622    2 -2.700    641 -642                $ grid at poly-absorber interface
            (604 : -641 : 656)          $ water @ full dia rod
            (652 : -656 : 654)          $ water @ ends
            (604 : -658 : 642)          $ water @ full dia rod
            (652 : -657 : 658)          $ water @ ends
            (637 : -660 : 661)    u=6   $ screw in 2nd middle BP
623    2 -2.700    637  628 -643           $ grid at top of absorber
          (645 : -646 : 643)            $ cap screw head
          (637 : -644 : 646)        u=6   $ top screw
```

```
624   40 -0.99704 -630 -100              $ water below grid plate
          (603 : -611 : 628)       u=6   $ the entire rod
625    2 -2.700    630 -632              $ bottom bundle plate
             (604 : -650 : 632)         $ water @ full dia rod
             (652 : -648 : 650)         $ water @ ends
             (637 : -611 : 638)    u=6   $ bottom screw
626    4 -0.99705 603 -604  650 -632         $ water in lower grid plate
            : 647 -652 648 -650     u=6
627    4 -0.99705  632 -634 -100           $ water between grid plates
          (603 : -611 : 628)       u=6   $ the entire rod
628    4 -0.99705 603 -604  634 -651        $ water in upper grid plate
             -100
            : 647 -652 651 -649
             -100
            : 603 -604  655 -635
             -100
            : 647 -652 653 -655
             -100                u=6
629    2 -2.700    634 -635              $ 1st middle bundle plate
             (604 : -634 : 651)         $ water @ full dia rod
             (652 : -651 : 649)         $ water @ ends
             (604 : -655 : 635)         $ water @ full dia rod
             (652 : -653 : 655)         $ water @ ends
```

```
        (637 : -639 : 640)      u=6   $ top screw
630   40 -0.99704  635 -100             $ water above grid plate
        (-641 : 642)                  $ grid at poly-absorber
        (-628 : 643)                  $ grid at top of absorber
        (603 : -611 : 628)      u=6   $ the entire rod
632    0        -630  100              $ void below grid plate
        (603 : -611 : 628)      u=6   $ the entire rod
633    0         632 -634  100          $ void between grid plates
        (603 : -611 : 628)      u=6   $ the entire rod
634    0        603 -604  634 -651      $ void in upper grid plate
           100
         : 647 -652 651 -649
           100
         : 603 -604  655 -635
           100
         : 647 -652 653 -655
           100              u=6
635    0         635  100              $ void above grid plate
        (-641 : 642)                  $ grid at poly-absorber
        (-628 : 643)                  $ grid at top of absorber
        (647 : -659 : 628)            $ top end of absorber rod
        (603 : -611 : 659)      u=6   $ the entire rod
636    5 -7.9     -637 662 -638       u=6 $ bottom screw
```

```
637    5 -7.9     -637 639 -640        u=6 $ top screw
638    5 -7.9     -637 644 -646        u=6 $ screw body above absorber
639    5 -7.9     -645 646 -643        u=6 $ cap screw head
640    3 -2.73    -647 657 -628             $ fueled section ends
              (637 : -660 : 661)         $ screw in 2nd middle BP
            (637 : -644 : 643)           $ top screw
             (-658 : 659)         u=6    $ fuel clad + part of caps
641   40 -0.99704 603 -604 641 -656         $ water in 2nd middle bundle plate
              -100
             : 647 -652 656 -654
              -100
             : 603 -604 658 -642
              -100
             : 647 -652 657 -658
              -100                u=6
642    0          603 -604 641 -656         $ void in 2nd middle bundle plate
               100
             : 647 -652 656 -654
               100
             : 603 -604 658 -642
               100
             : 647 -652 657 -658
               100                u=6
```

```
643    5 -7.9     -637 660 -661         u=6   $ screw in 2nd middle BP
644    4 -0.99705 -637 611 -662         u=6 $ bottom screw
c
c   Control Element with grid plates NO FUEL
c
301    4 -0.99705 -602  612 -614 -100  u=16 $ fuel volume under water
302    0          -602  612 -614  100  u=16 $ fuel volume above water
309    3 -2.73    -603  650 -651           $ fuel clad + part of caps
              (602 : -612 : 614)         $ inside of fueled section
              (637 : -611 : 638)         $ bottom screw
              (637 : -639 : 640)   u=16   $ top screw
312    3 -2.73    -647  648 -649           $ fueled section ends
              (-650 : 651)               $ fuel clad + part of caps
              (637 : -611 : 638)         $ bottom screw
              (637 : -639 : 640)   u=16   $ top screw
313    3 -2.73    -647  653 -654           $ top plug
              (637 : -639 : 640)         $ screw
              (637 : -660 : 661)         $ screw in 2nd middle BP
              (-655 : 656)        u=16   $ clad
314    3 -2.73    -603  655 -656           $ poly section clad tube
              (602 : -615 : 636)         $ inside
              (637 : -660 : 661)         $ screw in 2nd middle BP
            (637 : -639 : 640)      u=16   $ screw
```

```
316    7 -0.93    -601  615 -624       u=16 $ poly plug
317    0           601 -602  615 -624  u=16 $ gap at poly plug
318    0          -602  624 -636       u=16 $ void above poly
319    3 -2.73    -603  658 -659            $ absorber section clad tube
                (637 : -660 : 661)          $ screw in 2nd middle BP
                (637 : -644 : 643)          $ top screw
                (602 : -625 : 627)   u=16   $ inside
320    8 -1.500   -602  625 -626       u=16 $ absorber
321    0          -602  626 -627       u=16 $ gap above absorber
322    2 -2.700    641 -642                 $ grid at poly-absorber interface
                (604 : -641 : 656)          $ water @ full dia rod
                (652 : -656 : 654)          $ water @ ends
                (604 : -658 : 642)          $ water @ full dia rod
                (652 : -657 : 658)          $ water @ ends
                (637 : -660 : 661)   u=16   $ screw in 2nd middle BP
323    2 -2.700    637  628 -643            $ grid at top of absorber
             (645 : -646 : 643)             $ cap screw head
             (637 : -644 : 646)      u=16   $ top screw
324   40 -0.99704 -630 -100                 $ water below grid plate
             (603 : -611 : 628)      u=16   $ the entire rod
325    2 -2.700    630 -632                 $ bottom bundle plate
                (604 : -650 : 632)          $ water @ full dia rod
                (652 : -648 : 650)          $ water @ ends
```

```
        (637 : -611 : 638)   u=16   $ bottom screw
326    4 -0.99705 603 -604  650 -632          $ water in lower grid plate
       : 647 -652 648 -650    u=16
327    4 -0.99705  632 -634 -100           $ water between grid plates
      (603 : -611 : 628)       u=16   $ the entire rod
328    4 -0.99705 603 -604  634 -651        $ water in upper grid plate
        -100
       : 647 -652 651 -649
        -100
       : 603 -604  655 -635
        -100
       : 647 -652 653 -655
        -100                u=16
329    2 -2.700    634 -635                 $ 1st middle bundle plate
        (604 : -634 : 651)         $ water @ full dia rod
        (652 : -651 : 649)         $ water @ ends
        (604 : -655 : 635)         $ water @ full dia rod
        (652 : -653 : 655)         $ water @ ends
      (637 : -639 : 640)       u=16   $ top screw
330   40 -0.99704  635 -100               $ water above grid plate
      (-641 : 642)                   $ grid at poly-absorber
      (-628 : 643)                   $ grid at top of absorber
      (603 : -611 : 628)       u=16   $ the entire rod
```

```
332    0         -630  100                $ void below grid plate
            (603 : -611 : 628)      u=16   $ the entire rod
333    0          632 -634  100           $ void between grid plates
            (603 : -611 : 628)      u=16   $ the entire rod
334    0          603 -604  634 -651      $ void in upper grid plate
                100
              : 647 -652 651 -649
                100
              : 603 -604  655 -635
                100
              : 647 -652 653 -655
                100              u=16
335    0          635  100                $ void above grid plate
            (-641 : 642)                  $ grid at poly-absorber
            (-628 : 643)                  $ grid at top of absorber
            (647 : -659 : 628)            $ top end of absorber rod
            (603 : -611 : 659)      u=16   $ the entire rod
336    5 -7.9     -637 662 -638       u=16 $ bottom screw
337    5 -7.9     -637 639 -640       u=16 $ top screw
338    5 -7.9     -637 644 -646       u=16 $ screw body above absorber
339    5 -7.9     -645 646 -643       u=16 $ cap screw head
340    3 -2.73    -647 657 -628            $ fueled section ends
                (637 : -660 : 661)         $ screw in 2nd middle BP
```

```
         (637 : -644 : 643)          $ top screw
          (-658 : 659)        u=16   $ fuel clad + part of caps
341   40 -0.99704 603 -604 641 -656        $ water in 2nd middle bundle plate
           -100
          : 647 -652 656 -654
           -100
          : 603 -604 658 -642
           -100
          : 647 -652 657 -658
           -100              u=16
342    0         603 -604 641 -656        $ void in 2nd middle bundle plate
            100
          : 647 -652 656 -654
            100
          : 603 -604 658 -642
            100
          : 647 -652 657 -658
            100              u=16
343    5 -7.9     -637 660 -661        u=16   $ screw in 2nd middle BP
344    4 -0.99705 -637 611 -662        u=16 $ bottom screw
c
c  Volume above the wall
c
```

c 989   0   -1951 1952 -1953 1954 -1955 1956 1958 -918 $ bounds on the inner upper array

c   (1911 : -1912 : 1913 : -1914 : 1915 : -1916 : -1917) $ the inner array

c

c Water in the projection

c

c 990 40 -0.99704   -1951 1952 -1953 1954 -1955 1956 -921 924 $ bounds on the inner upper array

c

c Water below grid plate

c

c 991 40 -0.99704   -1951 1952 -1953 1954 -1955 1956 -1957 921 $ bounds on the inner upper array

c

c Outer wall of experiment container

c

c 992   2 -2.70   -1951 1952 -1953 1954 -1955 1956 1957 -1958 $ bounds on the inner upper array

c   (1941 : -1942 : 1943 : -1944 : 1945 : -1946 : -1947) $ the inner array

c

c Gap between absorber and outer wall

c

```
c 993    0            -1941 1942 -1943 1944 -1945 1946 1947 -1958 $ bounds on the inner
upper array
c                (1931 : -1932 : 1933 : -1934 : 1935 : -1936 : -1937)   $ the inner array
c
c  Absorber layer in experiment container
c
c 994   0          -1931 1932 -1933 1934 -1935 1936 1937 -1958 $ bounds on the inner
upper array
c                (1921 : -1922 : 1923 : -1924 : 1925 : -1926 : -1927)   $ the inner array
c
c  First wall of experiment container
c
c 995   2  -2.70      -1921 1922 -1923 1924 -1925 1926 1927 -1958 $ bounds on the inner
upper array
c                (1911 : -1912 : 1913 : -1914 : 1915 : -1916 : -1917)   $ the inner array
c
c  the inner array
c
996    0            -1901  1902 -1903  1904 -1905  1906  lat=2  u=20
                fill  -2:2  -2:2   0:0
     32 32 32 32 32
     32 32 31 31 32
     32 31 31 31 32
```

```
    32 31 31 32 32
    32 32 32 32 32
997   0            -1911 1912 -1913 1914 -1915 1916  924 -918 $ bounds on the inner upper
array
         fill=20
c 998   40  -0.99704   -921  924 -925                   $ bounds of the inner lower array
c                    -1911 1912 -1913 1914 -1915 1916
c                     fill=20
c
c  the outer array
c
999    4  -0.99705  -901  902 -903  904 -905  906  lat=2  u=10
                 fill -27:28 -27:27  0:0
c  1531 fuel rods 1531 total positions
    3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
    3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
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    3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 8 8
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    3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 8 8 8
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    3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 8 8 8 8
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    8 8 8 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
    3 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
    8 8 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
    3 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
    8 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
    3 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
    3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
    3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
    3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
c
c
1000  40  -0.99704   -911  912 -913  914 -915  916  921 -918 $ bounds on the upper array
           (1911 : -1912 : 1913 : -1914 : 1915 : -1916)   $ the inner array
       fill=10
c            (1911 : -1912 : 1913 : -1914 : 1915 : -1916)   $ the inner array
1001  40  -0.99704   -921  924 -925                    $ bounds of the lower array
              -941  942 -943  944 -945  946  917
           (1911 : -1912 : 1913 : -1914 : 1915 : -1916)   $ the inner array
c            (1911 : -1912 : 1913 : -1914 : 1915 : -1916)   $ the outside of the experiment
c            (1951 : -1952 : 1953 : -1954 : 1955 : -1956)   $ the outside of the experiment
              fill=10
c            (1911 : -1912 : 1913 : -1914 : 1915 : -1916)   $ the inner array
1002   2   -2.700    10   -12  -932                 $ bottom grid plate
```

```
           (911 : -912 : 913 : -914 : 915 : -916 : -921 : 918)  $ the array
            970  971  972  973  974  975            $ the holes
1003   2   -2.700   -961  962 -963  964 -965  966   14   -15     $ top grid plate
           (911 : -912 : 913 : -914 : 915 : -916 : -921 : 918)  $ the array
1004   9   -2.70    -961  962 -963  964 -965  966   28   -29     $ guide plate (always above
water)
           (911 : -912 : 913 : -914 : 915 : -916 : -921 : 918)  $ the array
1007  40  -0.99704   921 -922 -923 -100               $ reflector
           (911 : -912 : 913 : -914 : 915 : -916 : -921 : 918)  $ the array
               (-10 : 12 : 932)                 $ bottom grid plate
          (961 : -962 : 963 : -964 : 965 : -966 : -14 : 15) $ top grid plate
          (981 : 982 : -983 : 966 : -14 : 15)        $ +x arm of top grid plate
          (982 : -966 : -963 : -14 : 15)             $ +x arm of top grid plate
          (-984 : 985 : -986 : 962 : -14 : 15)       $ -x-y arm of top grid plate
          (985 : -962 : 964 : -14 : 15)              $ -x-y arm of top grid plate
          (-987 : 988 : -989 : -965 :  -14 : 15)     $ -x+y arm of top grid plate
          (988 : -961 : 965 : -14 : 15)              $ -x+y arm of top grid plate
           (-12 : 14 : 990)                 $ support post
           (-12 : 14 : 991)                 $ support post
           (-12 : 14 : 992)                 $ support post
           (-15 : 28 : 990)                 $ support post
           (-15 : 28 : 991)                 $ support post
           (-15 : 28 : 992)                 $ support post
```

```
           (801 : -803 : 804)                 $-x+y detector tube
           (801 : -803 : 806)                 $+x+y detector tube
           (810 : -811 : 812 : -814)            $-x+y detector poly
           (810 : -811 : 813 : -815)            $+x+y detector poly
1008  40  -0.99704  -921  924 -925 -100             $ water in the projection
            (941 : -942 : 943 : -944 : 945 : -946 : -917)   $ the lower array
1009   0             921 -922 -923  100            $ voided reflector (above water level)
           (911 : -912 : 913 : -914 : 915 : -916 : -921 : 918)  $ the array
              (-10 : 12 : 932)                 $ bottom grid plate
           (961 : -962 : 963 : -964 : 965 : -966 : -14 : 15) $ top grid plate
          (981 : 982 : -983 : 966 : -14 : 15)        $ +x arm of top grid plate
          (982 : -966 : -963 : -14 : 15)             $ +x arm of top grid plate
          (-984 : 985 : -986 : 962 : -14 : 15)       $ -x-y arm of top grid plate
          (985 : -962 : 964 : -14 : 15)              $ -x-y arm of top grid plate
          (-987 : 988 : -989 : -965 :  -14 : 15)      $ -x+y arm of top grid plate
          (988 : -961 : 965 : -14 : 15)              $ -x+y arm of top grid plate
          (961 : -962 : 963 : -964 : 965 : -966 : -28 : 29) $ guide plate
          (981 : 982 : -983 : 966 : -28 : 29)        $ +x arm of the guide plate
          (982 : -966 : -963 : -28 : 29)             $ +x arm of the guide plate
          (-984 : 985 : -986 : 962 : -28 : 29)       $ -x-y arm of the guide plate
          (985 : -962 : 964 : -28 : 29)              $ -x-y arm of the guide plate
          (-987 : 988 : -989 : -965 :  -28 : 29)      $ -x+y arm of the guide plate
          (988 : -961 : 965 : -28 : 29)              $ -x+y arm of the guide plate
```

```
          (-12 : 14 : 990)            $ support post
          (-12 : 14 : 991)            $ support post
          (-12 : 14 : 992)            $ support post
          (-15 : 28 : 990)            $ support post
          (-15 : 28 : 991)            $ support post
          (-15 : 28 : 992)            $ support post
          (801 : -803 : 804)          $-x+y detector tube
          (801 : -803 : 806)          $+x+y detector tube
          (810 : -811 : 812 : -814)   $-x+y detector poly
          (810 : -811 : 813 : -815)   $+x+y detector poly
1010  40  -0.99704  -921  924 -925  100      $ void in the projection
1011   2  -2.700    926 -922 -929  925       $ upper tank wall
              (-921 : 922 : 923)        $ water in upper tank
1012   2  -2.700    927 -922 -928  929       $ upper flange
1013   2  -2.700   -926  930 -931            $ projection wall
              (921 : -924 : 925)        $ projection
1014  40   -0.99704  10   -12   -970        $ lower grid plate hole 1
1015  40   -0.99704  10   -12   -971        $ lower grid plate hole 2
1016  40   -0.99704  10   -12   -972        $ lower grid plate hole 3
1017  40   -0.99704  10   -12   -973        $ lower grid plate hole 4
1018  40   -0.99704  10   -12   -974        $ lower grid plate hole 5
1019  40   -0.99704  10   -12   -975        $ lower grid plate hole 6
1020   2   -2.700   -981 -982  983 -966  14 -15  :   $ +x arm of top grid plate
```

```
              -982  966  963  14  -15
1021   2   -2.700     984 -985  986 -962  14 -15  :    $ -x-y arm of top grid plate
              -985  962 -964  14 -15
1022   2   -2.700     987 -988  989  965  14 -15  :    $ +x-y arm of top grid plate
              -988  961 -965  14 -15
1023   2   -2.700    12   -14   -990                 $ support post
1024   2   -2.700    12   -14   -991                 $ support post
1025   2   -2.700    12   -14   -992                 $ support post
1030   0            -801   802 -805                      $ -x+y detector well
             (820 : -821 : 822)                    $-x+y detector
1031   2   -2.700   -801   803 -804                       $ -x+y detector tube
             (-802 : 805)                        $-x+y well
1032   7   -0.93    -810   811 -812  814                  $ -x+y detector poly
1033   0            -801   802 -807                      $ +x+y detector well
             (820 : -821 : 824)                    $+x+y detector
1034   2   -2.700   -801   803 -806                       $ +x+y detector tube
             (-802 : 807)                        $+x+y well
1035   7   -0.93    -810   811 -813  815                  $ +x+y detector poly
1040  19  -10.0e-20 -820   821 -822  823                   $ -x+y thin detector
1041  19   -1.e-30  -820   821 -823                      $ -x+y volume detector
1042  19  -10.0e-20 -820   821 -824  825                   $ +x+y thin detector
1043  19   -1.e-30  -820   821 -825                      $ +x+y volume detector
1050   9   -2.700    -981 -982  983 -966  28 -29  :    $ +x arm of the guide plate
```

```
               -982  966  963  28 -29
1051   9   -2.700     984 -985  986 -962  28 -29  :    $ -x-y arm of the guide plate
               -985  962 -964  28 -29
1052   9   -2.700     987 -988  989  965  28 -29  :    $ +x-y arm of the guide plate
               -988  961 -965  28 -29
1053   2   -2.700    15   -28   -990                $ support post
1054   2   -2.700    15   -28   -991                $ support post
1055   2   -2.700    15   -28   -992                $ support post
c
c  ACRR fuel element from void05b.inp in D:\ng\smallNG\excalc\foils
c
c
c  Fuel Element
c
1101   4 -0.99705 -1101                u=31 $ water below bottom grid plate
1102  38  -2.70    1101  -1102              $ bottom grid plate
             (-1101 : 1109 : 1105)        $ bottom part of bottom GP hole
             (-1109 : 1110 : 1108)        $ conical part of bottom GP hole
             (-1110 : 1104 : 1106)  u=31   $ top part of bottom GP hole
1103   4 -0.99705  1102  -1103              $ water between grid plates
          (-1111:1112:1106:-1123:1122:-1118:-1121) $ +y bottom fin
          (-1114:1113:1106:-1123:1122:1118:-1121) $ -y+x bottom fin
          (-1116:1115:1106:-1123:1122:1118:-1121) $ -y-x bottom fin
```

```
          (-1111:1112:-1118:1120:-1133) $ +y top fin
          (-1114:1113:1118:1120:-1133) $ -y+x top fin
          (-1116:1115:1118:1120:-1133) $ -y-x top fin
            (1108 : -1123 : 1121)       $ stick on the bottom
            (1123 : 1122 : 1120)        $ conical part
            (-1122 : 1124 : 1120)       $ cylindrical part on top
            (-1131 : 1132 : 1120)       $ cylincrical part
            (-1132 : 1133 : 1120)       $ conical part
            (-1133 : 1135 : 1121)       $ stick
            (1120 : -1124 : 1131)  u=31   $ cladding
1104  38  -2.70    1103  -1104             $ top grid plate
             1107              u=31   $ hole in top grid plate
1105   4 -0.99705  1104  -100              $ water above grid plate
          (-1111:1112:-1118:1120:1138:-1121) $ +y top fin
          (-1114:1113:1118:1120:1138:-1121) $ -y+x top fin
          (-1116:1115:1118:1120:1138:-1121) $ -y-x top fin
            (-1131 : 1132 : 1120)       $ cylincrical part
            (-1132 : 1133 : 1120)       $ conical part
            (-1133 : 1135 : 1121)  u=31   $ stick
1106   4 -0.99705  1101  -1109  -1105       $ bottom part of bottom GP hole
          (-1111:1112:1108:1106:1122:-1118:-1121) $ +y bottom fin
          (-1114:1113:1108:1106:1122:1118:-1121) $ -y+x bottom fin
          (-1116:1115:1108:1106:1122:1118:-1121) $ -y-x bottom fin
```

```
    (1108 : -1123 : 1121)        $ stick on the bottom
    (1123 : 1122 : 1120)         $ conical part
    (-1122 : 1124 : 1120)  u=31   $ cylindrical part on top
1107   4 -0.99705  1109  -1110  -1108       $ conical part of bottom GP hole
  (-1111:1112:1108:1106:1122:-1118:-1121) $ +y bottom fin
  (-1114:1113:1108:1106:1122:1118:-1121) $ -y+x bottom fin
  (-1116:1115:1108:1106:1122:1118:-1121) $ -y-x bottom fin
    (1108 : -1123 : 1121)        $ stick on the bottom
    (1123 : 1122 : 1120)         $ conical part
    (-1122 : 1124 : 1120)  u=31   $ cylindrical part on top
1108   4 -0.99705  1110  -1102  -1106       $ top part of bottom GP hole
  (-1111:1112:1106:1122:-1118:-1121) $ +y bottom fin
  (-1114:1113:1106:1122:1118:-1121) $ -y+x bottom fin
  (-1116:1115:1106:1122:1118:-1121) $ -y-x bottom fin
    (1108 : -1123 : 1121)        $ stick on the bottom
    (1123 : 1122 : 1120)         $ conical part
    (-1122 : 1124 : 1120)  u=31   $ cylindrical part on top
1109   4 -0.99705  1103  -1104  -1107       $ hole in top grid plate
  (-1111:1112:-1118:1120:-1133:-1121) $ +y top fin
  (-1114:1113:1118:1120:-1133:-1121) $ -y+x top fin
  (-1116:1115:1118:1120:-1133:-1121) $ -y-x top fin
    (-1131 : 1132 : 1120)        $ cylincrical part
    (-1132 : 1133 : 1120)        $ conical part
```

```
              (-1133 : 1135 : 1121)  u=31   $ stick
1110   0          100                 u=31   $ void above the water line
c
c  bottom end fixture
c
1111  33  -8.03   -1108   1123  -1121   u=31 $ stick on the bottom
1112  33  -8.03   -1123  -1122  -1120       $ conical part
              (1127 : 1126 : 1125)   u=31   $ conical part of hole
1113  33  -8.03    1122  -1124  -1120       $ cylindrical part on top
              (-1126 : 1124 : 1125)         $ cylindrical part of hole
              (1127 : 1126 : 1125)   u=31   $ conical part of hole
1114   0          1126  -1124  -1125        $ cylindrical part of hole
              (1142 : 1127 : 1141)   u=31   $ bottom BeO reflector
1115   0         -1127  -1126  -1125        $ conical part of hole
              (1142 : 1127 : 1141)   u=31   $ bottom BeO reflector
1116  33  -8.03    1111  -1112  -1108  -1106 $ +y bottom fin
                1123  -1122   1118   1121 u=31
1117  33  -8.03    1114  -1113  -1108  -1106 $ -y+x bottom fin
                1123  -1122  -1118   1121 u=31
1118  33  -8.03    1116  -1115  -1108  -1106 $ -y-x bottom fin
                1123  -1122  -1118   1121 u=31
c
c  top end fixture
```

```
c
1121  33  -8.03    1131  -1132  -1120        $ cylindrical part
              (-1131 : 1136 : 1125)        $ cylindrical part of hole
              (-1136 : 1137 : 1125)  u=31   $ conical part of hole
1122  33  -8.03    1132  -1133  -1120        $ conical part
              (-1136 : 1137 : 1125)  u=31   $ conical part of hole
1123  33  -8.03    1133  -1135  -1121   u=31 $ stick
1124   0          1131  -1136  -1125        $ cylindrical part of hole
              (-1162 : 1143 : 1142)  u=31   $ top BeO reflector
1125   0          1136  -1137  -1125        $ conical part of hole
              (-1162 : 1143 : 1142)  u=31   $ top BeO reflector
1126  33  -8.03    1111  -1112   1118  -1120 $ +y top fin
                1133  -1138   1121   u=31
1127  33  -8.03    1114  -1113  -1118  -1120 $ -y+x top fin
                1133  -1138   1121   u=31
1128  33  -8.03    1116  -1115  -1118  -1120 $ -y-x top fin
               1133  -1138   1121   u=31
c
c  clad tube
c
1129  33  -8.03    1119  -1120   1124  -1131 $ cladding
                                u=31
1130   0         -1119   1124  -1131        $ inside of cladding
```

```
                (1142 : 1127 : 1141)         $ bottom BeO reflector
                (1150 : -1141 : 1162)        $ Nb cans
                (-1162 : 1143 : 1142)  u=31   $ top BeO reflector
c
c  BeO reflectors
c
1131  37  -2.80   -1142  -1127  -1141   u=31 $ bottom BeO reflector
1132  37  -2.80    1162  -1143  -1142   u=31 $ top BeO reflector
c
c  niobium cups
c
1140  34  -8.40    1151  -1150   1141  -1162 $ walls of Nb cans
                                    u=31
1141  34  -8.40    1141  -1152  -1151   u=31 $ floor of can 1
1142  34  -8.40    1153  -1154  -1151   u=31 $ floor of can 2
1143  34  -8.40    1155  -1156  -1151   u=31 $ floor of can 3
1144  34  -8.40    1157  -1158  -1151   u=31 $ floor of can 4
1145  34  -8.40    1159  -1160  -1151   u=31 $ floor of can 5
1146  34  -8.40    1161  -1162  -1151   u=31 $ lid
1147   0           1152  -1153  -1151        $ inside can 1
                (-1152 : 1177 : 1173)  u=31   $ fuel can 1
1148   0           1154  -1155  -1151        $ inside can 2
                (-1154 : 1180 : 1173)  u=31   $ fuel can 2
```

```
1149   0          1156  -1157  -1151       $ inside can 3
              (-1156 : 1183 : 1173)  u=31   $ fuel can 3
1150   0          1158  -1159  -1151       $ inside can 4
              (-1158 : 1186 : 1173)  u=31   $ fuel can 4
1151   0          1160  -1161  -1151       $ inside can 5
              (-1160 : 1189 : 1173)  u=31   $ fuel can 5
c
c  fuel
c
1160  31  -3.524   1152  -1177   1170  -1171 u=31 $ inner fuel        can 1
1161  31  -3.524   1152  -1175   1172  -1174 u=31 $ bottom pellet     can 1
1162  31  -3.524   1175  -1176   1172  -1173 u=31 $ 14 pellets        can 1
1163  31  -3.524   1176  -1177   1172  -1174 u=31 $ top pellet        can 1
1164   0          1152  -1177  -1170       u=31 $ hole              can 1
1165   0          1152  -1177   1171  -1172 u=31 $ gap               can 1
1166   0          1152  -1175   1174  -1173 u=31 $ outside bot pellet can 1
1167   0          1176  -1177   1174  -1173 u=31 $ outside top pellet can 1
1168  31  -3.524   1154  -1180   1170  -1171 u=31 $ inner fuel        can 2
1169  31  -3.524   1154  -1178   1172  -1174 u=31 $ bottom pellet     can 2
1170  31  -3.524   1178  -1179   1172  -1173 u=31 $ 14 pellets        can 2
1171  31  -3.524   1179  -1180   1172  -1174 u=31 $ top pellet        can 2
1172   0          1154  -1180  -1170       u=31 $ hole              can 2
1173   0          1154  -1180   1171  -1172 u=31 $ gap               can 2
```

```
1174   0          1154  -1178   1174  -1173 u=31 $ outside bot pellet can 2
1175   0          1179  -1180   1174  -1173 u=31 $ outside top pellet can 2
1176  31  -3.524   1156  -1183   1170  -1171 u=31 $ inner fuel        can 3
1177  31  -3.524   1156  -1181   1172  -1174 u=31 $ bottom pellet     can 3
1178  31  -3.524   1181  -1182   1172  -1173 u=31 $ 14 pellets        can 3
1179  31  -3.524   1182  -1183   1172  -1174 u=31 $ top pellet        can 3
1180   0          1156  -1183  -1170       u=31 $ hole             can 3
1181   0          1156  -1183   1171  -1172 u=31 $ gap              can 3
1182   0          1156  -1181   1174  -1173 u=31 $ outside bot pellet can 3
1183   0          1182  -1183   1174  -1173 u=31 $ outside top pellet can 3
1184  31  -3.524   1158  -1186   1170  -1171 u=31 $ inner fuel        can 4
1185  31  -3.524   1158  -1184   1172  -1174 u=31 $ bottom pellet     can 4
1186  31  -3.524   1184  -1185   1172  -1173 u=31 $ 14 pellets        can 4
1187  31  -3.524   1185  -1186   1172  -1174 u=31 $ top pellet        can 4
1188   0          1158  -1186  -1170       u=31 $ hole             can 4
1189   0          1158  -1186   1171  -1172 u=31 $ gap              can 4
1190   0          1158  -1184   1174  -1173 u=31 $ outside bot pellet can 4
1191   0          1185  -1186   1174  -1173 u=31 $ outside top pellet can 4
1192  31  -3.524   1160  -1189   1170  -1171 u=31 $ inner fuel        can 5
1193  31  -3.524   1160  -1187   1172  -1174 u=31 $ bottom pellet     can 5
1194  31  -3.524   1187  -1188   1172  -1173 u=31 $ 14 pellets        can 5
1195  31  -3.524   1188  -1189   1172  -1174 u=31 $ top pellet        can 5
1196   0          1160  -1189  -1170       u=31 $ hole             can 5
```

```
1197   0         1160  -1189   1171  -1172 u=31 $ gap              can 5
1198   0         1160  -1187   1174  -1173 u=31 $ outside bot pellet can 5
1199   0         1188  -1189   1174  -1173 u=31 $ outside top pellet can 5
c
1201   4 -0.99705   -100                  u=32 $ empty below waterline
1202   0          100                  u=32 $ empty above waterline
c
1100   0                                    $ external void (imp=0)
               (-926 : 922 : 929)               $ tank wall
               (-927 : 922 : 928)               $ flange
               (926 : -930 : 931)               $ projection wall
          (911 : -912 : 913 : -914 : 915 : -916 : -921 : 918)  $ the array
          (801 : -803 : 804)                    $-x+y detector tube
          (801 : -803 : 806)                    $+x+y detector tube

c
c fuel rod surfaces
c
1    cz    0.26289  $ fuel OD (0.207")
2    cz    0.284519 $ clad ID (0.01297" wall from measured mass)
3    cz    0.317475 $ clad OD (0.249980")
4    cz    0.333375 $ ID of hole in grid plate at fuel (0.260")
5    cz    0.17526  $ ID of spring
```

```
6    cz    0.22860  $ OD of spring
7    cz    0.26289  $ intermediate plug OD (0.207")
8    cz    0.26289  $ poly OD (0.207")
10   pz   -2.54     $ bottom of bottom grid plate
11   pz   -1.27     $ bottom of rod (.5" plug)
12   pz    0.0      $ bottom of fuel (47 pellets, 0.414" long)
13   pz   48.780    $ top of fuel (48.77954 cm fuel column)
14   pz   50.4952   $ bottom of upper grid plate
15   pz   53.0352   $ top of upper grid plate
16   pz   74.35596  $ bottom of top plug
17   pz   -0.4826   $ bottom of clad tube
18   pz   75.0824   $ top of clad tube
19   pz   76.89596  $ top of top plug
20   pz   23.39     $ bottom of midplane fuel
21   pz   25.39     $ top of midplane fuel
22   pz   48.280    $ bottom of upper fuel detector
23   pz    0.5      $ top of lower fuel detector
24   pz   50.53076  $ bottom of aluminum spacer
25   pz   53.07076  $ top of aluminum spacer
26   cz    0.17526  $ OD of hole in top plug
27   pz   75.81     $ bottom of hole in top plug
28   pz   70.8152   $ bottom of guide plate
29   pz   71.7677   $ top of guide plate
```

```
c
c Source surfaces
c
231   pz    24.31796    $ bottom of source
232   pz    25.51938   $ top of source
233   cz     0.29972   $ OD of source
234   pz    27.65552   $ top of plug in stick
235   pz    26.10358   $ top of screw
236   cz     0.12573   $ 3-48 screw
237   pz    26.2382    $ bottom of tube in stick
238   cz     0.4000    $ handle - wants to be 0.4064
239   pz    81.9277    $ top of handle
c
c Experiment Rod Surfaces
c
91    cz     0.3175    $ OD of experiment rod
92    pz    78.1812    $ top of experiment rod
93    pz    22.39      $ bottom of central detector zone
94    pz    26.39      $ top of central detector zone
9001  cz     0.309461  $ radial boundaries of central zone
9002  cz     0.301207
9003  cz     0.283981
9004  cz     0.265640
```

```
9005  cz    0.245934
9006  cz    0.224506
9007  cz    0.200805
9008  cz    0.173902
9009  cz    0.141990
9010  cz    0.100402
c
c Safety Element 1 surfaces
c
401 4 cz    0.26289  $ fuel OD (0.207")
402 4 cz    0.284519 $ clad ID (0.01297" wall from measured mass)
403 4 cz    0.317475 $ clad OD (0.249980")
404 4 cz    0.333375 $ ID of hole in grid plate at fuel (0.2522")
405 4 cz    0.17526  $ ID of spring
406 4 cz    0.22860  $ OD of spring
411 4 pz   -2.54     $ bottom of rod (1" plug)
412 4 pz    0.25908  $ bottom of fuel (47 pellets, 0.414" long)
413 4 pz   48.97608  $ top of fuel (48.77954 cm fuel column)
414 4 pz   50.2412   $ bottom of upper plug
415 4 pz   53.29936  $ bottom of poly
416 4 pz   -0.635    $ bottom of bottom groove
417 4 pz   -0.3175   $ top of bottom groove
418 4 pz   51.01082  $ bottom of top groove
```

```
419 4 pz    51.32832  $ top of top groove
420 4 pz    23.39     $ bottom of midplane fuel
421 4 pz    25.39     $ top of midplane fuel
422 4 pz    48.47608  $ bottom of upper fuel detector
423 4 pz     0.75908  $ top of lower fuel detector
424 4 pz    65.49136  $ top of poly plug
425 4 pz    68.84924  $ bottom of absorber
426 4 pz   140.07376  $ top of absorber
427 4 pz   140.57376  $ gap above absorber (0.5 cm)
428 4 pz   141.94536  $ plug above absorber (8")
430 4 pz    -2.54     $ bottom of lower grid plate
432 4 pz     0.0      $ top of lower grid plate
434 4 pz    50.50028  $ bottom of mid bundle plate 1
435 4 pz    53.04028  $ top of mid bundle plate 1
436 4 pz    65.79108  $ gap above poly
437 4 cz     0.1811   $ screws
438 4 pz    -0.3175   $ bottom screw top
439 4 pz    50.81778  $ bottom of screw
440 4 pz    52.72278  $ top of screw
441 4 pz    66.05016  $ bottom of the 2nd mid bundle plate
442 4 pz    68.59016  $ top of the 2nd mid bundle plate
443 4 pz   143.21536  $ top of the top bundle plate
444 4 pz   141.11224  $ bottom of top screw
```

```
445 4 cz     0.254    $ top cap screw head
446 4 pz   142.79372  $ countersink for cap screw
447 4 cz     0.2794   $ end cap ends
448 4 pz    -1.11252  $ bottom of fueled section
449 4 pz    51.6128   $ top of fueled section
450 4 pz    -0.50546  $ bottom of full diameter fueled rod
451 4 pz    51.00574  $ top of full diameter fueled rod
452 4 cz     0.28353  $ hole in bundle plate at ends
453 4 pz    51.92776  $ bottom of the poly section
454 4 pz    67.16268  $ top of the poly section
455 4 pz    52.53482  $ bottom of the full diameter poly section
456 4 pz    66.55562  $ top of the full diameter poly section
457 4 pz    67.47764  $ bottom of absorber rod
458 4 pz    68.0847   $ bottom of full diameter absorber rod
459 4 pz   141.3383   $ top of full diameter absorber rod
460 4 pz    66.36766  $ bottom of set screw in 2nd middle BP
461 4 pz    68.27266  $ top of set screw in 2nd middle BP
462 4 pz    -2.2225   $ bottom of set screw in lower bundle plate
c
c Safety Element 2 surfaces
c
501 5 cz     0.26289  $ fuel OD (0.207")
502 5 cz     0.284519 $ clad ID (0.01297" wall from measured mass)
```

```
503 5 cz     0.317475 $ clad OD (0.249980")
504 5 cz     0.333375 $ ID of hole in grid plate at fuel (0.2522")
505 5 cz     0.17526  $ ID of spring
506 5 cz     0.22860  $ OD of spring
511 5 pz    -2.54     $ bottom of rod (1" plug)
512 5 pz     0.25908  $ bottom of fuel (47 pellets, 0.414" long)
513 5 pz    48.97608  $ top of fuel (48.77954 cm fuel column)
514 5 pz    50.2412   $ bottom of upper plug
515 5 pz    53.29936  $ bottom of poly
516 5 pz    -0.635    $ bottom of bottom groove
517 5 pz    -0.3175   $ top of bottom groove
518 5 pz    51.01082  $ bottom of top groove
519 5 pz    51.32832  $ top of top groove
520 5 pz    23.39     $ bottom of midplane fuel
521 5 pz    25.39     $ top of midplane fuel
522 5 pz    48.47608  $ bottom of upper fuel detector
523 5 pz     0.75908  $ top of lower fuel detector
524 5 pz    65.49136  $ top of poly plug
525 5 pz    68.84924  $ bottom of absorber
526 5 pz   140.07376  $ top of absorber
527 5 pz   140.57376  $ gap above absorber (0.5 cm)
528 5 pz   141.94536  $ plug above absorber (8")
530 5 pz    -2.54     $ bottom of lower grid plate
```

```
532 5 pz     0.0      $ top of lower grid plate
534 5 pz    50.50028  $ bottom of mid bundle plate 1
535 5 pz    53.04028  $ top of mid bundle plate 1
536 5 pz    65.79108  $ gap above poly
537 5 cz     0.1811   $ screws
538 5 pz    -0.3175   $ bottom screw top
539 5 pz    50.81778  $ bottom of screw
540 5 pz    52.72278  $ top of screw
541 5 pz    66.05016  $ bottom of the 2nd mid bundle plate
542 5 pz    68.59016  $ top of the 2nd mid bundle plate
543 5 pz   143.21536  $ top of the top bundle plate
544 5 pz   141.11224  $ bottom of top screw
545 5 cz     0.254    $ top cap screw head
546 5 pz   142.79372  $ countersink for cap screw
547 5 cz     0.2794   $ end cap ends
548 5 pz    -1.11252  $ bottom of fueled section
549 5 pz    51.6128   $ top of fueled section
550 5 pz    -0.50546  $ bottom of full diameter fueled rod
551 5 pz    51.00574  $ top of full diameter fueled rod
552 5 cz     0.28353  $ hole in bundle plate at ends
553 5 pz    51.92776  $ bottom of the poly section
554 5 pz    67.16268  $ top of the poly section
555 5 pz    52.53482  $ bottom of the full diameter poly section
```

```
556 5 pz    66.55562  $ top of the full diameter poly section
557 5 pz    67.47764  $ bottom of absorber rod
558 5 pz    68.0847   $ bottom of full diameter absorber rod
559 5 pz   141.3383   $ top of full diameter absorber rod
560 5 pz    66.36766  $ bottom of set screw in 2nd middle BP
561 5 pz    68.27266  $ top of set screw in 2nd middle BP
562 5 pz    -2.2225   $ bottom of set screw in lower bundle plate
c
c Control Element surfaces
c
601 6 cz     0.26289  $ fuel OD (0.207")
602 6 cz     0.284519 $ clad ID (0.01297" wall from measured mass)
603 6 cz     0.317475 $ clad OD (0.249980")
604 6 cz     0.333375 $ ID of hole in grid plate at fuel (0.2522")
605 6 cz     0.17526  $ ID of spring
606 6 cz     0.22860  $ OD of spring
611 6 pz    -2.54     $ bottom of rod (1" plug)
612 6 pz     0.25908  $ bottom of fuel (47 pellets, 0.414" long)
613 6 pz    48.97608  $ top of fuel (48.77954 cm fuel column)
614 6 pz    50.2412   $ bottom of upper plug
615 6 pz    53.29936  $ bottom of poly
616 6 pz    -0.635    $ bottom of bottom groove
617 6 pz    -0.3175   $ top of bottom groove
```

```
618 6 pz    51.01082  $ bottom of top groove
619 6 pz    51.32832  $ top of top groove
620 6 pz    23.39     $ bottom of midplane fuel
621 6 pz    25.39     $ top of midplane fuel
622 6 pz    48.47608  $ bottom of upper fuel detector
623 6 pz     0.75908  $ top of lower fuel detector
624 6 pz    65.49136  $ top of poly plug
625 6 pz    68.84924  $ bottom of absorber
626 6 pz   140.07376  $ top of absorber
627 6 pz   140.57376  $ gap above absorber (0.5 cm)
628 6 pz   141.94536  $ plug above absorber (8")
630 6 pz    -2.54     $ bottom of lower grid plate
632 6 pz     0.0      $ top of lower grid plate
634 6 pz    50.50028  $ bottom of mid bundle plate 1
635 6 pz    53.04028  $ top of mid bundle plate 1
636 6 pz    65.79108  $ gap above poly
637 6 cz     0.1811   $ screws
638 6 pz    -0.3175   $ bottom screw top
639 6 pz    50.81778  $ bottom of screw
640 6 pz    52.72278  $ top of screw
641 6 pz    66.05016  $ bottom of the 2nd mid bundle plate
642 6 pz    68.59016  $ top of the 2nd mid bundle plate
643 6 pz   143.21536  $ top of the top bundle plate
```

```
644 6 pz   141.11224  $ bottom of top screw
645 6 cz     0.254    $ top cap screw head
646 6 pz   142.79372  $ countersink for cap screw
647 6 cz     0.2794   $ end cap ends
648 6 pz    -1.11252  $ bottom of fueled section
649 6 pz    51.6128   $ top of fueled section
650 6 pz    -0.50546  $ bottom of full diameter fueled rod
651 6 pz    51.00574  $ top of full diameter fueled rod
652 6 cz     0.28353  $ hole in bundle plate at ends
653 6 pz    51.92776  $ bottom of the poly section
654 6 pz    67.16268  $ top of the poly section
655 6 pz    52.53482  $ bottom of the full diameter poly section
656 6 pz    66.55562  $ top of the full diameter poly section
657 6 pz    67.47764  $ bottom of absorber rod
658 6 pz    68.0847   $ bottom of full diameter absorber rod
659 6 pz   141.3383   $ top of full diameter absorber rod
660 6 pz    66.36766  $ bottom of set screw in 2nd middle BP
661 6 pz    68.27266  $ top of set screw in 2nd middle BP
662 6 pz    -2.2225   $ bottom of set screw in lower bundle plate
c
c   detector wells
c
801   pz    89.2175    $ top of tube
```

```
802   pz     0.735     $ this is 0.25" above the bottom of the tube - bottom inside of tube
803   pz     0.1       $ this is 0.1 cm above the bottom grid plate - bottom of tube
804   c/z   32.385    6.400   3.175  $ 2.5" OD tube outside
805   c/z   32.385    6.400   2.8575 $ 2.25" ID of tube
806   c/z  -32.385   -6.400   3.175  $ 2.5" OD tube
807   c/z  -32.385   -6.400   2.8575 $ 2.25" ID of tube
810   pz    30.84848                 $ 11.82" above bottom of poly
811   pz     0.862                   $ bottom of poly - 0.3" bottom of the tube
812   c/z   32.385    6.400   5.75945 $ OD poly
813   c/z  -32.385   -6.400   5.75945 $ OD poly
814   c/z   32.385    6.400   3.30581 $ ID poly
815   c/z  -32.385   -6.400   3.30581 $ ID poly
c
c   PPS detectors
c
820   pz    19.41                    $ top
821   pz     4.17                    $ bottom
822   c/z   32.385    6.400   2.54    $ 2" OD detector volume
823   c/z   32.385    6.400   2.53492 $ 1.996" ID detector foil
824   c/z  -32.385   -6.400   2.54    $ 2" OD detector volume
825   c/z  -32.385   -6.400   2.53492 $ 1.996" ID detector foil
c
c cell boundaries
```

```
c
901  px    0.43000                       $ 0.860 cm pitch
902  px   -0.43000
903   p      1   1.7320508076  0  0.8600   $ 0.860 cm pitch
904   p      1   1.7320508076  0 -0.8600
905   p     -1   1.7320508076  0  0.8600
906   p     -1   1.7320508076  0 -0.8600
c
c  the outer array boundaries
c    the first number is 27 x pitch * cos(30)
c    the other one is twice that
c
911   py     20.10911
912   py    -20.10911
913   p     1.7320508076   1  0  40.21822
914   p     1.7320508076   1  0 -40.21822
915   p    -1.7320508076   1  0  40.21822
916   p    -1.7320508076   1  0 -40.21822
917   pz   -75
918   pz   140
c
c  the inner array boundaries
c    the first number is 4.5 x pitch * cos(30)
```

```
c    the other one is twice that
c
1911   py      5.58586
1912   py     -5.58586
1913   p     1.7320508076   1  0   11.17173
1914   p     1.7320508076   1  0  -11.17173
1915   p    -1.7320508076   1  0   11.17173
1916   p    -1.7320508076   1  0  -11.17173
1917   pz   -1.27
c 1911   py      1.86195
c 1912   py     -1.86195
c 1913   p     1.7320508076   1  0   3.72391
c 1914   p     1.7320508076   1  0  -3.72391
c 1915   p    -1.7320508076   1  0   3.72391
c 1916   p    -1.7320508076   1  0  -3.72391
c 1917   pz   -1.27
c
c  outside of the inner 0.0625" wall
c    the first number is 3.5 x pitch * cos(30) + 0.065"
c    the other one is twice that
c
1921   py      2.76549
1922   py     -2.76549
```

```
1923   p     1.7320508076   1  0   5.53097
1924   p     1.7320508076   1  0  -5.53097
1925   p    -1.7320508076   1  0   5.53097
1926   p    -1.7320508076   1  0  -5.53097
1927   pz   -1.42875
c
c  outside of the inner 0.040" thick Cd liner
c    the first number is 3.5 x pitch * cos(30) + 0.065" + 0.040"
c    the other one is twice that
c
1931   py      2.86709
1932   py     -2.86709
1933   p     1.7320508076   1  0   5.73417
1934   p     1.7320508076   1  0  -5.73417
1935   p    -1.7320508076   1  0   5.73417
1936   p    -1.7320508076   1  0  -5.73417
1937   pz   -1.53035
c
c  the inside of the 0.125" thick experiment can
c    the first number is 4.5 x pitch * cos(30) - 0.125 "
c    the other one is twice that
c
1941   py      3.03402
```

```
1942   py     -3.03402
1943   p     1.7320508076   1  0   6.06804
1944   p     1.7320508076   1  0  -6.06804
1945   p    -1.7320508076   1  0   6.06804
1946   p    -1.7320508076   1  0  -6.06804
1947   pz   -1.5304
c
c  the outside of the experiment can
c    the first number is 4.5 x pitch * cos(30)
c    the other one is twice that
c
1951   py      3.35152
1952   py     -3.35152
1953   p     1.7320508076   1  0   6.70304
1954   p     1.7320508076   1  0  -6.70304
1955   p    -1.7320508076   1  0   6.70304
1956   p    -1.7320508076   1  0  -6.70304
1957   pz   -2.54
1958   pz   76.0
c
c    the part of the array in the projection
c
941   py     16.45
```

```
942   py    -16.45
943   p     1.7320508076   1  0  32.9
944   p     1.7320508076   1  0 -32.9
945   p    -1.7320508076   1  0  32.9
946   p    -1.7320508076   1  0 -32.9
c
c    water level
c
100   pz    68.2752     $ top of the water - 68.2752 gives 6" above grid plate
c
c                 $ in the following "water" = water level (surface 100) if < 48.78
c                 $                          = 48.78 if water level is above top of fuel
40    pz    20.39   $ bottom of the first middle detector: water/2 - 6
41    pz    22.39   $ top of first detector: water/2 - 4
42    pz    24.39   $ top of second detector: water/2 - 2
43    pz    26.39   $ half of the water height, top of third detector: water/2
44    pz    28.39   $ top of fourth detector: water/2 + 2
45    pz    48.28   $ upper 1/2 cm of fuel under water: water - 0.5 OR 48.78 - 0.5
c
c    the tank
c
921   pz   -19.05      $ bottom inside of tank - 7.5" below top of bottom GP
922   pz    82.55      $ top of tank - 40" above bottom of tank water
```

```
923   cz    46.83125   $ inside of tank - 36.875" diameter
924   pz   -74.295     $ bottom inside of projection - 21.75" below bottom of tank water
925   cz    19.05      $ inside of projection - 15" diameter
926   pz   -21.59      $ bottom outside of tank - 1" thick
927   pz    81.28      $ top flange on tank - 1/2" thick
928   cz    50.00625   $ outside of top flange - 1" overhang
929   cz    47.46625   $ outside of tank - 1/4" wall
930   pz   -74.93      $ bottom outside of projection - 1/4" wall
931   cz    19.685     $ outside of projection - 1/4" wall
932   cz    46.355     $ outside curve of lower grid plate (36.5" OD)
933   cz    46.355     $ outside curve of upper grid plate (36.5" OD)
c
c    the upper grid plate - 16" hex
c
961   py     21.59
962   py    -21.59
963   p     1.7320508076   1  0  43.18
964   p     1.7320508076   1  0 -43.18
965   p    -1.7320508076   1  0  43.18
966   p    -1.7320508076   1  0 -43.18
c
c   lower grid plate holes
c
```

```
970   c/z   30.7959  17.78    5.08
971   c/z    0.0     35.56    5.08
972   c/z  -30.7959  17.78    5.08
973   c/z  -30.7959 -17.78    5.08
974   c/z    0.0    -35.56    5.08
975   c/z   30.7959 -17.78    5.08
c
c    arms on the upper grid plate
c
981   px    38.1762
982   py     2.54
983   py    -2.54
984   p     1   1.7320508076  0 -76.3524
985   p    -1.7320508076   1  0   5.08
986   p    -1.7320508076   1  0  -5.08
987   p     1  -1.7320508076  0 -76.3524
988   p     1.7320508076   1  0   5.08
989   p     1.7320508076   1  0  -5.08
990   c/z   35.56        0  1.27
991   c/z  -17.78  30.7959  1.27
992   c/z  -17.78 -30.7959  1.27
c
c surfaces for ACRR fuel element
```

```
c
c
c  the grid plates
c
1101 9 pz  11.33       $ bottom of bottom grid plate
1102 9 pz  16.41       $ top of bottom grid plate
1103 9 pz  80.55       $ bottom of top grid plate
1104 9 pz  83.09       $ top of top grid plate
1105 9 cz  1.5875      $ 1.25" dia through hole in bottom grid plate
1106 9 cz  1.8542      $ 1.46" dia cylindrical part of countersink
1107 9 cz  1.94945     $ 1.535" dia through hole in top grid plate
1108 9 z   15.14 1.8542  13.2858 0.0  $ cone of countersink
1109 9 pz  14.8733     $ plane where bottom cylinder meets cone
1110 9 pz  15.14       $ plane where top cylinder meets cone
c
c  fins on end fixtures
c
1111 9 px  -0.17526    $ fin plane (0.138" thick)
1112 9 px   0.17526    $ fin plane
1113 9  p   1 1.7320508076 0  0.35052
1114 9  p   1 1.7320508076 0 -0.35052
1115 9  p  -1 1.7320508076 0  0.35052
1116 9  p  -1 1.7320508076 0 -0.35052
```

```
1117 9 px   0.0
1118 9 py   0.0
c
c  bottom fixture
c
1119 9 cz  1.82118     $ ID of the cladding (1.455")
1120 9 cz  1.87198     $ OD of the fuel element 1.475" OD
1121 9 cz  0.7874      $ stick on the bottom
1122 9 pz  20.78388    $ plane where cone meets cylinder
1123 9 z   20.78388 1.87325  15.11714  0.0  $ cone
1124 9 pz  22.4425     $ top of fixture
1125 9 cz  1.48717     $ hole in fixture
1126 9 pz  21.1725     $ plane that separates cylinder from cone in hole
1127 9 z   21.1725 1.48717  20.4395 0.0  $ cone of hole
c
c  top fixture
c
1131 9 pz  76.3413     $ bottom of top fixture
1132 9 pz  77.99992    $ plane where cone meets cylinder
1133 9 z   77.99992 1.87325  83.63936 0.0 $ cone
1134 9 pz  87.18456    $ plane at top
1135 9 z   87.18456 0.7874  87.97196 0.0 $ cone at top
1136 9 pz  77.6113     $ plane that separates cylinder from cone in hole
```

```
1137 9 z   77.6113 1.48717  78.3443 0.0  $ cone in hole
1138 9 pz  84.0375     $ top of top fins
c
c  BeO reflectors
c
1141 9 pz  22.9886     $ top of bottom reflector
1142 9 cz  1.46177     $ OD of reflector
1143 9 z   77.1414 1.46177  77.8744 0.0  $ cone on top reflector
c
c  niobium cups
c
1150 9 cz  1.77038     $ OR of niobium cups (0.697")
1151 9 cz  1.73228     $ IR of niobium cups (0.015" wall)
1152 9 pz  23.0394     $ top floor 1
1153 9 pz  33.3264     $ bottom floor 2
1154 9 pz  33.3772     $ top floor 2
1155 9 pz  43.6642     $ bottom floor 3
1156 9 pz  43.7150     $ top floor 3
1157 9 pz  54.0020     $ bottom floor 4
1158 9 pz  54.0528     $ top floor 4
1159 9 pz  64.3398     $ bottom floor 5
1160 9 pz  64.3906     $ top floor 5
1161 9 pz  75.1856     $ lid bottom
```

```
1162 9 pz  75.2364     $ lid top
c
c  the fuel
c
1170 9 cz  0.2415      $ IR of inner pellet
1171 9 cz  1.1000      $ OR of inner pellet
1172 9 cz  1.1175      $ IR of outer pellet
1173 9 cz  1.684       $ OR of outer pellet
1174 9 cz  1.57986     $ OR of smaller outer pellet (0.041" smaller)
1175 9 pz  23.6744     $ fuel 1   can 1
1176 9 pz  32.5644     $ fuel 2   can 1
1177 9 pz  33.1994     $ fuel top can 1
1178 9 pz  34.0122     $ fuel 1   can 2
1179 9 pz  42.9022     $ fuel 2   can 2
1180 9 pz  43.5372     $ fuel top can 2
1181 9 pz  44.3500     $ fuel 1   can 3
1182 9 pz  53.2400     $ fuel 2   can 3
1183 9 pz  53.8750     $ fuel top can 3
1184 9 pz  54.6878     $ fuel 1   can 4
1185 9 pz  63.5778     $ fuel 2   can 4
1186 9 pz  64.2128     $ fuel top can 4
1187 9 pz  65.0256     $ fuel 1   can 5
1188 9 pz  73.9156     $ fuel 2   can 5
```

```
1189 9 pz  75.1856     $ fuel top can 5
c
c
c ACRR cell boundaries
c
1901  px    2.0855                         $ 4.1871 cm pitch
1902  px   -2.0855
1903   p      1   1.7320508076  0  4.1871   $ 4.1871 cm pitch
1904   p      1   1.7320508076  0 -4.1871
1905   p     -1   1.7320508076  0  4.1871
1906   p     -1   1.7320508076  0 -4.1871

c
c UO2 fuel
c Fuel density 10.2650 g/cc (derived from assembly records)
c average fuel column mass 108.7165 g (averaged from assembly records)
c given fuel pellet diameter 0.207"
c derived fuel column length 48.77954 cm
c
c 0.999845 UO2, the rest is impurities
c
c 0.02814% U-234 in uranium (ORNL measurement)
c 6.90339% U-235 in uranium (ORNL measurement)
```

```
c 0.06336% U-236 in uranium (ORNL measurement)
c
m1
    92234.80c  6.55010E-6
    92235.80c  1.60003E-3
    92236.80c  1.46230E-5
    92238.80c  2.12840E-2
     8016.80c  4.58104E-2
c now the impurities that were measured
c    47000.xxc  8.4242E-9  $Ag
c  Silver
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        107          51.839 %
c        109          48.161 %
     47107.80c 4.36702e-009
     47109.80c 4.05718e-009
c     5000.xxc  2.1614E-7  $B
c  Boron
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        10          19.9 %
c        11          80.1 %
```

```
     5010.80c 4.30119e-008
     5011.80c 1.73128e-007
c    48000.xxc  6.8189E-9  $Cd
c  Cadmium
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        106           1.25 %
c        108           0.89 %
c        110          12.49 %
c        111          12.8 %
c        112          24.13 %
c        113          12.22 %
c        114          28.73 %
c        116           7.49 %
     48106.80c 8.52363e-011
     48108.80c 6.06882e-011
     48110.80c 8.51681e-010
     48111.80c 8.72819e-010
     48112.80c 1.6454e-009
     48113.80c 8.3327e-010
     48114.80c 1.95907e-009
     48116.80c 5.10736e-010
    27059.80c  2.1608E-8  $Co
```

```
c    24000.xxc  2.5085E-6  $Cr
c  Chromium
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        50            4.345 %
c        52           83.789 %
c        53            9.501 %
c        54            2.365 %
     24050.80c 1.08994e-007
     24052.80c 2.10185e-006
     24053.80c 2.38333e-007
     24054.80c 5.9326e-008
c    29000.xxc  1.9358E-7  $Cu
c  Copper
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        63           69.17 %
c        65           30.83 %
     29063.80c 1.33899e-007
     29065.80c 5.96807e-008
c    26000.xxc  1.0305E-5  $Fe
c  Iron
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
```

```
c  Isotopic Mass    Atom Fraction
c        54            5.845 %
c        56           91.754 %
c        57            2.119 %
c        58            0.282 %
     26054.80c 6.02327e-007
     26056.80c 9.45525e-006
     26057.80c 2.18363e-007
     26058.80c 2.90601e-008
    25055.80c  2.8355E-7  $Mn
c  Molybdenum 1.2435e-007
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        92           14.84 %
c        94            9.25 %
c        95           15.92 %
c        96           16.68 %
c        97            9.55 %
c        98           24.13 %
c        100            9.63 %
     42092.80c 1.84535e-008
     42094.80c 1.15024e-008
     42095.80c 1.97965e-008
```

```
     42096.80c 2.07416e-008
     42097.80c 1.18754e-008
     42098.80c 3.00057e-008
     42100.80c 1.19749e-008
c    28000.xxc  3.4966E-6  $Ni
c  Nickel
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        58          68.0769 %
c        60          26.2231 %
c        61           1.1399 %
c        62           3.6345 %
c        64           0.9256 %
     28058.80c 2.38038e-006
     28060.80c 9.16917e-007
     28061.80c 3.98577e-008
     28062.80c 1.27084e-007
     28064.80c 3.23645e-008
c  Vanadium 1.4804E-08
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        50           0.25 %
c        51          99.75 %
```

23050.80c 3.701E-11

23051.80c 1.4767E-08

c 74000.xxc 3.5979E-9 $W

c Tungsten

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Atom Fraction

c 180 0.12 %

c 182 26.5 %

c 183 14.31 %

c 184 30.64 %

c 186 28.43 %

c 74180.66c 4.31748e-012 $ no MCNP XS for W-180

74182.80c 9.53444e-010

74183.80c 5.14859e-010

74184.80c 1.1024e-009

74186.80c 1.02288e-009

c impurities that were below the detection limit at half the limit

c 66000.xxc 4.2796E-10 $Dy - no Dy in MCNP cross sections

c 63000.xxc 4.5763E-10 $Eu

c Europium

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Atom Fraction

c 151 47.81 %

```
c       153          52.19 %
     63151.80c 2.18793e-010
     63153.80c 2.38837e-010
c    64000.xxc  4.4225E-10 $Gd
c  Gadolinium
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c       152           0.2 %
c       154           2.18 %
c       155          14.8 %
c       156          20.47 %
c       157          15.65 %
c       158          24.84 %
c       160          21.86 %
     64152.80c 8.845e-013
     64154.80c 9.64105e-012
     64155.80c 6.5453e-011
     64156.80c 9.05286e-011
     64157.80c 6.92121e-011
     64158.80c 1.09855e-010
     64160.80c 9.66759e-011
c    62000.xxc  5.2624E-10 $Sm
c  Samarium
```

```
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        144          3.07 %
c        147         14.99 %
c        148         11.24 %
c        149         13.82 %
c        150          7.38 %
c        152         26.75 %
c        154         22.75 %
c     62144.49c 1.61556e-011 $ no MCNP XS for Sm-144
    62147.80c 7.88834e-011
c     62148.49c 5.91494e-011 $ no MCNP XS for Sm-148
    62149.80c 7.27264e-011
    62150.80c 3.88365e-011
    62152.80c 1.40769e-010
c     62154.49c 1.1972e-010 $ no MCNP XS for Sm-154
c
c    6061 aluminum
c    composition from Kaiser certified test report
c    density 2.700
c
m2   13027.80c  -0.9606
c     14000.xxx  -0.0072
```

```
     14028.80c  -0.006615 14029.80c  -0.000348 14030.80c  -0.000237
c    26000.xxx  -0.0062
     26054.80c  -0.000350 26056.80c  -0.005698 26057.80c  -0.000134
     26058.80c  -0.000018
c    29000.xxx  -0.0031
     29063.80c  -0.002123 29065.80c  -0.000977
     25055.80c  -0.009
c  Magnesium
c     1.04 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c       24          77.95 %
c       25          10.28 %
c       26          11.77 %
      12024.80c -0.0081068
      12025.80c -0.00106913
      12026.80c -0.00122407
c    24000.xxx  -0.002
     24050.80c  -0.000083 24052.80c  -0.001674 24053.80c  -0.000193
     24054.80c  -0.000049
c  Tin
c     0.12 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
```

```
c  Isotopic Mass    Mass Fraction
c        112           0.91439 %
c        114           0.63327 %
c        115           0.3291 %
c        116          14.196 %
c        117           7.5631 %
c        118          24.055 %
c        119           8.604 %
c        120          32.907 %
c        122           4.7545 %
c        124           6.0434 %
     50112.80c -1.09727e-005
     50114.80c -7.59927e-006
     50115.80c -3.94916e-006
     50116.80c -0.000170352
     50117.80c -9.0757e-005
     50118.80c -0.000288661
     50119.80c -0.000103248
     50120.80c -0.000394886
     50122.80c -5.70546e-005
     50124.80c -7.25207e-005
c  Titanium
c     0.02 wt %
```

```
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        46            7.9201 %
c        47            7.2978 %
c        48           73.845 %
c        49            5.5322 %
c        50            5.4049 %
     22046.80c -1.58402e-005
     22047.80c -1.45956e-005
     22048.80c -0.00014769
     22049.80c -1.10644e-005
     22050.80c -1.08098e-005
c  Vanadium
c     0.01 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        50            0.24512 %
c        51           99.755 %
     23050.80c -2.4512e-007
     23051.80c -9.97549e-005
c
c   3003 aluminum
c   average values where a range is specified
```

```
c    half of max values where only a maximum is specified
c    density 2.73 g/cc
c
m3   13027.80c  -0.97925
c     29000.xxx  -0.00125
     29063.80c  -0.000856 29065.80c  -0.000394
c     26000.xxx  -0.0035
     26054.80c  -0.000198 26056.80c  -0.003217 26057.80c  -0.000076
     26058.80c  -0.000010
     25055.80c  -0.0125
c     14000.xxx  -0.003
     14028.80c  -0.002756 14029.80c  -0.000145 14030.80c  -0.000099
c  Tin
c      0.05 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        112           0.91439 %
c        114           0.63327 %
c        115           0.3291 %
c        116          14.196 %
c        117           7.5631 %
c        118          24.055 %
c        119           8.604 %
```

```
c        120          32.907 %
c        122           4.7545 %
c        124           6.0434 %
     50112.80c -4.57196e-006
     50114.80c -3.16636e-006
     50115.80c -1.64548e-006
     50116.80c -7.09801e-005
     50117.80c -3.78154e-005
     50118.80c -0.000120275
     50119.80c -4.30199e-005
     50120.80c -0.000164536
     50122.80c -2.37727e-005
     50124.80c -3.0217e-005
c
c    water
c      Temperature: 25 C
c      rho: 0.99705
c
m4    1001.80c  6.6659E-2
     8016.80c  3.3329E-2
c mt4   hh2o.25t
c
c    water for reflector
```

```
c      Temperature: 25 deg C
c      rho: 0.99704
c
m40   1001.80c  6.6659E-2
      8016.80c  3.3329E-2
c mt40  hh2o.25t
c
c    stainless steel 304
c    0.19 Cr, 0.0925 Ni, 0.02 Mn, 0.01 Si, balance (0.6875) Fe
c    density 7.9
c
m5   14028.80c  -0.009187 14029.80c  -0.000483 14030.80c  -0.000329
     24050.80c  -0.00794  24052.80c  -0.15903  24053.80c  -0.01838
     24054.80c  -0.00465
     25055.80c  -0.02
     26054.80c  -0.03851  26056.80c  -0.63213  26057.80c  -0.01472
     26058.80c  -0.00214
     28058.80c  -0.06237  28060.80c  -0.02465  28061.80c  -0.00106
     28062.80c  -0.00351  28064.80c  -0.00091
c
c    polyethylene (CH2)
c      density 0.93
c
```

```
m7    6000.80c  1          1001.80c  2
mt7   poly.20t
c
c    Boron Carbide (B4C)
c      crystal density 2.52 g/cc (Hdbk Chem/Phys, 64th ed, p. B-76)
c      max packing density (1.7 per Jim Fisk)
c      the pellets supplied by Framatome ANP will be 70-76% of theoretical
c        density - 1.764 - 1.9152 g/cc
c      these atom densities give a mass density of 1.5 g/cc
c
m8    5010.80c  1.2968E-2  5011.80c  5.2197E-2
      6000.80c  1.6320E-2
c     26000.xxx  1.6175E-5
c  Iron
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        54           5.845 %
c        56          91.754 %
c        57           2.119 %
c        58           0.282 %
      26054.80c 9.45429e-007
      26056.80c 1.48412e-005
      26057.80c 3.42748e-007
```

```
     26058.80c 4.56135e-008
c     14000.xxx  3.2163E-6
c  Silicon
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        28          92.2297 %
c        29           4.6832 %
c        30           3.0872 %
     14028.80c 2.96638e-006
     14029.80c 1.50626e-007
     14030.80c 9.92936e-008
    15031.80c  5.8328E-6
    16032.80c  5.6341E-6
     7014.80c  3.8695E-5
     8016.80c  5.6460E-5
c
c
c   aluminum tooling plate
c   composition from certified test report
c   density 2.70
c
m9   13027.80c  -0.9229
c  Silicon
```

```
c    0.5 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c       28          91.873 %
c       29           4.8318 %
c       30           3.2948 %
      14028.80c -0.00459367
      14029.80c -0.000241589
      14030.80c -0.000164739
c  Iron
c    0.6 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c       54           5.6456 %
c       56          91.902 %
c       57           2.1604 %
c       58           0.29254 %
      26054.80c -0.000338733
      26056.80c -0.00551409
      26057.80c -0.000129622
      26058.80c -1.75527e-005
c  Copper
c    1.2 wt %
```

```
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        63           68.499 %
c        65           31.501 %
     29063.80c -0.00821993
     29065.80c -0.00378007
     25055.80c -0.0075
c  Magnesium
c     1.6 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        24           77.95 %
c        25           10.28 %
c        26           11.77 %
     12024.80c -0.012472
     12025.80c -0.00164482
     12026.80c -0.00188319
c  Chromium
c     0.06 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        50            4.1737 %
c        52           83.699 %
```

```
c        53          9.6736 %
c        54          2.4534 %
      24050.80c -2.50421e-005
      24052.80c -0.000502196
      24053.80c -5.80415e-005
      24054.80c -1.47202e-005
c  Zinc
c     3 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        64         47.54 %
c        66         28.126 %
c        67          4.196 %
c        68         19.475 %
c        70          0.66295 %
      30064.80c -0.0142619
      30066.80c -0.0084379
      30067.80c -0.00125881
      30068.80c -0.00584256
      30070.80c -0.000198884
c
c   stainless steel 316L
c   0.17 Cr, 0.12 Ni, 0.01 Mn, 0.00015 C, 0.000225 P, 0.00015 S
```

```
c   0.005 Si, 0.0025 Mo, balance (0.669475) Fe
c   density 8.0
c
m10
c  Iron 0.057754
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        54            5.845 %
c        56           91.754 %
c        57            2.119 %
c        58            0.282 %
     26054.80c 0.00337572
     26056.80c 0.0529916
     26057.80c 0.00122381
     26058.80c 0.000162866
c  Chromium 0.015751
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        50            4.345 %
c        52           83.789 %
c        53            9.501 %
c        54            2.365 %
     24050.80c 0.000684381
```

24052.80c 0.0131976

24053.80c 0.0014965

24054.80c 0.000372511

c Nickel 0.0098498

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Atom Fraction

c 58 68.0769 %

c 60 26.2231 %

c 61 1.1399 %

c 62 3.6345 %

c 64 0.9256 %

28058.80c 0.00670544

28060.80c 0.00258292

28061.80c 0.000112278

28062.80c 0.000357991

28064.80c 9.11697e-005

c Manganese 0.00087692

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Atom Fraction

c 55 100 %

25055.80c 0.00087692

c Carbon 6.0167e-005

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

```
c  Isotopic Mass    Atom Fraction
c        12           98.93 %
c        13            1.07 %
     6000.80c 6.0167e-005
c  Phosphorus 6.0167e-005
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        31           100 %
     15031.80c 6.0167e-005
c  Sulfur 2.2536e-005
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        32           94.93 %
c        33            0.76 %
c        34            4.29 %
c        36            0.02 %
     16032.80c 2.13934e-005
     16033.80c 1.71274e-007
     16034.80c 9.66794e-007
     16036.80c 4.5072e-009
c  Silicon 2.2536e-005
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
```

```
c       28          92.2297 %
c       29           4.6832 %
c       30           3.0872 %
     14028.80c 2.07849e-005
     14029.80c 1.05541e-006
     14030.80c 6.95731e-007
c  Molybdenum 0.0012554
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c       92          14.84 %
c       94           9.25 %
c       95          15.92 %
c       96          16.68 %
c       97           9.55 %
c       98          24.13 %
c       100          9.63 %
     42092.80c 0.000186301
     42094.80c 0.000116125
     42095.80c 0.00019986
     42096.80c 0.000209401
     42097.80c 0.000119891
     42098.80c 0.000302928
     42100.80c 0.000120895
```

```
c
c    Tantalum  16.65 g/cc
c
c  Tantalum 5.5413E-02
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        180           0.012 %
c        181          99.988 %
m11
     73180.80c 6.64956E-06
     73181.80c 5.54064E-02
c
c   6061 aluminum
c   composition from Kaiser certified test report
c   density 2.700
c
m12
     13027.80c  -0.9770
c  Silicon
c     0.62 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        28          91.873 %
```

```
c        29          4.8318 %
c        30          3.2948 %
     14028.80c -0.00569615
     14029.80c -0.000299571
     14030.80c -0.000204276
c  Iron
c     0.17 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        54          5.6456 %
c        56         91.902 %
c        57          2.1604 %
c        58          0.29254 %
     26054.80c -9.59745e-005
     26056.80c -0.00156233
     26057.80c -3.67263e-005
     26058.80c -4.97325e-006
c  Copper
c     0.23 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        63         68.499 %
c        65         31.501 %
```

```
  29063.80c -0.00157549
  29065.80c -0.000724513
c  Manganese
  25055.80c  -0.0002
c  Magnesium
c     1.2 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        24          77.95 %
c        25          10.28 %
c        26          11.77 %
  12024.80c -0.009354
  12025.80c -0.00123361
  12026.80c -0.00141239
c  Chromium
c     0.06 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        50           4.1737 %
c        52          83.699 %
c        53           9.6736 %
c        54           2.4534 %
  24050.80c -2.50421e-005
```

```
     24052.80c -0.000502196
     24053.80c -5.80415e-005
     24054.80c -1.47202e-005
c
c  Cadmium
c    Density 8.64 g/cc (matweb.com)
c
m13
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Atom Fraction
c        106           1.25 %
c        108           0.89 %
c        110          12.49 %
c        111          12.8 %
c        112          24.13 %
c        113          12.22 %
c        114          28.73 %
c        116           7.49 %
     48106.80c 1.25E-02
     48108.80c 8.9E-03
     48110.80c 1.249E-01
     48111.80c 1.28E-01
     48112.80c 2.413E-01
```

```
     48113.80c 1.222E-01
     48114.80c 2.873E-01
     48116.80c 7.49E-02
c
c    fully enriched uranium for PPS detectors
m19    92235.80c -0.93      92238.80c -0.07
c
c  ACRR materials - added 30 to material number
c
c      original fuel in code short on U-235 by 3.6 gm (97.536 gm should be 101.1211 gm)
c        c     uo2-beo fuel (3.276 g/cc)
c       m1      4009.50c -0.27958     8016.50c -0.52162    92235.50c -6.3958e-2
c             92238.50c -1.2238e-1  92234.50c -4.5605e-4  92236.50c -4.3631e-4
c             41093.50c -0.01157
c     uo2-beo fuel (3.276 g/cc with no hole)
m31      4009.80c -0.282817
         8016.80c -0.527675
                 92235.80c -6.6309e-2
        92238.80c -1.22309e-1
                 92234.80c -4.5482e-4
                 92236.80c -4.3587e-4
mt31 beo.60t
c       no nb mixed in       41093.50c -0.01157
```

```
c    water (1 g/cc)
m32     1001.80c  2          8016.80c  1
c    ss 304 (7.95 g/cc)
m33
c  Silicon
c     0.59 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        28          91.873 %
c        29           4.8318 %
c        30           3.2948 %
      14028.80c -0.00542053
      14029.80c -0.000285075
      14030.80c -0.000194392
       24050.80c -0.00806  24052.80c -0.15526
       24053.80c -0.01760  24054.80c -0.00437
       25055.80c -0.017  26054.80c -0.03993  26056.80c -0.63126
       26057.80c -0.01473  26058.80c -0.00213
       28058.80c -0.07062  28060.80c -0.026987 28061.80c -0.00114
       28062.80c -0.00372  28064.80c -0.00093
c    niobium (8.4 g/cc)
m34    41093.80c  1
c    beo (2.8 g/cc)
```

```
m37      4009.80c  0.5           8016.80c  0.5
mt37 beo.60t
c    al 6061 (2.7 g/cc)
m38
c  Magnesium
c     1 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        24          77.95 %
c        25          10.28 %
c        26          11.77 %
      12024.80c -0.007795
      12025.80c -0.00102801
      12026.80c -0.00117699
       13027.80c -0.968
c  Silicon
c     0.6 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        28          91.873 %
c        29           4.8318 %
c        30           3.2948 %
      14028.80c -0.00551241
```

14029.80c -0.000289907

14030.80c -0.000197686

c Chromium

c 0.35 wt %

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Mass Fraction

c 50 4.1737 %

c 52 83.699 %

c 53 9.6736 %

c 54 2.4534 %

24050.80c -0.000146079

24052.80c -0.00292948

24053.80c -0.000338576

24054.80c -8.58677e-005

25055.80c -0.0015

c Iron

c 0.7 wt %

c Source for Isotopic Atom Fractions: Chart of the Nuclides 16th ed.

c Isotopic Mass Mass Fraction

c 54 5.6456 %

c 56 91.902 %

c 57 2.1604 %

c 58 0.29254 %

```
     26054.80c -0.000395189
     26056.80c -0.00643311
     26057.80c -0.000151226
     26058.80c -2.04781e-005
c  Copper
c     0.4 wt %
c  Source for Isotopic Atom Fractions:  Chart of the Nuclides 16th ed.
c  Isotopic Mass    Mass Fraction
c        63           68.499 %
c        65           31.501 %
     29063.80c -0.00273998
     29065.80c -0.00126002
c
c  END of ACRR fuel materials
c
f1014:n     (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179
          1184 1185 1186 1187 1192 1193 1194 1195< (996 [-2 -2 0]))
f1024:n     (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179
          1184 1185 1186 1187 1192 1193 1194 1195< (996 [-2 -1 0]))
f1034:n     (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179
          1184 1185 1186 1187 1192 1193 1194 1195< (996 [-2 0 0]))
f1044:n     (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179
          1184 1185 1186 1187 1192 1193 1194 1195< (996 [-2 1 0]))
```

f1054:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [-2 2 0]))

f1064:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [-1 -2 0]))

f1074:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [-1 -1 0]))

f1084:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [-1 0 0]))

f1094:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [-1 1 0]))

f1104:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [-1 2 0]))

f1114:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [0 -2 0]))

f1124:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [0 -1 0]))

f1134:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [0 0 0]))

f1144:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [0 1 0]))

f1154:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [0 2 0]))

f1164:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179

1184 1185 1186 1187 1192 1193 1194 1195< (996 [1 -2 0]))

f1174:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [1 -1 0]))

f1184:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [1 0 0]))

f1194:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [1 1 0]))

f1204:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [1 2 0]))

f1214:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [2 -2 0]))

f1224:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [2 -1 0]))

f1234:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [2 0 0]))

f1244:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [2 1 0]))

f1254:n (1160 1161 1162 1163 1168 1169 1170 1171 1176 1177 1178 1179 1184 1185 1186 1187 1192 1193 1194 1195< (996 [2 2 0]))

f1004:n (1 < (999 [-7:7 -7:7 0])) (2 < (999 [-7:7 -7:7 0])) (3 < (999 [-7:7 -7:7 0])) (4 < (999 [-7:7 -7:7 0])) (5 < (999 [-7:7 -7:7 0])) (6 < (999 [-7:7 -7:7 0])) (7 < (999 [-7:7 -7:7 0]))

```
     t
c
f4:n    (1 < (999 [-7:7 -7:7 0])) (2 < (999 [-7:7 -7:7 0]))
     (3 < (999 [-7:7 -7:7 0])) (4 < (999 [-7:7 -7:7 0]))
     (5 < (999 [-7:7 -7:7 0])) (6 < (999 [-7:7 -7:7 0]))
     (7 < (999 [-7:7 -7:7 0]))
     t
fc4  Neutron Flux in the Fuel Underwater in the Central Assembly
c    238-group SCALE structure
e4        1e-011     1e-010     5e-010   7.5e-010     1e-009
       1.2e-009   1.5e-009     2e-009   2.5e-009     3e-009
         4e-009     5e-009   7.5e-009     1e-008  2.53e-008
         3e-008     4e-008     5e-008     6e-008     7e-008
         8e-008     9e-008     1e-007  1.25e-007    1.5e-007
      1.75e-007     2e-007  2.25e-007    2.5e-007  2.75e-007
         3e-007  3.25e-007    3.5e-007  3.75e-007     4e-007
       4.5e-007     5e-007   5.5e-007     6e-007  6.25e-007
       6.5e-007     7e-007   7.5e-007     8e-007   8.5e-007
         9e-007  9.25e-007    9.5e-007  9.75e-007     1e-006
      1.01e-006  1.02e-006  1.03e-006  1.04e-006  1.05e-006
      1.06e-006  1.07e-006  1.08e-006  1.09e-006    1.1e-006
      1.11e-006  1.12e-006  1.13e-006  1.14e-006  1.15e-006
     1.175e-006    1.2e-006 1.225e-006  1.25e-006    1.3e-006
```

1.35e-006	1.4e-006	1.45e-006	1.5e-006	1.59e-006
1.68e-006	1.77e-006	1.86e-006	1.94e-006	2e-006
2.12e-006	2.21e-006	2.3e-006	2.38e-006	2.47e-006
2.57e-006	2.67e-006	2.77e-006	2.87e-006	2.97e-006
3e-006	3.05e-006	3.15e-006	3.5e-006	3.73e-006
4e-006	4.75e-006	5e-006	5.4e-006	6e-006
6.25e-006	6.5e-006	6.75e-006	7e-006	7.15e-006
8.1e-006	9.1e-006	1e-005	1.15e-005	1.19e-005
1.29e-005	1.375e-005	1.44e-005	1.51e-005	1.6e-005
1.7e-005	1.85e-005	1.9e-005	2e-005	2.1e-005
2.25e-005	2.5e-005	2.75e-005	3e-005	3.125e-005
3.175e-005	3.325e-005	3.375e-005	3.46e-005	3.55e-005
3.7e-005	3.8e-005	3.91e-005	3.96e-005	4.1e-005
4.24e-005	4.4e-005	4.52e-005	4.7e-005	4.83e-005
4.92e-005	5.06e-005	5.2e-005	5.34e-005	5.9e-005
6.1e-005	6.5e-005	6.75e-005	7.2e-005	7.6e-005
8e-005	8.2e-005	9e-005	0.0001	0.000108
0.000115	0.000119	0.000122	0.000186	0.0001925
0.0002075	0.00021	0.00024	0.000285	0.000305
0.00055	0.00067	0.000683	0.00095	0.00115
0.0015	0.00155	0.0018	0.0022	0.00229
0.00258	0.003	0.00374	0.0039	0.006
0.00803	0.0095	0.013	0.017	0.025

```
          0.03    0.045    0.05    0.052    0.06
          0.073    0.075    0.082    0.085    0.1
          0.1283    0.15    0.2    0.27    0.33
          0.4    0.42    0.44    0.47    0.4995
          0.55    0.573    0.6    0.67    0.679
          0.75    0.82    0.8611    0.875    0.9
          0.92    1.01    1.1    1.2    1.25
          1.317    1.356    1.4    1.5    1.85
          2.354    2.479    3    4.304    4.8
          6.434    8.187    10    12.84    13.84
          14.55    15.68    17.33    20
c
f14:n   1   2   3   4   5   6   7
      451 452 453 454 455 456 457
      551 552 553 554 555 556 557
      651 652 653 654 655 656 657  t
fc14   Neutron Flux in the Fuel Underwater Everywhere
c    238-group SCALE structure
e14         1e-011    1e-010    5e-010    7.5e-010    1e-009
          1.2e-009    1.5e-009    2e-009    2.5e-009    3e-009
          4e-009    5e-009    7.5e-009    1e-008    2.53e-008
          3e-008    4e-008    5e-008    6e-008    7e-008
          8e-008    9e-008    1e-007    1.25e-007    1.5e-007
```

1.75e-007	2e-007	2.25e-007	2.5e-007	2.75e-007
3e-007	3.25e-007	3.5e-007	3.75e-007	4e-007
4.5e-007	5e-007	5.5e-007	6e-007	6.25e-007
6.5e-007	7e-007	7.5e-007	8e-007	8.5e-007
9e-007	9.25e-007	9.5e-007	9.75e-007	1e-006
1.01e-006	1.02e-006	1.03e-006	1.04e-006	1.05e-006
1.06e-006	1.07e-006	1.08e-006	1.09e-006	1.1e-006
1.11e-006	1.12e-006	1.13e-006	1.14e-006	1.15e-006
1.175e-006	1.2e-006	1.225e-006	1.25e-006	1.3e-006
1.35e-006	1.4e-006	1.45e-006	1.5e-006	1.59e-006
1.68e-006	1.77e-006	1.86e-006	1.94e-006	2e-006
2.12e-006	2.21e-006	2.3e-006	2.38e-006	2.47e-006
2.57e-006	2.67e-006	2.77e-006	2.87e-006	2.97e-006
3e-006	3.05e-006	3.15e-006	3.5e-006	3.73e-006
4e-006	4.75e-006	5e-006	5.4e-006	6e-006
6.25e-006	6.5e-006	6.75e-006	7e-006	7.15e-006
8.1e-006	9.1e-006	1e-005	1.15e-005	1.19e-005
1.29e-005	1.375e-005	1.44e-005	1.51e-005	1.6e-005
1.7e-005	1.85e-005	1.9e-005	2e-005	2.1e-005
2.25e-005	2.5e-005	2.75e-005	3e-005	3.125e-005
3.175e-005	3.325e-005	3.375e-005	3.46e-005	3.55e-005
3.7e-005	3.8e-005	3.91e-005	3.96e-005	4.1e-005
4.24e-005	4.4e-005	4.52e-005	4.7e-005	4.83e-005

```
4.92e-005   5.06e-005   5.2e-005   5.34e-005   5.9e-005
6.1e-005   6.5e-005   6.75e-005   7.2e-005   7.6e-005
8e-005   8.2e-005   9e-005   0.0001   0.000108
0.000115   0.000119   0.000122   0.000186   0.0001925
0.0002075   0.00021   0.00024   0.000285   0.000305
0.00055   0.00067   0.000683   0.00095   0.00115
0.0015   0.00155   0.0018   0.0022   0.00229
0.00258   0.003   0.00374   0.0039   0.006
0.00803   0.0095   0.013   0.017   0.025
0.03   0.045   0.05   0.052   0.06
0.073   0.075   0.082   0.085   0.1
0.1283   0.15   0.2   0.27   0.33
0.4   0.42   0.44   0.47   0.4995
0.55   0.573   0.6   0.67   0.679
0.75   0.82   0.8611   0.875   0.9
0.92   1.01   1.1   1.2   1.25
1.317   1.356   1.4   1.5   1.85
2.354   2.479   3   4.304   4.8
6.434   8.187   10   12.84   13.84
14.55   15.68   17.33   20
c
*f7:n   1  2  3  4  5  6  7  t
fc7 Fission Dep in all ordinary fuel underwater - not normalized as others
```

```
c
*f17:n    451 452 453 454 455 456 457
          551 552 553 554 555 556 557
          651 652 653 654 655 656 657 t
fc17 Fission Dep in all CE/SE fuel underwater - not normalized as others
c
        t
c
c  the PPS detectors
c
*f687:n    1040
*f697:n    1042
*f787:n    1041
*f797:n    1043
c
c  Neutron spectrum in the experiment rod detectors
c
fc914 Neutron spectrum in central 4 cm of the experiment rods
f914:n    1901 1902 1903 1904 1905 1906 1907 1908 1909
          1910  t
c
c     238-group SCALE structure
e914          1e-011      1e-010      5e-010    7.5e-010      1e-009
```

1.2e-009	1.5e-009	2e-009	2.5e-009	3e-009
4e-009	5e-009	7.5e-009	1e-008	2.53e-008
3e-008	4e-008	5e-008	6e-008	7e-008
8e-008	9e-008	1e-007	1.25e-007	1.5e-007
1.75e-007	2e-007	2.25e-007	2.5e-007	2.75e-007
3e-007	3.25e-007	3.5e-007	3.75e-007	4e-007
4.5e-007	5e-007	5.5e-007	6e-007	6.25e-007
6.5e-007	7e-007	7.5e-007	8e-007	8.5e-007
9e-007	9.25e-007	9.5e-007	9.75e-007	1e-006
1.01e-006	1.02e-006	1.03e-006	1.04e-006	1.05e-006
1.06e-006	1.07e-006	1.08e-006	1.09e-006	1.1e-006
1.11e-006	1.12e-006	1.13e-006	1.14e-006	1.15e-006
1.175e-006	1.2e-006	1.225e-006	1.25e-006	1.3e-006
1.35e-006	1.4e-006	1.45e-006	1.5e-006	1.59e-006
1.68e-006	1.77e-006	1.86e-006	1.94e-006	2e-006
2.12e-006	2.21e-006	2.3e-006	2.38e-006	2.47e-006
2.57e-006	2.67e-006	2.77e-006	2.87e-006	2.97e-006
3e-006	3.05e-006	3.15e-006	3.5e-006	3.73e-006
4e-006	4.75e-006	5e-006	5.4e-006	6e-006
6.25e-006	6.5e-006	6.75e-006	7e-006	7.15e-006
8.1e-006	9.1e-006	1e-005	1.15e-005	1.19e-005
1.29e-005	1.375e-005	1.44e-005	1.51e-005	1.6e-005
1.7e-005	1.85e-005	1.9e-005	2e-005	2.1e-005

2.25e-005	2.5e-005	2.75e-005	3e-005	3.125e-005
3.175e-005	3.325e-005	3.375e-005	3.46e-005	3.55e-005
3.7e-005	3.8e-005	3.91e-005	3.96e-005	4.1e-005
4.24e-005	4.4e-005	4.52e-005	4.7e-005	4.83e-005
4.92e-005	5.06e-005	5.2e-005	5.34e-005	5.9e-005
6.1e-005	6.5e-005	6.75e-005	7.2e-005	7.6e-005
8e-005	8.2e-005	9e-005	0.0001	0.000108
0.000115	0.000119	0.000122	0.000186	0.0001925
0.0002075	0.00021	0.00024	0.000285	0.000305
0.00055	0.00067	0.000683	0.00095	0.00115
0.0015	0.00155	0.0018	0.0022	0.00229
0.00258	0.003	0.00374	0.0039	0.006
0.00803	0.0095	0.013	0.017	0.025
0.03	0.045	0.05	0.052	0.06
0.073	0.075	0.082	0.085	0.1
0.1283	0.15	0.2	0.27	0.33
0.4	0.42	0.44	0.47	0.4995
0.55	0.573	0.6	0.67	0.679
0.75	0.82	0.8611	0.875	0.9
0.92	1.01	1.1	1.2	1.25
1.317	1.356	1.4	1.5	1.85
2.354	2.479	3	4.304	4.8
6.434	8.187	10	12.84	13.84

```
          14.55      15.68      17.33        20
c
c  experiment rod detectors
c
fc924 Captures in the central 4 cm of the experiment rods
f924:n    1901 1902 1903 1904 1905 1906 1907 1908 1909
        1910  t
fm924   (1 11 102) $ experiment rod captures
c
c     238-group SCALE structure
e924         1e-011      1e-010      5e-010    7.5e-010      1e-009
          1.2e-009    1.5e-009      2e-009    2.5e-009      3e-009
            4e-009      5e-009    7.5e-009      1e-008   2.53e-008
            3e-008      4e-008      5e-008      6e-008      7e-008
            8e-008      9e-008      1e-007   1.25e-007    1.5e-007
         1.75e-007      2e-007   2.25e-007    2.5e-007   2.75e-007
            3e-007   3.25e-007    3.5e-007   3.75e-007      4e-007
          4.5e-007      5e-007    5.5e-007      6e-007   6.25e-007
          6.5e-007      7e-007    7.5e-007      8e-007    8.5e-007
            9e-007   9.25e-007    9.5e-007   9.75e-007      1e-006
         1.01e-006   1.02e-006   1.03e-006   1.04e-006   1.05e-006
         1.06e-006   1.07e-006   1.08e-006   1.09e-006    1.1e-006
         1.11e-006   1.12e-006   1.13e-006   1.14e-006   1.15e-006
```

1.175e-006	1.2e-006	1.225e-006	1.25e-006	1.3e-006
1.35e-006	1.4e-006	1.45e-006	1.5e-006	1.59e-006
1.68e-006	1.77e-006	1.86e-006	1.94e-006	2e-006
2.12e-006	2.21e-006	2.3e-006	2.38e-006	2.47e-006
2.57e-006	2.67e-006	2.77e-006	2.87e-006	2.97e-006
3e-006	3.05e-006	3.15e-006	3.5e-006	3.73e-006
4e-006	4.75e-006	5e-006	5.4e-006	6e-006
6.25e-006	6.5e-006	6.75e-006	7e-006	7.15e-006
8.1e-006	9.1e-006	1e-005	1.15e-005	1.19e-005
1.29e-005	1.375e-005	1.44e-005	1.51e-005	1.6e-005
1.7e-005	1.85e-005	1.9e-005	2e-005	2.1e-005
2.25e-005	2.5e-005	2.75e-005	3e-005	3.125e-005
3.175e-005	3.325e-005	3.375e-005	3.46e-005	3.55e-005
3.7e-005	3.8e-005	3.91e-005	3.96e-005	4.1e-005
4.24e-005	4.4e-005	4.52e-005	4.7e-005	4.83e-005
4.92e-005	5.06e-005	5.2e-005	5.34e-005	5.9e-005
6.1e-005	6.5e-005	6.75e-005	7.2e-005	7.6e-005
8e-005	8.2e-005	9e-005	0.0001	0.000108
0.000115	0.000119	0.000122	0.000186	0.0001925
0.0002075	0.00021	0.00024	0.000285	0.000305
0.00055	0.00067	0.000683	0.00095	0.00115
0.0015	0.00155	0.0018	0.0022	0.00229
0.00258	0.003	0.00374	0.0039	0.006

```
      0.00803    0.0095    0.013    0.017    0.025
      0.03    0.045    0.05    0.052    0.06
      0.073    0.075    0.082    0.085    0.1
      0.1283    0.15    0.2    0.27    0.33
      0.4    0.42    0.44    0.47    0.4995
      0.55    0.573    0.6    0.67    0.679
      0.75    0.82    0.8611    0.875    0.9
      0.92    1.01    1.1    1.2    1.25
      1.317    1.356    1.4    1.5    1.85
      2.354    2.479    3    4.304    4.8
      6.434    8.187    10    12.84    13.84
      14.55    15.68    17.33    20
c
c  experiment rod detectors
c
fc904 Captures in the central 4 cm of the experiment rods
f904:n    1901 1902 1903 1904 1905 1906 1907 1908 1909
      1910  t
fm904   (1 11 102) $ experiment rod captures
c
c
c
imp:n    1 480r 0
```

```
mode   n
kcode  10000  1  50  1000
ksrc   10 10 17.55
prdmp    0  0  0  1
print    -128
lost   1000 10
tr4   0.   0.   0.  $ SE1 0=up  -68.57746=down
tr5   0.   0.   0.  $ SE2 0=up  -68.57746=down
tr6   0.   0.   0.  $ CE  0=up  -68.57746=down
tr9   0.   0. -23.0394 $ ACRR fuel element
kopts  kinetics=yes
c ctme   125
```

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VITA

Ashley Rachel Raster was born in St. Charles, Missouri. She attended elementary school in the Francis Howell School District and graduated from Francis Howell North High School in June 2018. She began studying in August 2018 at Missouri University of Science and Technology for her Bachelor of Science in Nuclear Engineering, which was received in May 2021. She also started a graduate program in August 2021 and received her Master of Science in Nuclear Engineering from Missouri University of Science and Technology in May 2022.