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Rev. 1

HTR-Proteus Pebble Bed Experimental Program Cores 9 & 10: Columnar Hexagonal Point-on-Point Packing with a 1:1 Moderator-to-Fuel Pebble Ratio

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March 2014

Idaho National Laboratory

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HTR-PROTEUS PEBBLE BED EXPERIMENTAL PROGRAM CORES 9 & 10: COLUMNAR HEXAGONAL POINT-ON-POINT PACKING WITH A 1:1 MODERATOR-TO-FUEL PEBBLE RATIO

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Gas Cooled (Thermal) Reactor – GCR

PROTEUS-GCR-EXP-004
CRIT-REAC

Status of Compilation / Evaluation / Peer Review

Section 1	Compiled	Independent Review	Working Group Review	Approved
1.0 DETAILED DESCRIPTION				
1.1 Description of the Critical and / or Subcritical Configuration	YES	YES	YES	YES
1.2 Description of Buckling and Extrapolation Length Measurements	NA	NA	NA	NA
1.3 Description of Spectral Characteristics Measurements	NA	NA	NA	NA
1.4 Description of Reactivity Effects Measurements	YES	YES	YES	YES
1.5 Description of Reactivity Coefficient Measurements	NA	NA	NA	NA
1.6 Description of Kinetics Measurements	NA	NA	NA	NA
1.7 Description of Reaction-Rate Distribution Measurements	NA	NA	NA	NA
1.8 Description of Power Distribution Measurements	NA	NA	NA	NA
1.9 Description of Isotopic Measurements	NA	NA	NA	NA
1.10 Description of Other Miscellaneous Types of Measurements	NA	NA	NA	NA
Section 2	**Evaluated**	**Independent Review**	**Working Group Review**	**Approved**
2.0 EVALUATION OF EXPERIMENTAL DATA				
2.1 Evaluation of Critical and / or Subcritical Configuration Data	YES	YES	YES	YES
2.2 Evaluation of Buckling and Extrapolation Length Data	NA	NA	NA	NA
2.3 Evaluation of Spectral Characteristics Data	NA	NA	NA	NA
2.4 Evaluation of Reactivity Effects Data	YES	YES	YES	YES
2.5 Evaluation of Reactivity Coefficient Data	NA	NA	NA	NA
2.6 Evaluation of Kinetics Measurements Data	NA	NA	NA	NA
2.7 Evaluation of Reaction Rate Distributions	NA	NA	NA	NA
2.8 Evaluation of Power Distribution Data	NA	NA	NA	NA
2.9 Evaluation of Isotopic Measurements	NA	NA	NA	NA
2.10 Evaluation of Other Miscellaneous Types of Measurements	NA	NA	NA	NA

Section 3	Compiled	Independent Review	Working Group Review	Approved
3.0 BENCHMARK SPECIFICATIONS				
3.1 Benchmark-Model Specifications for Critical and / or Subcritical Measurements	YES	YES	YES	YES
3.2 Benchmark-Model Specifications for Buckling and Extrapolation Length Measurements	NA	NA	NA	NA
3.3 Benchmark-Model Specifications for Spectral Characteristics Measurements	NA	NA	NA	NA
3.4 Benchmark-Model Specifications for Reactivity Effects Measurements	YES	YES	YES	YES
3.5 Benchmark-Model Specifications for Reactivity Coefficient Measurements	NA	NA	NA	NA
3.6 Benchmark-Model Specifications for Kinetics Measurements	NA	NA	NA	NA
3.7 Benchmark-Model Specifications for Reaction-Rate Distribution Measurements	NA	NA	NA	NA
3.8 Benchmark-Model Specifications for Power Distribution Measurements	NA	NA	NA	NA
3.9 Benchmark-Model Specifications for Isotopic Measurements	NA	NA	NA	NA
3.10 Benchmark-Model Specifications of Other Miscellaneous Types of Measurements	NA	NA	NA	NA
Section 4	**Compiled**	**Independent Review**	**Working Group Review**	**Approved**
4.0 RESULTS OF SAMPLE CALCULATIONS				
4.1 Results of Calculations of the Critical or Subcritical Configurations	YES	YES	YES	YES
4.2 Results of Buckling and Extrapolation Length Calculations	NA	NA	NA	NA
4.3 Results of Spectral Characteristics Calculations	NA	NA	NA	NA
4.4 Results of Reactivity Effect Calculations	YES	YES	YES	YES
4.5 Results of Reactivity Coefficient Calculations	NA	NA	NA	NA
4.6 Results of Kinetics Parameter Calculations	NA	NA	NA	NA
4.7 Results of Reaction-Rate Distribution Calculations	NA	NA	NA	NA
4.8 Results of Power Distribution Calculations	NA	NA	NA	NA
4.9 Results of Isotopic Calculations	NA	NA	NA	NA
4.10 Results of Calculations of Other Miscellaneous Types of Measurements	NA	NA	NA	NA
Section 5	**Compiled**	**Independent Review**	**Working Group Review**	**Approved**
5.0 REFERENCES	YES	YES	YES	YES
Appendix A: Computer Codes, Cross Sections, and Typical Input Listings	YES	YES	YES	YES

HTR-PROTEUS PEBBLE BED EXPERIMENTAL PROGRAM
CORES 9 & 10: COLUMNAR HEXAGONAL POINT-ON-POINT PACKING WITH A 1:1 MODERATOR-TO-FUEL PEBBLE RATIO

IDENTIFICATION NUMBER: PROTEUS-GCR-EXP-004
CRIT-REAC

KEY WORDS: control rod worths, critical facility, graphite-moderated, graphite-reflected, intermediate enriched uranium dioxide, Paul Scherrer Institut, pebble bed arrangement, PROTEUS, TRISO, zero-power experiment

SUMMARY

1.0 DETAILED DESCRIPTION

PROTEUS is a zero-power research reactor based on a cylindrical graphite annulus with a central cylindrical cavity; it is a part of the Paul Scherrer Institute (formerly EIR, Eidgenossisches Institut fur Reaktorforschung) and is situated near Würenlingen in the canton of Aargau in northern Switzerland. The graphite annulus remains basically the same for all experimental programs, but the contents of the central cavity are changed according to the type of reactor being investigated. Through most of its service history, PROTEUS has represented light-water reactors, but from 1992 to 1996 PROTEUS was configured as a pebble-bed reactor (PBR) critical facility and designated as HTR-PROTEUS. The nomenclature was used to indicate that this series consisted of High Temperature Reactor experiments performed in the PROTEUS assembly. During this period, seventeen critical configurations were assembled and various reactor physics experiments were conducted. These experiments included measurements of criticality, differential and integral control rod and safety rod worths, kinetics, reaction rates, water ingress effects, and small sample reactivity effects (Ref. 3).

HTR-PROTEUS was constructed, and the experimental program was conducted, for the purpose of providing experimental benchmark data for assessment of reactor physics computer codes. Considerable effort was devoted to benchmark calculations as a part of the HTR-PROTEUS program. References 1 and 2 provide detailed data for use in constructing models for codes to be assessed. Reference 3 is a comprehensive summary of the HTR-PROTEUS experiments and the associated benchmark program. This document draws freely from these references.

Four benchmark reports were prepared to document evaluation of the experimental configurations according to core packing and the moderator-to-fuel pebble ratios:

- PROTEUS-GCR-EXP-001
  - Cores 1, 1A, 2, and 3
  - Hexagonal Close Packing
  - 1:2 Moderator-to-Fuel Pebble Ratio
- PROTEUS-GCR-EXP-002
  - Core 4
  - Random Packing
  - 1:1 Moderator-to-Fuel Pebble Ratio
- PROTEUS-GCR-EXP-003
  - Cores 5, 6, 7, and 8
  - Columnar Hexagonal Point-On-Point Packing
  - 1:2 Moderator-to-Fuel Pebble Ratio
- PROTEUS-GCR-EXP-004
  - Cores 9 and 10
  - Columnar Hexagonal Point-On-Point Packing
  - 1:1 Moderator-to-Fuel Pebble Ratio

In its deployment as a pebble bed reactor critical facility from 1992 to 1996, the reactor was designated as HTR-PROTEUS. This experimental program was performed as part of an International Atomic Energy Agency (IAEA) Coordinated Research Project (CRP) on the Validation of Safety Related Physics Calculations for Low Enriched HTGRs (High Temperature Gas-cooled Reactors). Additional historical data regarding this IAEA CRP and the PROTEUS facility are provided in Appendix D (Ref. 3). Figure 1.0-1 shows a generic HTR-PROTEUS configuration.

Within this project, critical experiments were conducted for graphite moderated LEU (low enriched uranium) systems to determine core reactivity, flux and power profiles, reaction-rate ratios, the worth of control rods (both in-core and reflector based), the worth of burnable poisons, kinetic parameters, and the effects of moisture ingress on these parameters. Fuel for the experiments was provided by the KFA Research Center in Jülich, Germany. Initial criticality was achieved on July 7, 1992. These experiments were conducted over a range of experimental parameters such as carbon-to-uranium ratio (C/U), core height-to-diameter ratio, and simulated moisture concentration (Ref. 3).

In any PBR, the fuel elements are spherical "pebbles" roughly the size of billiard balls, composed of a graphite matrix in which thousands of tiny (~1 mm diameter) coated fuel particles are embedded. These particles are known as tristructural-isotropic (TRISO) and are composed of a central UO_2 kernel surrounded by thin layers of graphite and silicon-carbide.

In the PROTEUS set of experiments, ten different core configurations were constructed and studied. Several cores had more than one reference state either to test reproducibility or further simplify or improve upon the core configuration from the previous reference state. This means that there are slight changes but the basic core configuration remains the same. Core 4 is the only configuration using randomly placed pebbles in the core barrel. All other configurations used hand-stacked pebbles in known packing configurations. The experimenters used the term "deterministic" to denote these regular core lattices. These lattices were either hexagonal close-packed (HCP) or columnar hexagonal point-on-point (CHPOP) configurations. The former arrangement can be visualized as oranges placed in a crate (Figure 1.0-2). In the latter configuration, the pebbles in successive layers form columns without any relative lateral displacement (Figure 1.0-3). The deterministic arrangements are considered much more useful for benchmarking reactor physics computer codes.

Theoretical pebble packing fractions for the HCP and CHPOP configurations are 0.7405 and 0.6046, respectively. A reference value for the random packing of pebbles in the HTR-PROTEUS assembly is

0.61.[a] The packing fraction of the CHPOP configuration is very close to that of a PBR, as a value of 0.61 is a good approximation for the inner part of a PBR, whereas the packing fraction decreases at the core/reflector interface.[b]

Table 1.0-1 provides a brief explanation of the cores and their reference states. Additional descriptions of each core and reference state will appear throughout the reports.

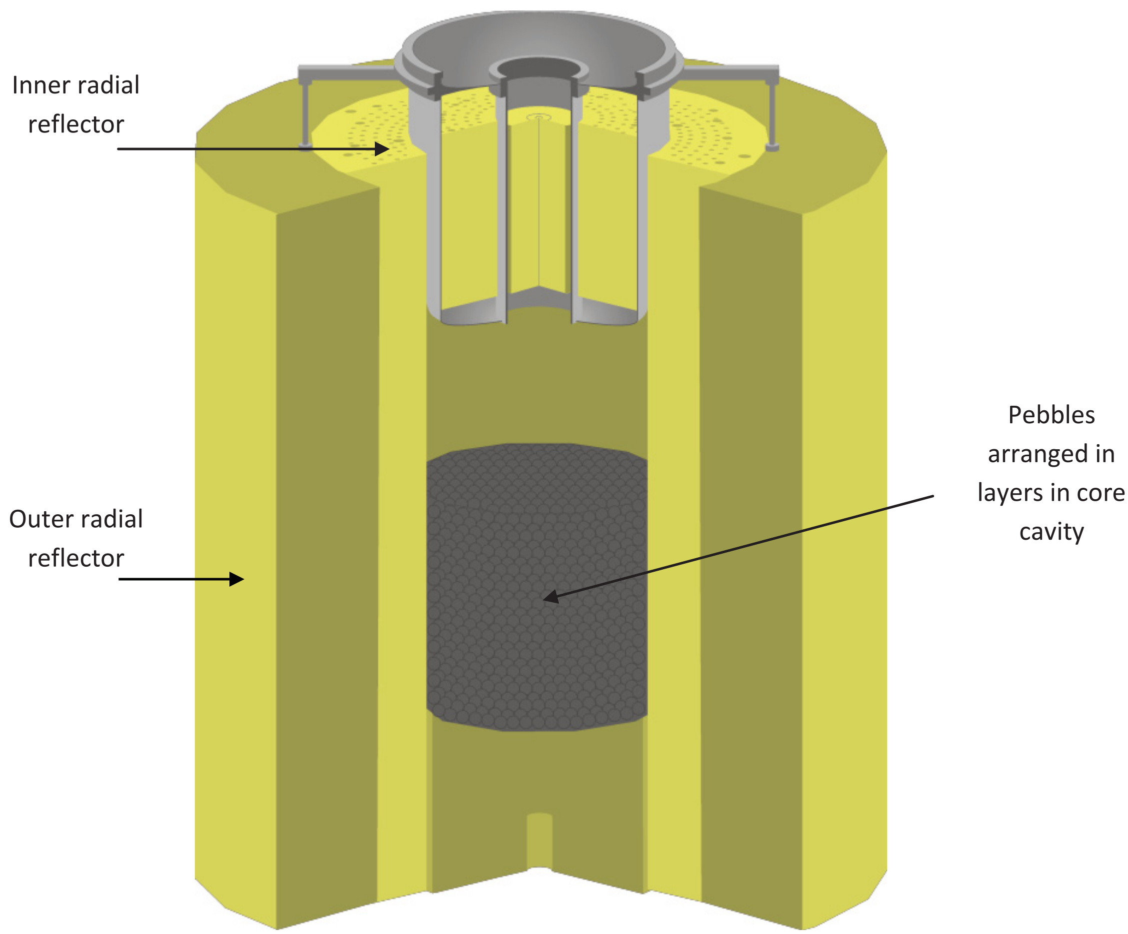

Figure 1.0-1. Generic HTR-PROTEUS Configuration (derived from Ref. 2).

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[a] Difilippo, F. C., "Monte Carlo Calculations of Pebble Bed Benchmark Configurations of the PROTEUS Facility," Nucl. Sci. Eng., 143, 240-253 (2003).
[b] Personal communication with Oliver Köberl at PSI (September 2, 2011).

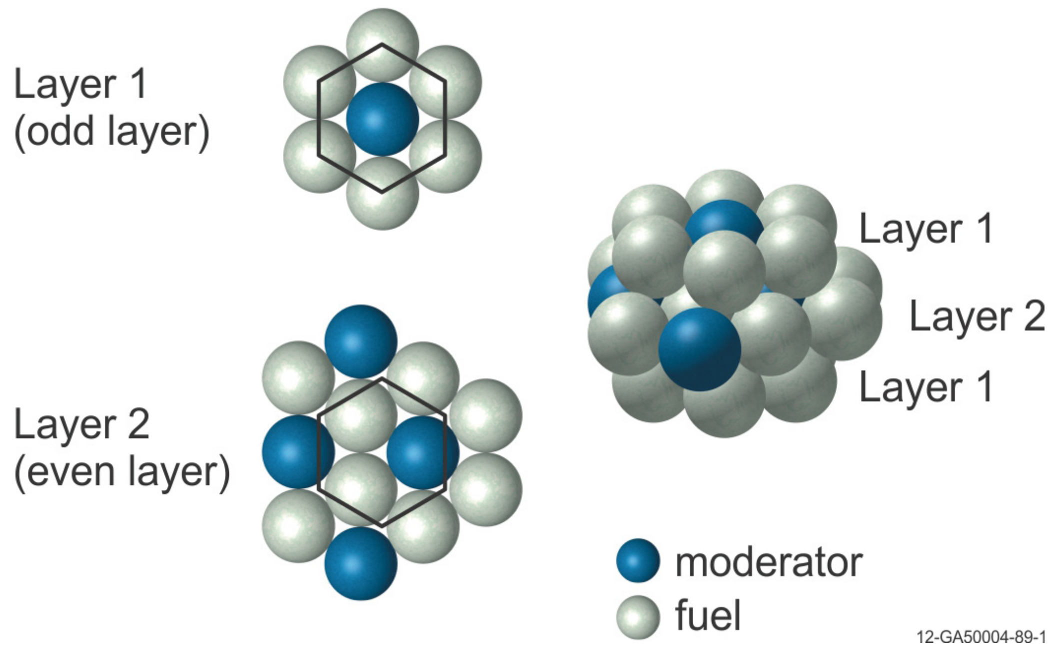

Figure 1.0-2. Subunit for Construction of the Hexagonal Close-Packed (HCP) Cell.

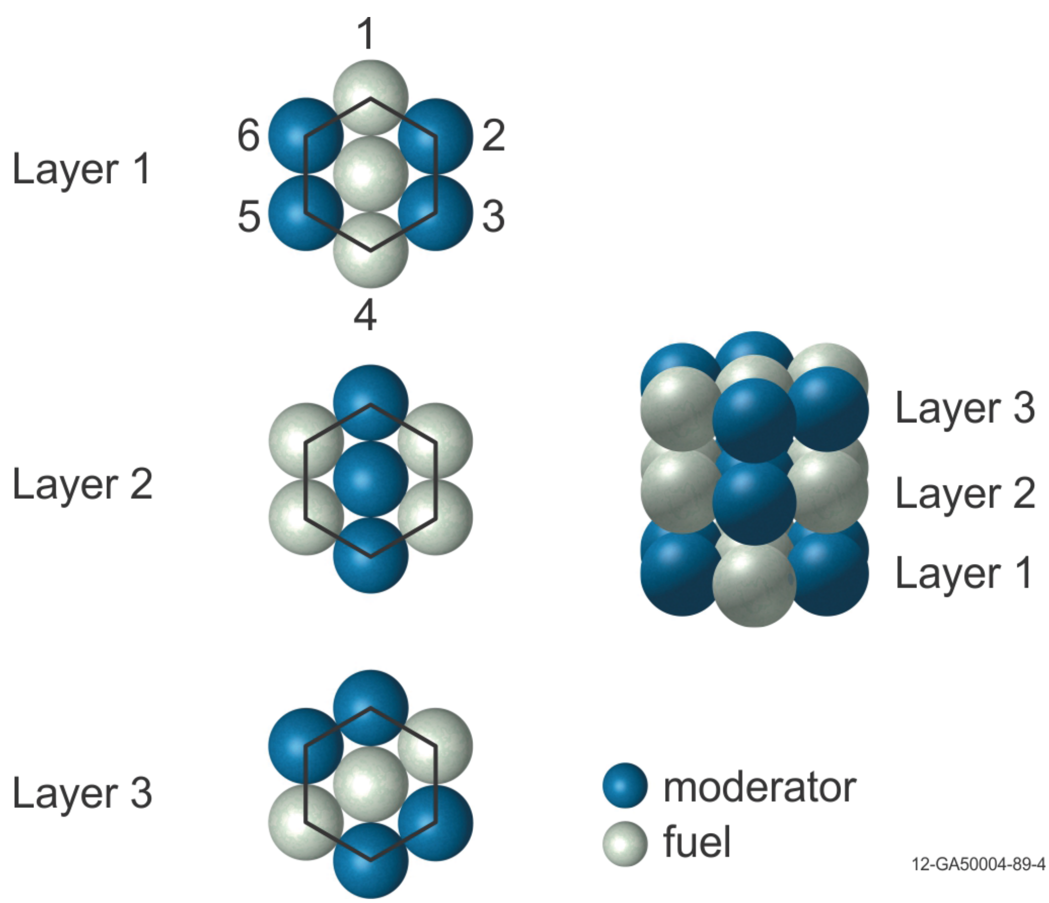

Figure 1.0-3. Subunit for Construction of the Columnar Hexagonal Point-On-Point (CHPOP) Cell.

Table 1.0-1. HTR-PROTEUS Core Configurations (Ref. 1 and 3).

Core	State	Notes
1	1	Only configuration that used ZEBRA control rods. Hexagonal close-packed pebbles.
1A	1 2	Equivalent to Core 1, ZEBRA control rods replaced with withdrawable control rods. Repeat of State #1 to check reproducibility with minor configuration changes.
2	1	Similar to Core 1A with decreased core height and increased upper graphite reflection. Used to investigate "cavity effect".
3	1	Similar to Core 1A with polyethylene rods added to simulate water ingress. Every available vertical channel between pebbles contained an 8.9–mm-diameter polyethylene rod.
4.1 4.2 4.3	1 1 1	Random pebble loading using separate fuel and moderator pebble delivery tubes. Random pebble loading using a single pebble delivery tube. Random pebble loading using a single pebble delivery tube (core reload for reproducibility).
5	1 2 3	Columnar hexagonal point-on-point packing implemented to improve homogeneity of core. Coolant channels in bottom reflector open. Equivalent to Core 5, State #1, with coolant channels in bottom reflector filled with graphite. Repeat of State #2 to check reproducibility and complete some additional reactor physics measurements.
6	1	Similar to Core 5 with hollow polyethylene rods added to simulate water ingress. Copper wire absorbers were placed within the polyethylene rods to compensate for the positive reactivity addition. Maximum polyethylene loading.
7	1	Similar to Core 5 with polyethylene rods added to simulate water ingress. Maximum polyethylene loading compensated by reduced core height.
8	1	Similar to Core 5 with short polyethylene rods added to simulate water ingress in lower core region. Every vertical channel contained a 15 cm long triangular polyethylene rod.
9	1 2	Columnar hexagonal point-on-point packing with increased moderator pebble content. Essentially Core 5 with an equal number of fuel and moderator pebbles Repeat of State #1 with additional layer of moderator pebbles.
10	1	Similar to Core 9 with polyethylene rods added to simulate water ingress. Maximum polyethylene loading compensated by reduced core height.

Acceptable benchmark experiments evaluated in this report include the following:

- Core 9
  - Critical configuration
  - Control rod worths (4)
  - Control rod bank worth (full and partial)
  - Autorod insertion
  - Individual and combined safety/shutdown rod worths (10)
- Core 10
  - Critical configuration
  - Control rod worths (4)
  - Control rod bank worth (full and partial)
  - Autorod insertion
  - Individual and combined safety/shutdown rod worths (10)

1.1 Description of the Critical and / or Subcritical Configuration

1.1.1 Overview of Experiment

Only Cores 9 and 10 are evaluated in this benchmark report due to similarities in their construction. The other core configurations of the HTR-PROTEUS program are evaluated in their respective reports as outlined in Section 1.0.

Cores 9 and 10 were evaluated and determined to be acceptable benchmark experiments.

1.1.2 Geometry of the Experiment Configuration and Measurement Procedure

The PROTEUS assembly can basically be described as a graphite cylinder with an outer diameter of 3262 mm and a height of 3304 mm. It has a central cavity that sits 780 mm above the bottom of the radial and lower axial reflectors and consists of a 22-sided polygon with a flat-to-flat separation distance of 1250 mm. Random or deterministic lattices of pure graphite moderator pebbles and fuel (16.7 wt.% enriched in ^{235}U) pebbles were arranged within this cavity. Additional graphite filler pieces were utilized to provide support for the irregular outer surface of the deterministic pebble arrangements, providing a 12-sided core cavity region with a flat-to-flat separation distance of ~1205 mm. A removable, 1235-mm-high, upper axial reflector assembly consisted of an aluminum tank containing a 780-mm-high graphite reflector; normally an air gap was between the upper reflector and the topmost layer of the pebble bed. An aluminum safety ring is located 1764 mm above the floor of the cavity to prevent the upper reflector from falling onto the pebble bed. Reactor shutdown was achieved using four boron-steel rods placed at a radius of 680 mm; reactor control was typically performed using four fine control rods placed at a radius of 900 mm. In Core 1, however, Cd Shutter, or ZEBRA type, rods were used in place of the fine control rods. Water ingress was simulated by using polyethylene rods introduced axially into vertical channels of the deterministic cores (Ref. 2). Schematic representations of the PROTEUS assembly are shown in Figures 1.1-1 and 1.1-2.

While there are many components of the PROTEUS that remain unchanged throughout the course of the HTR-PROTEUS experiments, many parameters did change between experiments, such as the use of graphite filler pieces, control rod types and locations, the presence of polyethylene rods to simulate water ingress, core pebble packing, and conditions at criticality. Section 1.1.2.1 provides information regarding general components common to all HTR-PROTEUS configurations. Section 1.1.2.2 provides information specific to the core configurations evaluated in this report.

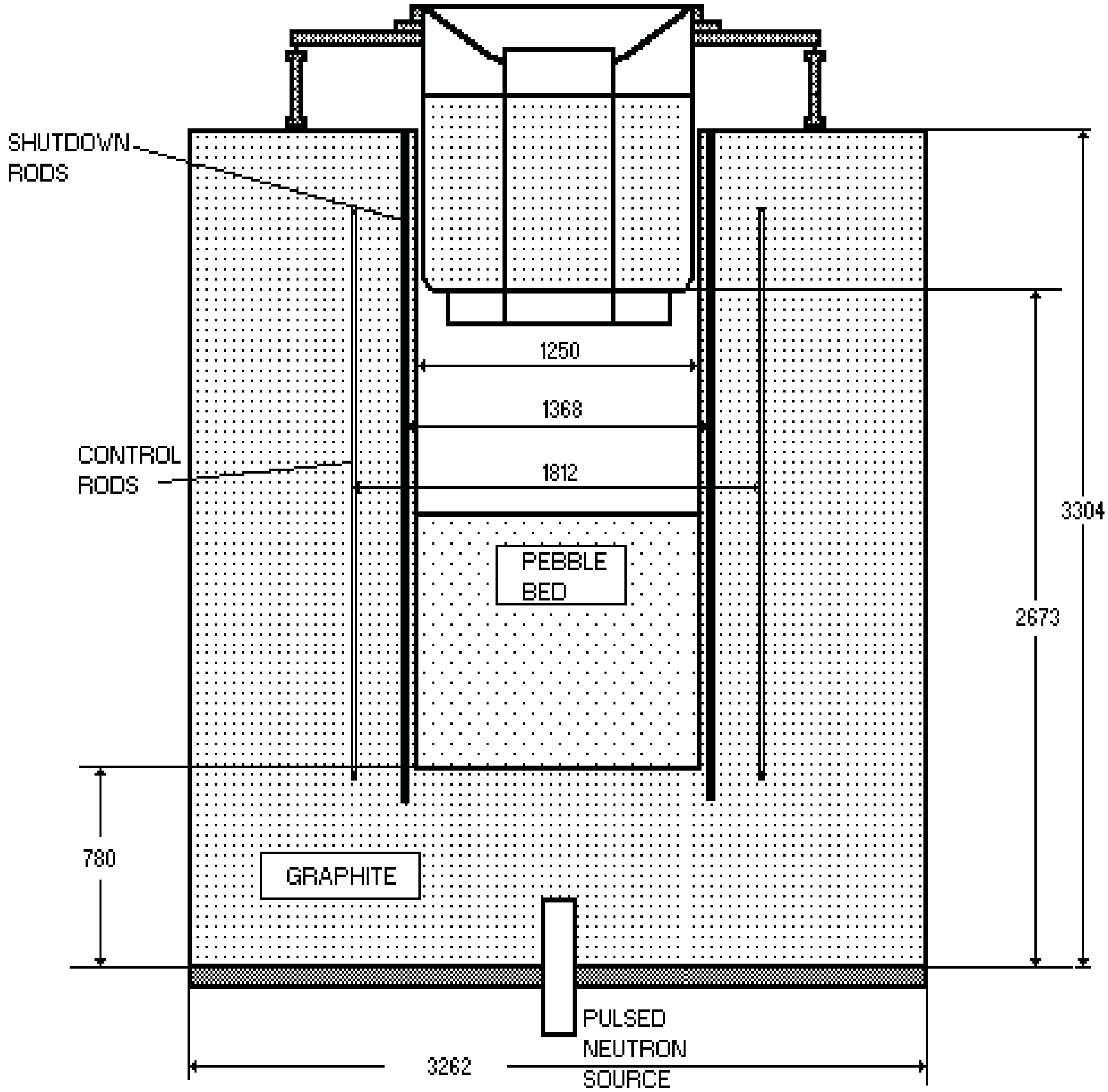

Figure 1.1-1. Schematic Side View of the HTR-PROTEUS Facility (dimensions in mm), (Ref. 2 and 3).

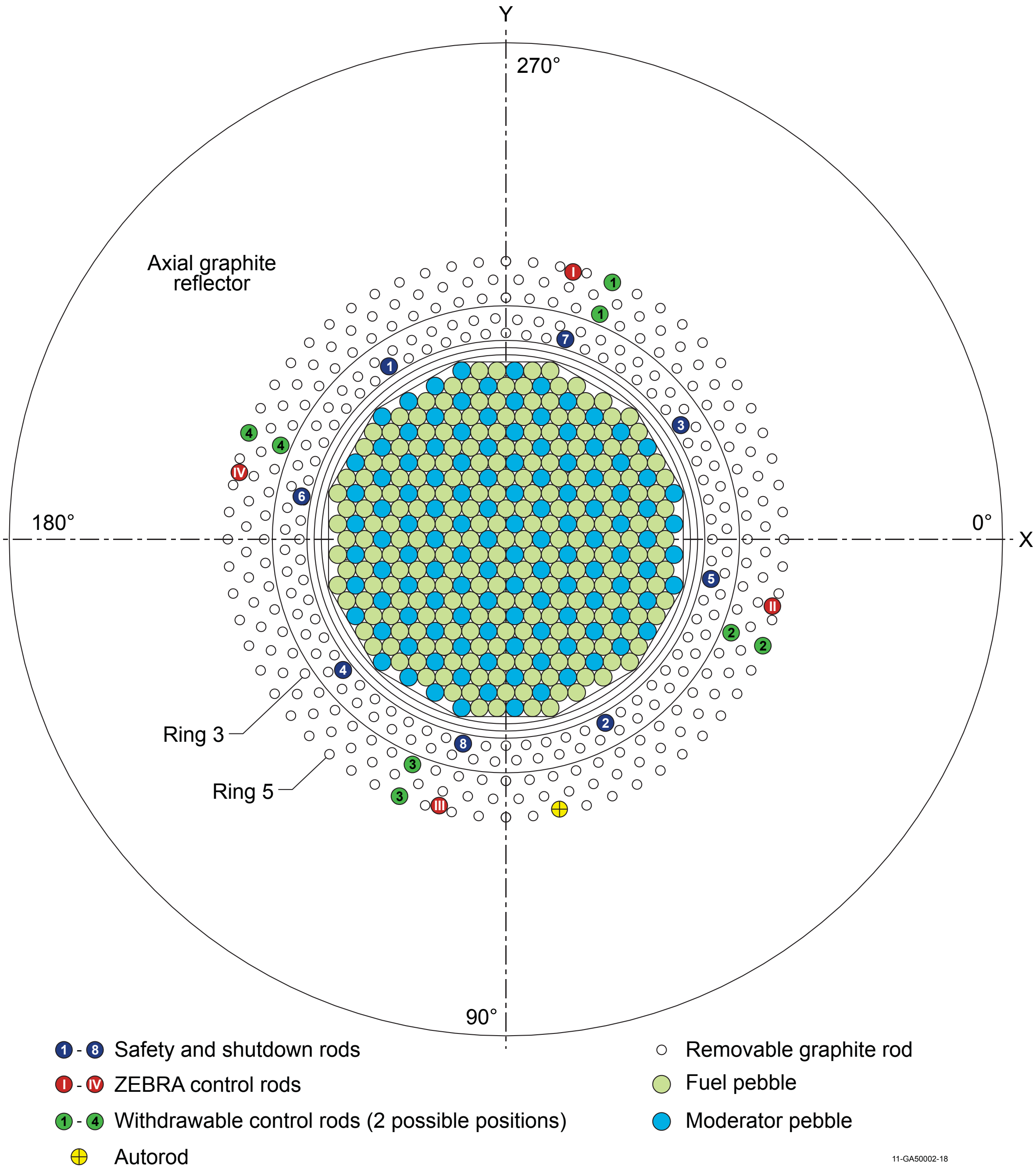

Figure 1.1-2a. HTR-PROTEUS Control Rod Positions and Bore Hole Locations (derived from Ref. 2).

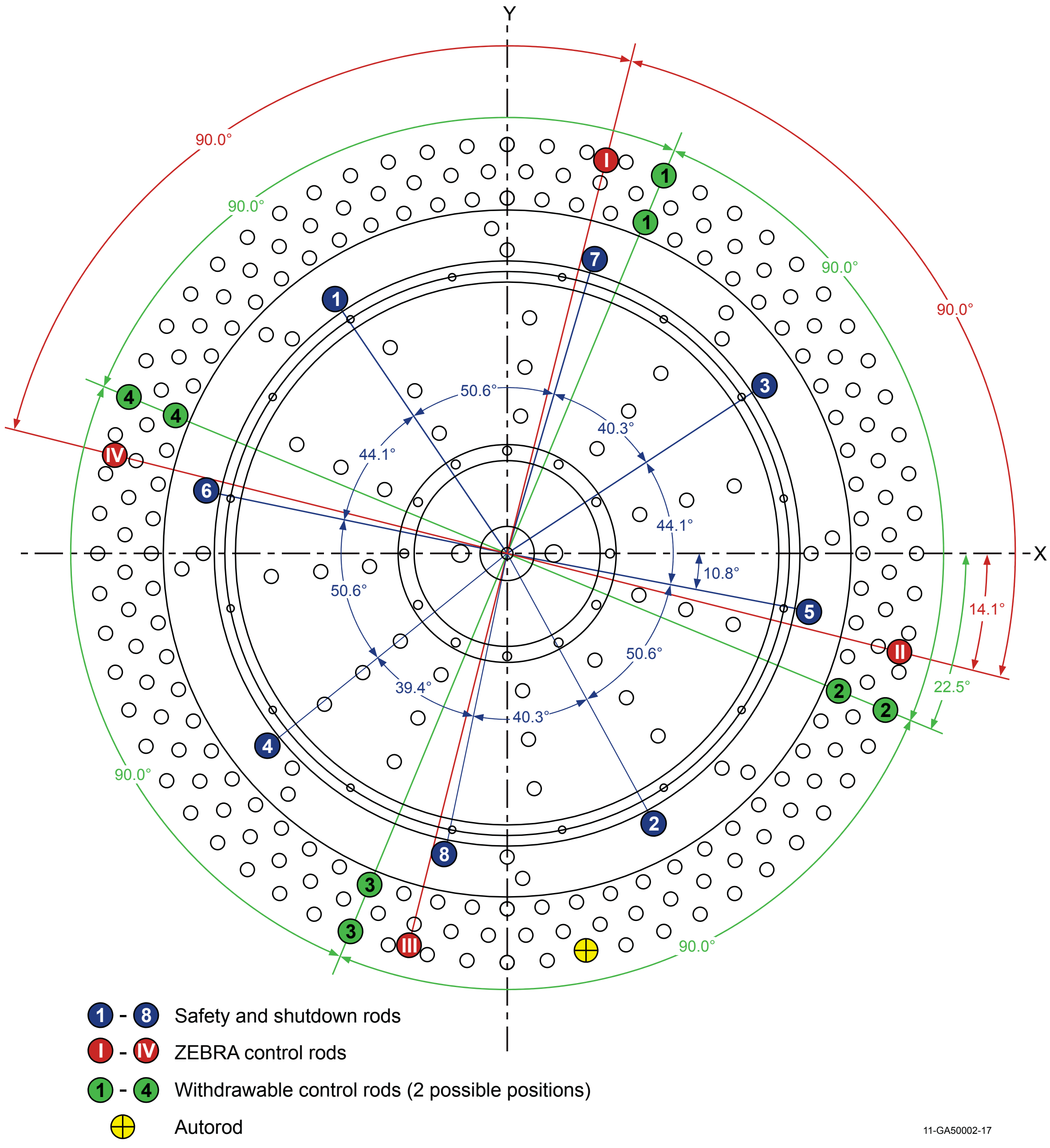

Figure 1.1-2b. HTR-PROTEUS Control Rod Positions and Bore Hole Locations (Ref. 2).

1.1.2.1 General HTR-PROTEUS Components

The following components are common to all HTR-PROTEUS core configurations.

Concrete

Concrete shielding surrounds the reactor system entirely (Ref. 2). The reactor is surrounded by 800 mm of concrete shielding. No significant room return effects from neutron streaming were measured.[a]

Steel Plate Pedestal

The PROTEUS assembly rests upon a stainless steel plate pedestal.[b]

Radial Reflector

The radial reflector was a 22-sided polygon with a height of 3304 mm and outer diameter of 3262 mm (see Figures 1.1-1 and 1.1-3). A central cavity sat with its base 780 mm above the reflector base and had a flat-to-flat separation distance of 1250 mm (Ref. 2 and 3). The central cavity contained fuel (16.7 wt.% enriched in ^{235}U) and moderator (pure graphite) pebbles either deterministically or randomly arranged in one of several different geometrical arrangements. Graphite filler pieces were placed at the core-reflector boundary to support the stacked pebble structures (Ref. 3).

The external boundary of the 22-sided polygon had sides located 1631.6 mm from the center, which would be an equivalent area cylinder of 1637.7 mm radius. The internal cavity was a 22-sided polygon with sides 626 mm from the center, which would be an equivalent area cylinder of 628.4 mm radius. In summary, the cavity had an average radial thickness ~1029 mm of graphite, and lower and upper axial thicknesses 780 mm of graphite.[b]

A cylindrical version of the radial reflector would have the following radius (the first value represents an equal perimeter, and the second value represents an equal area): external radius, 1643.6 and 1637.7 mm, respectively; internal radius for the 22-sided cavity, 630.6 and 628.4 mm, respectively.[c]

The radial reflector contains various minor penetrations serving as control rod and instrumentation channels. The reflector contained 308 C-Driver channels (see Figure 1.1-3), which were vertical channels of 27.43 mm diameter running the full height of the radial reflector and were left over from previous PROTEUS experiments. These channels were arranged in five concentric rings. Unless otherwise stated, these channels were filled with 26.5 mm diameter graphite rods (Ref. 2). These rods were relatively easy to remove and useful in estimating the effect of missing graphite (Ref. 3).

Attached to one side of the radial reflector was a reactor thermal column, which was a quasi-rectangular structure with a height and width of 1200 mm and a depth of ~500 mm. Its top surface was situated 1120 mm from the upper surface of the radial reflector (Ref. 2).

A safety ring was included in the design as an additional safety measure in the unlikely event that the upper axial reflector should fall into the cavity. It was comprised of a Peraluman ring 10 mm thick with inner and outer radii of 604 and 700 mm, respectively. It was situated 1764 mm above the floor of the cavity, as depicted in Figure 1.1-4 (Ref. 2).

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[a] Williams, T., "HTR PROTEUS CORE 1: Reactivity Corrections for the Critical Balance," TM-41-93-20, Paul Scherrer Institut, Villigen, October 7, 1993.
[b] Difilippo, F. C., "Monte Carlo Calculations of Pebble Bed Benchmark Configurations of the PROTEUS Facility," *Nucl. Sci. Eng.*, **143**, 240-253 (2003).
[c] Difilippo, F. C., "Applications of Monte Carlo Simulations of Thermalization Processes to the Nondestructive Assay of Graphite," *Nucl. Sci. Eng.*, **133**, 163-177 (1999).

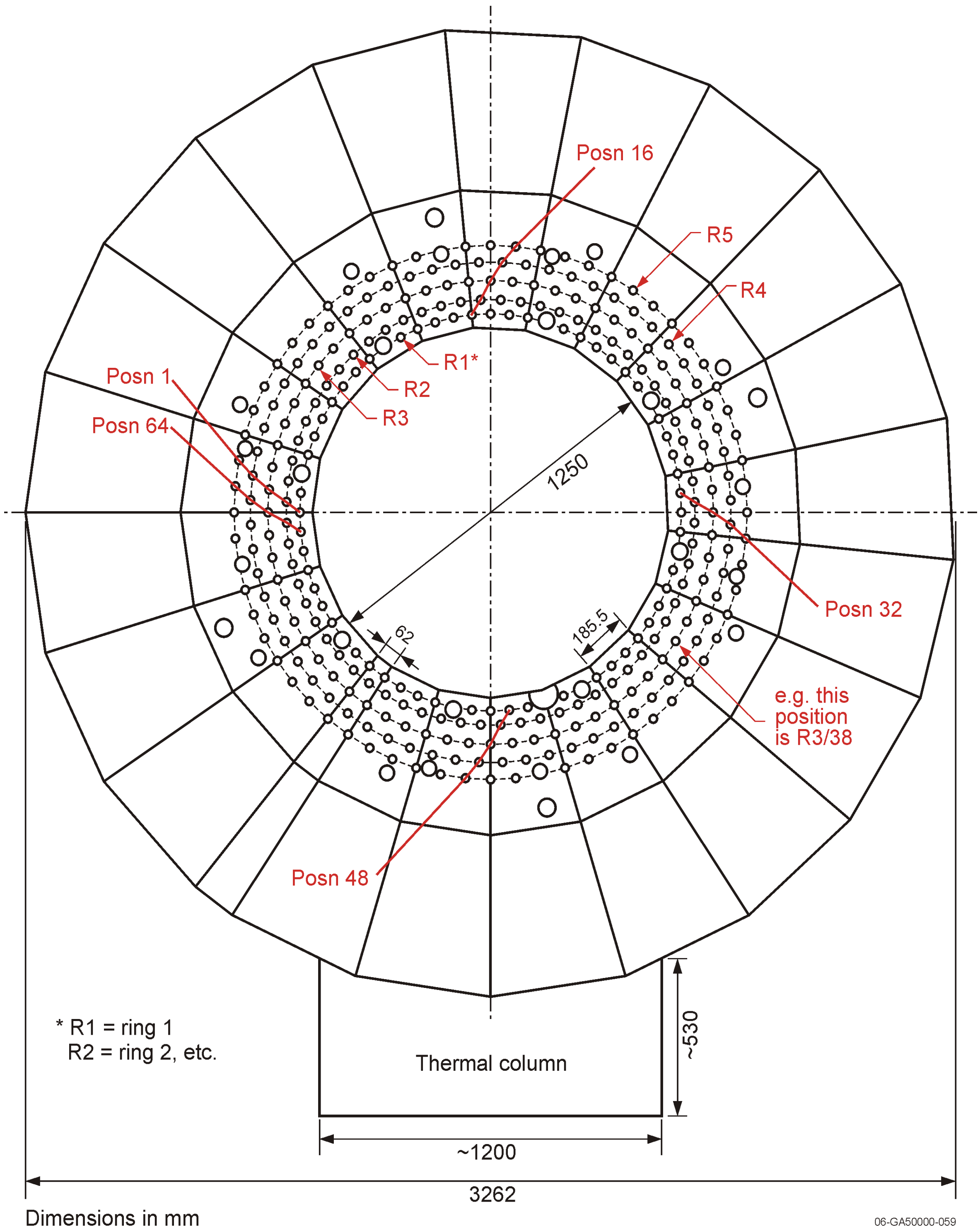

Figure 1.1-3. Cross Section View of the Radial Reflector (Ref. 2).

The radial reflector contained various minor penetrations for the introduction of instrumentation and sources. Explicit geometries and descriptions are unavailable. When not in use, the penetrations were filled with graphite plugs.

Upper Axial Reflector

Detailed drawings of the upper axial reflector and its aluminum housing are shown in Figures 1.1-4 through 1.1-6. The graphite has two components; the first component is a central cylinder of 394 mm diameter with a central, open, 27.43 mm diameter channel, surrounded by the second component, an annulus with an inner diameter of 418.6 mm and an outer diameter of 1234 mm. The annulus contains 33 coolant channels corresponding with those found in the lower axial reflector. All 34 channels are always open. The outer graphite annulus includes a separate outer shell consisting of 36 smaller, individual rectangular pieces that do not fit exactly flush with the bulk graphite. The upper axial reflector graphite had a height of 780 mm (Ref. 2).

The upper reflector tank is a complex structure that supports the upper axial graphite reflector in place above the cavity. It was comprised of two main parts, an inner and an outer tank. The inner tank, which contained the graphite cylinder, was removable, and it had to be removed before the outer tank could be removed. The outer tank contained the graphite annulus. The dimensions and layout of the upper reflector are shown in Figures 1.1-4 through 1.1-6. A steel lid and flanges, external to the core reflector, were used to hold the upper reflector above the core cavity (Ref. 2).

The upper axial reflector closed the cavity at a height of 1863 mm from the bottom of the cavity.[a]

[a] Difilippo, F. C., "Monte Carlo Calculations of Pebble Bed Benchmark Configurations of the PROTEUS Facility," *Nucl. Sci. Eng.*, **143**, 240-253 (2003).

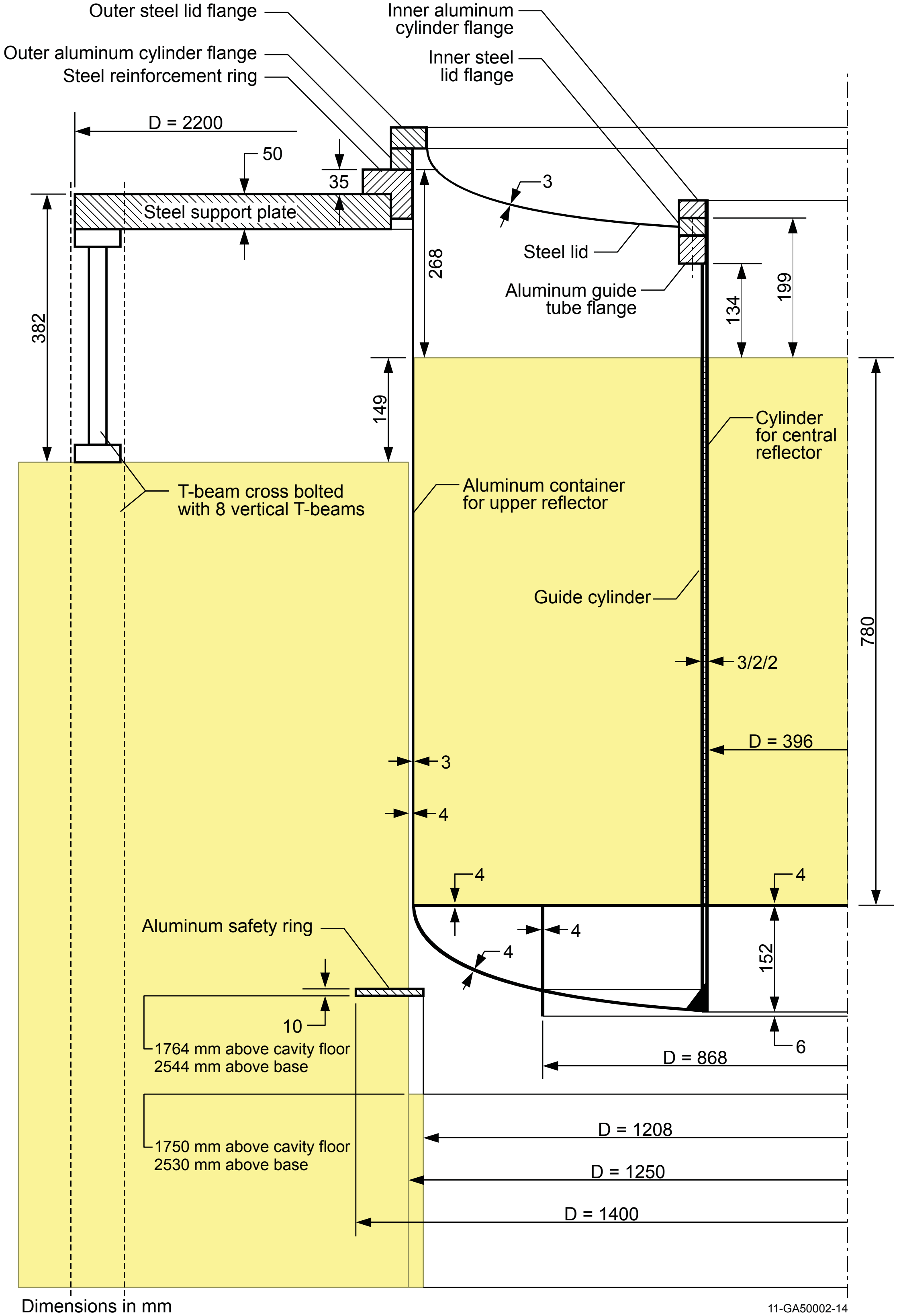

Figure 1.1-4. Placement of the Upper Axial Reflector (Ref. 2).

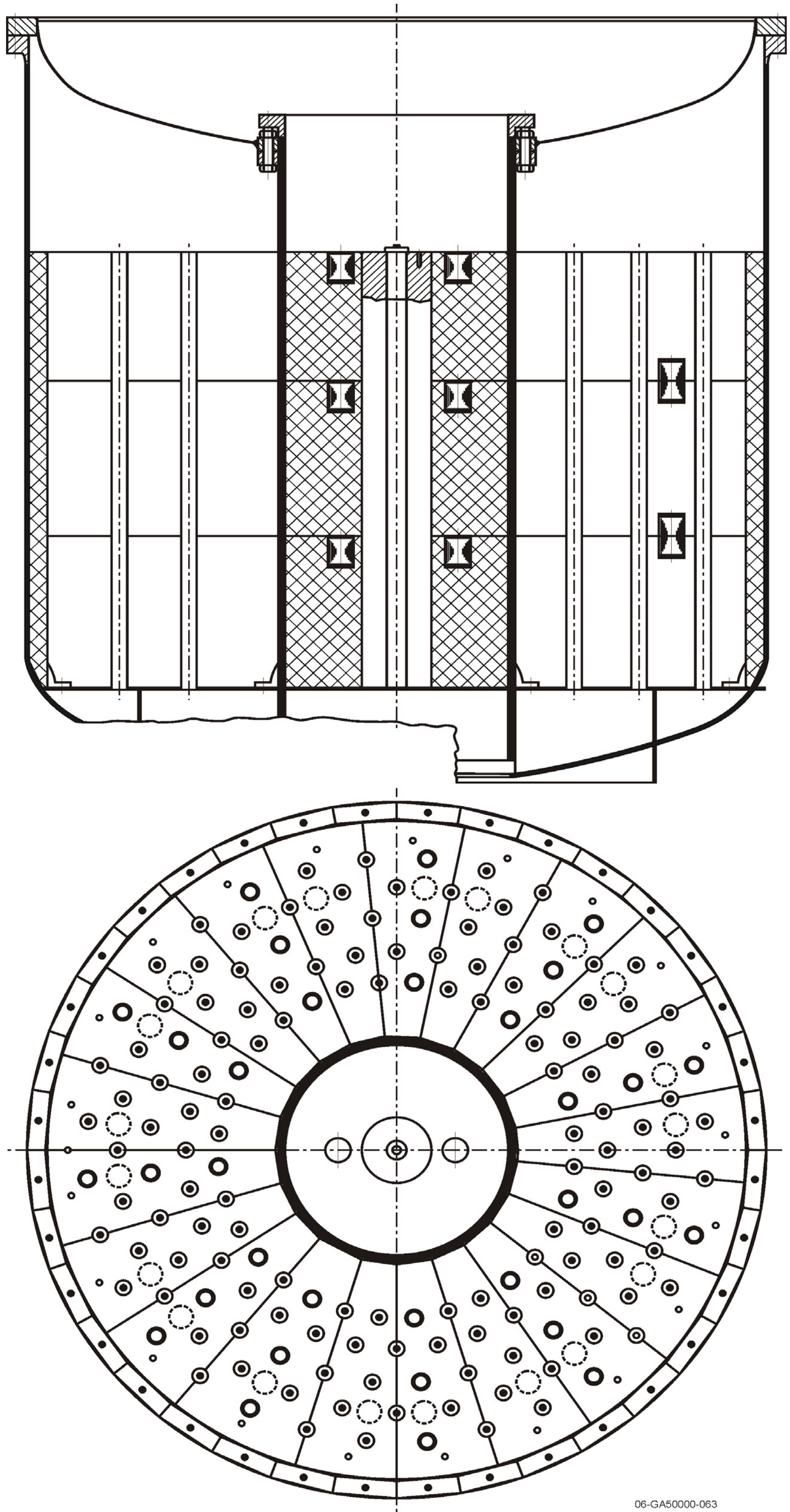

Figure 1.1-5. Non-dimensional Cross Sections of the Upper Axial Reflector (Ref. 2).

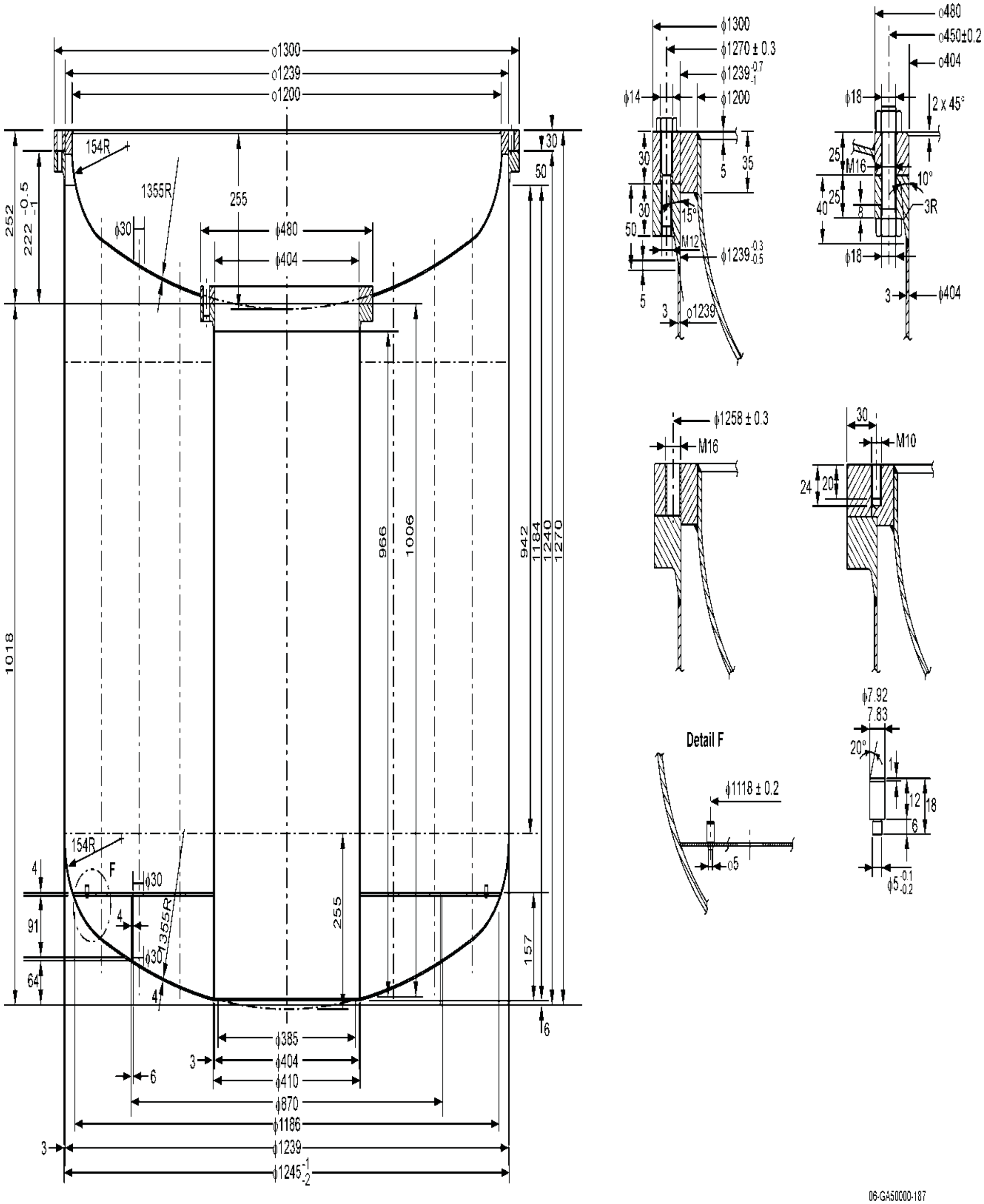

Figure 1.1-6. Details of the Main Aluminum Structure of the Upper Axial Reflector (Ref. 2).
Units are in millimeters.

Lower Axial Reflector

The lower axial reflector is 780 mm thick and contains, for historical reasons, 160 symmetrically positioned 27.42 mm diameter channels. At least 127 of these channels were filled with 780 mm long, 26.5 mm diameter graphite rods. The dimensions of the lower axial reflector are shown in Figure 1.1-7; the positions of the 33 (typically open) coolant channels are also indicated. The open channels are arranged in three concentric rings of radii 300, 410, and 515 mm, with each ring containing eleven channels. The channels in each ring are positioned at azimuthal angles of 16.875, 50.625, 84.375, 118.125, 140.625, 174.375, 208.125, 241.875, 275.625, 309.375, and 343.125º, as measured in the clockwise direction from the +x-axis, as shown in Figure 1.1-2 (Ref. 2). In some of the core configurations all of the coolant channels in the lower axial reflector were filled with graphite plugs (Ref. 3). In all the deterministic cores, ~12 pebbles were directly over one of the 33 cooling channels in the lower axial reflector. To avoid pebble displacement in these cases, special aluminum plugs were developed to support the pebbles in Core 1. In later cores, simple graphite rods were used (Ref. 3).

A special, 121 mm diameter, channel was provided in the center of the lower axial reflector with approximately 500 mm of graphite separating it from the core. This channel could be used for measurements using the pulsed neutron source. The pulsed neutron source, when used for subcriticality measurements, was partially inserted into the lower axial reflector. When not in use, it was replaced with a plug of graphite of dimensions 250 mm in height and 120 mm in diameter (Ref. 2 and 3).

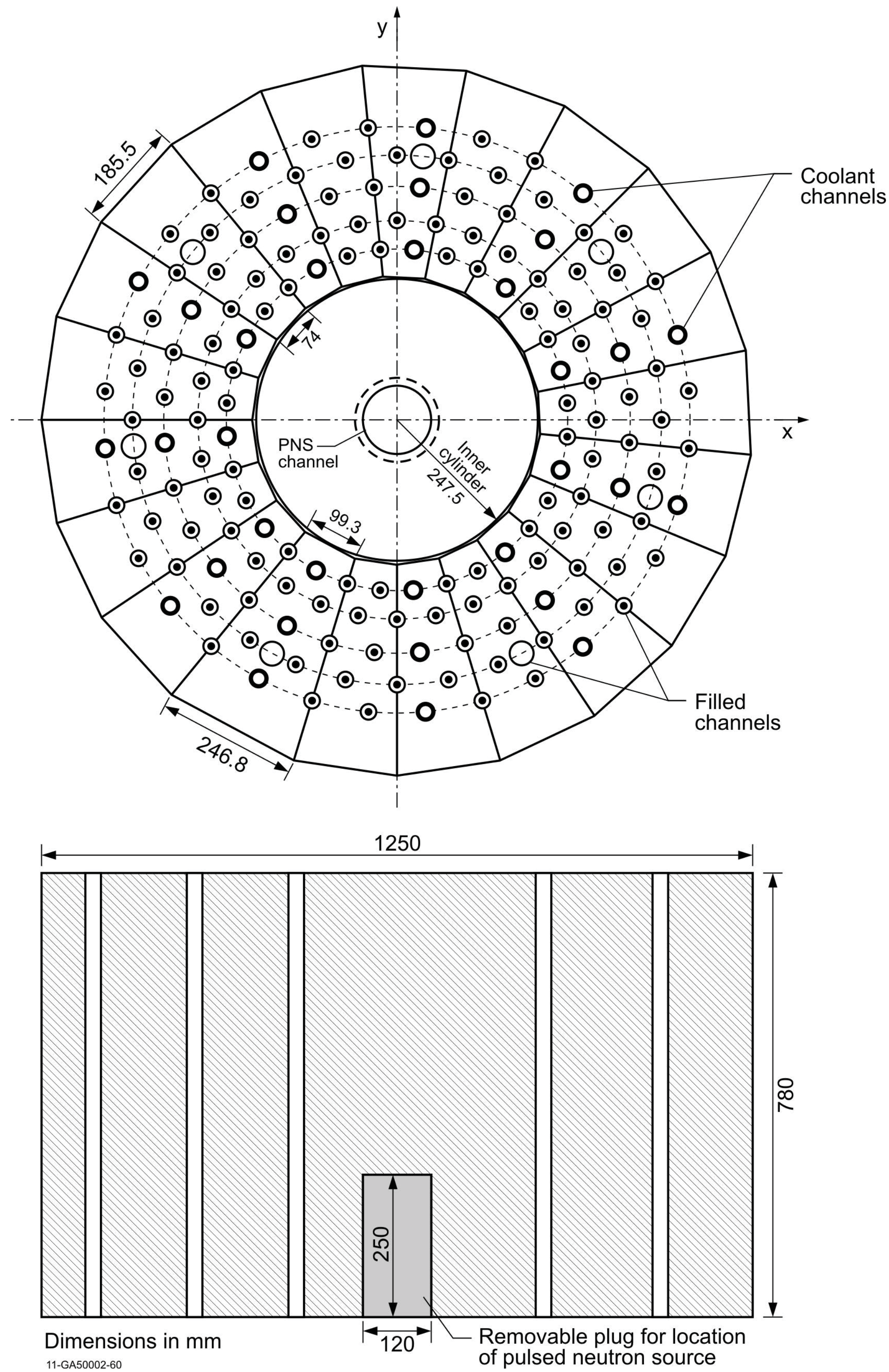

Figure 1.1-7. Details of the Lower Axial Reflector. Note the 33 coolant channels, the small air gap between outer and inner parts, and the position of the pulsed source channel (Ref. 2).

Safety/Shutdown Rods

There were eight, identical, borated-steel safety/shutdown rods located adjacent to the core in the radial reflector (see Figure 1.1-2). These rods were separated into two groups of four rods (rods 1-4 and rods 5-8). One of these groups was selected as the "safety rod" group and the other as the "shutdown rod" group. These rods were not used as control rods, such as the four ZEBRA type rods used in Core 1 or the withdrawable stainless steel control rods used in Cores 1A through 10 (Ref. 2 and 3).

Rods numbered 1 through 4 are the shutdown rods and rods numbered 5 through 8 are the safety rods.[a]

The safety/shutdown rods consisted of 35 mm diameter borated steel rod sections enclosed in 18/8 stainless steel tubes with an inside diameter of 36 mm and outside diameter of 40 mm. The rods were located in 45 mm inner diameter graphite guide tubes within the radial reflector. The centers of the guide tubes were 684 mm from the center of the core, or about 59 mm from the inner surface of the radial reflector (without filler pieces). The azimuthal positions of the eight rods are shown in Figure 1.1-2, in which the slight azimuthal asymmetry of the rod positions should be noted (Ref. 2 and 3).

A diagram of a safety/shutdown rod is shown in Figure 1.1-8; the borated steel portion of the rods was 2100 mm in length. The fully in and out positions of the rods are shown in Figure 1.1-9; the rods traveled a total distance of 2900 mm (2530 mm free fall plus 370 mm braking distance) from fully withdrawn to fully inserted positions. When fully inserted, the bottom of the borated steel region is located 350 mm below the bottom of the reactor cavity with the top of the borated steel region slightly above the top of the 1730 mm high cavity. When fully withdrawn, the bottom of the borated steel region is 26 mm below the top surface of the radial reflector (Ref. 2).

Each rod contains six, 35 mm diameter, 350 mm long, cylindrical pieces of borated steel. Aluminum and steel shock dampers were located under each of the safety/shutdown rods, as shown in Figure 1.1-9, to prevent damage in case one of the rod cables should fail. A gap of approximately 30 mm separated the bottom of the safety rod from the upper, aluminum part of the shock damper. The aluminum parts of the shock damper was comprised of a 280.5 mm long hollow tube with 29 mm inner diameter, 40 mm outer diameter, and capped at both ends with aluminum of 2 mm thickness. The steel parts of the shock dampers (end caps, springs, and damper chamber) were affixed to the underside of the lower support plate, which itself is ~75 mm thick; only a fraction of the total mass of these components resided within the graphite reflector (Ref. 2).

The safety rods were always maintained in withdrawn positions, i.e., out of the reflector. Criticality was achieved when the four shutdown rods were also fully withdrawn and only the four control rods and the autorod were partially inserted for fine control.[b,c]

[a] Köberl, O., and Seiler, R., "Detailed Analysis of Pebble-Bed HTR PROTEUS Experiments with the Monte Carlo Code TRIPOLI4," Proc. 2nd Int. Topical Mtg. on High Temperature Reactor Technology, Beijing, China, September 22-24, 2004.
[b] Chawla, R., Joneja, O. P., Rosselet, M., and Williams, T., "Definition and Analysis of an Experimental Benchmark on Shutdown Rod Worths in LEU-HTR Configurations," *Nucl. Technol.*, **139**, 50-60 (2002).
[c] Köberl, O., Seiler, R., and Chawla, R., "Experimental Determination of the Ratio of 238U Capture to 235U Fission in LEU-HTR Pebble-Bed Configurations," *Nucl. Sci. Eng.*, **146**, 1-12 (2004).

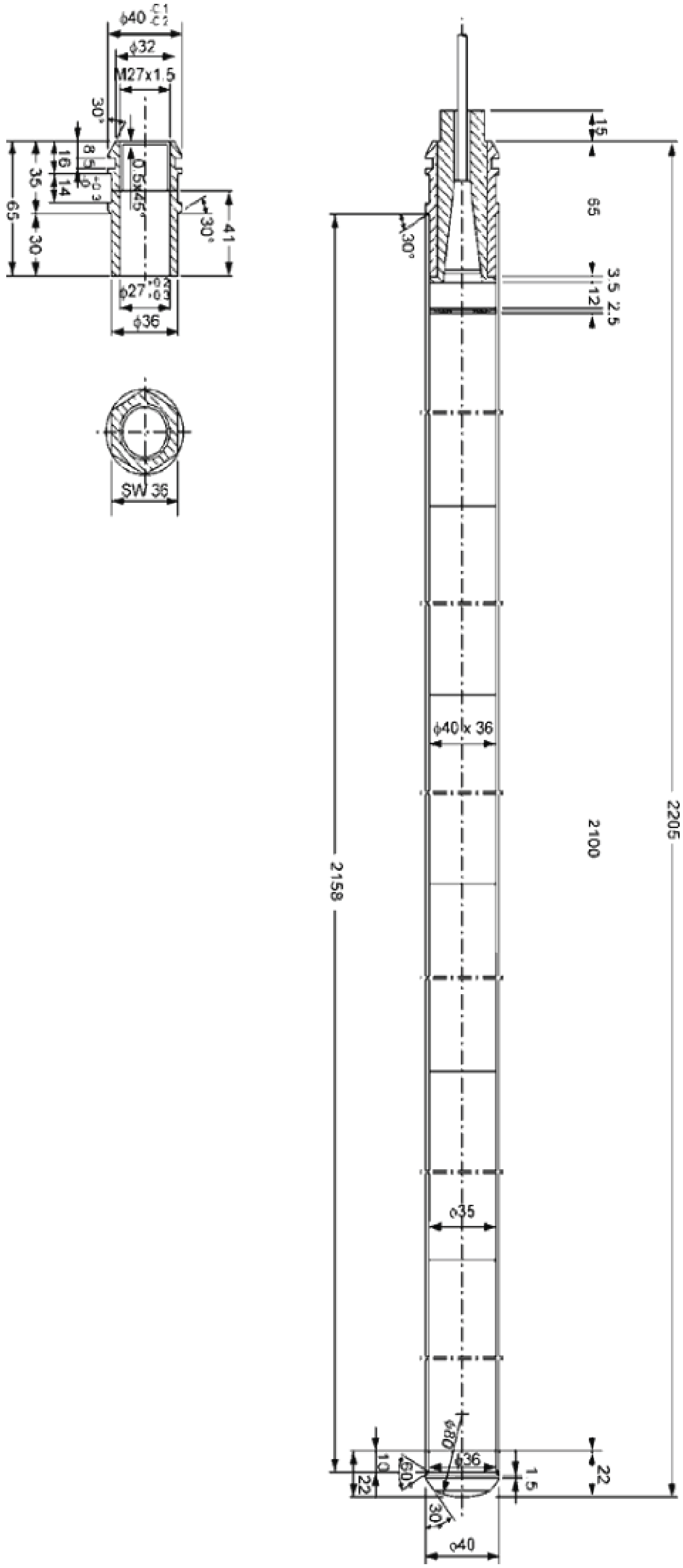

Figure 1.1-8. Details of Safety/Shutdown Rods (Ref. 2). Units are in millimeters.

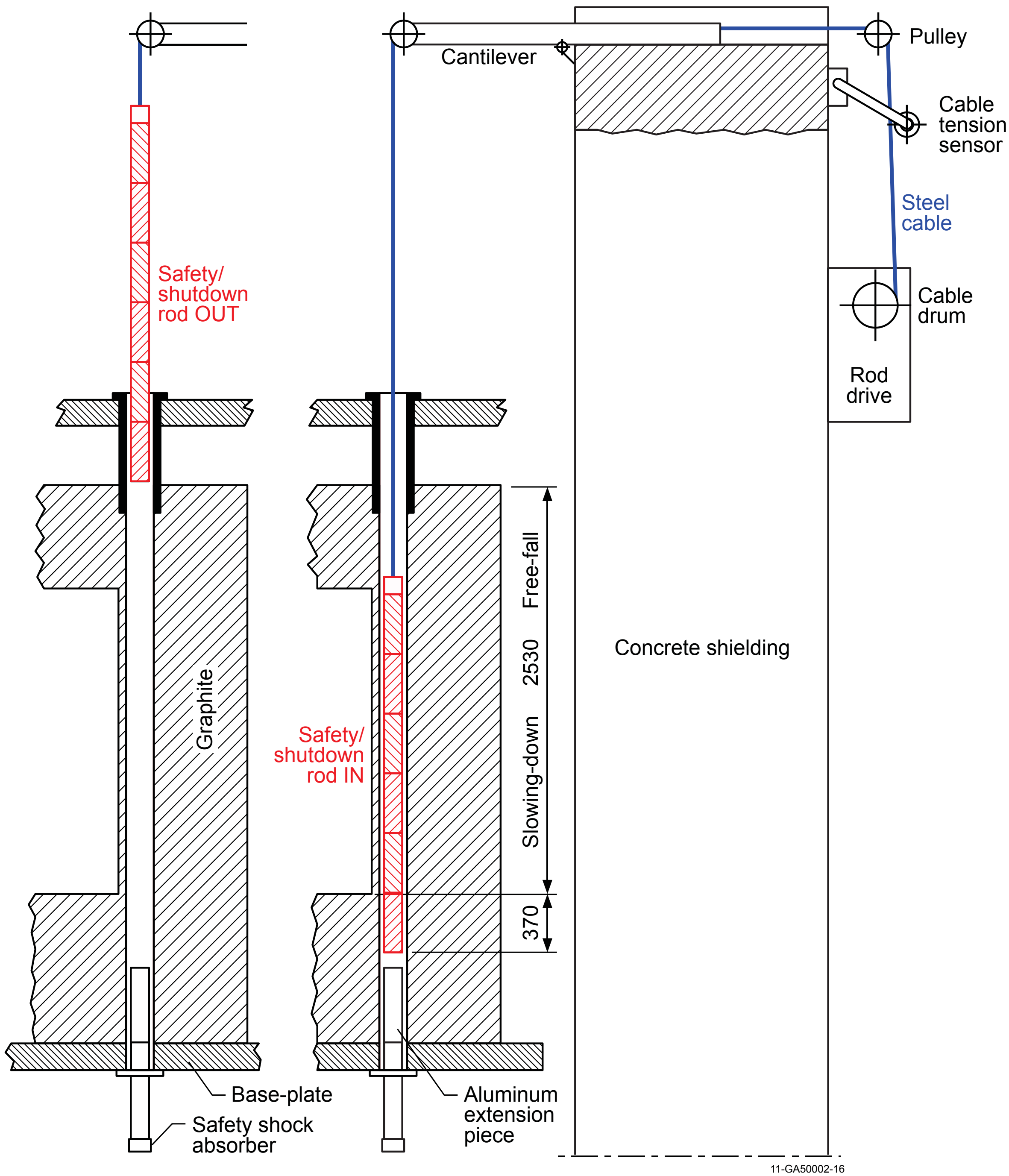

Figure 1.1-9. Safety/shutdown Rod Movement (Ref. 2). Units are in millimeters.

Automatic Control Rod (Autorod)

A single, fine control rod (Figure 1.1-10) was utilized to automatically maintain reactor criticality at a nominal required power. It responded to signals from a single ionization chamber (deviation channel) located in the radial reflector 810 mm above the cavity floor and ~500 mm from the outer radial boundary of the core. The rod itself is located in a vertical channel with an inside diameter of 55 mm situated 890 mm from the radial center of the system; it was located azimuthally ~80º from the x-direction in a clockwise direction (see Figure 1.1-2). The rod was comprised of a wedge shaped copper plate supported within an aluminum tube with an outer diameter of 44 mm. The copper plate was 3 mm thick, 2300 mm long, and 39 mm at its wide end with a reduction in width along its length of 17 mm per meter. The rod was fully inserted when the position display showed 0 mm and the pointed end of the copper plate was flush with the underside of the steel plate upon which the reactor stands. The complete withdrawal of the autorod was indicated by a display of 1000 mm when the pointed end of the copper plate was ~200 mm above the base of the core cavity and the blunt end was 79 mm below the top of the radial reflector graphite. Because the rod remains within the system even when fully "withdrawn" it has a significant rest worth that is larger than the total max-min worth of the rod.

The worth of the autorod exhibits a linear response over the range of 200 to 800 mm with a differential control rod worth of 6.3×10^{-3} ¢/mm (β_{eff} = 0.00723) and an uncertainty of around 5 %. The autorod response was intercalibrated with the ZEBRA (and later withdrawable) control rods.[a]

[a] Williams, T., "HTR PROTEUS CORE 1: Reactivity Corrections for the Critical Balance," TM-41-93-20, Paul Scherrer Institut, Villigen, October 7, 1993.

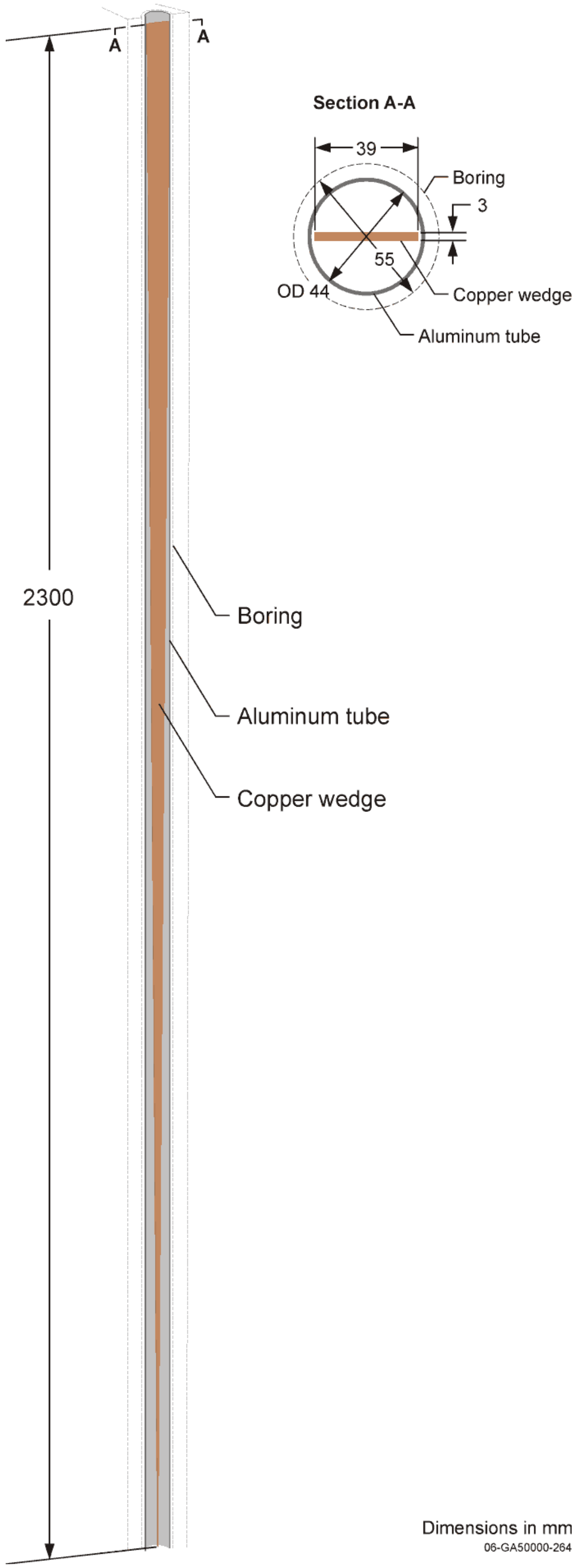

Figure 1.1-10. Automatic Control Rod (derived from Ref. 2).

Static Measurement Rods

Simulated control rods were manufactured for these experiments to investigate the spatial dependence of control rod worths in a particular configuration; this was necessary because the operational control rods were very restricted in their locational possibilities. These rods were designed to be inserted in either C-Driver channels in the radial reflector or into a specially designed graphite sleeve which replaced a column of pebbles in the columnar hexagonal cores. Because the core and radial reflectors were of significantly different heights, two pairs of rods were produced; apart from the axial dimensions, they were nominally identical (Ref. 2 and 3).

The rods consisted of cylindrical assemblies with an outer diameter of 26 mm and 2 mm thick Peraluman R-257 wall. The shorter pair of tubes contained eleven, 22 mm diameter, borated steel pieces of various lengths between 120 and 180 mm, totaling 1581 ± 1 mm in each assembly. The longer pair contained a total of 1711 ± 1 mm of borated steel pieces. The longer rods also contained a graphite filler piece, above the borated steel section, with a length of 1414 mm. Figure 1.1-11 and 1.1-12 show the long and short variations of the static measurement rods, respectively. The dimensions of both pairs of rods were arranged such that the borated steel regions were similarly located with respect to the axial position of the fuelled region. When the longer rods were resident in the radial reflector, the bottom of the hole in the upper hanger was flush with the upper surface of the upper steel support plate. When the shorter rod was inserted in the core region, it rested on the cavity floor. The graphite sleeve for the shorter rods (shown in Figure 1.1-13) had a length of 1730 mm, an inner diameter of 27 mm, and an outer diameter of 60 mm (Ref. 2).

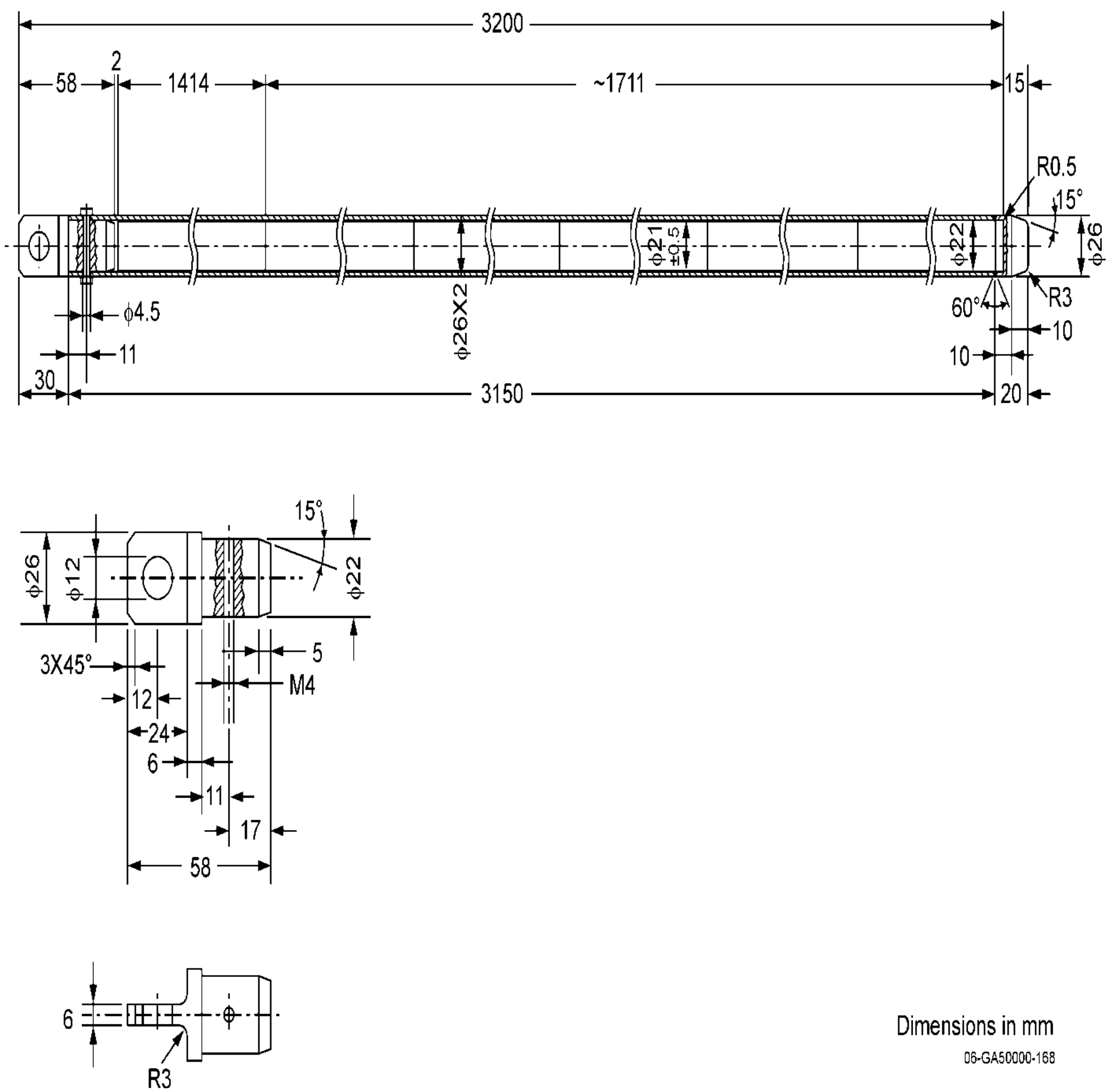

Figure 1.1-11. Details of the Long Static Measurement Rod (Ref. 2).

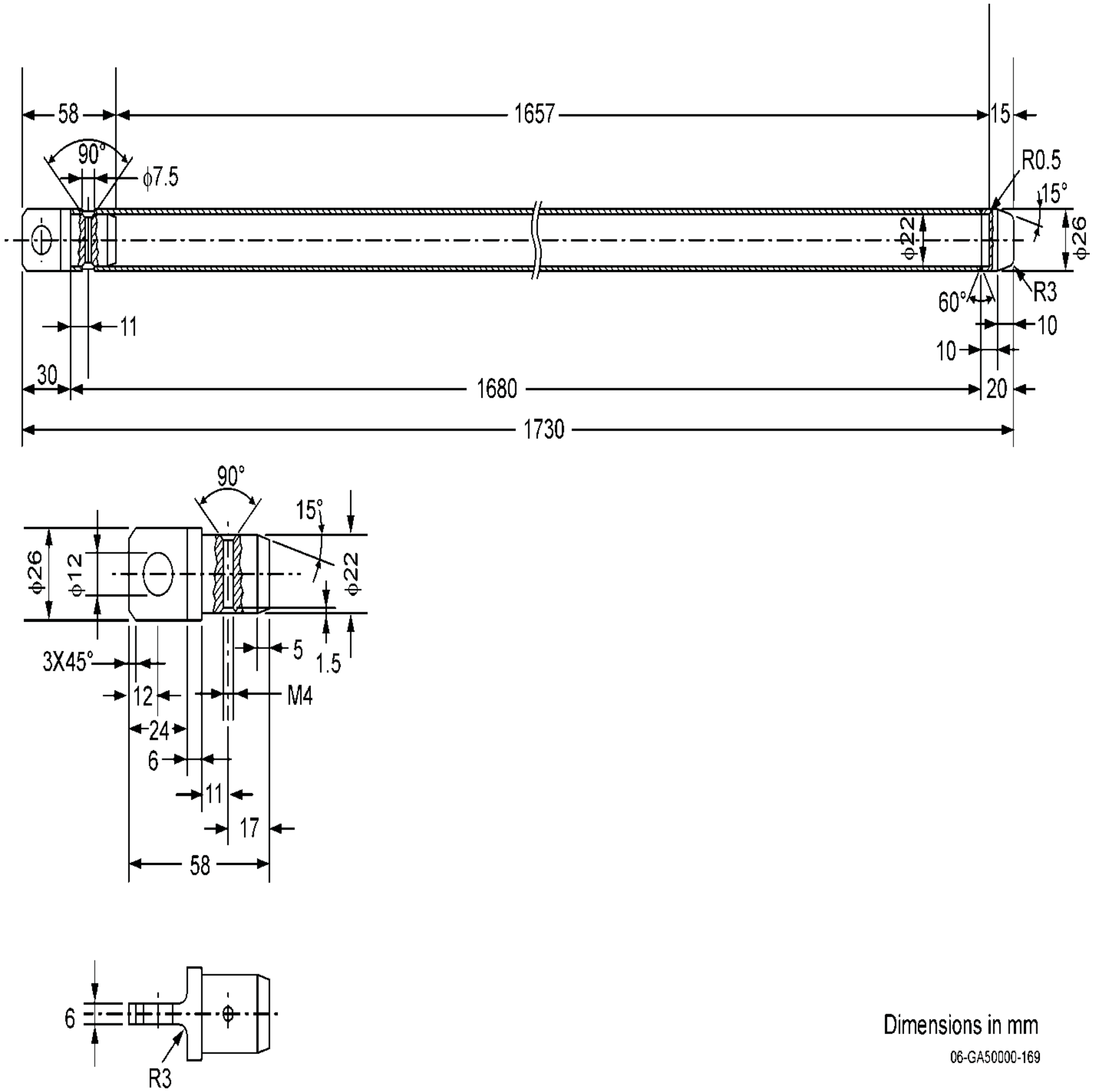

Figure 1.1-12. Details of the Short Static Measurement Rod (Ref. 2).

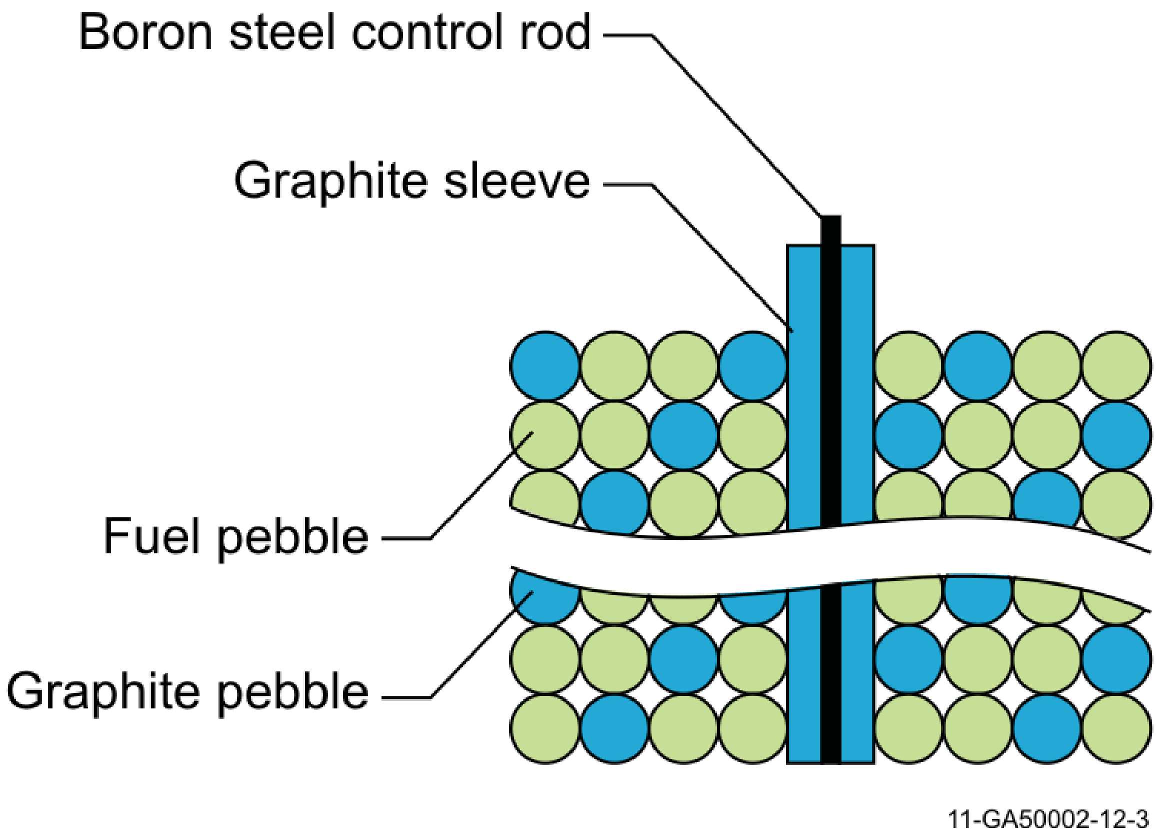

Figure 1.1-13. Graphite Sleeve for Short Static Measurement Rod (Ref. 2).

Fuel Pebbles

The fuel pebble physical properties are provided in Table 1.1-1. Unless otherwise noted, these properties were obtained from the original quality control records. The specified values are averages with their corresponding 1σ standard deviations. The diameter and mass of the fuel pebbles were measured at PSI on August 17, 1992, and again on October 30, 1995. The masses of the fuel pebbles did not change significantly over the >3 year time period. However, there was a slight reduction in the fuel pebble diameter, presumably due to slight indentations of the surface caused during the loading process, and is considered insignificant.[a] Measurements performed on August 17, 1992, are recommended by PSI for use in modeling these experiments (Ref. 2 and 3). The construction and dimensions of the fuel pebble are shown in Figure 1.1-14.

Fuel for the experiments was provided by the KFA Research Center in Jülich, Germany (Ref. 3).

Arbeitsgemeinschaft Versuchsreaktor (AVR)-type fuel pebbles were employed in the HTR-PROTEUS experiments. Fuel particles were distributed randomly throughout the graphite matrix of the fuel pebbles.[b]

Some 5460 LEU AVR fuel pebbles were transferred from the LEU HTR experimental program in the AVR test facility to the PROTEUS facility in March and April of 1992.[c]

There are 9394 fuel kernels in the fuel region of each fuel pebble.[d]

[a] The HTR-PROTEUS Core 5 had been loaded three times over the course of 1.5 years; the variation in the reactivity was insignificant, which is a strong indication that the change in mass was negligible.
[b] Chawla, R., Joneja, O. P., Rosselet, M., and Williams, T., "Definition and Analysis of an Experimental Benchmark on Shutdown Rod Worths in LEU-HTR Configurations," *Nucl. Technol.*, **139**, 50-60 (2002).
[c] Brogli, R., Mathews, D., and Seiler, R., "HTR Roteus Experiments," Proc. 2nd JAERI Symposium on HTGR Technologies, Oarai, Japan, October 21-23, 1992, p. 233-239, JAERI-M 92-215 (1993).
[d] Difilippo, F. C., "Monte Carlo Calculations of Pebble Bed Benchmark Configurations of the PROTEUS Facility," *Nucl. Sci. Eng.*, **143**, 240-253 (2003).

Table 1.1-1. Fuel Pebble Physical Specifications (Ref. 2 and 3).[(a)]

^{234}U mass per fuel pebble	0.008	±	0.001	gram
^{235}U mass per fuel pebble	1.000	±	0.010	gram
^{236}U mass per fuel pebble	0.005	±	0.001	gram
^{238}U mass per fuel pebble	4.953	±	0.050	gram
Total uranium mass per fuel pebble	5.966	±	0.060	gram
Carbon mass per fuel pebble	193.1	±	0.2	gram
Total mass per fuel pebble[(b),(c)]	202.22	±	0.18	gram
Fuel pebble inner (fueled) zone radius[(d)]	2.350[(f)]	±	0.025	cm
Fuel pebble outer radius	3.0006	±	0.002	cm
Radius of fuel particles (UO_2 substrates)[(e)]	0.02510[(f)]	±	0.0010[(g)]	cm
Thickness of particle buffer coatings (C)	0.00915	±	0.0025[(h)]	cm
Thickness of particle inner PyC coatings[(e)]	0.00399	±	0.0010[(h)]	cm
Thickness of particle SiC coatings	0.00353	±	0.0004[(h)]	cm
Thickness of particle outer PyC coatings[(e)]	0.00400	±	0.0008[(h)]	cm
Density of fuel particles (UO_2 substrates)	10.88	±	0.04	g/cm^3
Density of fuel particle buffer coatings (C)	1.10	+0	-0.11[(i)]	g/cm^3
Density of fuel particle inner PyC coatings	1.90	±	0.05	g/cm^3
Density of fuel particle SiC coatings	3.20	±	0.02	g/cm^3
Density of fuel particle outer PyC coatings	1.89	±	0.05	g/cm^3

(a) The fuel pebble masses and outer diameters were measured at PSI on August 17, 1992, and October 30, 1995. The second series of measurements indicated a significant reduction of the pebble diameter over the 3 years of operation; however, since the mass measurements indicated no such decrease it was assumed that the apparent diameter reduction was due to indentations in the pebbles caused during handling and not from a general loss of material.
(b) The total mass of oxygen and silicon in the fuel pebbles was not reported.
(c) There is a discrepancy of 0.86 g (0.43 %) in the total fuel pebble mass of 201.4 g computed from the individual components provided in the table as compared with the measured fuel mass of 202.22 ± 0.18 g on August 17, 1992.
(d) The 47 ± 0.5 mm diameter of the fuelled region obtained from neutron radiographs made by E. Lehmann at the PSI Saphir reactor corresponds with the 47 mm diameter fuelled region given by Gontard et al. (KFA Jülich report HBK-IB-10/86).
(e) There are slight differences in the reported radius/thickness between this table and Figure 1.1-14; the differences are within their reported 1σ uncertainties.
(f) The last significant digit on these two values, zero, is not reported in Reference 3 but is reported in Reference 2.
(g) The uncertainty in the UO_2 particle radius is a 90 % confidence value.
(h) The uncertainties in the particle coating thicknesses are 95 % (2σ) confidence values.
(i) The density of the fuel particle buffer coatings is stated to be ≤1.1 g/cm^3. The one-sided 10 % uncertainty (1σ) was assumed by the authors of the reference reports in the absence of measured data.

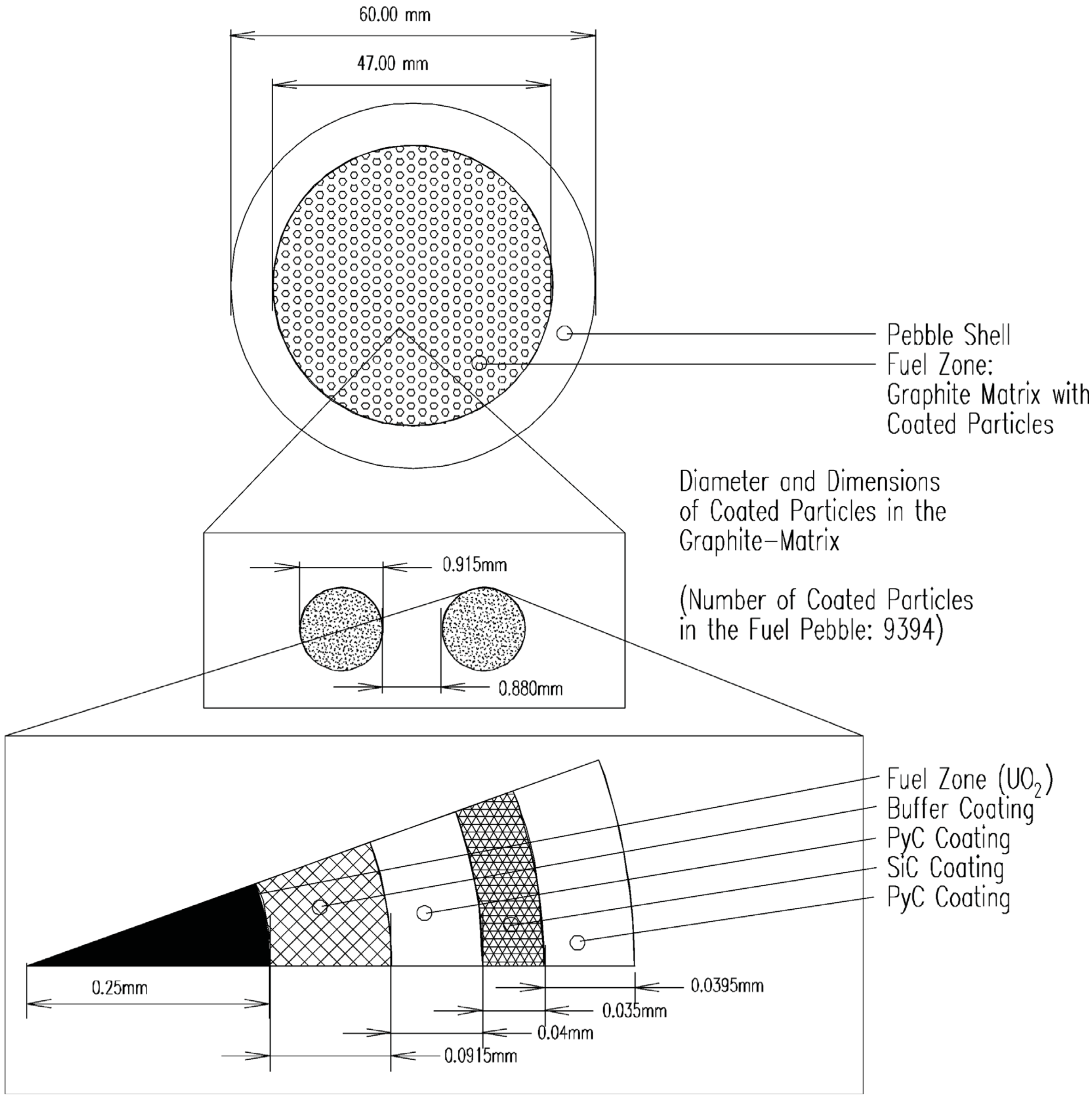

Figure 1.1-14. HTR-PROTEUS Fuel Pebble and Coated Fuel Particle (Ref. 2 and 3).

Moderator Pebbles

The physical properties of the moderator pebbles (Table 1.1-2) were obtained from measurements performed at PSI on August 17, 1992, May 3, 1995, and October 30, 1995. These values correspond well with those provided in relevant quality control records. The specified values are averages with a 1σ standard deviation. There were no significant changes noted in the properties of the moderator pebbles throughout the course of these experiments (Ref. 2).

Table 1.1-2. Moderator Pebble Physical Specifications (Ref. 2 and 3).

Moderator Pebble Mass	190.54	±	1.44	g
Moderator Pebble Outer Radius	2.9979	±	0.0015	cm

Start-Up Source

The reactor start-up sources were normally in their "in" position during reactor operation. At low fluxes their reactivity effect is positive by virtue of the apparent enhanced neutron multiplication; at normal operating fluxes of $>10^7$ n/cm^2/s, their effect was negative due to parasitic neutron absorption in the source and casing. The start-up sources pass through horizontal aluminum guide tubes situated in the radial reflector at about the level of the cavity floor (Ref. 3).

Detectors

There are a total of eight detection channels used for nuclear instrumentation: three safety channels, two impulse channels, one logarithmic channel, one linear channel, and one deviation channel. Apart from the two impulse channels, which were fission chambers, all the instrumentation consisted of large ionization chambers (220 mm × 90 mm Ø) situated in horizontal channels in the reflector at a radius of ~1000 mm (Ref. 3).

Temperature Sensors

There are typically four separate temperature sensors in the system: two in the core and two in the radial reflector (Ref. 3).

1.1.2.2 Components Unique to Cores 9 and 10

The following components are unique to core configurations 9 and 10.

Graphite Fillers

Graphite filler pieces were utilized to support the outer surfaces of the various deterministic configurations and to modify the shape of the cavity floor to avoid ordering effects in random core configurations (Ref. 2). The graphite filler pieces used to modify the cavity floor were not used for Cores 9 and 10.

For the hexagonal close packed cores, the 22-sided cavity is converted to a 12-sided one using twelve graphite pieces running from the bottom of the cavity to just beneath the aluminum safety ring (1750 mm). Each graphite piece is unique, as shown in Figures 1.1-15 (Ref. 2). These graphite filler pieces serve as axial modifiers to the core cavity.

The 12-sided polygon cavity developed with the graphite fillers had a height of 1729 mm with sides at alternated distances of 601.5 and 603 mm from the center. The equivalent area cylinder would have a radius of 608.3 mm.[a]

A cylindrical version of the 12-sided polygon cavity would have a radius (the first value represents an equal perimeter, and the second value represents an equal area) of 615.4 and 608.3 mm, respectively.[b]

The graphite filler pieces numbered as pieces 13 and 14 in Figure 1.1-16 were not used in Cores 9 and 10 (Ref. 2).

[a] Difilippo, F. C., "Monte Carlo Calculations of Pebble Bed Benchmark Configurations of the PROTEUS Facility," *Nucl. Sci. Eng.*, **143**, 240-253 (2003).
[b] Difilippo, F. C., "Applications of Monte Carlo Simulations of Thermalization Processes to the Nondestructive Assay of Graphite," *Nucl. Sci. Eng.*, **133**, 163-177 (1999).

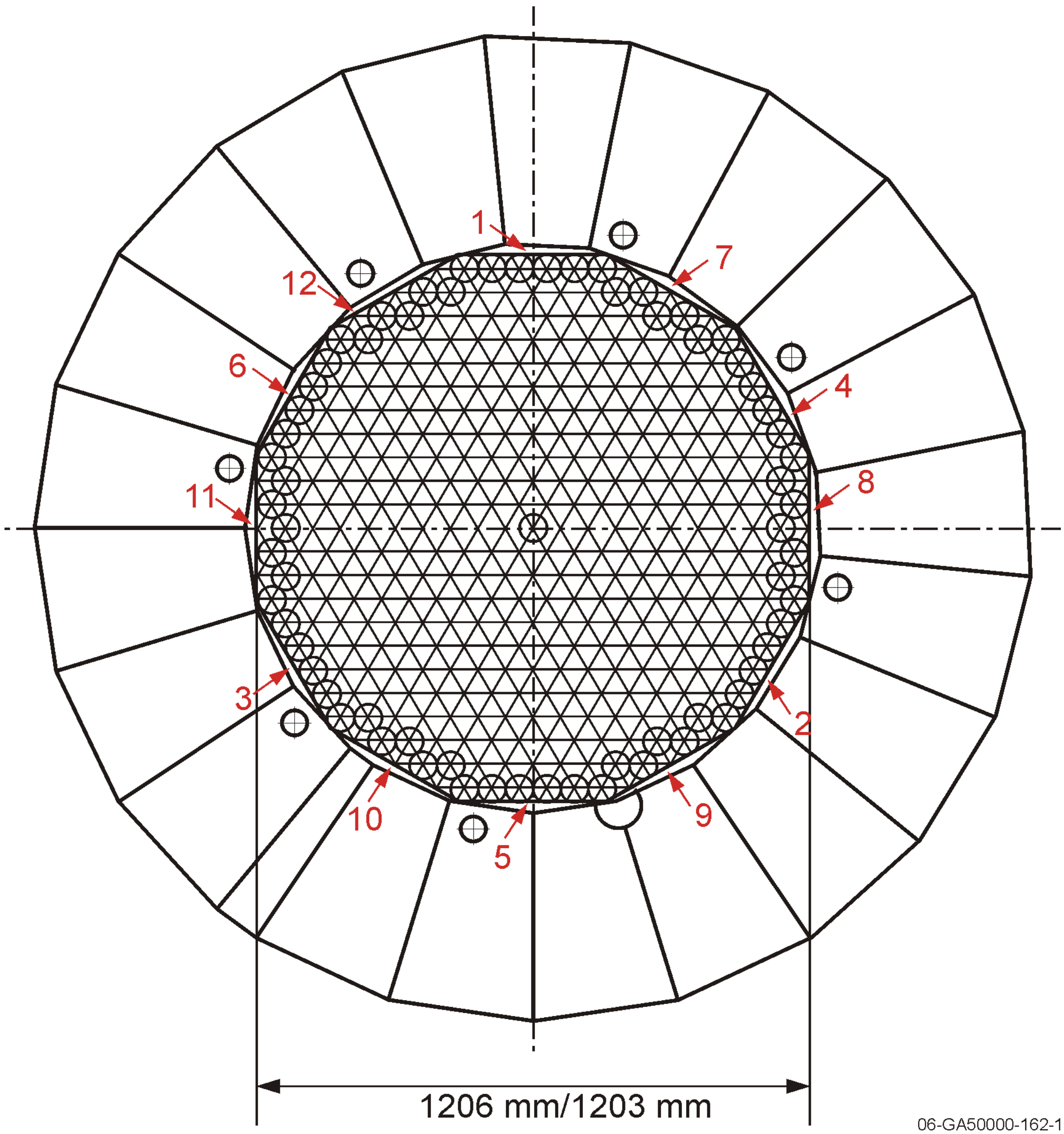

Figure 1.1-15. Positioning of the Graphite Filler Pieces used in the Deterministic Cores (Ref. 2).

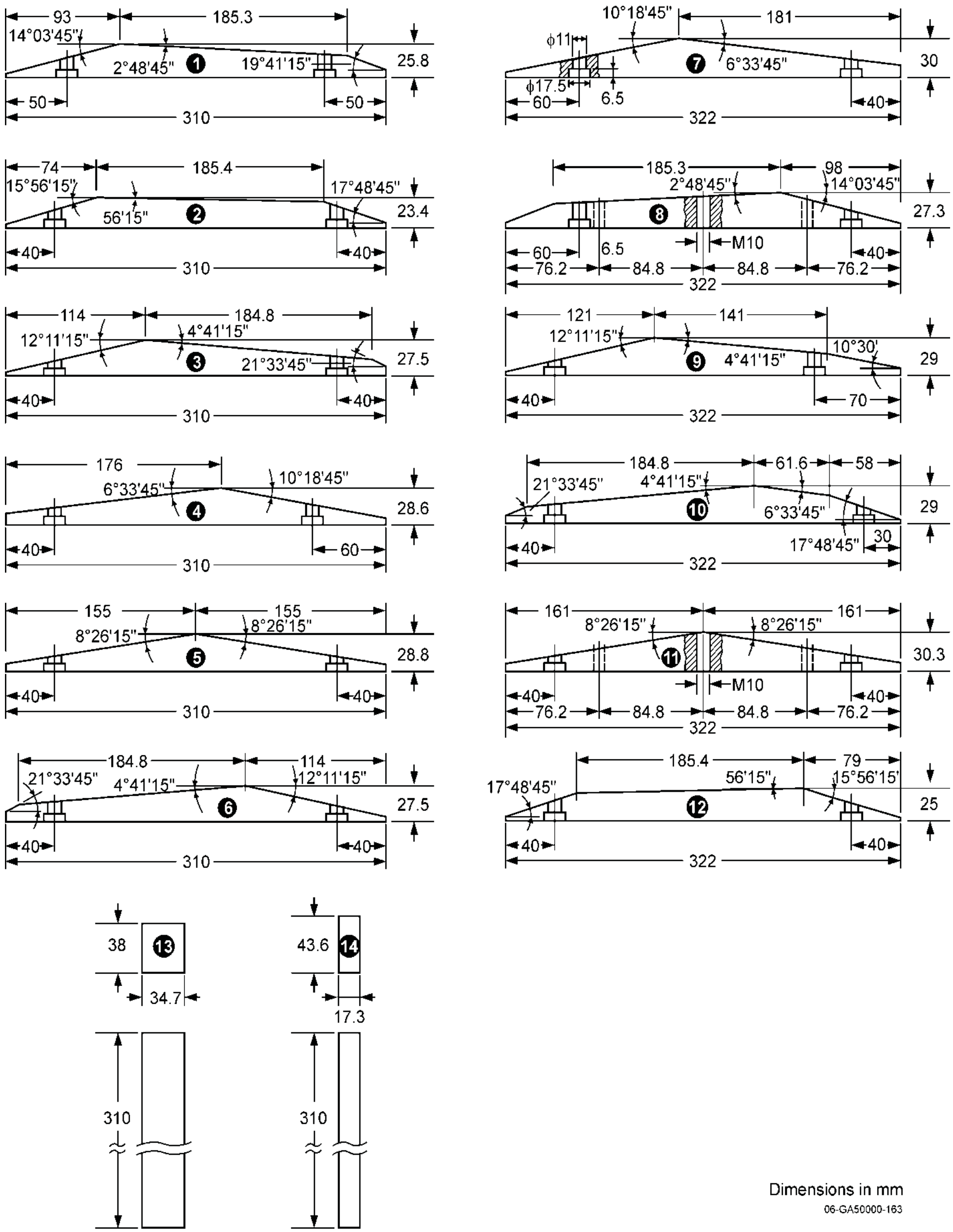

Figure 1.1-16. Graphite Filler Pieces used in the Deterministic Cores (Ref. 2). The position numbers are engraved into the top of each graphite filler piece.

ZEBRA Control Rods

The ZEBRA control rods were not used in the experiments with Cores 9 and 10.

Withdrawable Stainless Steel Control Rods

The ZEBRA type control rods used in Core 1were replaced with four withdrawable stainless steel control rods for Cores 1A through 10. The stainless steel rods were placed in four C-Driver channels, instead of the channels used for the ZEBRA rods, but close to the original ZEBRA positions (see Figure 1.1-2). These rods were intended to increase operational flexibility and were designed to operate at two radii: 789 mm (ring 3) or 906 mm (ring 5). They were exclusively used in ring 5 throughout the measurements due to the thermal flux gradient in the radial reflector at these positions (Ref. 2 and 3).

Each rod was comprised of two concentric stainless steel tubes. The inner stainless steel (type St1.4301) tube had an inner diameter of 9.5 mm, outer diameter of 13.5 mm, and length of 2150 mm; this tube could contain various materials, such as B_4C pellets, to further adjust the rods' worth. The outer stainless steel (type St1.4541) rod had an inner diameter of 14 mm, outer diameter of 22 mm, and length of 2149 mm; this rod was added as a means of increasing rod mass to achieve a satisfactory cable tension. Stainless steel plugs were used to seal both ends of the tubes. The total rod length, including end-stops, was 2200 mm. Technical drawings of these rods are provided in Figure 1.1-17. The rods are fully inserted when the base of the cavity in the inner tube corresponded to the core cavity floor with the tips of the rods lying 25 mm below this; the indicated rod position on the control panel was 2500 mm. The rods are fully withdrawn when the control panel indicated ~6 mm and the rod tips were just 49 mm below the upper surface of the radial reflector. The total rod range was 2494 mm. The bottom of each control rod channel was filled with a 26.5 mm diameter, 730 mm long graphite plug, leaving an air gap of 25 mm below the rod tip (Ref. 2).

No inserts were placed within these stainless steel control rods (Ref. 2).

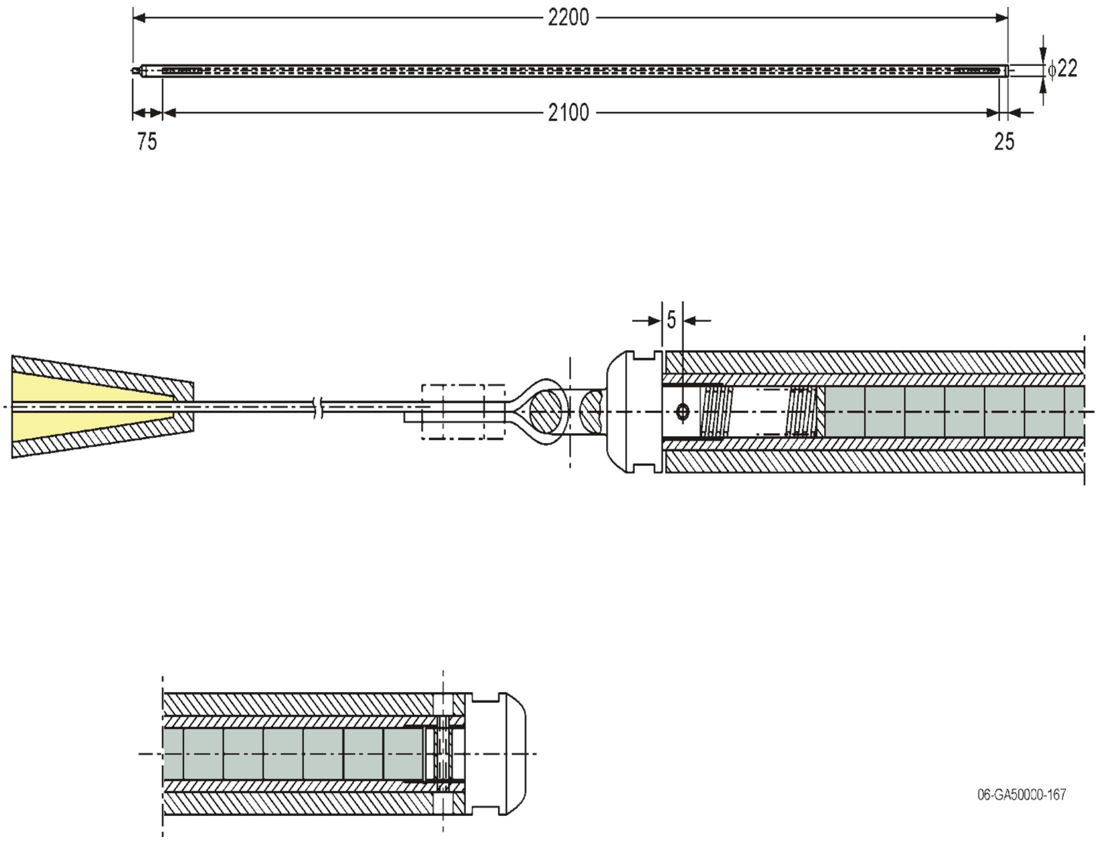

Figure 1.1-17. Details of the Withdrawable Stainless Steel Control Rods (Ref. 2).
Units are in millimeters.

Polyethylene Rods

One of the primary goals of the HTR-PROTEUS project was to measure the effect of accidental water ingress into the core. The use of water in the experiments was forbidden and impractical; the presence of moisture was simulated with polyethylene (CH_2) rods. Different shapes and sizes of polyethylene rods were introduced into the cores to simulate a range of water densities in the void spaces between the pebbles. The dimensions and specific linear densities of the various polyethylene rods are shown in Figure 1.1-18. Most of the rods were either unmachined, or machined down to the reported diameter from a larger diameter rod. Measurements at PSI showed that the 6 and 9 mm diameter unmachined rods demonstrated higher homogeneity than the machined versions. Additionally, the unmachined rods had not been exposed to extra 'impurity hazardous' machining environments (Ref. 2 and 3). Only the 6.5-, 8.3-, and 8.9-mm-diameter rods, and the triangular rods, were used to establish the critical core configurations of the HTR-PROTEUS experiments.

Polyethylene rods were not used in the experiments with Core 9. A total of 654 polyethylene rods were placed in the inter-pebble channels (no edge channels) of Core 10. Each rod had a diameter of 6.5 mm (see Figure 1.1-18) and a total length of 1450 (60 mm × 24 layers + 10 mm) ± 5 mm (Ref. 1).

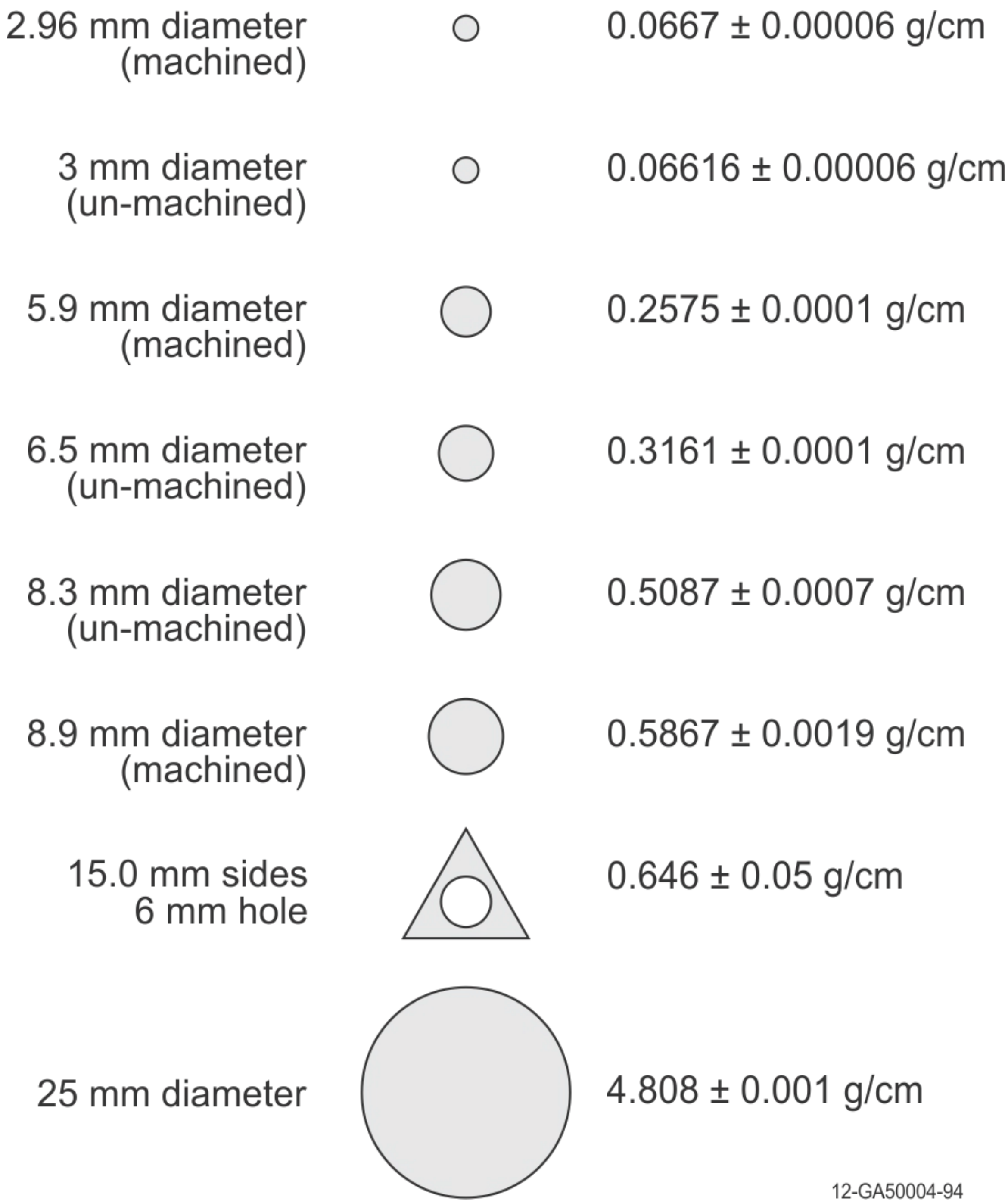

Figure 1.1-18. Physical Properties of Available Polyethylene Rods (Ref. 2 and 3).
Reference 3 states that the sides of the triangular rod are 13.5 mm; however, the resultant mass density calculates to be ~1.3 g/cm^3, much greater than a typical density of 0.94 g/cm^3.

Copper Wire

Copper wire was not used in the experiments with Cores 9 and 10.

Core Pebble Packing

Cores 9 and 10 were deterministically stacked in Columnar Hexagonal Point-On-Point (CHPOP) cells, as shown in Figure 1.0-3.

The deterministic configurations were loaded by hand; the fueling machine was used to deliver pebbles to the loading personnel. To facilitate access to the pebble bed, a specially constructed, shielded “loading-basket” was used. Special anodized aluminum “tripods” were constructed to facilitate with the loading of the point-on-point cores; the tripods were then removed when the layer was complete (Ref. 3).

Core Configurations

Tables 1.1-3 through 1.1-5 provide detailed summaries of the core description and critical balance information for Cores 9 and 10. Figures 1.1-19 through 1.1-31 provide scale drawings for each different pebble layer, indicating the exact type and position of every pebble, polyethylene rod, and graphite filler piece in the system. Some cores had more than one reference state, indicating either that one or more critical configurations was constructed for this core, for instance with and without the coolant channels being filled in the lower axial reflector, or, that the core was unloaded and loaded again at a later date (Ref. 1).

- Core 9 (reference state #1): Table 1.1-3 and Figures 1.1-19 through 1.1-24
- Core 9 (reference state #2): Table 1.1-4 and Figures 1.1-19 through 1.1-25
- Core 10 (reference state #1): Table 1.1-5 and Figures 1.1-26 through 1.1-31

Where possible, experimental conditions had been measured directly (indicated by **M** in the tables) but in a few cases the values were estimated (**E**).

Excess reactivity worths for individual components in each core configuration are discussed in Section 1.1.5.

Table 1.1-3. Core 9 (Reference State #1) Critical Information (Ref. 1 and 3).[(a)]

Core Description			
1st Criticality	February 22, 1996		
Unloaded	May 8, 1996		
Nominal Pebble Ratio	1:1 moderator:fuel		
Pebble Count	27 layers[(b)]		
Pebble Packing	Columnar Hexagonal Point-on-Point		
Polyethylene Loading	None		
Critical Balance			
Date	February 22, 1996		
Critical Loading	27 layers	**M**[(c)]	See Figure 1.1-19 through 1.1-24
Critical Height	1.62 m	**M**	27×6 cm[(d)]
Rod Positions (Control/Autorod)	0/258 mm	**M**	0/1000 mm = fully out[(e)]
Nominal Flux	5×10^7 n/cm^2/s	**M**	
Hall Temperature	19.6 ºC	**M**	
Core Temperatures (Center/Edge)	N/A	**M**	
Reflector Temperatures (R2,47/R2,15)[(f)]	N/A	**M**	
Air Pressure	980 mbar	**M**	
Air Humidity	25 %	**M**	

(a) Core 9 was, apart from the random cores 4(1,2,3), the first loading of a 1:1 (moderator:fuel pebble ratio) core in HTR-PROTEUS. The individual layer loading patterns shown in Figure 1.1-20 through 1.1-25 were chosen both as a result of consideration of the homogeneity of the system, in both the horizontal and vertical planes, and upon consideration of the ease of loading. Channels in the lower axial reflector were filled.
(b) With 27 layers loaded, the system was just critical with all control rods fully withdrawn and the channels in the lower axial reflector filled. For the operational loading, an extra layer of moderator pebbles was added to bring the critical control rod positions into a convenient range (see Core 9, reference state #2).
(c) Directly measured experimental measurements are indicated with an **M**; sometimes a few values were estimated, and indicated with an **E**.
(d) In the columnar hexagonal point-on-point packed cores the height of each layer is ~6 cm, the approximate diameter of the pebbles. See Figure 1.0-3.
(e) The withdrawable control rods and autorod are considered fully withdrawn when their positions indicate 0 and 1000 mm, respectively.
(f) The nomenclature for the channels in the radial reflector is described in Figure 1.1-3.

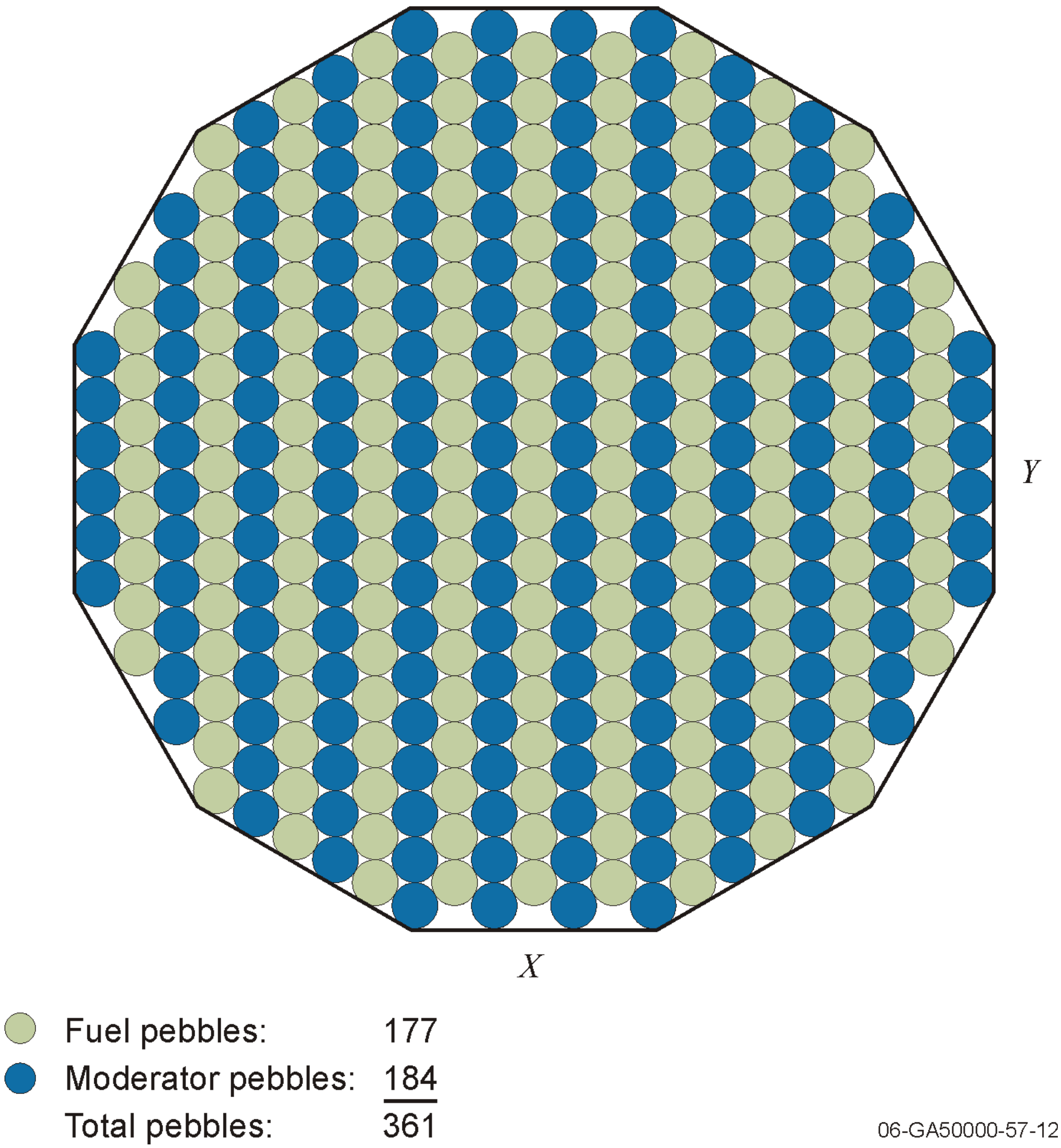

Figure 1.1-19. Layers 1, 7, 13, 19, and 25 of Core 9 (Ref. 1).

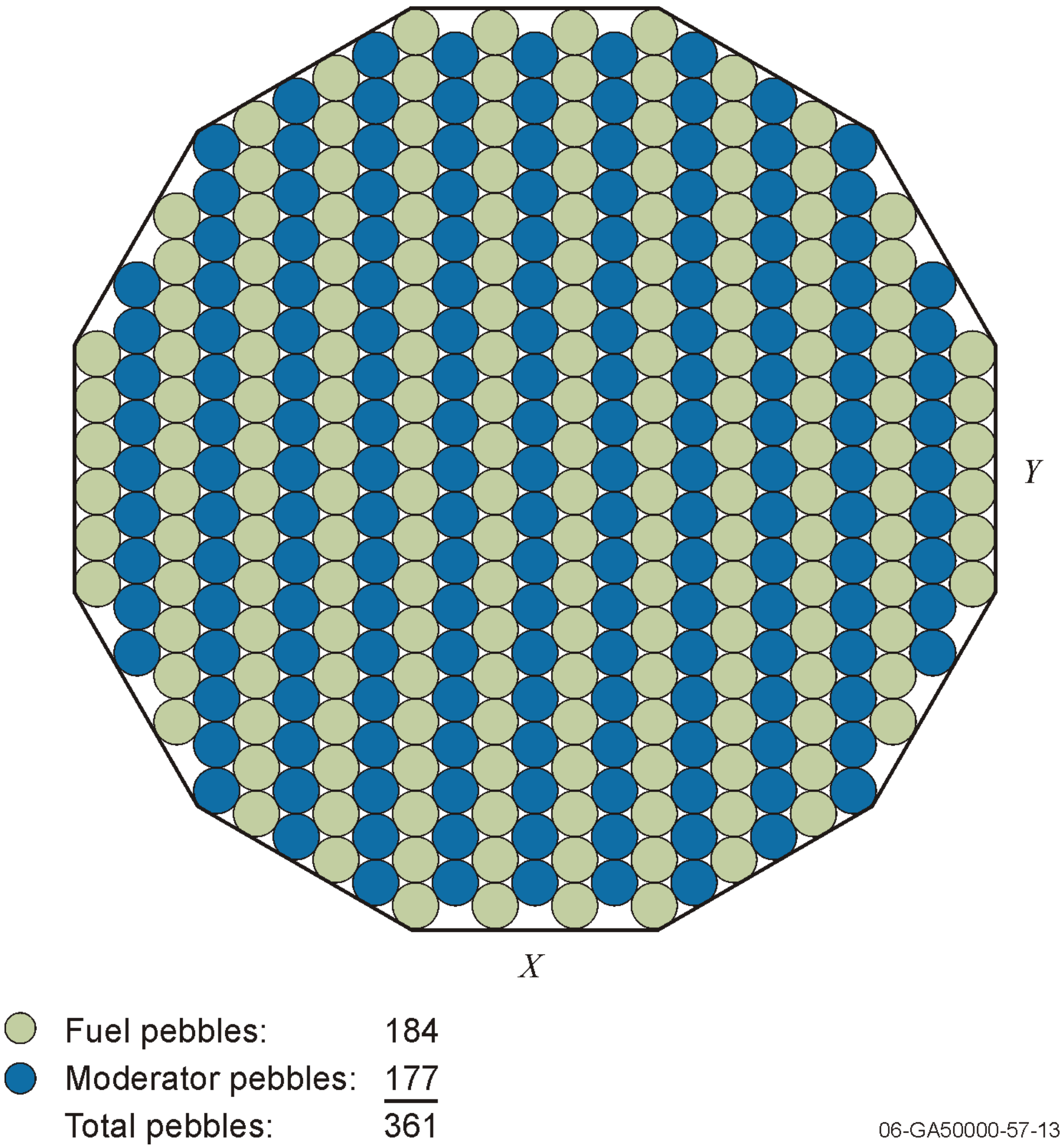

Figure 1.1-20. Layers 2, 8, 14, 20, and 26 of Core 9 (Ref. 1).

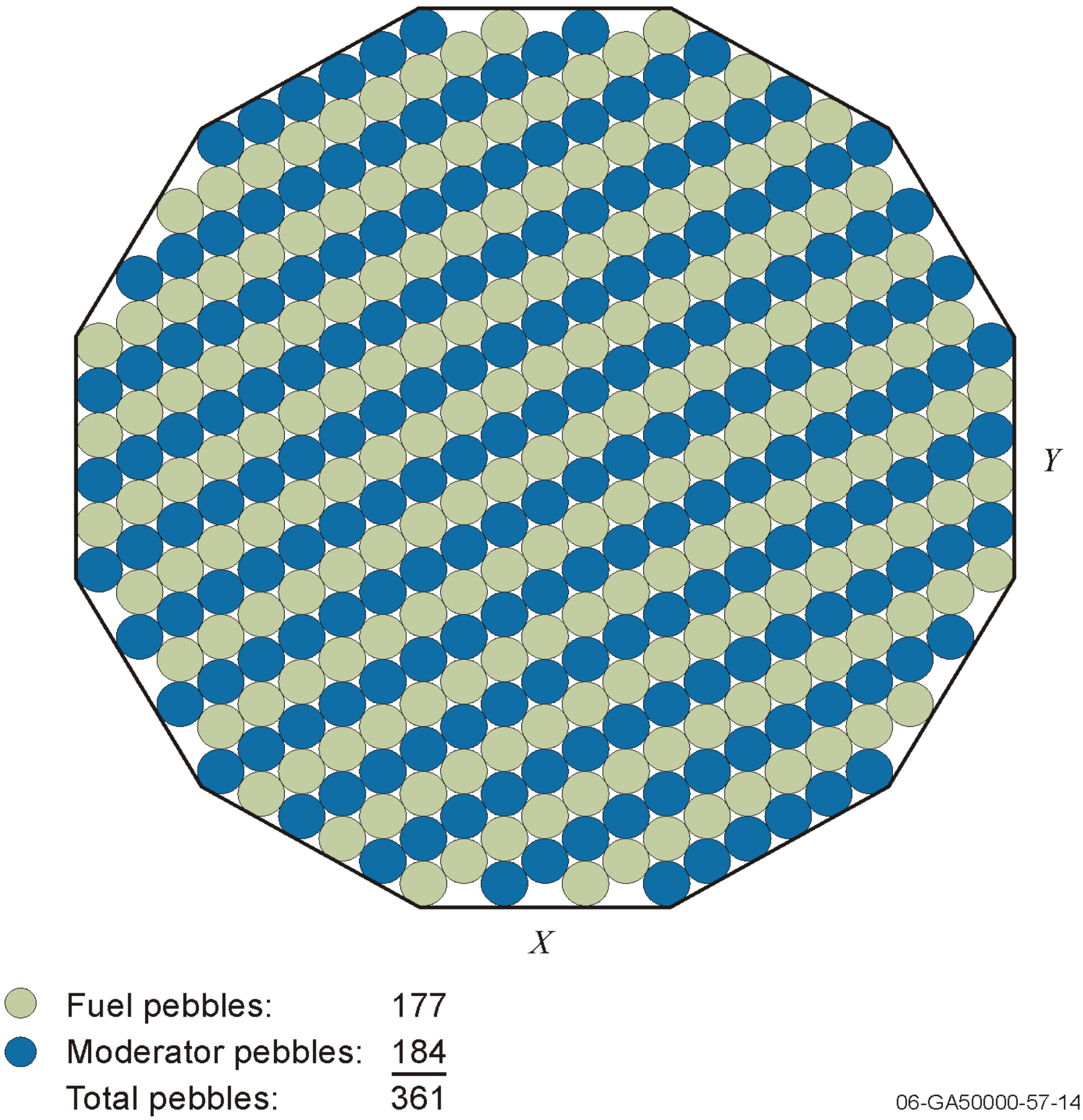

Figure 1.1-21. Layers 3, 9, 15, 21, and 27 of Core 9 (Ref. 1).

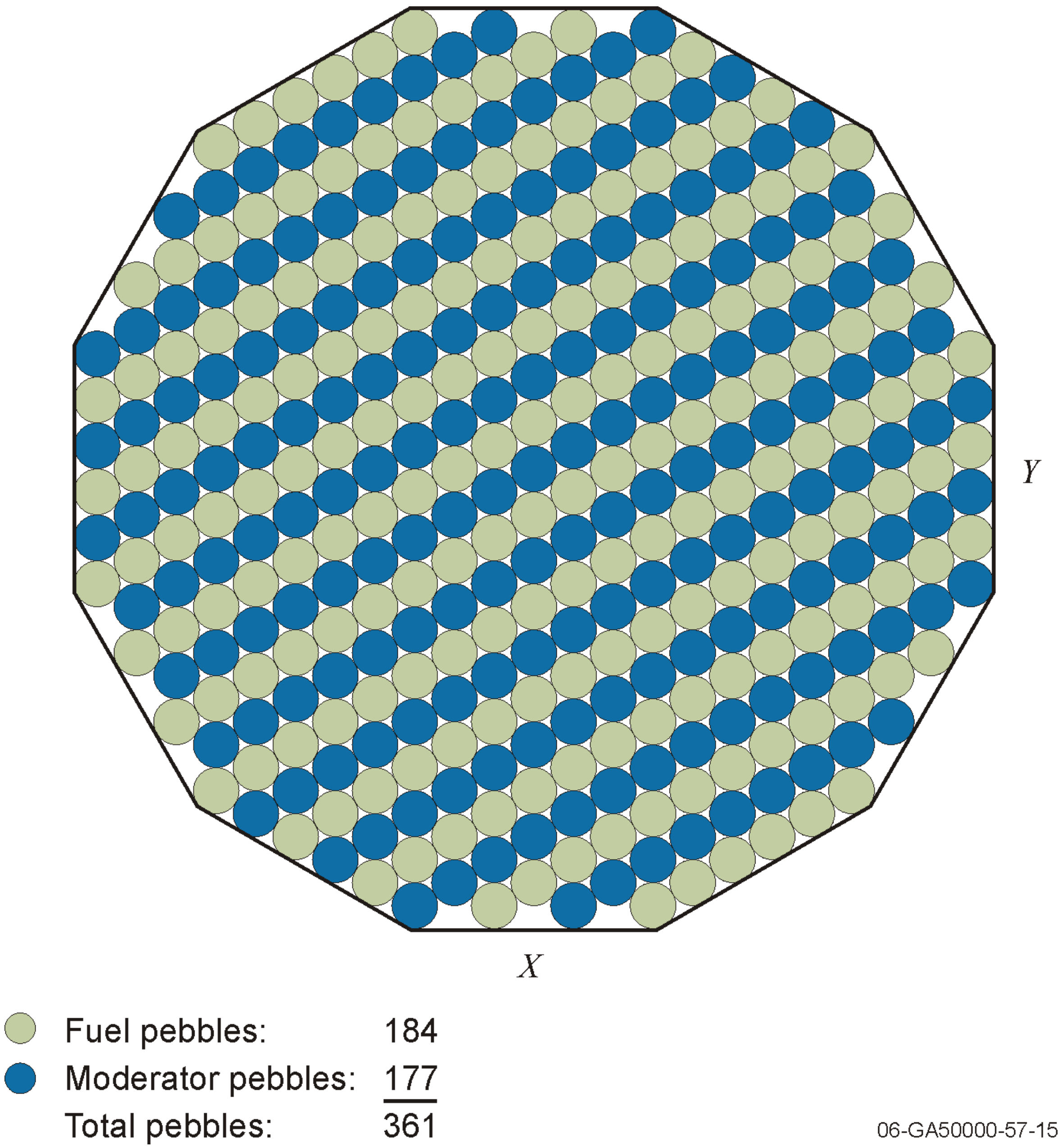

Figure 1.1-22. Layers 4, 10, 16, and 22 of Core 9 (Ref. 1).

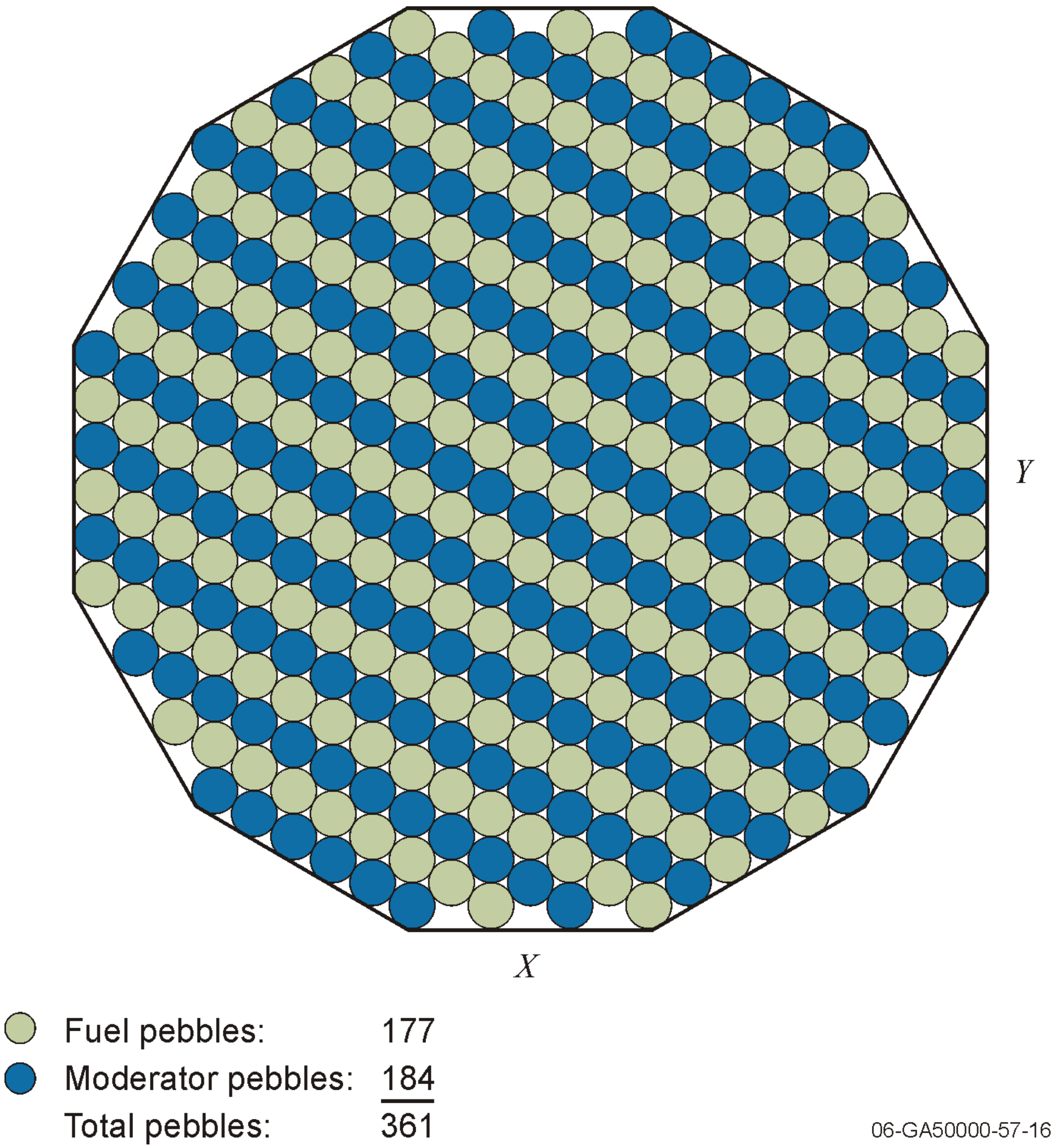

Figure 1.1-23. Layers 5, 11, 17, and 23 of Core 9 (Ref. 1).

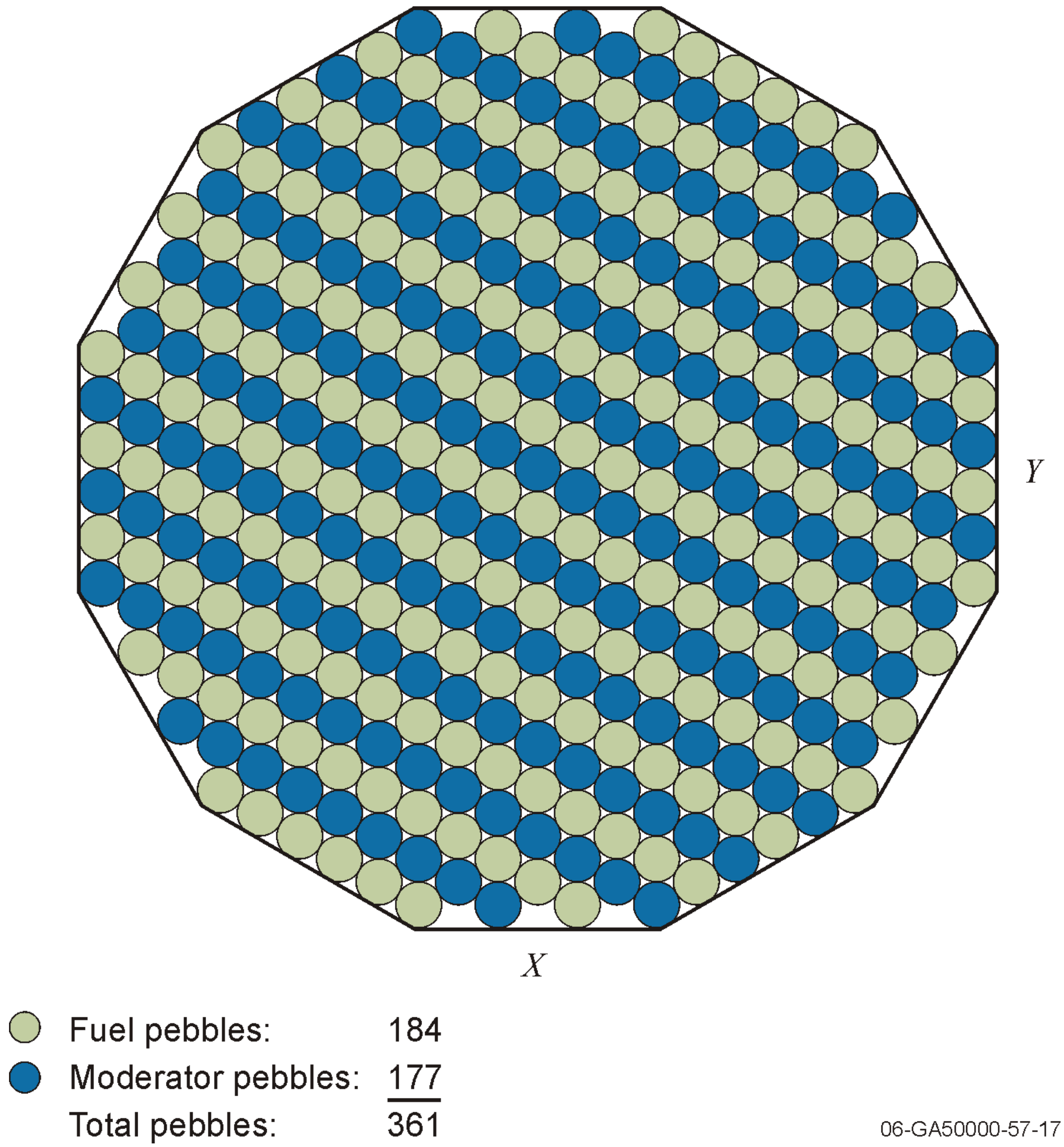

Figure 1.1-24. Layers 6, 12, 18, and 24 of Core 9 (Ref. 1).

Table 1.1-4. Core 9 (Reference State #2) Critical Information (Ref. 1 and 3). [(a)]

Core Description			
1st Criticality	February 22, 1996		
Unloaded	May 8, 1996		
Nominal Pebble Ratio	1:1 moderator:fuel		
Pebble Count	27 layers + 1 pure moderator		
Pebble Packing	Columnar Hexagonal Point-on-Point		
Polyethylene Loading	None		
Critical Balance			
Date	February 23, 1996		
Critical Loading	27+1 layers	**M**[(b)]	See Figures 1.1-19 through 1.1-25
Critical Height	1.68 m	**M**	28×6 cm[(c)]
Rod Positions (Control/Autorod)	1620/25 mm	**M**	0/1000 mm = fully out[(d)]
Nominal Flux	5×10^7 n/cm^2/s	**M**	
Hall Temperature	19.2 ºC	**M**	
Core Temperatures (Center/Edge)	N/A	**M**	
Reflector Temperatures (R2,47/R2,15)[(e)]	N/A	**M**	
Air Pressure	981 mbar	**E**	
Air Humidity	25 %	**E**	

(a) This configuration differs from reference state #1 only in the fact that an extra layer of moderator pebbles was loaded to make the configuration slightly more reactive and thus bring the control rods into an operationally convenient position. It is included here as it provides a clean comparison between control rod worths and core height.
(b) Directly measured experimental measurements are indicated with an **M**; sometimes a few values were estimated, and indicated with an **E**.
(c) In the columnar hexagonal point-on-point packed cores the height of each layer is ~6 cm, the approximate diameter of the pebbles. See Figure 1.0-3.
(d) The withdrawable control rods and autorod are considered fully withdrawn when their positions indicate 0 and 1000 mm, respectively.
(e) The nomenclature for the channels in the radial reflector is described in Figure 1.1-3.

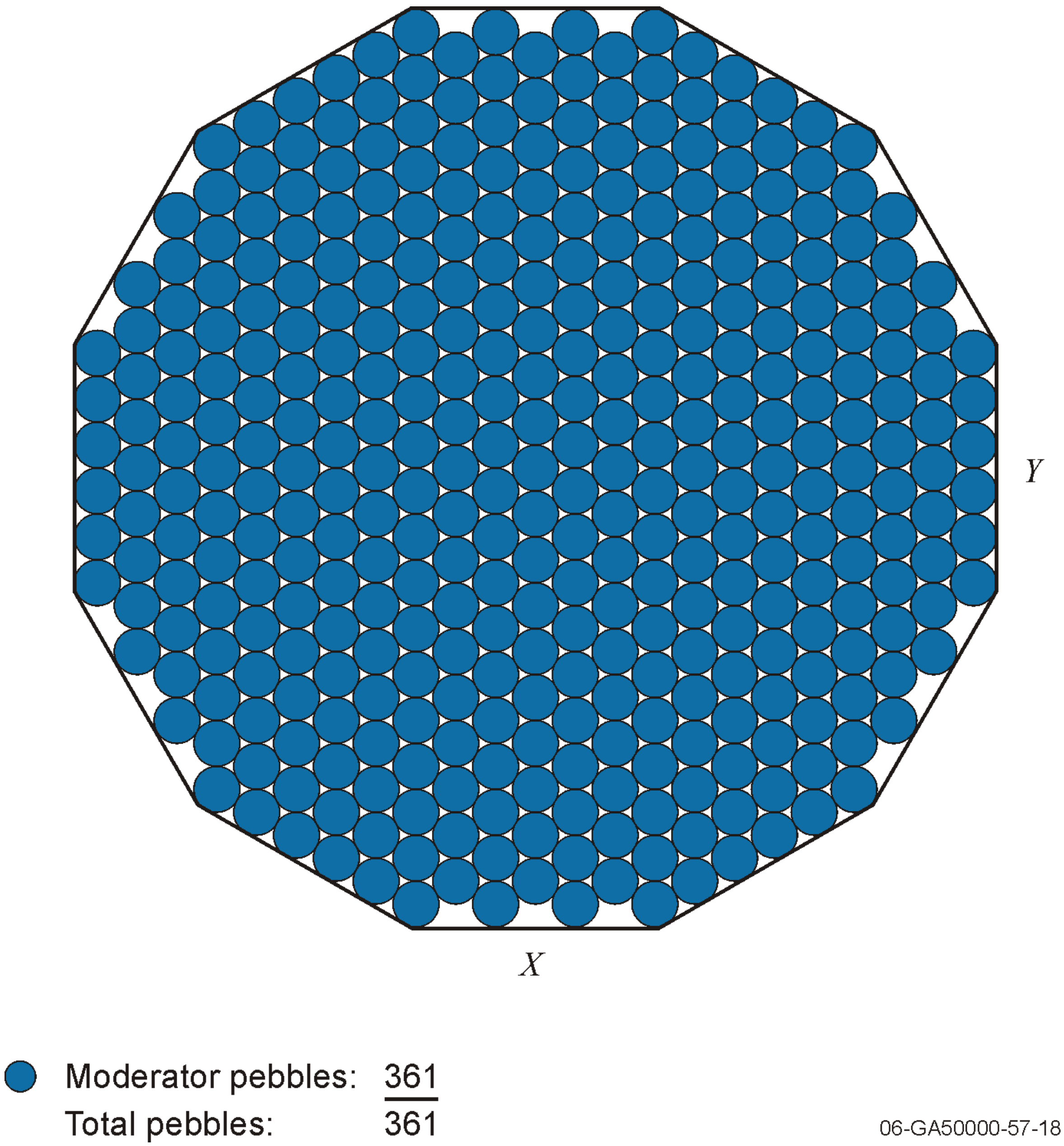

Figure 1.1-25. Additional Moderator Layer (28th) of Core 9, Reference State #2 (Ref. 1).

Table 1.1-5. Core 10 (Reference State #1) Critical Information (Ref. 1 and 3).[(a)]

Core Description			
1st Criticality	May 10, 1996		
Unloaded	October 1996		
Nominal Pebble Ratio	1:1 moderator:fuel		
Pebble Count	24 layers		
Pebble Packing	Columnar Hexagonal Point-on-Point		
Polyethylene Loading	654 6.5 mm rods having a length of 1450 mm		
Critical Balance			
Date	July 5, 1996		
Critical Loading	24 layers	**M**[(b)]	See Figure 1.1-26 through 1.1-31
Critical Height	1.44 m	**M**	24×6 cm[(c)]
Rod Positions (Control/Autorod)	1540/15 mm	**M**	0/1000 mm = fully out[(d)]
Nominal Flux	5×10^7 n/cm^2/s	**M**	
Hall Temperature	21.7 ºC	**M**	
Core Temperatures (Center/Edge)	N/A	**M**	
Reflector Temperatures (R2,47/R2,15/R2,63)[(e)]	N/A	**M**	
Air Pressure	975.9 mbar	**E**	
Air Humidity	74 %	**E**	

(a) Core 10 is a repeat of the Core 9 geometry with the addition of 654, 6.5-mm-diameter polyethylene rods and a correspondingly reduced core height. The polyethylene rods had a length of 1450 (60 mm × 24 layers + 10 mm) ± 5 mm. The channels in the lower axial reflector were filled.
(b) Directly measured experimental measurements are indicated with an **M**; sometimes a few values were estimated, and indicated with an **E**.
(c) In the columnar hexagonal point-on-point packed cores the height of each layer is ~6 cm, the approximate diameter of the pebbles. See Figure 1.0-3.
(d) The withdrawable control rods and autorod are considered fully withdrawn when their positions indicate 0 and 1000 mm, respectively.
(e) The nomenclature for the channels in the radial reflector is described in Figure 1.1-3.

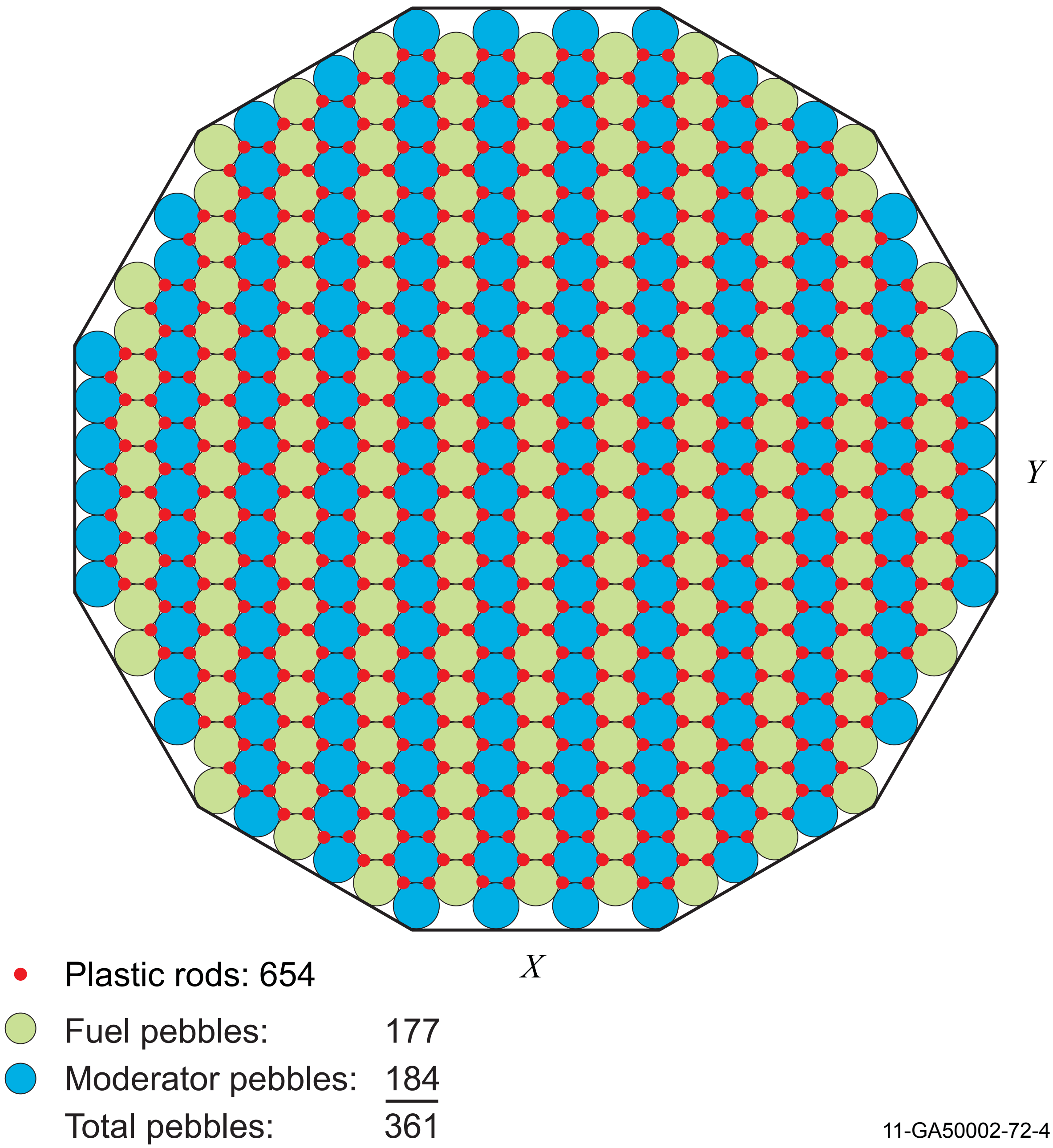

Figure 1.1-26. Layers 1, 7, 13, 19, and 25 of Core 10 (Ref. 1).

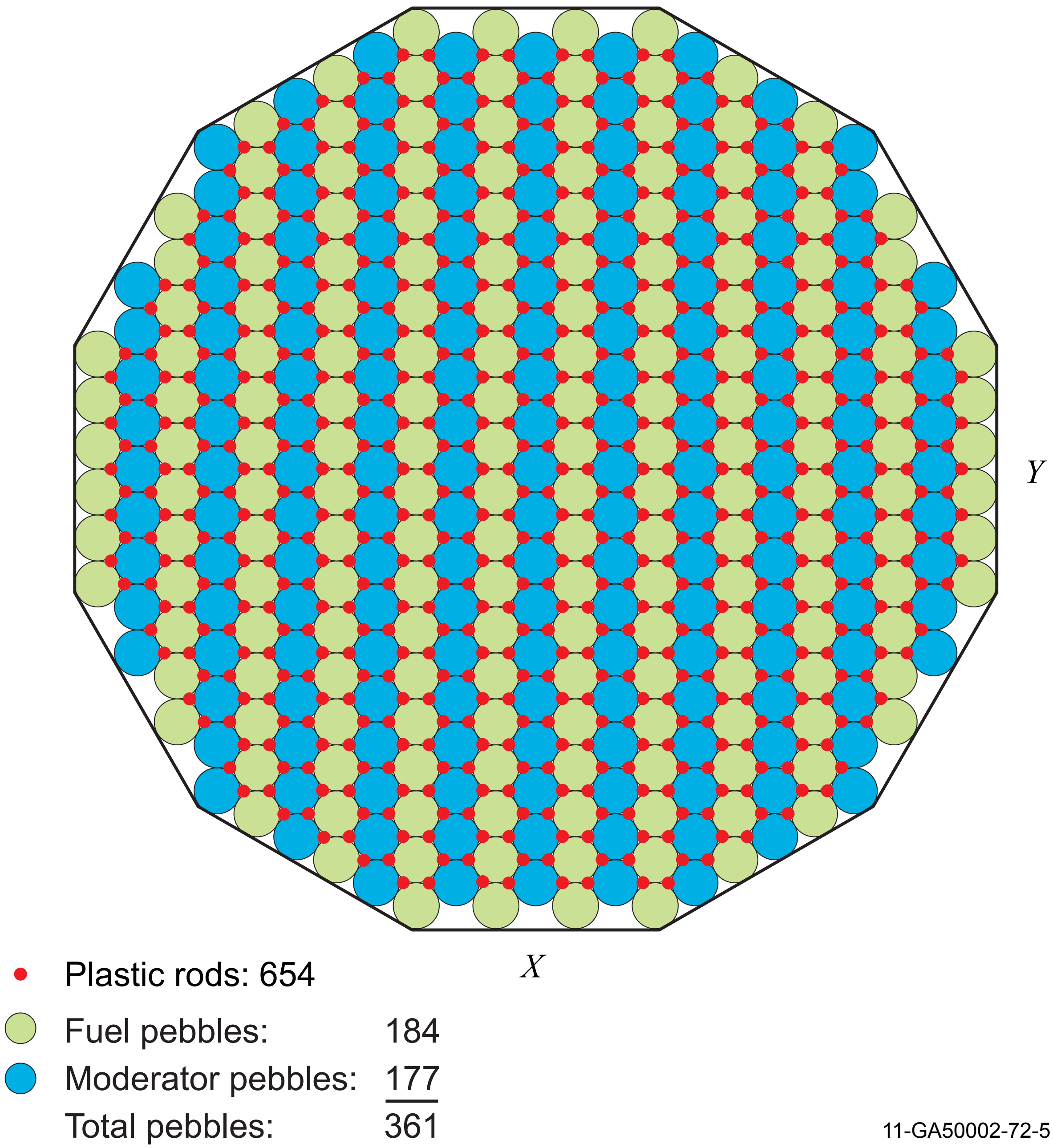

Figure 1.1-27. Layers 2, 8, 14, 20, and 26 of Core 10 (Ref. 1).

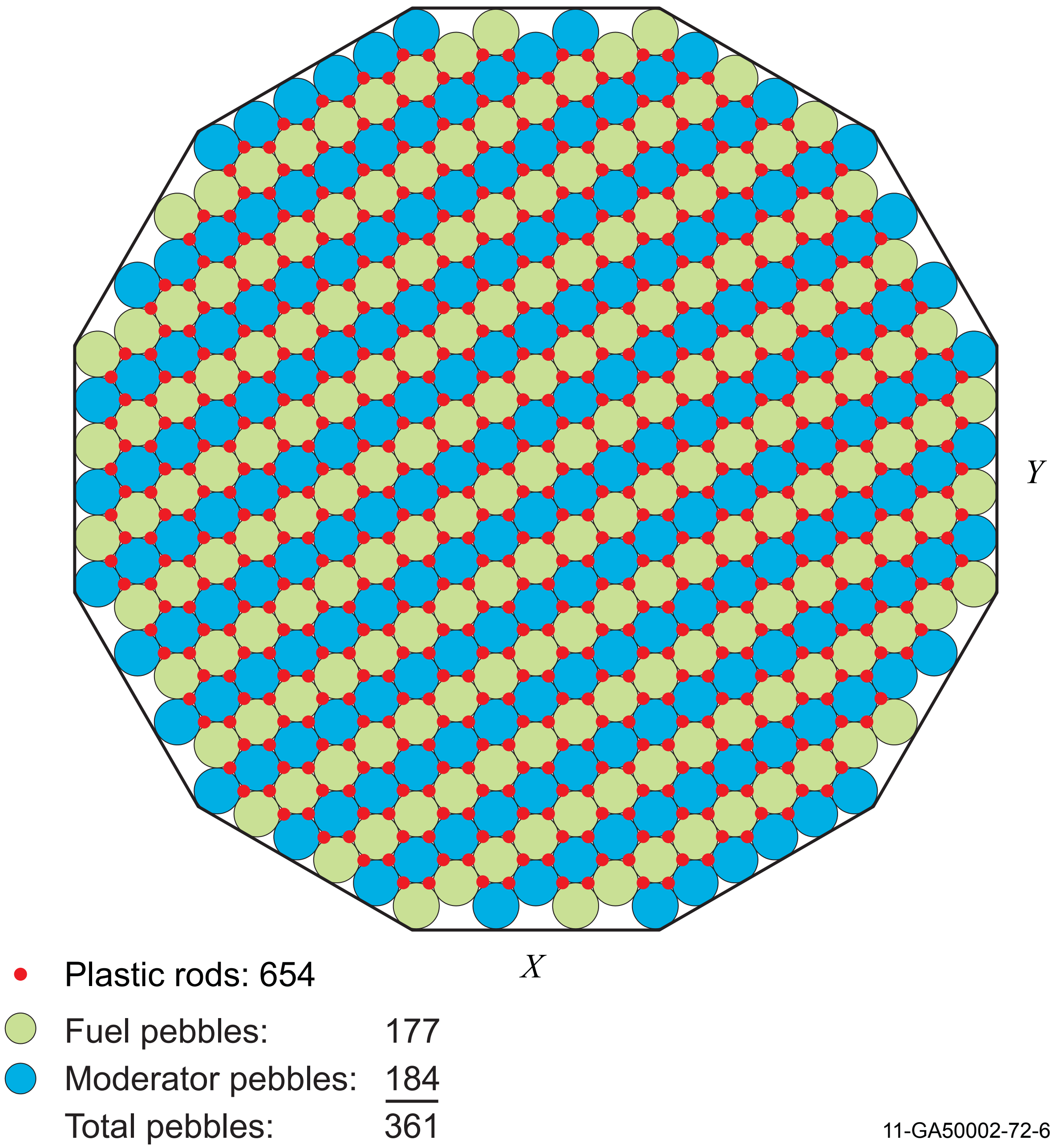

Figure 1.1-28. Layers 3, 9, 15, 21, and 27 of Core 10 (Ref. 1).

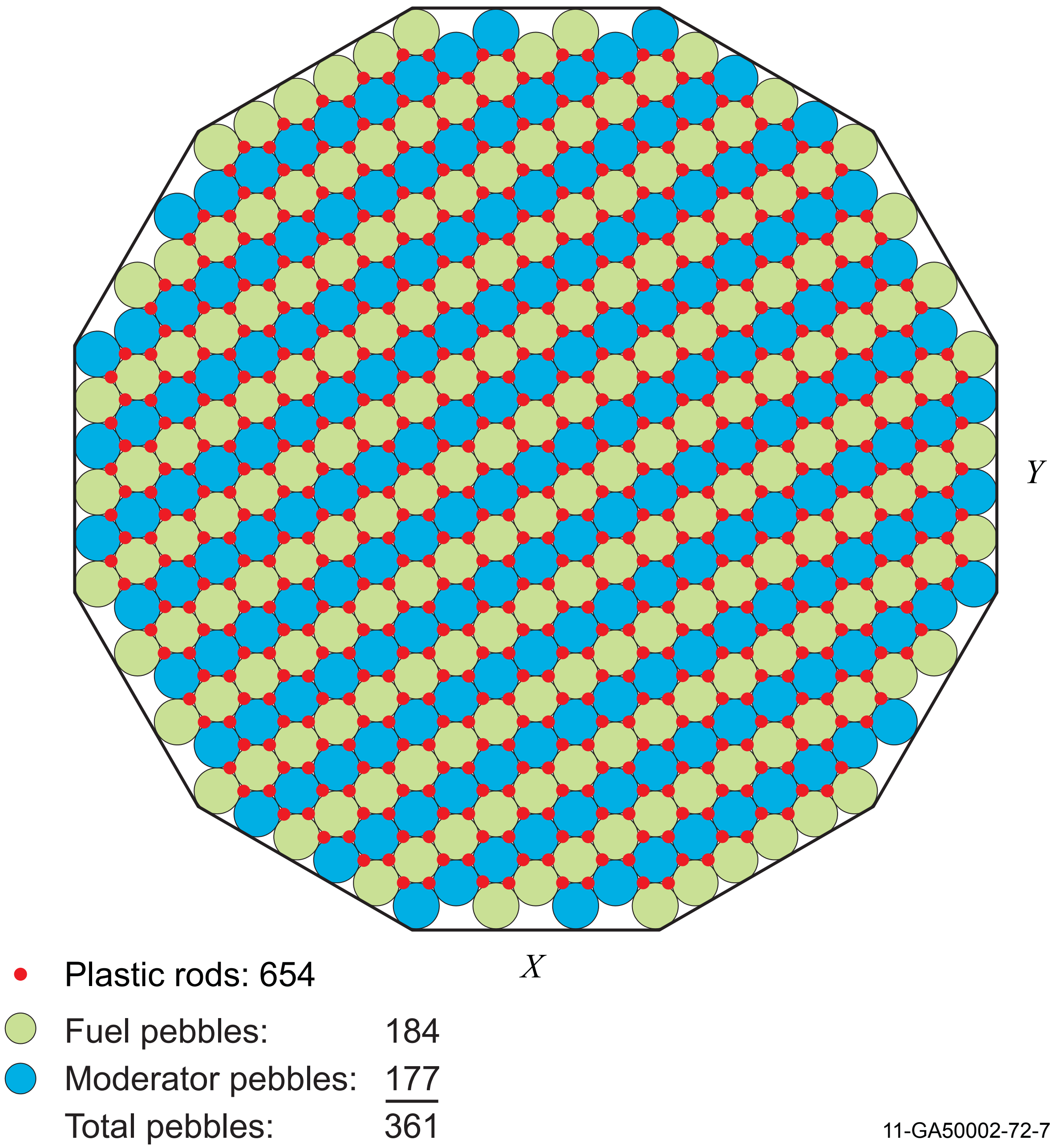

Figure 1.1-29. Layers 4, 10, 16, and 22 of Core 10 (Ref. 1).

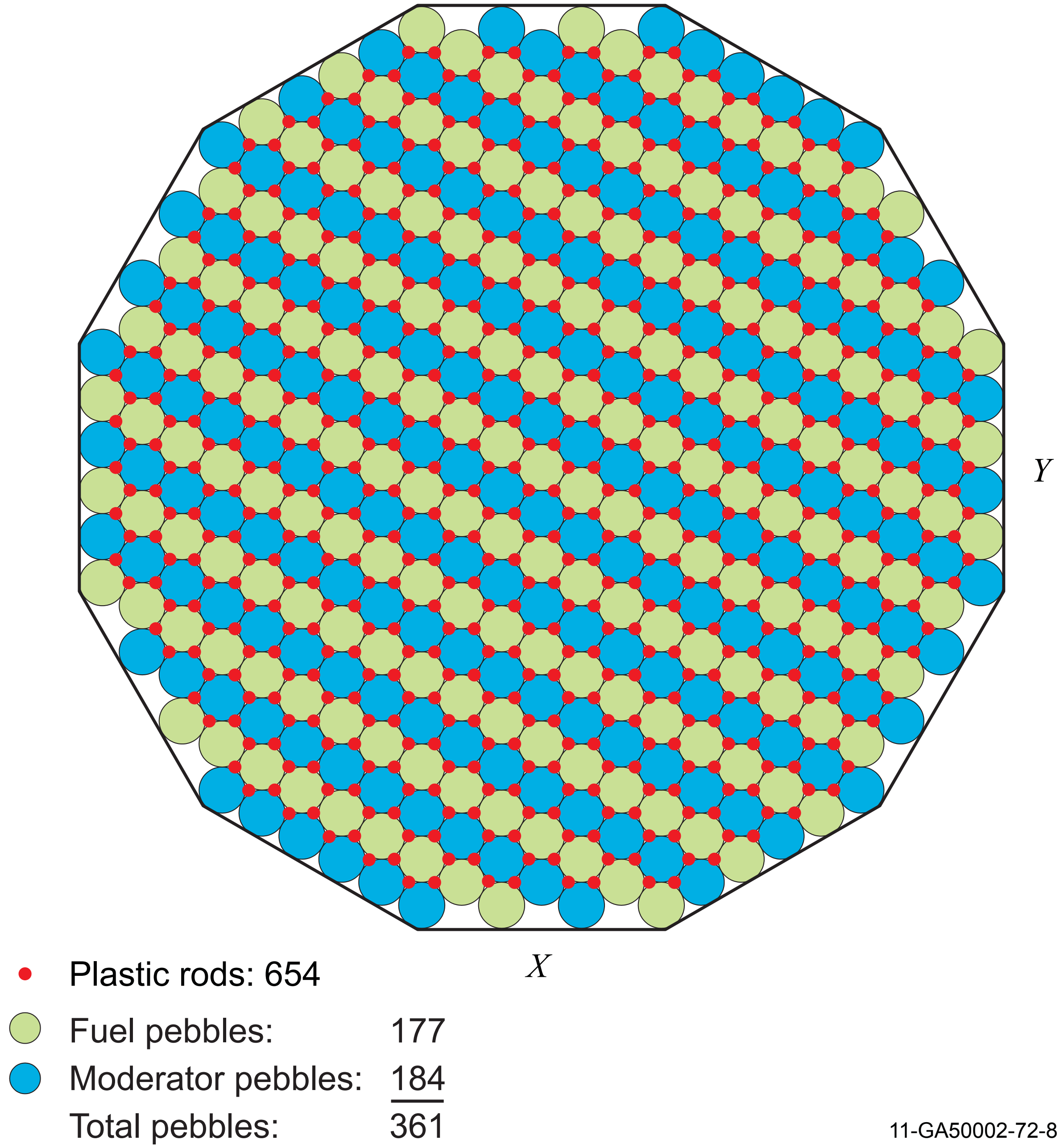

Figure 1.1-30. Layers 5, 11, 17, and 23 of Core 10 (Ref. 1).

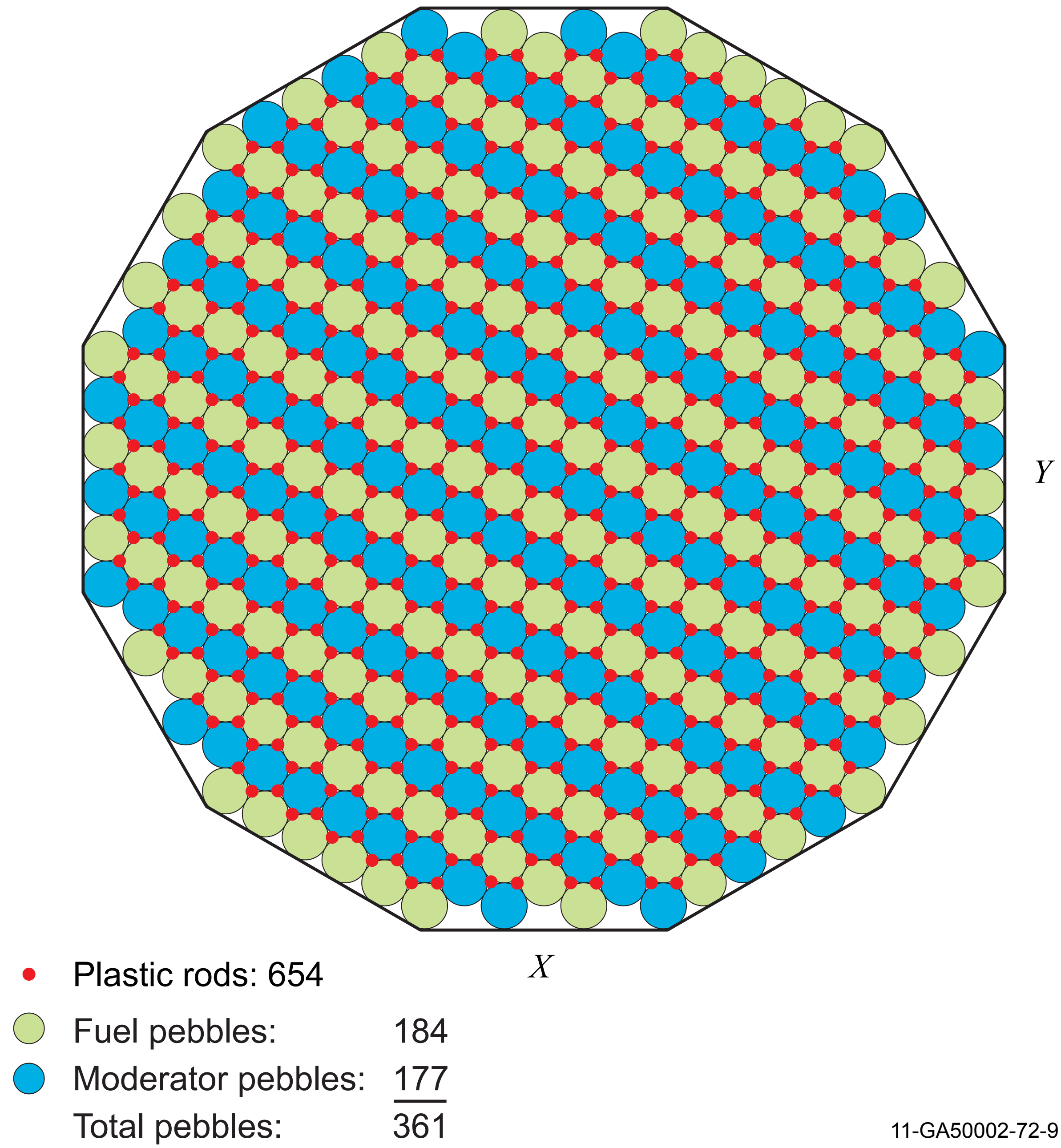

Figure 1.1-31. Layers 6, 12, 18, and 24 of Core 10 (Ref. 1).

1.1.2.3 Experimental Procedure

The approach to critical for each configuration was accompanied by the usual "inverse counts versus core loading" plot with an extrapolation to 1/counts = 0 being made after each pebble loading step to give the predicted critical loading. After the first two loading steps, which were administratively limited to 1/3 and 1/6 of the number of pebbles predicted for the critical loading respectively, the remaining steps were limited to one half of the predicted additional number of pebbles required to achieve criticality, or the worth of the control rod bank, whichever was the larger value. The count rates were measured using neutron detectors situated in the radial reflector. Because the loading of a pebble bed involves a continuous core height and thus core-detector geometry change, it was expected that the approach curves would show considerable spatial dependence. For this reason, early loadings were monitored with additional detectors. The approach curves showed considerable non-linearity for detectors close to the core, with a noticeable effect as the core upper surface reached the axial position of the detector. For this reason, all subsequent approaches were performed with detectors situated further out in the radial reflector (Ref. 3).

Criticality is established and power is raised by means of control rod movements. Criticality is maintained via the autorod, which is a single, radial-reflector-based rod driven automatically by the signal from a "deviation channel", to maintain reactor power and thus criticality. Since the deviation channel was comprised of an ionization chamber situated in the radial reflector, the signal noise, and hence accuracy of the determination of a critical configuration, was determined by the flux level in the reactor. The autorod itself was typically worth a total of less than 0.1$ and the uncertainty in its position represented much less than ±5 % of this range, even at relatively low fluxes. An uncertainty of <±0.005$ was typically regarded as negligible (Ref. 3).

1.1.3 Material Data

While there are many components of the PROTEUS that remain unchanged throughout the course of the HTR-PROTEUS experiments, many parameters did change between experiments, such as the use of graphite filler pieces, control rod types and locations, the presence of polyethylene rods to simulate water ingress, core pebble packing, and conditions at criticality. Section 1.1.3.1 provides information regarding general components common to all HTR-PROTEUS configurations. Section 1.1.3.2 provides information specific to the core configurations evaluated in this report.

The PROTEUS was a zero-power critical facility. It was operated at low power and temperatures; therefore, burnup of the fuel, activation of the graphite, and heating effects were negligible.

1.1.3.1 General HTR-PROTEUS Components

The following components are common to all HTR-PROTEUS core configurations.

Concrete

Concrete shielding material properties were not provided in the references. It is indicated elsewhere that barium concrete walls surrounded the experimental facility.[a]

Steel Plate Pedestal

The stainless steel plate pedestal material properties were not available.

[a] Difilippo, F. C., "Monte Carlo Calculations of Pebble Bed Benchmark Configurations of the PROTEUS Facility," *Nucl. Sci. Eng.*, **143**, 240-253 (2003).

Radial Reflector

The HTR-PROTEUS reflectors consist of graphite of various ages from several different sources. The older graphite is mainly of type “Reactor Grade A” and made by British Achesons Electrodes Ltd., of Sheffield, England, in about 1968. Some less important sections, away from the core region, were made from a similar grade material from stock material at the facility. The new graphite was manufactured in Chedde, France, by the Sociéte des Electrodes et Réfractaires Savoie in several batches over the period 1991 to 1993. The location, densities, and nominal, “as delivered”, impurity contents for the graphite are summarized in Table 1.1-6 (Ref. 2).

No attempt was made to describe the impurity content of individual reflector components. A recommended global value was measured and reported, an equivalent boron content of 4.09 ± 0.05 mbarn, which includes absorbed moisture and intergranular nitrogen from air (Ref. 3).[a]

Pulsed neutron measurements were performed in the empty PROTEUS graphite reflectors (lower axial and radial) to determine the effective impurity content. The corrected measurements provide a nominal ^{10}B absorption cross section in the cavity of 2.69 ± 0.16 mbarn, which is equivalent to a concentration of 0.2696 and 0.2591 ppm for the radial and axial graphite reflectors, respectively.[b]

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[a] Williams, T., Mathews, D., and Yamane, T., “Measurement of the Absorption Properties of the HTR-PROTEUS Reflector Graphite by Means of a Pulsed-Neutron Technique,” TM-41-93-34, Paul Scherrer Institut, Villigen, October 3, 1995.
[b] Difilippo, F. C., “Applications of Monte Carlo Simulations of Thermalization Processes to the Nondestructive Assay of Graphite,” *Nucl. Sci. Eng.*, **133**, 163-177 (1999).

Table 1.1-6. Summary of Reactor Graphite in HTR-PROTEUS (Ref. 2 and 3).

Graphite Type	Occurrence	Density (g/cm^3)	Nominal σ_a (mbarn/atom)[(a)]
Old graphite remaining from previous experiments (~1968)	Majority of system	1.76 ± 0.01[(b)]	3.785 ± 0.3[(b)]
New graphite for HTR PROTEUS – Batch 1 (~1991) PSI Order Numbers 34618, 37129	1. Central part bottom axial reflector 2. Central part top axial reflector 3. Filler rods for ≈ 50 % “C-Driver” channels (inner channels) 4. Top 12 cm of radial reflector 5. Filler pieces to adjust cavity shape for required geometry	1.75 ± 0.007[(c)]	3.77 ± 0.09[(c)]
New graphite for HTR PROTEUS – Batch 2 (~1993) PSI Order Numbers 40442, 40901	1. Filler rods for ≈ 50 % “C-Driver” channels (outer channels) 2. Filler pieces for old ZEBRA rod channels 3. Alternative central part of bottom reflector with longitudinal channel to allow axial traverses	1.78[(d)]	4.08[(d)]
Moderator pebbles	Core	1.68 ± 0.03[(e)]	4.79[(e)]
Fuel pebbles	Core	1.73[(e)]	0.3829[(e)] ppm B

(a) σ_a is the neutron absorption cross section of the graphite.
(b) Reactor-based measurements reported in N.R.E. PROTEUS Construction Manual Section A.
(c) Reactor-based measurements SERS Test Certificates January 25, 1991, and October 10, 1991.
(d) Reactor-based measurements SERS Test Certificates January 7, 1993.
(e) Chemical analyses HOBEG GmbH Test Certificates for fuel and moderator pebbles.

The apparent density of seven samples from each of the four separate graphitizing heats (batches) of the Achesons graphite were measured (twenty-eight samples altogether). An average density of 1.763 ± 0.012 g/cm^3 was obtained (1σ standard deviation based on the twenty-eight reported results). Quality control documentation for the new graphite claimed densities between 1.75 and 1.78 g/cm^3, consistent with the older graphite value. The old graphite comprises the majority of the reflector system (Ref. 2).

Four samples of reflector graphite were heated to 500 ºC under vacuum for five hours at PSI on May 14, 1993. The results are shown in Table 1.1-7. Sample number three was from new graphite manufactured in 1990;[a] the other three samples were from the older 1968 graphite. The average weight loss of the older samples was 0.0241 wt.%, compared to a loss of 0.0156 wt.% for the newer graphite. The weight loss was assumed to be primarily due to the removal of absorbed moisture (Ref. 2).

[a] It is unclear how a piece of new graphite manufactured in 1990 was used in this analysis when the new graphite was delivered in batches over the course of 1991 to 1993.

Table 1.1-7. Reflector Graphite Weight Loss During Heating in a Vacuum (Ref. 2).

Sample Number (Graphite Type)	Diameter (cm)	Length (cm)	Original Mass (g)	Mass Loss (g)	Mass Loss (wt.%)
1 (old)	4.4	6.0	150.742385	0.02033	0.0135
2 (old)	4.0	4.1	85.523130	0.02866	0.0335
3 (new)	2.65	6.0	57.980115	0.009055	0.0156
4 (old)	2.5	6.0	46.172465	0.01161	0.0251

The safety ring was comprised of Peraluman-300 (Table 1.1-8) and had a total mass of 10.42 kg (Ref. 2).

Table 1.1-8. Peraluman-300 (Ref. 2).

Element	Composition (wt.%)
B	<0.001
Mg	<3.1
Al	95.55
Si	0.4
Mn	<0.5
Fe	0.3
Cu	0.05
Zn	0.1
Ga	<0.01
Cd	<0.001

Upper Axial Reflector

The total mass of the graphite contained in the upper axial reflector was 1585.64 kg (Ref. 2).

The location of old and new graphite in the upper axial reflector is shown in Table 1.1-6.

The aluminum housing consisted of Peraluman-300, shown in Table 1.1-8. The total mass of Peraluman contained in this structure, below the upper surface of the graphite, was 71.48 kg (Ref. 2).

Lower Axial Reflector

The total mass of the graphite contained in the lower axial reflector was not reported.

The location of old and new graphite in the lower axial reflector is shown in Table 1.1-6.

Graphite Plugs

New graphite was used for the graphite plugs placed into holes in the reflectors (Table 1.1-6).

Safety/Shutdown Rods

The borated steel rod sections contain nominally 5 wt.% boron and are enclosed in 18/8 stainless steel tubes. The borated steel used in the HTR-PROTEUS experiments was similar to those used in previous PROTEUS experiments but was manufactured in 1991 by Böhler AG, Edelstahlwerke, Düsseldorf, Germany for the HTR-PROTEUS experiments. The steel was chemically analyzed by the manufacturer and by PSI. The Böhler measurements, performed on June 14, 1991, indicated a boron content of 4.95 %; the PSI measurements, performed on January, 8, 1992, indicated a boron content of 4.70 %. Böhler indicated that their chemical analyses were performed prior to the final casting and machining steps and that some boron could have been lost during these steps. It was not originally reported whether these measurements were performed in at.% or wt.%; the measurements were believed to be in wt.% (Ref. 2).[a]

The borated steel density, 6.878 g/cc, was measured at PSI on December 15, 1993, and has the composition shown in Table 1.1-9. The 18/8 stainless steel cladding material (Table 1.1-10) had specified elemental compositions and density, 7.92 g/cc (Ref. 2).

The aluminum parts of the shock damper were pure aluminum alloy with a measured mass of 633.65 g (Ref. 2).

Table 1.1-9. Borated Steel (Ref. 2).[(a)]

Element	Composition (wt.%)
^{10}B	0.94
^{11}B	3.76
Si	1.02
Cr	40.4
Mn	1.30
Fe	41.8
Ni	9.83
Total	99.05

a. Measurement performed on January 8, 1992, by R. Keil of PSI.

Table 1.1-10. 18/8 Stainless Steel (Ref. 2).

Element	Composition (wt.%)
Cr	18
Fe	74
Ni	8

Automatic Control Rod (Autorod)

The autorod is comprised of a copper plate within an aluminum tube. Detailed material properties were not available in the reference reports.

Static Measurement Rods

The static measurement rods were comprised of a Peraluman R-257 tube containing borated steel pieces. The Peraluman R-257 density was 2.65 g/cm^3 with the specified composition shown in Table 1.1-11. Peraluman R-257 has lower neutron absorption than Peraluman-300 due to the reduced manganese content. The borated steel had a nominal boron content of 5 wt.%. Some borated steel sections were analyzed separately at PSI on January 8, 1992 (see Table 1.1-9). The borated steel density was measured on December 17, 1993, using three as-built pieces; the density was 7.199 ± 0.029 g/cc. The long pair of

[a] A boron content of ~5 wt.% is equal to ~20 at.%; therefore, the assumption that the original measurements were reported in wt.% is correct.

rods also contained a graphite filler piece. The short pair of rods was placed within a graphite sleeve, which had a mass of 6.80 kg (Ref. 2).

Table 1.1-11. Peraluman R-257 (Ref. 2).

Element	Composition (wt.%)
B	<0.001
Mg	<2.8
Al	96.658
Si	0.2
Mn	<0.01
Fe	0.2
Cu	0.02
Zn	0.1
Ga	<0.01
Cd	<0.001

Fuel Pebbles

Fuel masses are shown in Table 1.1-1.

Impurities in the UO_2 used in the TRISO fuel particles are provided in Table 1.1-12. The specified values are averages taken from the fuel pebble quality control records. Impurity estimates for five elements contributing less than 1 % of the total boron equivalent were not given (Ref. 2).

The graphite impurities in the assembled fuel pebbles are provided in Table 1.1-13. The specified values are averages taken from the fuel pebble quality control records. Impurity estimates for five elements contributing less than 1 % of the total boron equivalent were not given (Ref. 2).

Table 1.1-12. UO_2 Impurities (Ref. 2).

Element	Concentration (ppm by wt.)
Ag	<0.2
B	0.085
Ca	51
Cd	<0.2
Cl	<3
Co	<1
Cr	23
Dy	<0.02
Eu	<0.02
Fe	28
Gd	<0.02
Li	<1
Mn	7.5
Mo	<3
Ni	2.5
S	<0.04
Ti	<10
V	<10

Table 1.1-13. Fuel Pebble Graphite Impurities (Ref. 2).

Element	Concentration (ppm by wt.)
Ag	<0.2
B	0.101
Ca	9.28
Cd	<0.103
Cl	<3
Co	<0.13
Cr	1.81
Dy	<0.01
Eu	<0.01
Fe	2.95
Gd	<0.01
Li	<1
Mn	0.43
Ni	<1
S	<0.011
Ti	0.497
V	<0.433

Moderator Pebbles

Moderator pebble impurities are given in Table 1.1-14, and were obtained from the moderator pebble quality control records. Uncertainties for the moderator pebble impurities were not available, and values for fourteen elements contributing less than 0.1 % to the total boron equivalent were not given. The table does not include values for absorbed moisture in the pebbles. The quantity of moisture contained in the pebbles was measured at PSI by randomly selecting two moderator pebbles and heating them to 500 ºC under vacuum for five hours. Each pebble showed a weight loss of 0.02 g, 0.01 wt.% (Ref. 2).

Table 1.1-14. Moderator Pebble Impurities (Ref. 2).

Element	Concentration (ppm by wt.)
B	0.76
Ca	129
Cd	<0.6
Cl	18.64
Dy	0.065
Eu	0.13
Fe	5.9
Gd	0.040
Li	0.88
Ni	0.78
S	140
Si	35
Sm	0.086
Ti	10
V	13

Start-Up Source

The material properties of the start-up source were not available in the reference reports.

Detectors

The material properties of the detectors (six ionization chambers and two fission chambers) were not available in the reference reports.

Temperature Sensors

The material properties of the temperature sensors were not available in the reference reports.

1.1.3.2 Components Unique to Cores 9 and 10

The following components are unique to core configurations 9 and 10.

Graphite Fillers

The total mass of the twelve filler pieces used to convert the 22-sided cavity into a 12-sided one was 211.2 kg (Ref. 2).

ZEBRA Control Rods

The ZEBRA control rods were not used in the experiments with Cores 9 and 10.

Withdrawable Stainless Steel Control Rods

The inner tube of the withdrawable stainless steel control rods was St1.4301 (Table 1.1-15) and the outer tube was St1.4541 (Table 1.1-16). Both steels had a density of 7.9 g/cm^3 (Ref. 2).

Table 1.1-15. St1.4301 (Ref. 2).

Element	Composition (wt.%)
C	≤0.07
Si	≤1.0
Mn	≤2.0
Cr	17.0-20.0
Ni	9.0-11.5

Table 1.1-16. St1.4541 (Ref. 2).

Element	Composition (wt.%)
C	≤0.10
Si	≤1.0
Mn	≤2.0
Cr	17.0-19.0
Ni	9.0-11.5
Ti	≥x %C

Polyethylene Rods

Great care was taken during the manufacture of the plastic to avoid contamination with foreign isotopes. Samples of the polyethylene were sent for an elemental analysis to three independent organic chemistry laboratories; unfortunately, the results from one laboratory were inconsistent with the others, leading to additional uncertainty in the CH_2 stoichiometry. The recommended value is $CH_{2.03\pm0.03}$, which is consistent with the elemental analyses and experimental comparisons between CH_2 and H_2O worths in Cores 5, 7, and 9. The linear densities of the polyethylene rods are shown in Figure 1.1-18 (Ref. 2).

Copper Wire

Copper wire was not used in the experiments with Cores 9 and 10.

Ambient Air

Ambient (hall) temperatures, air pressure, and humidity for HTR-PROTEUS critical experiments, Cores 9 and 10, are provided in the following tables:

- Core 9 (reference state #1): Table 1.1-3
- Core 9 (reference state #2): Table 1.1-4
- Core 10 (reference state #1): Table 1.1-5

1.1.4 Temperature Data

Room (hall) temperatures for HTR-PROTEUS critical experiments, Cores 9 and 10, are provided in the following tables (core and reflector temperatures were not measured):

- Core 9 (reference state #1): Table 1.1-3
- Core 9 (reference state #2): Table 1.1-4
- Core 10 (reference state #1): Table 1.1-5

The reactor was operated at room temperature with the power limited to 1 kW so that no active cooling systems were required.[a]

1.1.5 Additional Information Relevant to Critical and Subcritical Measurements

An estimate of excess reactivity, in units of dollars, was provided for each of the core configurations. The value of β_{eff} is provided for each case. The excess reactivity was provided in terms of individual component worths such that users could pick and choose which simplifications to incorporate into their models. Where possible, the component worths had been measured directly in the relevant configurations (indicated by **M** in the tables) but in many cases the values had to be calculated (**C**), estimated (**E**), or scaled from another configuration (**S**). Most reference component worth measurements were performed in Cores 1 and 5 (Ref. 1). These measurements represent deviations of the real-life assembly from an ideal, clean core configuration. The effects of these deviations are quantified; an example of how these measurements were performed was provided elsewhere for Core 1.[b] Reactivity corrections for Cores 9 and 10, provided in the original references, are summarized in the following tables:

- Core 9 (reference state #1): Table 1.1-17
- Core 9 (reference state #2): Table 1.1-18
- Core 10 (reference state #1): Table 1.1-19

The worth of various core components was provided to allow for the development of simplified models for calculation of the HTR-PROTEUS experiments. The measured worths of the individual components are normally evaluated against the worths of the ZEBRA/control rods, which were carefully calibrated using the stable period technique, or against the autorod worth, which had been subsequently inter-calibrated with the ZEBRA/control rods (Ref. 3).

A small degree of inhomogeneity in the radial graphite reflector was inevitable. Axial holes were required for control and shutdown rod insertion and radial and axial holes for nuclear instrumentation. The C-Driver holes in the inner radial reflector, left over from the previous experiments, had to be filled with graphite rods. These rods were relatively easy to remove and useful in estimating the effect of missing graphite. Correction for the air gaps between the 27.5 mm ID C-Driver channels and the

[a] Köberl, O., Seiler, R., and Chawla, R., "Experimental Determination of the Ratio of 238U Capture to 235U Fission in LEU-HTR Pebble-Bed Configurations," *Nucl. Sci. Eng.*, **146**, 1-12 (2004).
[b] Williams, T., "HTR PROTEUS CORE 1: Reactivity Corrections for the Critical Balance," TM-41-93-20, Paul Scherrer Institut, Villigen, October 7, 1993.

26.5 mm OD graphite filler rods were calculated by V. D. Davidenko of the Kurchatov Institute using the Cristall code system (Ref. 3).

No explicit measurements were performed to determine the worth of the four empty ZEBRA/control rod channels. The values reported in the tables were made on the basis of the results of the C-Driver hole measurements. For safety reasons, the worth of the eight safety and shutdown rod channels cannot be measured and their values were calculated at PSI using the TWODANT code. It was considered reasonable to include them in the calculational model, removing them from the reactivity excess list (Ref. 3).

The upper and lower axial reflectors were furnished with 33 “ventilation holes” to enable air-cooling of the core. The axial thermal flux peak is strongly shifted downwards and graphite density variations in the upper part of the lower axial reflector were of greater significance than those above. Unfortunately, for practical reasons, it was difficult to measure the effect in the lower reflector and satisfactory measurements could only be made in the upper axial reflector. In the upper reflector, measurements were performed with 11 of the 33 holes plugged with graphite. Because full access to the ventilation holes in the lower axial reflector is impeded from below, it was not possible to measure their worth in the usual manner. At best, it was possible to partially fill some of the channels with graphite and linearly scale the effect to 33 filled channels. In some of the core configurations all of the coolant channels in the lower axial reflector were filled with graphite plugs (Ref. 3).

In all the deterministic cores, ~12 pebbles were directly over one of the 33 cooling channels in the lower axial reflector. To avoid pebble displacement in these cases, special aluminum plugs were developed to support the pebbles in Core 1. In later cores, simple graphite rods were used (Ref. 3).

The reactor start-up sources were normally in their “in” position during reactor operation. At low fluxes their reactivity effect is positive by virtue of the apparent enhanced neutron multiplication; at normal operating fluxes of $>10^7$ n/cm^2/s, their effect was negative due to parasitic neutron absorption in the source and casing. The start-up sources pass through horizontal aluminum guide tubes situated in the radial reflector at about the level of the cavity floor. The worth of these penetrations were also measured (Ref. 3).

The pulsed neutron source, when used for subcriticality measurements, was partially inserted into the lower axial reflector. Its reactivity worth was measured by replacing it with a plug of graphite of dimensions 250 mm × 120 mm Ø (Ref. 3).

The worth of one of the six ionization chambers compared with a graphite plug was measured by opening a plugged channel and inserting a spare ionization chamber. The worth of one of the two impulse channels in the outer radial reflector was also measured by means of filling a similar channel first with a replacement detector and then with a graphite plug (Ref. 3).

The temperature sensors were systematically removed from the system in order to assess their reactivity worths (Ref. 3).

The value of β_{eff} was calculated for each of the cores (Ref. 3).

Table 1.1-17. Core 9 (Reference State #1) Reactivity Corrections (Ref. 1 and 3).

Reactivity Corrections to Critical Loading	No.		Total ¢			Comments
Control Rod Insertion (0 mm)[(a)]	4	M	0			No Control Rod Insertion
Control Rod Channels[(b)]	4	S	-2.5	±	0.3	Scaled from Core 5
Autorod Rest Worth[(b)]	1	S	-12.5	±	0.5	Scaled from Core 5
Autorod Insertion (258 mm)[(b)]	1	S	-7.5	±	0.5	Scaled from Core 5
Autorod Channel[(b)]	1	S	-0.7	±	0.3	Scaled from Core 5
Safety and Shutdown Rod Channels[(b)]	8	S	-32	±	8	Scaled from Core 5
Empty Channels R2[(b,c)]	3	S	-5	±	1	Scaled from Core 5
Air Gaps in C-Driver Holes[(b,d)]	320	S	-10.5			Scaled from Core 5
Channels in Upper Reflector[(e)]	34					No Estimate
Channels in Lower Reflector	0					Channels Filled
Start-up Sources[(b)]	2	M	-4	±	1	
Start-up Source Penetrations[(b)]	2	S	-1	±	0.2	Core 5 Value
Nuclear Instrumentation (Ionization)[(b)]	6	S	-9.0	±	1.5	Scaled from Core 5
Nuclear Instrumentation (Fission)[(b)]	2	S	-1.0	±	0.7	Scaled from Core 5
Total Correction			86	±	9	
Corrected k_{eff} (β_{eff} = 0.00720)			1.0062	±	0.0007	

(a) The control rods were fully withdrawn for this critical balance. The control rods were however calibrated in Core 9 reference state #2 and found to have a total worth of 152 ± 2 cents. This value is significantly larger than the Core 5 value, not due to the increased core moderation in Core 9, which would tend to reduce rod worths, but rather from the increased core height and corresponding active length of the rods.

(b) Only a few individual component worths were measured in Core 9. Therefore, in order to obtain an estimate of the reactivity excess, the component worths measured in Core 5 were scaled by the ratio of the control rod bank worths in the two cores, namely Core 9/Core 5 = 152¢/134¢ = 1.14. The same comment applies also to the autorod, which was measured in Core 5 to have a max-min worth of -8.9 cents and scaled in Core 9 to a value of 10.1 cents.

(c) R2 and R3 indicate the second and third rings, respectively, of the C-Driver channels.

(d) Corrects for the air gaps between the 27.5 mm ID C-Driver channels and the 26.5 mm OD graphite filler rods. The value here was calculated by V. D. Davidenko of the Kurchatov Institute using the Cristall code system.

(e) No measurement was made of this effect and no justifiable basis could be found for its estimate. The channels in the upper reflector must therefore be included in any Core 9 model.

Table 1.1-18. Core 9 (Reference State #2) Reactivity Corrections (Ref. 1 and 3).

Reactivity Corrections to Critical Loading	**No.**		**Total ¢**			**Comments**
Control Rod Insertion (1620 mm)[a]	4	M	-70.4	±	1.0	Calibrated via Stable Period
Control Rod Channels[b]	4	S	-2.5	±	0.3	Scaled from Core 5
Autorod Rest Worth	1	S	-12.5	±	0.5	Scaled from Core 5
Autorod Insertion (25 mm)[c]	1	S	-10.0	±	0.5	Scaled from Core 5
Autorod Channel	1	S	-0.7	±	0.3	Scaled from Core 5
Safety and Shutdown Rod Channels[d]	8	S	-32	±	8	Scaled from Core 5
Empty Channels R2[e]	3	S	-5	±	1	Scaled from Core 5
Air Gaps in C-Driver Holes[f]	320	S	-10.5			Scaled from Core 5
Channels in Upper Reflector	34					No Estimate
Channels in Lower Reflector	0					Channels Filled
Start-up Sources	2	M	-4	±	1	
Start-up Source Penetrations	2	S	-1	±	0.2	Core 5 Value
Nuclear Instrumentation (Ionization)	6	S	-9.0	±	1.5	Scaled from Core 5
Nuclear Instrumentation (Fission)	2	S	-1.0	±	0.7	Scaled from Core 5
Total Correction			159	±	10	
Corrected k_{eff} (β_{eff} = 0.00720)			1.01142[g]	±	0.0007	

(a) The control rods are fully inserted when 2500 mm is indicated. Control rod bank calibrations in this configuration were found to be 152 ± 2 cents.

(b) The worth of the new control rod channels was assumed to be the same as that of the ZEBRA rod channels in Core 1. Although the ZEBRA rod channels are somewhat larger than the new control rod channels, it is considered that the small size of the correction and its associated uncertainty justifies this approximation. The uncertainty was slightly increased.

(c) Calibrated in Core 5 and scaled by 1.14 for Core 9 (see footnote b in Table 1.1-17).

(d) For safety reasons the worth of these eight channels cannot be measured and the values were calculated at PSI using the TWODANT code. Independent calculations by V. D. Davidenko of the Kurchatov Institute yielded a value of 16.6 cents for this core.

(e) R2 indicates the second ring of the C-Driver channels.

(f) Corrects for the air gaps between the 27.5 mm ID C-Driver channels and the 26.5 mm OD graphite filler rods. The value here was calculated by V. D. Davidenko of the Kurchatov Institute using the Cristall code system.

(g) This value had been originally reported as 1.0142, which did not agree with a total correction of 158.6 ¢, the sum of the individual reactivity corrections, converted to Δk_{eff} with the reported β_{eff} of 0.00720. It was later corrected in Köberl, O., Seiler, R., "Detailed Analysis of Pebble-Bed HTR PROTEUS Experiments with the Monte Carlo Code TRIPOLI4, *2nd Intern. Topical Meeting on High Tempertaure Reactor Technology*, Beijing, China, September 22-24 (2004).

Table 1.1-19. Core 10 (Reference State #1) Reactivity Corrections (Ref. 1 and 3).

Reactivity Corrections to Critical Loading	**No.**		**Total ¢**			**Comments**
Control Rod Insertion (1540 mm)[a]	4	M	-36.8	±	1	Measured Core 10
Control Rod Channels[b]	4	S	-2.0	±	0.2	Core 1A Value
Autorod Rest Worth[b]	1	S	-7.7	±	0.5	Core 1A Value
Autorod Insertion (15 mm)	1	M	-7	±	0.4	Measured Core 10
Autorod Channel[b]	1	S	-0.5	±	0.3	Core 1A Value
Safety and Shutdown Rod Channels[b,c]	8	C,S	-24	±	6	Core 1A Value
Empty Channels R2[d]	3	S	-4	±	1	Scaled from Core 1A
Air Gaps in C-Driver Holes[b,e]	320	C,S	-8.3			Core 1A Value
Channels in Upper Reflector[b]	34	S	-3.6	±	2.0	Core 1A Value
Channels in Lower Reflector	0					
Start-up Source Penetrations[b]	2	S	-1	±	0.2	Core 1A Value
Nuclear Instrumentation (Ionization)[b]	6	S	-8.4	±	1.2	[f]
Nuclear Instrumentation (Fission)[b]	2	S	-0.8	±	0.6	Core 1A Value
Total Correction			104	±	7	
Corrected k_{eff} (β_{eff} = 0.00720)			1.0075	±	0.0001	

(a) The control rods are fully inserted when 2500 mm is indicated. The control rod bank was calibrated via a stable period technique and found to be 109.6 cents.
(b) Since the core height and control bank worths in Core 10 are similar to those in Core 1A, it was considered to be justified to use some of the component worths measured in Core 1A directly in Core 10 with a small arbitrary increase in the uncertainties.
(c) For safety reasons the worth of these eight channels cannot be measured and the values were calculated at PSI using the TWODANT code. Independent calculations by V. D. Davidenko of the Kurchatov Institute yielded a value of 16.6 cents for this core.
(d) R2 indicates the second ring of the C-Driver channels.
(e) Corrects for the air gaps between the 27.5 mm ID C-Driver channels and the 26.5 mm OD graphite filler rods. The value here was calculated by V. D. Davidenko of the Kurchatov Institute using the Cristall code system.
(f) No information was provided in either reference for the source of this bias; it is most likely derived from the Core 1A value, as discussed in footnote (b).

1.2 Description of Buckling and Extrapolation Length Measurements

Buckling and extrapolation length measurements were performed but have not yet been evaluated.

1.3 Description of Spectral Characteristics Measurements

Spectral characteristics measurements were performed but have not yet been evaluated.

1.4 Description of Reactivity Effects Measurements

1.4.1 Overview of Experiment

Only Cores 9 and 10 are evaluated in this benchmark report due to similarities in their construction. The other core configurations of the HTR-PROTEUS program are evaluated in their respective reports as outlined in Section 1.0. An overview of the general timeline for each core configuration and the associated test matrix can be found in Appendix D.

Experimental data in this section include rod worth measurements performed for the safety/shutdown rods, withdrawable control rods, and the autorod. Additional measurements for the worth of graphite-plugged holes in the reflectors were also evaluated. Measured worth corrections for the start-up source, with associated graphite penetrations, and nuclear instrumentation were not evaluated because insufficient data were available to model them.

Sixteen reactivity effects measurements apiece for both Cores 9 and 10 (total of 32 measurements) were evaluated and determined to be acceptable benchmark experiments.

1.4.2 Geometry of the Experiment Configuration and Measurement Procedure

The geometry of the core configurations and individual reactor components is provided in Section 1.1.2. Changes from the nominal configurations of the critical core configurations and a description of the measurement procedures are provided below.

1.4.2.1 Reactivity Measurements in the HTR-PROTEUS

An important aspect of the HTR-PROTEUS experimental program was to maintain the accurate measurement of the reactivity worth of absorber rods in the core and reflector across various configurations with a range of moderation properties. Requirements included utilization of a method that would: be compatible with small, highly reflected thermal systems; be applicable to highly subcritical cores; have limited dependence upon calculations; have complimentary techniques to other methods with characterizable uncertainties; and be economically feasible. The methods ultimately selected for the HTR-PROTEUS experiments were the pulsed neutron source (PNS) and inverse kinetics (IK) techniques (Ref. 3).

The accurate, unambiguous measurement of reactivity values in graphite-moderated, highly-reflected systems such as the HTR-PROTEUS is a difficult task. Relatively long characteristic timescales render most methods (e.g., PNS, noise, and source jerk) problematic due to the inherent difficulty in separating prompt and delayed decay modes. The long diffusion lengths transport local effects far into the system, challenging the limits of the point reactor approximation techniques (i.e. IK, SP, etc.). The distinct two-zone nature of the system leads to additional complications associated with spectral effects (kinetic distortion) that require intuitive detector placement, correction factors, or both (Ref. 6).

A more thorough discussion of the theory and methods for these techniques can be found in Section 6 of Reference 3, Chapter 2 of Reference 4, as well as various technical reports from PSI.[a,b]

[a] Rosselet, M., “Reactivity Measurement on HTR-PROTEUS Core 5 with the PNS Technique and Preliminary Investigations for the Use of an Epithermal Neutron Detector,” TM-41-94-23, Paul Sherrer Institut, Villigen, November 21, 1994.
[b] Rosselet, M., “PNS Measurements using Epithermal Neutron Detectors in HTR-PROTEUS Core 7,” TM-41-95-17, Paul Sherrer Institut , Villigen, October 16, 1995.

For each measurement of a particular subcritical state, the following procedure was implemented:

1. The detection system was switched on and allowed to stabilize.
2. A critical balance was established with the PNS and neutron detectors in place, and the reactor start-up sources withdrawn (to avoid unnecessary background interference).
3. The autorod (and control rod) positions are frozen.
4. The subcritical state of interest is established, this may involve the insertion of the shutdown rods, the removal of the upper reflector, the insertion of a dummy control rod, etc.
5. The PNS is switched on and the multichannel-analyzer system channel width, pulse-rate, and number of channels (invariably 512) adjusted as required. The system is pulsed for ~15 minutes, without measuring, to allow an equilibrium state of the delayed neutron background to develop.
6. When a stable equilibrium has been achieved, the multichannel-analyzer system is triggered and data is accumulated until satisfactory statistics are obtained.
7. The accumulation is stopped, the PNS is switched off, the total number of measured pulses and the total measurement time are recorded.
8. After a suitable delay, to allow the flux to stabilize, the measurement is repeated, without pulsing, to establish the background contribution to the measurement.
9. The stored raw data is then processed to calculate the desired reactivity worth measurement (Ref. 3)

Uncertainties in PNS measurements normally comprise statistical uncertainties in the measured data and systematic uncertainties associated with the data utilized to convert the measured parameter to reactivity. Statistical uncertainties are reduced by increasing the count rates and measuring times of individual measurements or repeating measurements. The first method is limited by the properties of the counting system such as the dead time and detector efficiency. The second method is effective, but more costly in time and effort. The experimenters recommended that to reduce the uncertainty associated with use of a particular set of delayed neutron data would require the use of a better data set. A summary of typical uncertainties in three PNS techniques over a range of reactivities is shown in Table 1.4-1. There are large uncertainties for measurements with an absolute value of reactivity less than 1$; for the inhour technique this is due to the prompt and delayed terms in the inhour equation being very similar leading to a small value with a large uncertainty. The other two, area ratio, methods have a large uncertainty in the correction factor. For larger measured worths, the uncertainties rapidly decrease. The generation time dominates the prompt approximation of the inhour method and the minimum uncertainty limit is 3% for the area ratio methods. The statistical uncertainties in all three methods are insignificant compared with those associated with the delayed neutron data (Ref. 3).

Table 1.4-1. Typical Uncertainties for Three PNS Techniques (Ref. 3).

Technique	**Nominal Reactivity ($)**	**-0.15**	**-1.0**	**-5.6**	**-12.0**
Inhour	Measured Reactivity ±Total Uncertainty (±Statistical Uncertainty)	-0.15 ± 68 % (±7.5 %)	-1.01 ± 11 % (±0.8 %)	-5.52 ± 6 % (±0.5 %)	-11.5 ± 5.5 % (±0.3 %)
Sjöstrand		-0.156 ± 27 %	-0.987 ± 3.6 %	-5.879 ± 3.6 %	-11.77 ± 3.0 %
Gozani		-0.163 ± 27 %	-1.01 ± 3.7 %	-5.84 ± 3.3 %	-11.59 ± 3.1 %

For negative reactivities rod-drop measurements needed a small detection dead time. In order to have good statistics a high count rate at critical before the rod drop is necessary. Two approaches were utilized:

1. Initially low dead-time detectors were unavailable and the detectors for the PNS measurements, with dead times of 1.4 ± 0.1 μsec were used. Use of a single detector gave unacceptably large uncertainties on the derived reactivities. A method was developed using two detectors, with different sensitivities, situated close together in the system (near the outer surface of the system because of their high efficiencies). The responses of these detectors were fitted over a small overlap range directly following the rod drop to give a composite response with the effect of a

time-dependent sensitivity. This approach was considered somewhat messy and time consuming but unavoidable.

2. From Core 5 onwards, a new measuring system was available that had been previously used for IK measurements on the SAPHIR reactor. It had the advantage of a very small dead time with each amplified pulse having a width of only a few nanoseconds. Count rates approached some 800,000 counts per second without significant dead time effects (Ref. 3).

All rod-drop measurements were carried out in a similar manner:

1. Establish a critical state with the reactor start-up sources withdrawn and the detectors in place. When stable, freeze all control absorbers.
2. Trigger the multichannel-analyzer system with a channel width of 0.1 seconds and at least 2048 measurement channels. Channel widths greater than 0.1 seconds were shown in simulations to lead to systematic errors in the estimated reactivity due to an inability to resolve the “drop-region”. Narrower channel widths led to very poor statistics and significant “rounding-down” effects.
3. After a nominal 20 seconds, to establish the initial critical flux level and to measure the initial reactivity (nominally 0), the required shutdown rod configuration (normally 1, 2, 3 or 4 rods, occasionally 8) is dropped.
4. The same measurement is repeated to check for reproducibility and to reduce uncertainties.
5. The same configuration is measured with the detectors in a different position in the system, to provide measurements of the same parameter with different spatial correction factors.
6. The stored raw data are then processed to calculate the desired reactivity worth measurement (Ref. 3).

For small positive reactivities, such as differential calibration of control-rods in HTR-PROTEUS, the stable period (SP) technique was exclusively used. The experimental setup for the SP measurements was very similar to that used for the PNS measurements. The experimental procedure was as follows:

1. Establish a critical state with the required detectors in place. When stable, freeze all control absorbers.
2. Trigger the multichannel-analyzer system, which has been configured with a channel width of 1 second and 4096 measurement channels.
3. After a nominal 20 seconds (to establish a start reactivity, nominally = 0.0, but cannot be judged exactly due to drift, statistical fluctuations of the autorod position, etc.) the control rods are driven out the required amount (corresponding to a few cents, maximum 10 cents).
4. The measurement is ceased when the count-rate becomes too high (dead-time consideration).
5. The stored raw data are then processed to calculate the desired reactivity worth measurement (Ref. 3).

The uncertainty in the reactivity obtained via SP measurements arises from the statistical uncertainties in the measured data and systematic uncertainties associated with the data used in the inhour equation used to derive reactivity. The statistical uncertainties can be reduced by increasing count rates and measuring times in individual measurements or by repeating measurements. The former method is limited by the properties particular to the counting system, namely dead-time and detector efficiency, and the latter method, although effective, is expensive in time and effort. Reductions in the uncertainties associated with the use of delayed neutron data can only be achieved by using a better data set. A sample measurement of the worth of Control Rod 4 in Core 5 inserted from 2500 to 2100 mm demonstrated an uncertainty of 3.7 % in the measured worth. The statistical uncertainty was 0.17 % of the measured worth, or ~5 % of the total uncertainty. Further evaluation of the uncertainties indicated that the contribution of the prompt term of the reactivity calculation was only ~2 % while the largest contributor to this uncertainty (> 50 % for the second delayed group) had relatively low uncertainties and thus did not contribute more significantly to the total uncertainty in the reactivity measurement (Ref. 3).

For the reactivity measurements reported in Ref. 3, the uncertainties are associated mainly with the statistical uncertainties inherent in the measurement itself. Uncertainties were not applied to the calculated delayed neutron parameters. In general, the delayed neutron data were based upon the JEF-1.1

evaluation. While the slight energy dependence of the total yield was ignored, the energy dependence of the delayed neutron spectra was not. It was demonstrated that the delayed neutron data available in ENDF/B-VI and JEF-2.2 were not acceptable for predicting the behavior of control rods in the HTR-PROTEUS experiments.[a]

1.4.2.2 Control Rod Worth Measurements

Individual integral control rod worth measurements were reported for the four withdrawable stainless steel control rods described in Section 1.1.2.2.

The reactivity worth of the withdrawable control rods was measured using IK techniques. Two experimental approaches were tested in HTR-PROTEUS:

1. The reactor was in a critical state with the rod of interest completely inserted. Then, the rod was completely withdrawn in a few (typically three or four) steps. After each step, the reactor was made critical with the other rods. The positive reactivity of each step was determined with the IK equation and the stable reactor period technique.
2. The reactor was in a critical state with the rod of interest completely withdrawn. Then the rod was driven in completely, which takes 156 s. The reactivity was determined via the inverse kinetics equation.

With the first approach, only the integral worth was obtained, whereas with the second approach, both the integral and the differential rod worth could be obtained. While only the first approach was used in Core 5 and both approaches in Core 7, only the second approach was utilized in Cores 9 and 10 (Ref. 3).

The results of the SP and IK techniques for the positive reactivity steps were seen to agree within 0.7 %. The comparison to the results of the second approach showed that they agreed within 1.7 %. All results agree within 2σ and only the average of all techniques was reported. It should be noted that there is an observable asymmetry in the worths of the control rods caused by the shadowing effect of the relatively low-worth autorod. The worth of the control rods in Positions 2 and 3 are slightly lower than those in Positions 1 and 4. Reported control rods worths for Cores 9 and 10 are in Table 1.4-2 (Ref. 3 and 4).

Table 1.4-2. The Integral Worth of the Control Rods (dollarcents). [1$ = 720 pcm] (Ref. 3 and 4).[(a)]

Rod	Core 9	Core 10
1	39.69 ± 0.09	28.19 ± 0.070
2	39.04 ± 0.09	27.85 ± 0.084
3	39.07 ± 0.09	27.64 ± 0.074
4	39.61 ± 0.09	28.15 ± 0.071
Average of Rods 1 and 4	39.65 ± 0.06[(b)]	28.17 ± 0.05
Bank Worth (Sum of the Rods)	157.41 ± 0.18	111.83 ± 0.15

(a) Evaluator’s Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.
(b) This value was incorrectly reported as 36.65 in Ref. 3.

[a] Williams, T., “On the Choice of Delayed Neutron Parameters for the Analysis of Kinetics Experiments in ^{235}U Systems,” *Ann. Nucl. Energy*, **23**, 1261-1265 (1996).

Additional reactivity corrections were measured for the critical core loadings to account for insertion of the control rods (Ref. 2 and 3). Worth corrections related to direct measurements of control rod bank insertions for Cores 9 (State #2) and 10 are as follows:

1. Core 9 (State #2) partial control rod bank insertion of 1620 mm, measured via SP, -70.4 ± 1.0 ¢,
2. Core 9 full control rod bank worth, or worth of inserting all control rods at once, is 152 ± 2 ¢,
3. Core 10 partial control rod insertion of 1540 mm, -36.8 ± 1 ¢, and
4. Core 10 full control rod bank worth, or worth of inserting all control rods at once, is 109.6 ¢, calibrated via SP technique.

The control rods were fully withdrawn for Core 9 (State #1). The reported value of β_{eff} is 0.00720 for each case.

Reference 5 indicates a partial control rod bank insertion worth of -70.4 ¢ (-507 pcm) worth for Core 9, with a reported value of β_{eff} of 720 pcm.

1.4.2.3 Autorod Worth Measurements

Autorod worth measurements were reported for the autorod described in Section 1.1.2.1.

Additional reactivity corrections were measured for the critical core loadings to account for the presence of the autorod (Ref. 2 and 3). Worth corrections related to the presence of the autorod for Cores 9 (States #1 and 2) and 10 are as follows:

1. Core 9 autorod rest worth (i.e. the worth of removing the absorber rod after it has been fully withdrawn), scaled from Core 5 worth measurement, -12.5 ± 0.5 ¢,
2. Core 9 (State #1) partial autorod insertion of 258 mm, scaled from Core 5 worth measurement, -7.5 ± 0.5 ¢,
3. Core 9 (State #2) partial autorod insertion of 25 mm, scaled from Core 5 worth measurement, -10.0 ± 0.5 ¢,[a]
4. Core 9 max-min worth of 10.1 ¢, scaled from Core 5 worth measurement,
5. Core 10 autorod rest worth, scaled from Core 1A worth measurement, -7.7 ± 0.5 ¢, and
6. Core 10 partial autorod insertion of 15 mm, directly measured in Core 10, -7 ± 0.4 ¢.[b]

The reported value of β_{eff} of 0.00720 for each case.

The worth of the autorod was determined by hand control while measuring reactivity via the inverse kinetics technique and simultaneously measuring the position of the autorod. The measured integral reactivity worths, i.e. the reactivity differences between the fully inserted and fully withdrawn states, is reported in Table 1.4-3 (Ref. 4).

[a] Note that State #2 of Core 9 had an additional layer of moderator pebbles placed on top of the pebble configuration of State #1. Hence the apparent inconsistency in autorod worths reported for the two configurations of Core 9.

[b] Comparison of autorod worth measurements between Cores 9 and 10 is difficult due to the change in spectra from the addition of polyethylene rods, to modification in number of stacked pebble layers, and the change in control rod insertion depths.

Table 1.4-3. The Integral Worth of the Autorod (dollarcents). [1$ = 720 pcm] (Ref. 4).[(a)]

Core	9	10
Autorod Worth	9.18 ± 0.06	6.96 ± 0.044

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.

1.4.2.4 Safety/Shutdown Rod Worth Measurements

Individual integral safety/shutdown rod worth measurements were reported for the shutdown rods described in Section 1.1.2.1.

In their fully withdrawn state the tips of the eight boron-steel safety/shutdown rods are slightly dipping into the radial reflector; it was demonstrated in Core 1 that there was no reactivity worth associated with their presence.[a]

Figure 1.4-1 shows an example of a typical detector response, with corresponding reactivity results, during a rod-drop experiment. At the time t = 11 s, three shutdown rods, having a total worth of ~8 $, were inserted in HTR-PROTEUS Core 10. The reactivity change, as a function of time, was plotted with each point having its properly derived 1σ statistical uncertainty. Since only the integral rod worth is being measured, the average values deduced for reactivity both before and after the drop can be used, which correspondingly reduces the uncertainty. The IK technique is only applicable to transient system measurements that normally start from a critical or near-critical state. Measurement of a constant subcritical system requires the PNS method (Ref. 10).

[a] Williams, T., Bourguin, P, and Chawla, R. "HTR PROTEUS CORE 1: Reactivity Corrections for the Critical Balance," TM-41-93-20, Paul Sherrer Institut, Villigen, October 7, 1993.

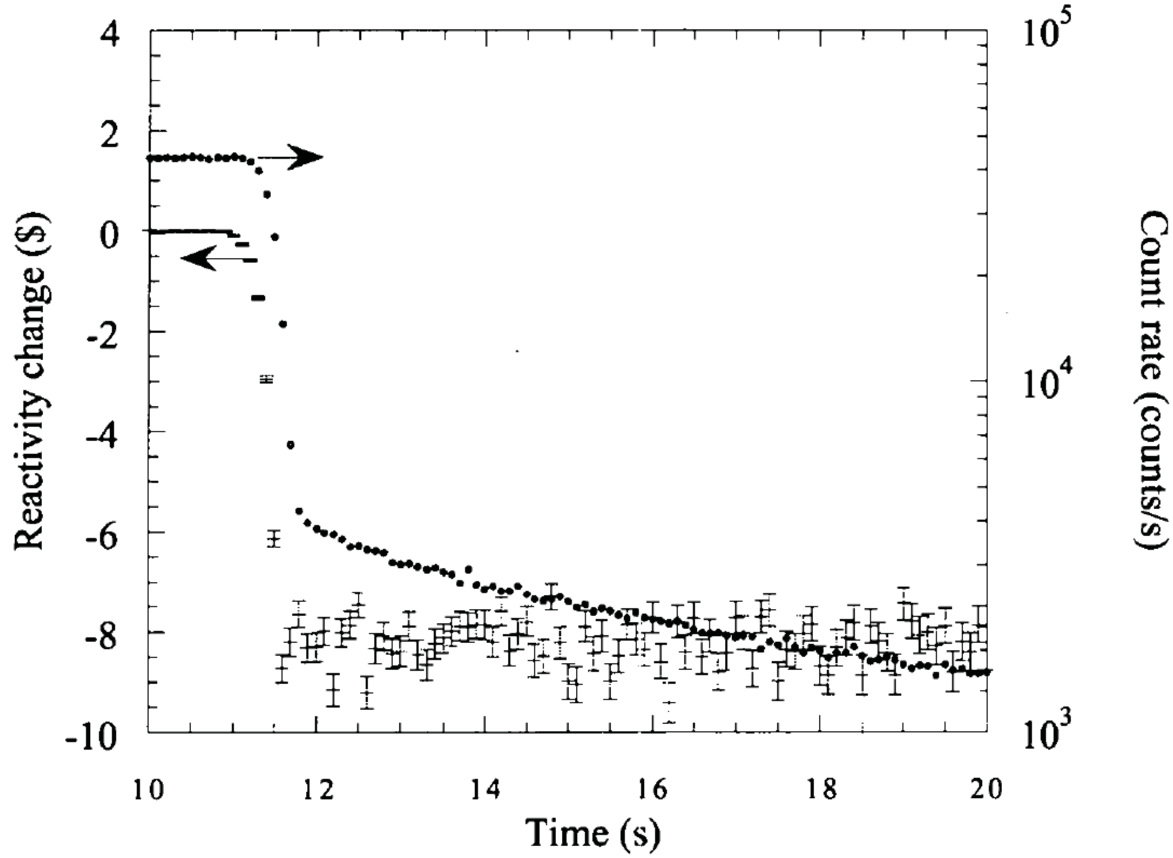

Figure 1.4-1. Example Count Rate and Reactivity Change Following Absorber Rod Insertion in Core 10 (Ref. 10).

Figure 1.4-2 shows a typical detector response for a PNS measurements of a subcritical Core 10 with four shutdown rods inserted. After the perturbations from the spatial harmonics, the first part of the response can be approximated by a single exponential corresponding to the prompt neutron decay; the second half is due to the delayed neutrons. A common criticism of the PNS method is that measured reactivity values depend upon correction factors and/or kinetics parameters that need to be calculated using the same neutronics codes as those being validated by said measurements. For example, the area-ratio method must be corrected for kinetic distortion, which arises from spatial and spectral differences of the prompt and delayed neutron fluxes during a transient. The inhour (Simmons-King) method calculates a reactivity value independent of kinetic distortion, but the results is strongly dependent upon a calculation of the prompt neutron generation time (Ref. 10).

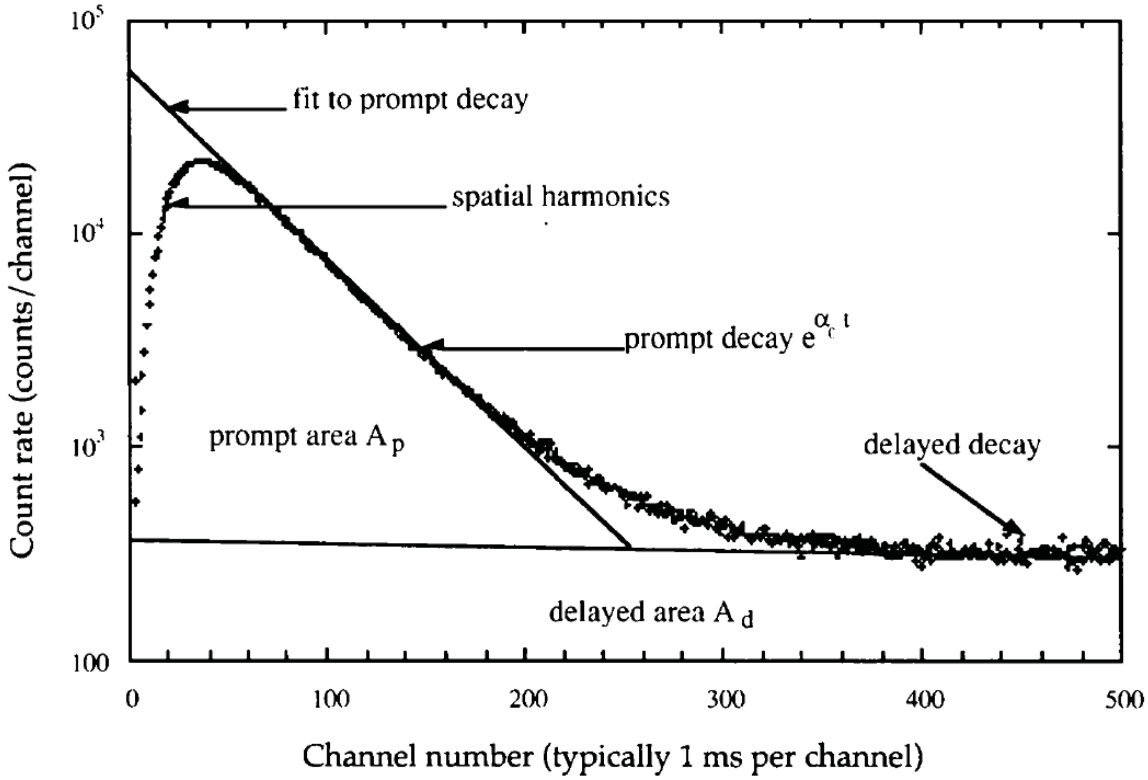

Figure 1.4-2. Example Count Rate Response for a Pulsed Neutron Source Measurement (Ref. 10).

The combination of an undermoderated core and strongly interacting reflector zones renders accurate subcriticality measurements particularly difficult in a small-sized pebble-bed HTR. This is due to the strong spatial effects in the system requiring relatively large calculated correction factors in the interpretation of both IK and PNS measurements. To reduce this dependence of conventional experimental techniques on calculational results, new techniques based on the use of epithermal neutron detectors were developed and applied in the HTR-PROTEUS program. The sensitivity to calculated correction factors and/or kinetic parameters was shown to be considerably reduced for both types of measurements (Ref. 3 and 10). The experimental procedures and extended analytical methodology required for the interpretation of the epithermal measurement techniques is provided in Ref. 7 and 8.

Different combinations of shutdown rods were measured applying in each case a variety of experimental methods. These ranged, from conventional (thermal) and newly developed (epithermal) IK and PNS techniques, using both Simmons-King and Gozani theories to analyze the PNS measurements. Generally statistical uncertainties were smaller in experiments using thermal detectors. However the lower sensitivity to correction factors in epithermal measurements yielded more reliable results. A parallel application of several different techniques was used to check for any systematic errors. The spatial dependence of the IK measurements and PNS measurements using Gozani theory were corrected; the uncertainties correspond to the 1σ statistical error for cases where only one measurement was made and in the other cases the uncertainties are standard deviations on the average values. A variance-weighted average was also calculated; however the uncertainty was tabulated as the square-root of the sum of the squares instead of the inverse of the squared uncertainty because of the small experimental sample size. Reactivity worth measurements for various shutdown rod combinations are shown in Table 1.4-4 for Core 9 and 1.4-5 for Core 10 (Ref. 3 and 6).

It should be noted that there is an observable asymmetry in the worths of the shutdown rods caused by the shadowing effect of the relatively low-worth autorod, albeit slightly smaller in effect than in the control rods (Ref. 3).

Comparison of Figures 1.4-3 and 1.4-4 demonstrate how use of epithermal measurements can effectively reduce the magnitude of the correction factors; furthermore, the perturbation of the epithermal flux is appreciably smaller compared to the thermal flux perturbation (Ref. 10).

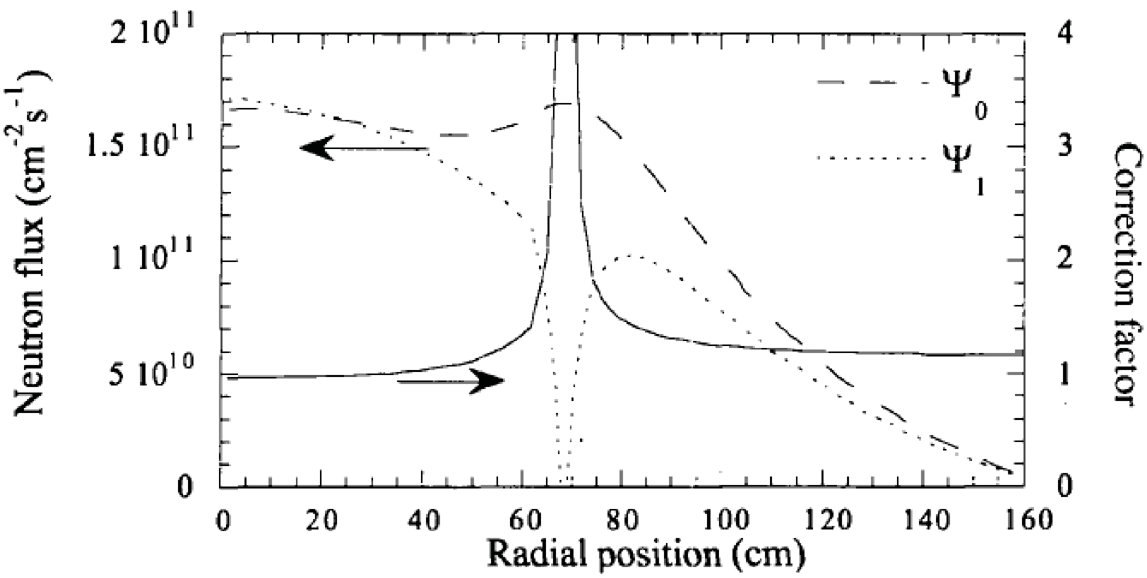

Figure 1.4-3. Calculated Thermal (E<0.625 eV) Fluxes Before (Ψ_0) and After (Ψ_1) the Insertion of a Shutdown Rod in Core 10, and Correction Factor for the Reactivity Measured with the IK Technique (Ref. 10).

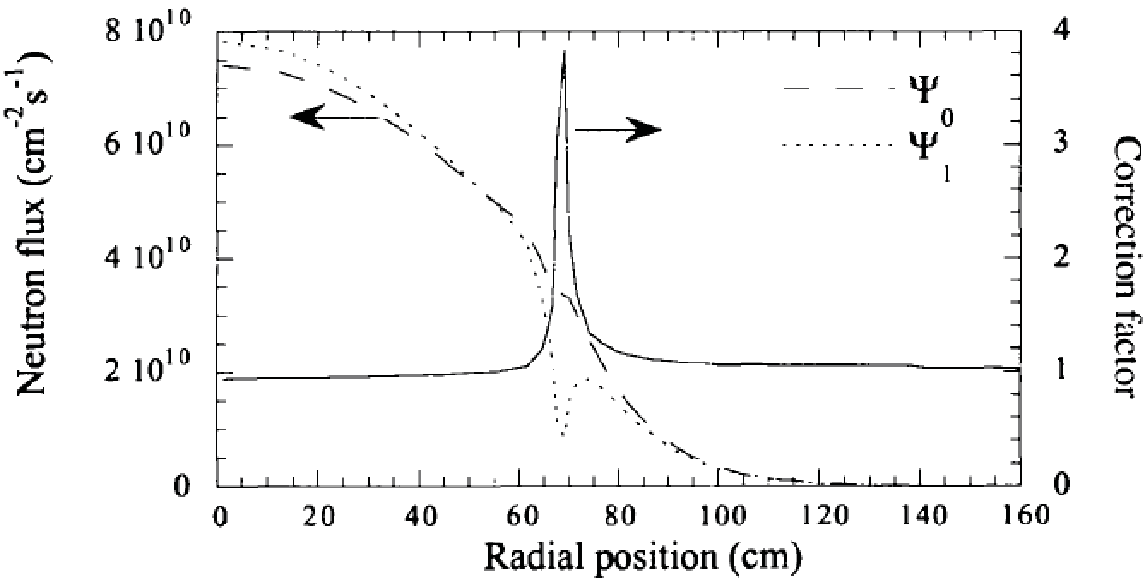

Figure 1.4-4. Calculated Epithermal (0.625 eV<E<750 eV) Fluxes Before (Ψ_0) and After (Ψ_1) the Insertion of a Shutdown Rod in Core 10, and Correction Factor for the Reactivity Measured with the IK Technique (Ref. 10).

Table 1.4-4. Reactivity Worth Measurements for Various Combinations of the Shutdown Rods in Core 9 [The values in square brackets represent the number of measurements made for a given configuration] (Ref. 3, 6, 9, and 10).[(a)]

Rods Inserted	**6[(b)]**	**5-6**	**5-6-7**	**5-6-7-8**
Thermal IK measurement ($)	-3.73 ± 0.02 [2]	-7.71 ± 0.09 [2]	-11.69 ± 0.23 [2]	-16.00 ± 0.41 [2]
Epithermal IK measurement ($)	-3.63 ± 0.08 [1]	--	-11.36 ± 0.20 [2]	--
Thermal Simmons-King PNS measurement ($)	-3.69 ± 0.06 [3]	-7.74 ± 0.19 [5]	-11.63 ± 0.33 [3]	-15.63 ± 0.53 [6]
Thermal Gozani PNS measurement ($)	-3.77 ± 0.01 [2]	-7.88 ± 0.05 [3]	-12.25 ± 0.11 [2]	-16.39 ± 0.36 [4]
Epithermal Gozani PNS measurement ($)	-3.73 ± 0.08 [4]	-7.85 ± 0.14 [5]	-11.85 ± 0.24 [4]	-16.43 ± 0.45 [8]
Weighted Average ($) (worth per rod)	**-3.74 ± 0.01**	**-7.82 ± 0.06 (-3.91)**	**-11.83 ± 0.10 (-3.94)**	**-16.17 ± 0.24 (-4.04)**

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.

(b) This rod number is reported as 6 in Ref. 3 and 5 in Ref. 5 and 6. Comparison with results reported for Rods 5 and 6 in Ref. 7 support that the actual rod number is 6. This is also confirmed with Ref. 10.

Table 1.4-5. Reactivity Worth Measurements for Various Combinations of the Shutdown Rods in Core 10 [The values in square brackets represent the number of measurements made for a given configuration] (Ref. 3, 6, 9, and 10).[(a)]

Rods Inserted	**6[(b)]**	**5-6**	**5-6-7**	**5-6-7-8**
Thermal IK measurement ($)	-2.75 ± 0.02 [1]	-6.17 ± 0.07 [2]	-9.38 ± 0.60 [3]	-12.99 ± 1.3 [2]
Epithermal IK measurement ($)	-2.63 ± 0.06 [1]	-5.56 ± 0.10 [1]	-8.61 ± 0.34 [6]	-11.80 ± 0.19 [3]
Thermal Simmons-King PNS measurement ($)	-2.65 ± 0.05 [4]	-5.48 ± 0.12 [4]	-8.42 ± 0.33 [4]	-11.42 ± 0.32 [8]
Thermal Gozani PNS measurement ($)	-2.69 ± 0.06 [4]	-5.72 ± 0.30 [4]	-9.38 ±0.15 [4]	-12.12 ± 0.37 [8]
Epithermal Gozani PNS measurement ($)	-2.59 ± 0.05 [1]	-5.47 ± 0.16 [1]	-8.64 ± 0.18 [1]	-11.71 ± 0.28 [9]
Weighted Average[(c)] ($) (worth per rod)	**-2.66 ± 0.03**	**-5.54 ± 0.09 (-2.77)**	**-8.91 ± 0.13 (-2.97)**	**-11.74 ± 0.16 (-2.94)**

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.

(b) This rod number is reported as 6 in Ref. 3 and 5 in Ref. 5 and 6 for Core 9. Comparison with results reported for Rods 5 and 6 in Ref. 7 support that the actual rod number is 6. This rod should similarly be labeled as number 6 in Core 10. This is also confirmed with Ref. 10.

(c) The results obtained from the thermal IK measurements were not considered while deducing the weighted-average values. The large discrepancy as regard to the other techniques was probably due to an inadequacy of the Core 10 r-Θ TWODANT model used for the calculation of the correction factors.

The different methods generally show good agreement for Cores 9 and 10 with one exception. In Core 10, the results obtained with the thermal IK technique generally show large discrepancies with respect to the others, possibly due to an inadequacy of the model used to calculate the correction factor. The epithermal IK measurements are very consistent; this emphasizes the reduced dependence on calculations. The same r-Θ model was used to correct the epithermal measurements but the corrections were much smaller than for the thermal measurements; epithermal results were not significantly impacted by the inadequacy of the model (Ref. 3 and 10).

The individual rod worth increases slightly with the number of rods inserted. The reactivity worth of the four shutdown rods inserted is always bigger than four times the worth on an individual rod. This arises from positive shadowing effects reported for HTR-PROTEUS measurements, which is less pronounced in Cores 9 and 10 than in earlier HTR-PROTEUS configurations. Also, the worth of the shutdown rods decreases when the effect of water ingress was simulated. This is seen by comparing rod worths between Cores 9 and 10 (Ref. 3 and 6).

Asymmetry effects on the early HTR-PROTEUS cores were investigated. It was shown that anti-shadowing effects for absorber rods in the radial reflector were significant. The presence of a cavity above the core reduced cross-core anti-shadowing effects.[a]

The relative quality of the thermal and epithermal measurements was evaluated by grouping the measurements separately and taking an equally-weighted average of the experimental measurements. As indicated previously, the erratic IK thermal measurement for Core 10 was neglected. There was no significant difference between thermal or epithermal measurements for Core 9. Up to a 10 %

[a] Williams, T., Chawla, R., Hager, H., Mathews, D., Seiler, R., "Absorber-Rod Interaction and Asymmetry Effects in Experimental LEU-HTR Configurations," *Proc. 1994 ANS Topical Mtg. on Advances in Reactor Physics*, Knoxville, TN, April 11-15, 1994.

discrepancy was identified for Core 10 between the thermal and epithermal measurements. The comparison of the average epithermal and thermal worths for Cores 9 and 10 are shown in Tables 1.4-6 and 1.4-7, respectively.

Table 1.4-6. Averaged Reactivity Worth Measurements the Shutdown Rods in Core 9 (Ref. 6).[a]

Rods Inserted	**6[b]**	**5-6**	**5-6-7**	**5-6-7-8**
Thermal measurements ($)	-3.73 ± 0.02	-7.78 ± 0.07	-11.86 ± 0.14	-16.01 ± 0.25
Epithermal measurements ($)	-3.68 ± 0.06	-7.85 ± 0.14	-11.61 ± 0.16	-16.43 ± 0.45

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.
(b) This rod number is reported as 6 in Ref. 3 and 5 in Ref. 5 and 6. Comparison with results reported for Rods 5 and 6 in Ref. 7 support that the actual rod number is 6.

Table 1.4-7. Averaged Reactivity Worth Measurements the Shutdown Rods in Core 10 (Ref. 6).[a]

Rods Inserted	**6[b]**	**5-6**	**5-6-7**	**5-6-7-8**
Thermal measurements ($)	-2.70 ± 0.03	-5.79 ± 0.11	-9.06 ± 0.23	-12.18 ± 0.46
Epithermal measurements ($)	-2.61 ± 0.04	-5.52 ± 0.09	-8.63 ± 0.19	-11.76 ± 0.17

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.
(b) This rod number is reported as 6 in Ref. 3 and 5 in Ref. 5 and 6 for Core 9. Comparison with results reported for Rods 5 and 6 in Ref. 7 support that the actual rod number is 6. This rod should similarly be labeled as number 6 in Core 10.

Corrected IK measurements of the reactivity worth of various combinations of shutdown rods in Core 9 and 10 are reported for individual detector positions in Tables 1.4-8 and 1.4-9, respectively (Ref. 7 and 10).

Table 1.4-8. Corrected Results of IK Measurements of the Reactivity Worth of Various Combinations of the Shutdown Rods in Core 9 (Ref. 7 and 10).[(a)]

Shutdown Rods Inserted in the Reactor	Detector Position	Corrected Reactivity Measured with Thermal Detectors ($)	Corrected Reactivity Measured with Epithermal Detectors ($)
5	1[(b)]	-3.69 ± 0.02	
	2[(c)]	-3.61 ± 0.03	
6	1	-3.72 ± 0.01	-3.63 ± 0.08
	2	-3.73 ± 0.02	
5,6	1	-7.69 ± 0.05	
	2	-7.72 ± 0.07	
5,6,7	1	-11.61 ± 0.12	-11.23 ± 0.34
	2	-11.76 ± 0.13	-11.49 ± 0.37
5,6,7,8	1	-16.10 ± 0.17	
	2	-15.89 ± 0.19	

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.
(b) Position 1: detector in the radial reflector close to Rod 7.
(c) Position 2: detector in the radial reflector close to Rod 8.

Table 1.4-9. Corrected Results of IK Measurements of the Reactivity Worth of Various Combinations of the Shutdown Rods in Core 10 (Ref. 7 and 10).[(a)]

Shutdown Rods Inserted in the Reactor	Detector Position	Corrected Reactivity Measured with Thermal Detectors ($)	Corrected Reactivity Measured with Epithermal Detectors (Cd Shielding) ($)	Corrected Reactivity Measured with Epithermal Detectors (Cd + In Shielding) ($)
5	3[(b)]	-2.75 ± 0.02		-2.63 ± 0.06
6	3	-2.79 ± 0.02		
5,6	3	-6.17 ± 0.04		-5.56 ± 0.10
5,6,7	1[(c)]	-8.72 ± 0.08	-8.26 ± 0.21	-8.18 ± 0.15
	2[(d)]	-9.60 ± 0.08	-8.99 ± 0.20	-8.94 ± 0.13
	3	-9.83 ± 0.06	-8.68 ± 0.26	-8.60 ± 0.15
5,6,7,8	1	-12.04 ± 0.13		-11.70 ± 0.30
	2			-11.71 ± 0.40
	3	-13.94 ± 0.13		-11.98 ± 0.35

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.
(b) Position 3: detector at the radial center of the core.
(c) Position 1: detector in the radial reflector close to Rod 7.
(d) Position 2: detector in the radial reflector close to Rod 8.

The measurements on Cores 9 and 10 were performed for various subcritical configurations with the detectors at several different positions that corresponded to significantly different spatial perturbations. This was done so that a group of measurements representing the same measured parameter could be assessed to obtain an indication of the uncertainty and reliability of the calculational correction factors being applied. Sufficient measurements were performed to show the important differences between the different techniques (Ref. 7 and 10).

Insertion of absorber rods induced local flux perturbations that had a more significant impact on thermal measurements. It was reported that the discrepancy on the reactivity measured at the same two positions, with three shutdown rods inserted into Core 9, is only 1.4 ± 2.9 % with epithermal detectors and 2.3 ± 4.5 % in the thermal detectors; this demonstrates the different magnitudes of spatial perturbations with their impact on the derived correction factors.[a] The difference between thermal results for corrected detector measurement worths during the 4-rod insertion in Core 10 is ~16 % while it is < 2.5 % for the epithermal detectors. There is much better agreement between thermal and epithermal results in Core 9 than in Core 10; the experimenters believed this was due to modeling weaknesses of the r-Θ model when calculating the correction factors for the water-moderated core. The calculated β_{eff} values were 0.00717 and 0.00720 for Cores 9 and 10, respectively (Ref. 7 and 10).

Further discussion of the IK and PNS method using thermal and epithermal measurements, and calculation of correction factors for Cores 9 and 10 can be found in Reference 10.

[a] Regardless of what was reported here in Reference 7, the differences are within the statistics of the measurements.

Reference 5 reports the shutdown rod worths for Core 9, as shown in Table 1.4-10, and indicates that Ref. 6 is the initial source of these data. Comparison with Table 1.4-6 confirms that Ref. 5 repeats the measurements reported for the averaged reactivity worth of just the epithermal measurements.

Table 1.4-10. Reactivity Worth Measurements for Various Combinations of the Shutdown Rods in Core 9 (Ref. 5).[(a)]

Rods Inserted	6[(b)]	5-6	5-6-7	5-6-7-8
Experimental Worth ($)	-3.68(6)	-7.85(14)	-11.61(16)	-16.43(45)

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.
(b) This rod number is reported as 6 in Ref. 3 and 5 in Ref. 5 and 6. Comparison with results reported for Rods 5 and 6 in Ref. 7 support that the actual rod number is 6.

An earlier references reported slightly different values for PNS shutdown rod worth measurements in Core 9. Results are shown in Table 1.4-11 (Ref. 8).

Table 1.4-11. Reactivity Worth Measurements for Combinations of Shutdown Rods in Core 9 (Ref. 8).[(a)]

Number of Rods Inserted[(b)]	**Simmons-King Reactivity ($)**	**Corrected Thermal Gozani Reactivity ($)**	**Corrected Epithermal Gozani Reactivity ($)**
1	-3.64 ± 0.03	-3.70 ± 0.05	-3.62 ± 0.02
2	-7.74 ± 0.09	-7.83 ± 0.42	-7.89 ± 0.14
3	-11.63 ± 0.08	-11.91 ± 0.78	-12.03 ± 0.21
4	-15.63 ± 0.12	-15.52 ± 1.72	-16.81 ± 0.54

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.
(b) The rod positions that correspond with each measurement were not reported.

Additional IK measurement rod worths (corrected for spatial dependence and neutron spectrum change) were reported for Cores 9 and 10 in Ref. 4. For both sets of measurements, the results from the second detector were reported as "suspiciously high" and thus results from this detector were not deemed acceptable by the experimenters, as the same problem existed when taking measurements with the autorod. Measured shutdown rod worths for Core 9 are in Table 1.4-12 and Core 10 in Table 1.4-13 (Ref. 4).

Table 1.4-12. Measured Shutdown Rod Worths (in $) in Core 9 (Ref. 4).[(a)]

Rods Inserted	Detector 1	Detector 2[(b)]
5	3.558 ± 0.008	4.880 ± 0.040
6	3.594 ± 0.005	4.185 ± 0.019
7	3.578 ± 0.006	4.040 ± 0.016
8	3.482 ± 0.007	-
5+6	7.48 ± 0.013	8.71 ± 0.042
5+7	7.19 ± 0.017	-
5+8	7.15 ± 0.019	-
5+6+7+8	15.25 ± 0.050	-

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.
(b) Results from Detector 2 deemed unacceptable by experimenters.

Table 1.4-13. Measured Shutdown Rod Worths (in $) in Core 10 (Ref. 4).[(a)]

Rods Inserted	Detector 1	Detector 2[(b)]	Detector 3	Weighted Average[(c)]
5	2.72 ± 0.006	3.10 ± 0.010	2.63 ± 0.007	2.75 ± 0.12
6	2.74 ± 0.007	2.92 ± 0.010	2.71 ± 0.009	2.77 ± 0.06
7	2.73 ± 0.049	2.92 ± 0.010	2.60 ± 0.009	2.74 ± 0.09
8	2.67 ± 0.008	2.56 ± 0.010	2.51 ± 0.026	2.62 ± 0.04
5+6	5.79 ± 0.012	6.43 ± 0.028	5.52 ± 0.015	5.76 ± 0.18
5+7	5.65 ± 0.015	6.17 ± 0.021	5.26 ± 0.012	5.54 ± 0.23
5+8	5.59 ± 0.013	6.25 ± 0.022	5.35 ± 0.017	5.64 ± 0.22
5+6+7+8	12.63 ± 0.025	12.93 ± 0.066	11.57 ± 0.045	12.43 ± 0.32

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.
(b) Results from Detector 2 deemed unacceptable by experimenters.
(c) The reported weighted average appears to include Detector 2 measurements.

Information regarding the thermal neutron detectors was unavailable.

The epithermal neutron detectors consisted of high-efficiency BF_3 proportional counters shielded with 0.5 mm of Cd, which suppresses ~99.9 % of the thermal flux (<0.3 eV) and only 1.2 % of the epithermal (> 1 eV). However, the overall efficiency of the detector is drastically reduced. A test in the thermal column of the PROTEUS demonstrated that the Cd-shielded detector had a count rate of about 0.15 % of that of an unshielded one. Polyethylene was introduced (8 mm thick) to thermalize the epithermal neutrons that passed through the Cd shielding, thus increasing the efficiency by a factor of 2 (Ref. 10).

Figure 1.4-5 shows a schematic of the two types of BF_3 epithermal detectors typically utilized. Some measurements were tested with an additional layer of 0.5 mm of indium to increase the detection threshold energy. The efficiency was reduced to the point that the detectors were useless for PNS measurements but still usable for IK measurements in Core 10 (Ref. 10).

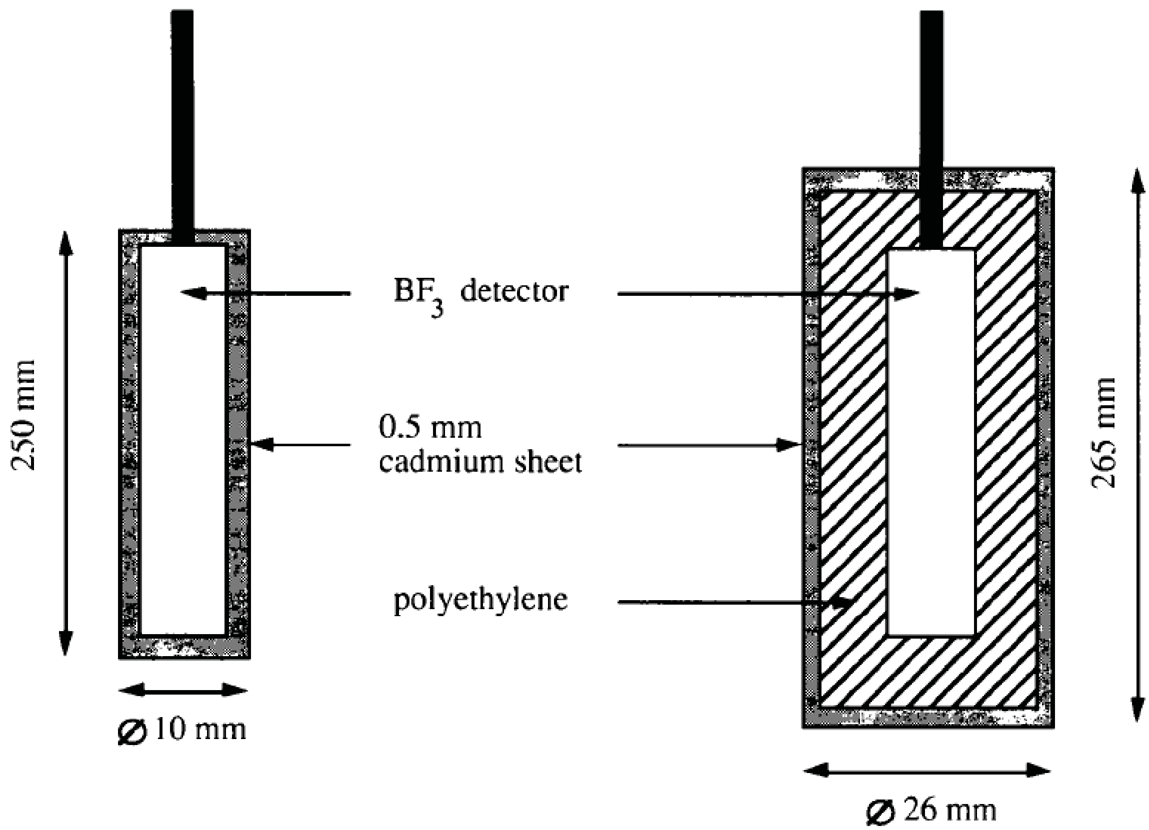

Figure 1.4-5. Schematic View of BF_3 Detectors Shielded with Cd (Ref. 10).

Epithermal measurements for the IK measurements were performed in three different positions, with the radial and azimuthal locations displayed in Figure 1.4-6. In Core 10, the epithermal measurements were performed with detectors shielded by cadmium and indium, as well as detectors shielded only by cadmium. The detectors containing polyethylene were not used for the IK measurements because the count rates were sufficiently high without it. As seen in Table 1.4-9, there was excellent agreement between the results obtained with the two types of shielding, which confirmed that the small difference in threshold energy did not influence the epithermal results (Ref. 10).

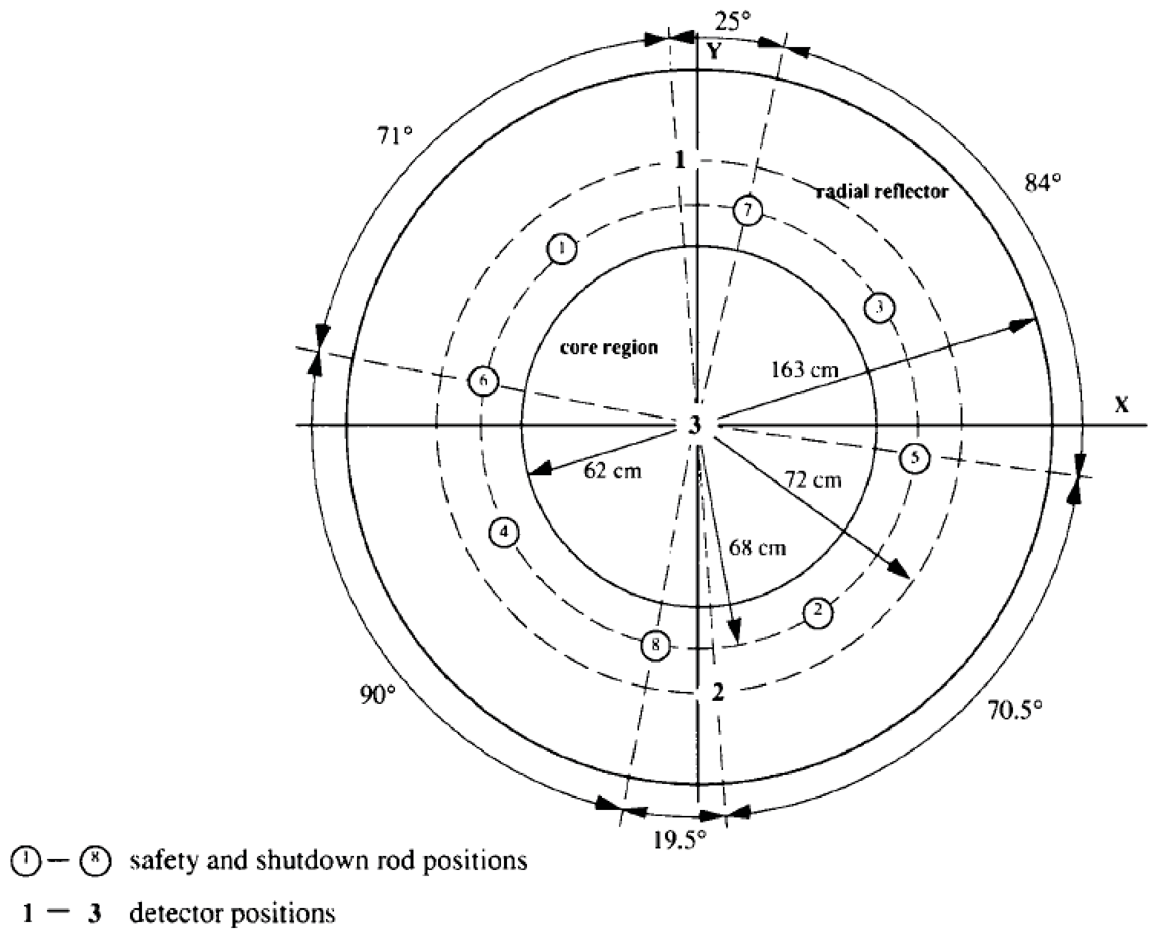

Figure 1.4-6. Horizontal Cross Section Indicating Radial and Azimuthal Locations of the Shutdown Rods and Detectors in the Various Cores (Ref. 10).

The uncertainties (1σ statistical errors) on the epithermal measurements are seen to be somewhat larger than those on the thermal measurements. The conventional (thermal) IK measurements utilized a special detector (and associated electronics) with a very small dead time of 0.5 μs to enable the measurement of high count rates at critical with improved statistics after the rod drop. This detector had a lower efficiency than the BF_3 detectors used in the PNS measurements, resulting in poor statistics for epithermal measurements. Therefore epithermal IK measurements were performed using the same detectors as those utilized in the epithermal PNS measurements. The dead time of these detectors was 1.4 μs, which was the limiting factor for obtaining count rates at critical. The statistical uncertainty is thus effectively a limitation imposed by the reactor conditions and the detector used for the experiments, and not of the epithermal technique itself. Equivalent accuracies should be achievable with the epithermal and thermal techniques under appropriate operational conditions (Ref. 10).

I general schematic showing positions of various detectors and the Pulsed Neutron Source for Core 5 is shown in Figure 1.4-7. A similar diagram for Cores 9 and 10 was unavailable.

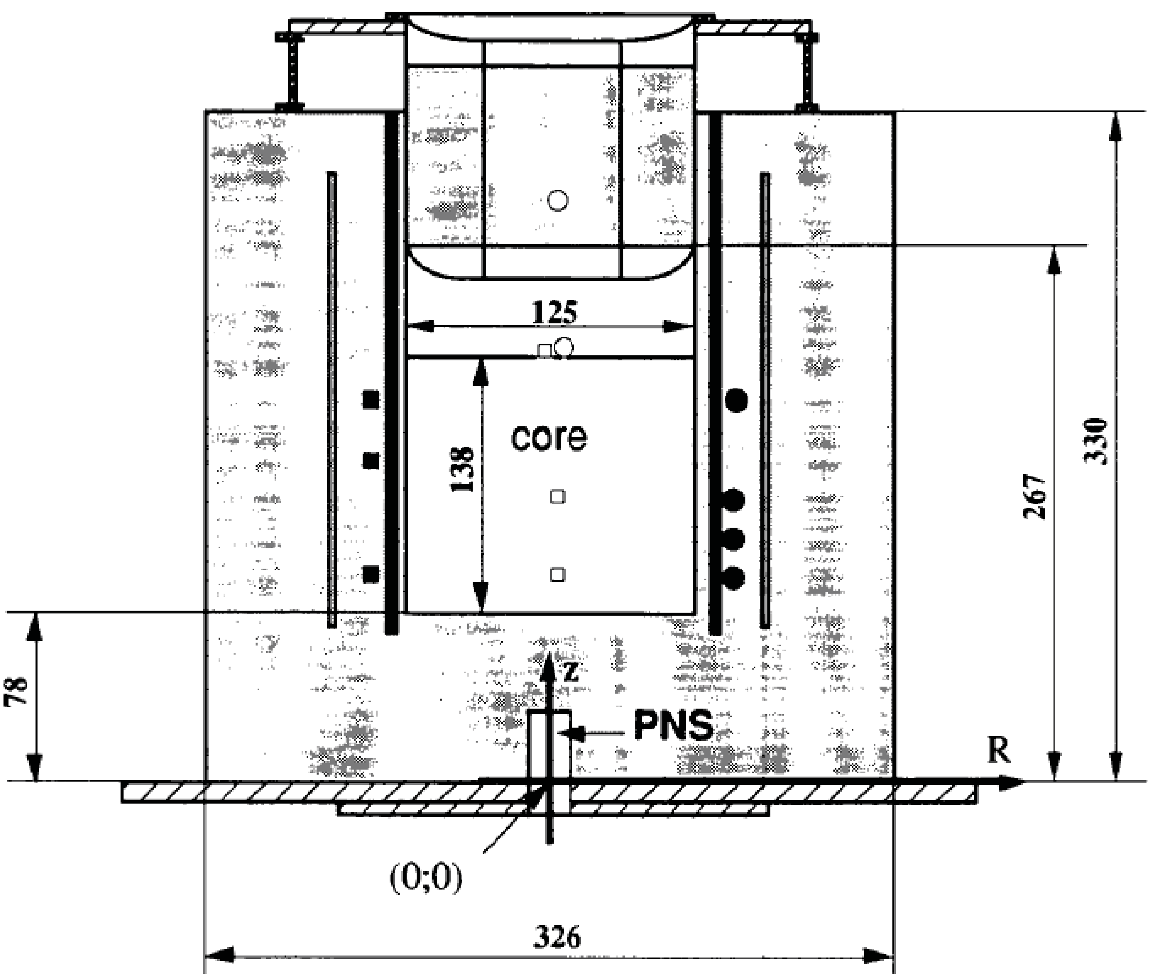

Figure 1.4-7. Schematic View Showing Positions of the Detectors and the PNS in Core 5. Circles and squares denote epithermal and thermal detector positions, respectively. Dimensions are in cm (Ref. 10).

1.4.2.5 Graphite Plug Worth Measurements

Additional reactivity corrections were measured for the critical core loadings to account for holes and penetrations in the graphite reflectors. Worth corrections related to holes and penetrations in the graphite reflectors that can be filled with plugs for Cores 9 and 10 are in Tables 1.4-14 and 1.4-15, respectively. Where possible, the component worths had been measured directly in the relevant configurations (indicated by **M** in the tables), but in many cases the values had to be scaled from another configuration (**S**). The reported value of β_{eff} is 0.00720 for each case.

The effective worths of penetrations in the graphite reflectors were effectively measured by comparing core reactivity for conditions where the holes contain graphite rods/plugs (i.e. the holes were filled) and conditions where the graphite has been removed.[a]

Table 1.4-14. Reactivity Worths for Graphite Holes and Penetrations in Core 9 (Ref. 1 and 3).

Reactivity Component	**No.**		**Total ¢[(a)]**			**Comments**
Control Rod Channels[(b,c)]	4	S	-2.5	±	0.3	Scaled from Core 5
Autorod Channel[(b)]	1	S	-0.7	±	0.3	Scaled from Core 5
Empty Channels R2[(b,d)]	3	S	-5	±	1	Scaled from Core 5
Channels in Upper Reflector[(e)]	34					No Estimate
Channels in Lower Reflector	0					Channels Filled

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.
(b) Only a few individual component worths were measured in Core 9. Therefore, in order to obtain an estimate of the reactivity excess, the component worths measured in Core 5 were scaled by the ratio of the control rod bank worths in the two cores, namely Core 9/Core 5 = 152¢/134¢ = 1.14.
(c) The worth of the new control rod channels was assumed to be the same as that of the ZEBRA rod channels in Core 1. Although the ZEBRA rod channels are somewhat larger than the new control rod channels, it is considered that the small size of the correction and its associated uncertainty justifies this approximation. The uncertainty was slightly increased.
(d) R2 indicates the second ring of the C-Driver channels.
(e) No measurement was made of this effect and no justifiable basis could be found for its estimate.

Table 1.4-15. Reactivity Worths for Graphite Holes and Penetrations in Core 10 (Ref. 1 and 3).

Reactivity Corrections to Critical Loading	**No.**		**Total ¢[(a)]**			**Comments**
Control Rod Channels[(b)]	4	S	-2.0	±	0.2	Core 1A Value
Autorod Channel[(b)]	1	S	-0.5	±	0.3	Core 1A Value
Empty Channels R2[(c)]	3	S	-4	±	1	Scaled from Core 1A
Channels in Upper Reflector[(b)]	34	S	-3.6	±	2.0	Core 1A Value
Channels in Lower Reflector	0					

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.
(b) Since the core height and control bank worths in Core 10 are similar to those in Core 1A, it was considered to be justified to use some of the component worths measured in Core 1A directly in Core 10 with a small arbitrary increase in the uncertainties.
(c) R2 indicates the second ring of the C-Driver channels.

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[a] Williams, T., Bourguin, P, and Chawla, R. "HTR PROTEUS CORE 1: Reactivity Corrections for the Critical Balance," TM-41-93-20, Paul Sherrer Institut, Villigen, October 7, 1993.

Reference 5 indicates a control rod channel worth of -2.5 ¢ (-18 pcm) worth for Core 9, with a reported value of β_{eff} of 720 pcm.

The three empty channels in the radial reflector, R2, were positions 15, 47, and 63, which were used for temperature measurements in the reflector. See Figure 1.1-3 for the location of these channels.

1.4.2.6 Source/Instrumentation Worth Measurements

Additional reactivity corrections were measured for the critical core loadings for the start-up sources, with associated penetrations, and nuclear instrumentation. No further details are available beyond their measured worth and comments regarding how the worth values were obtained. Worth corrections related to source/instrumentation measurements for Cores 9 and 10 are in Tables 1.4-16 and 1.4-17, respectively. Where possible, the component worths had been measured directly in the relevant configurations (indicated by **M** in the tables) but in many cases the values had to be scaled from another configuration (**S**). The reported value of β_{eff} is 0.00720 for each case.

Table 1.4-16. Reactivity Worths for Source/Instrumentation Components of Core 9 (Ref. 1 and 3).

Reactivity Component	No.		Total ¢[a]			Comments
Start-up Sources	2	M	-4	±	1	
Start-up Source Penetrations	2	S	-1	±	0.2	Core 5 Value
Nuclear Instrumentation (Ionization)	6	S	-9.0	±	1.5	Scaled from Core 5
Nuclear Instrumentation (Fission)	2	S	-1.0	±	0.7	Scaled from Core 5

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.

Table 1.4-17. Reactivity Worths for Source/Instrumentation Components of Core 10 (Ref. 1 and 3).

Reactivity Component	No.		Total ¢[a]			Comments
Start-up Source Penetrations	2	S	-1	±	0.2	Core 1A Value
Nuclear Instrumentation (Ionization)	6	S	-8.4	±	1.2	
Nuclear Instrumentation (Fission)	2	S	-0.8	±	0.6	Core 1A Value

(a) Evaluator's Note: Reported uncertainty is statistical and does not include additional sources of uncertainty such as from delayed neutron data.

1.4.3 Material Data

The materials in the core were those described in Section 1.1.3.

1.4.4 Temperature Data

Room (hall) temperatures for HTR-PROTEUS critical experiments, Cores 9 and 10, are provided in the following tables (core and reflector temperatures were not measured):

- Core 9 (Reference State #1): Table 1.1-3
- Core 9 (Reference State #2): Table 1.1-4
- Core 10 (Reference State #1): Table 1.1-5

The reactor was operated at room temperature with the power limited to 1 kW so that no active cooling systems were required.[a]

Environmental conditions when additional reactor physics measurements were performed would be very similar to those recorded for the critical configurations.

1.4.5 Additional Information Relevant to Reactivity Effects Measurements

Additional information is not available.

[a] Köberl, O., Seiler, R., and Chawla, R., "Experimental Determination of the Ratio of 238U Capture to 235U Fission in LEU-HTR Pebble-Bed Configurations," *Nucl. Sci. Eng.*, **146**, 1-12 (2004).

1.5 Description of Reactivity Coefficient Measurements

Reactivity coefficient measurements were performed but have not yet been evaluated.

1.6 Description of Kinetics Measurements

Kinetics measurements were performed but have not yet been evaluated.

1.7 Description of Reaction-Rate Distribution Measurements

Reaction-rate distribution measurements were performed but have not yet been evaluated.

1.8 Description of Power Distribution Measurements

Power distribution measurements were not performed.

1.9 Description of Isotopic Measurements

Isotopic measurements were not performed.

1.10 Description of Other Miscellaneous Types of Measurements

Other miscellaneous types of measurements were not performed.

2.0 EVALUATION OF EXPERIMENTAL DATA

Two benchmark experiments were evaluated in this report: Cores 9 and 10. These core configurations represent the columnar hexagonal point-on-point (CHPOP) configurations of the HTR-PROTEUS experiment with a moderator-to-fuel pebble ratio of 1:1. Cores 9 and 10 use withdrawable, hollow, stainless steel control rods. Core 9 has 27 pebble layers; a second configuration, or state, of Core 9 that included a 28th layer of just moderator pebbles was not evaluated as it was very similar in core design and implemented to perform core operations after initial criticality was attained. Core 10 retains the same pebble loading as Core 9, but to a height of 24 layers. It has polyethylene rods inserted between pebbles to simulate water ingress.

Monte Carlo n-Particle (MCNP) version 5-1.60 calculations were utilized to estimate the biases and uncertainties associated with the experimental results in this evaluation. MCNP is a general-purpose, continuous-energy, generalized-geometry, time-dependent, coupled n-particle Monte Carlo transport code.[a] The Evaluated Neutron Data File library, ENDF/B-VII.0,[b] nuclear data was also used in this evaluation. The statistical uncertainty in k_{eff} and Δk_{eff} is ≤0.00007 and ≤0.00010, respectively. Calculations were performed with 1,650 generations with 100,000 neutrons per generation. The k_{eff} estimates (with the first 150 generations skipped) are the result of 150,000,000 neutron histories.

2.1 Evaluation of Critical and / or Subcritical Configuration Data

The benchmark critical configurations for Cores 9 and 10 will be referred to as Cases 1 and 2, respectively. Both methods of identification are utilized throughout the rest of this report to facilitate users with differing familiarities with HTR-PROTEUS and IRPhEP benchmark format.

Variations of the benchmark model provided in Section 3 were utilized with perturbations of the model parameters to estimate uncertainties in k_{eff} due to uncertainties in parameter values defining the benchmark experiment. Some perturbations required more detail than that retained in the benchmark model. More detailed models (Appendix C) were utilized to evaluate these uncertainties. Transformation from the detailed model to the benchmark model is described in Section 3.1.1.1. Where applicable, comparison of the upper and lower perturbation k_{eff} values to evaluate the uncertainty in the eigenvalue were utilized to minimize correlation effects, if any, induced by comparing all perturbations to the original benchmark model configuration, as discussed elsewhere.[c]

Unless specifically stated otherwise, all uncertainty values in this section correspond to 1σ. When the change in k_{eff} between the base case and the perturbed model (single-sided perturbation), or two perturbed models (double-sided perturbation directly comparing an upper and a lower perturbation from the base case), is less than the statistical uncertainty of the Monte Carlo results, the changes in the variable are amplified, if possible, and the calculations repeated. The resulting calculated change is then scaled back, using a scaling factor, corresponding to the actual uncertainty, assuming that it is linear, which should be adequate for these changes in k_{eff}. Throughout Section 2, the difference in eigenvalues computed using the perturbation method described is denoted with Δk_p; the scaled 1σ uncertainty is denoted as Δk_{eff}. All Δk_{eff} uncertainties are considered to be absolute values whose magnitude applies both positively and negatively to the experimental k_{eff}, as shown in Tables 2.1-45 and 2.1-46. Negative signs are retained in other tables in Section 2, where the effective uncertainty is reported for a given uncertainty perturbation, to demonstrate whether the effect in k_{eff} was directly or indirectly proportional to the uncertainty.

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[a] X-5 Monte Carlo Team, "MCNP – a General Monte Carlo n-Particle Transport Code, version 5," LA-UR-03-1987, Los Alamos National Laboratory (2003).
[b] M. B. Chadwick, et al., "ENDF/B-VII.0: Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology," *Nucl. Data Sheets*, **107**: 2931-3060 (2006).
[c] D. Mennerdahl, "Statistical Noise for Nuclear Criticality Safety Specialists," *Trans. Am. Nucl. Soc.*, **101**: 465-466 (2009).

Evaluated uncertainties ≤0.00010 are considered negligible because their calculated worth is within the statistical uncertainty of the Monte Carlo approach being utilized.

Elemental data such as molecular weights and isotopic abundances were taken from the 16th edition of the Chart of the Nuclides.[a] These values are summarized in Appendix E.

Milling and finishing of the graphite components to tight tolerances would be necessary to fit all the components of this assembly together. Small dimensional inconsistencies would result in increased void fractions between graphite components. The effect of these void fractions would be minor compared to the uncertainty in graphite density. The dimensions of some of the graphite parts used in this experiment series are often recorded with many significant digits. While the number of significant digits may not always represent the accuracy or precision of their respective measured value, it is assumed by the evaluator that an uncertainty of ±1 in the last reported significant digit should be adequate in evaluating the uncertainty in reported graphite dimensions. Similar discussion of tight manufacturing tolerances and the resultant small or negligible uncertainties can be found in other gas-cooled thermal reactor benchmarks (HTTR-GCR-RESR-001, -002, -003, and HTR10-GCR-RESR-001).

The total evaluated uncertainty in k_{eff} for this experiment is provided in Section 2.1.11; individual uncertainties are summed under quadrature to obtain the total uncertainty in the experimental k_{eff}.

When evaluating parameters such as measured diameters, heights, and mass, all parts of a given type are perturbed at the same time: e.g., the uranium mass in all fuel pebbles is simultaneously increased or decreased. Then the calculated uncertainty is reduced by the square root of the number of components perturbed, representative of a random uncertainty. For many of these uncertainties, there is insufficient information available to evaluate what portion of the total evaluated uncertainty is systematic instead of random. All uncertainties involving the perturbation of multiple assembly components are treated as 15% systematic in this evaluation, unless otherwise specified.

This assumption provides a basic prediction of the effect on k_{eff}. Most systematic uncertainties should be below 50 % of the total uncertainty and above the historic approach of ignoring the unknown systematic components (i.e., treat it with a 0 % probability). In actuality, careful experimenters may have an unknown systematic uncertainty that is approximately 10-15 % of their total reported uncertainty. Because significant effort had gone into the development of benchmark quality HTR-PROTEUS experiments, a systematic uncertainty of 15 % is assumed. Evaluated uncertainties are listed as calculated, such that the readers may themselves adjust results according to some desired systematic-to-random uncertainty ratio.

The following evaluated uncertainties would have both systematic and random uncertainties (Table 2.1-1). Many of these uncertainties are negligible without adjusting the computed value to account for multiple assembly components (i.e., treating the uncertainty as 100 % systematic is still negligible). The systematic and random components are only evaluated in more detail when the evaluated uncertainty (assuming 100 % systematic) is not negligible (>0.00010).

[a] E. M. Baum, H. D. Knox, and T. R. Miller, *Nuclides and Isotopes: 16th Edition*, Knolls Atomic Power Laboratory (2002).

Table 2.1-1. Summary of Uncertainties with Systematic and Random Components.

• Radial Reflector – C-Driver Positions – C-Driver Hole Diameter – ZEBRA Rod Hole Positions – ZEBRA Rod Hole Diameter – ZEBRA Hole Filler Diameter – ZEBRA Hole Filler Length – Safety/Shutdown Rod Positions – Safety/Shutdown Rod Hole Diameter – C-Driver Plug Diameter – C-Driver Plug Length • Upper Axial Reflector – Coolant Channel Positions – Coolant Channel Diameter – Plug Diameter – Plug Length • Lower Axial Reflector – Coolant Channel Positions – Coolant Channel Diameter – Plug Diameter – Plug Length • Safety/Shutdown Rods – Borated Steel Rod Diameter – Borated Steel Rod Length – Steel Tube Diametrical Thickness – Steel Tube Length	• Fuel Pebbles – Kernel Radius – Buffer Thickness – IPyC Thickness – SiC Thickness – OPyC Thickness – Fuel Zone Radius – Pebble Radius – Total Uranium Mass – Total Carbon Mass • Moderator Pebbles – Radius – Mass • Graphite Fillers – Axial Modifier Thickness – Axial Modifier Height • Stainless Steel Control Rods – Inner Tube Diametrical Thickness – Outer Tube Diametrical Thickness – Length of Tubes and End Plugs • Polyethylene Rods – Diameter – Length • Measurements – Safety/Shutdown Rod Positions – Withdrawable Control Rod Positions – Core Height

2.1.1 Streamlining the Uncertainty Analysis

A comprehensive uncertainty analysis was performed for the initial HTR-PROTEUS configurations, Cores 1, 1A, 2, and 3 (PROTEUS-GCR-EXP-001). The evaluated uncertainty for many of the perturbed parameters were determined to be negligible ($\leq$0.00010 Δk), resulting in a much shorter list of uncertainties actually contributing to the total uncertainty (see Section 2.1.22 of PROTEUS-GCR-EXP-001). A summary of negligible uncertainties pertinent to the current benchmark configurations is provided in Table 2.1-2; these uncertainties were not evaluated as their contribution to the total uncertainty in the benchmark configurations is judged to be negligible. Table 2.1-3 contains a list of uncertainties that are individually evaluated in this report. Uncertainties relating to the ZEBRA control rods and associated holes were not evaluated as they were only pertinent in Core 1. Uncertainties in the polyethylene rod diameter, length, and impurity content were included in this analysis because Core 10 contains significantly more polyethylene rods than Core 3.

Table 2.1-2. Summary of Negligible Uncertainties Not Evaluated for Cores 9 and 10.

• Concrete – Thickness – Density – Composition • Steel Plate Pedestal – Thickness – Density – Composition • Radial Reflector – Inner Diameter – Outer Diameter – Height – C-Driver Hole Positions – C-Driver Hole Diameter – Autorod Hole Position – Autorod Hole Diameter – ZEBRA Rod Hole Positions – ZEBRA Rod Hole Diameter – ZEBRA Hole Filler Diameter – ZEBRA Hole Filler Length – ZEBRA Hole Filler Density – ZEBRA Hole Filler Impurity Content – Safety/Shutdown Rod Positions – Safety/Shutdown Rod Hole Diameter – Thermal Column Width – Thermal Column Depth – Thermal Column Height – Safety Ring Vertical Thickness – Safety Ring Diametrical Thickness – Safety Ring Density – C-Driver Plug Diameter – C-Driver Plug Length – C-Driver Plug Impurities • Upper Axial Reflector – Cylinder Diameter – Annulus Inner Diameter – Annulus Outer Diameter – Annulus Geometry – Height – Graphite Mass – Graphite Impurity Content – Coolant Channel Positions – Coolant Channel Diameter – Plug Diameter – Plug Length – Plug Density – Plug Impurity Content – Aluminum Density	• Lower Axial Reflector – Annulus Inner Diameter – Annulus Outer Diameter – Cylinder Density – Cylinder Impurity Content – Coolant Channel Positions – Coolant Channel Diameter – Plug Diameter – Plug Length – Plug Density – Plug Impurity Content – Source Position Diameter – Source Position Length – Source Plug Diameter – Source Plug Length – Source Plug Density – Source Plug Impurity Content • Safety/Shutdown Rods – Borated Steel Rod Diameter – Borated Steel Rod Length – Borated Steel Density – Boron Content of Borated Steel – Borated Steel Composition – Steel Tube Diametrical Thickness – Steel Tube Length – Steel Tube Density – Steel Tube Composition – Shock Damper Dimensions – Shock Damper Mass – Shock Damper Composition • Autorod – Copper Wedge Length – Copper Wedge Density – Copper Wedge Composition – Tube Thickness – Tube Length – Tube Density – Tube Composition

Table 2.1-2. (cont'd.). Summary of Negligible Uncertainties Not Evaluated for Cores 9 and 10.

• Fuel Pebbles – Quantity of Pebbles – Pebble Packing Fraction – Pebble Random Packing – Buffer Thickness – IPyC Thickness – SiC Thickness – OPyC Thickness – Fuel Zone Radius – Pebble Radius – ^{236}U Isotopic Content – ^{238}U Isotopic Content – Total Carbon Mass – Total Pebble Mass – Kernel Density – Buffer Density – IPyC Density – SiC Density – OPyC Density – Kernel Impurity Content – Buffer Impurity Content – IPyC Impurity Content – SiC Impurity Content – OPyC Impurity Content	• Moderator Pebbles – Quantity of Pebbles – Radius • Graphite Fillers – Axial Modifier Thickness – Axial Modifier Height – Axial Modifier Mass • Stainless Steel Control Rods – Inner Tube Diametrical Thickness – Outer Tube Diametrical Thickness – Length of Tubes and End Plugs – Inner Tube Density – Outer Tube Density – Inner Tube Composition • Measurements – Measurement of k_{eff} – Autorod Position – Safety/Shutdown Rod Positions – Withdrawable Control Rod Positions – Temperature • Ambient Air – Temperature – Pressure – Humidity • Isotopic Abundance of Boron

Table 2.1-3. Summary of Uncertainties Evaluated for Cores 9 and 10.

• Radial Reflector – Density – Impurity Content – Safety Ring Composition – C-Driver Plug Density • Upper Axial Reflector – Location – Aluminum Support Structure Dimensions – Aluminum Composition • Lower Axial Reflector – Cylinder Diameter – Height – Annulus Density – Annulus Impurity Content • Autorod – Copper Wedge Thickness – Orientation of Copper Wedge • Fuel Pebbles – TRISO Random Packing – Kernel Radius – ^{234}U Isotopic Content – ^{235}U Isotopic Content – Pebble Uranium Mass – Fueled Zone Impurity Content – Unfueled Zone Impurity Content – Pebble Water Content – Oxygen-to-Uranium Ratio	• Moderator Pebbles – Mass – Impurity Content – Water Content • Stainless Steel Control Rods – Outer Tube Composition • Polyethylene Rods – Diameter – Length – Density – H:C Ratio – Impurity Content • Measurements – Stacked Pebble Height

2.1.2 Radial Reflector

2.1.2.1 Graphite Density

The graphite for the majority of the system, which includes much of the radial reflector and thermal column, was reported to have a density of 1.76 ± 0.01 g/cm^3 (Table 1.1-6), obtained from reactor-based measurements. Measurement of 28 graphite samples resulted in an apparent average density of 1.763 ± 0.012 g/cm^3. A value of 1.76 ± 0.012 g/cm^3 (1σ) was selected to represent the graphite utilized in the radial reflector and thermal column, using the reported average density from the construction of the assembly and the larger uncertainty obtained from apparent density measurements. All graphite (excluding pebbles) used in the HTR-PROTEUS experiments are assumed to have the same density uncertainty unless otherwise specified.

The density of the radial reflector surrounding the core, and the thermal column, was 1.76 g/cm^3. The uncertainty in the density was 0.012 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.036 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in the density of the radial reflector. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-4.

Table 2.1-4. Effect of Uncertainty in Graphite Density.

Case (Core)	**Deviation**	Δk_p	±	$\sigma_{\Delta kp}$	**Scaling Factor**	Δk_{eff} **(1σ)**	±	$\sigma_{\Delta keff}$
1 (9)	±0.036 g/cm^3	0.00306	±	0.00005	3	0.00102	±	0.00002
2 (10)	±0.036 g/cm^3	0.00244	±	0.00004	3	0.00081	±	0.00001

2.1.2.2 Graphite Impurities

Various values were reported for the nominal absorption cross section or boron content for the graphite material used in the core (Table 1.1-6). Subtraction of the absorption cross section of graphite (~3.5 mbarn/atom) allows for estimation of the equivalent boron content (EBC) using nominal boron data (3,840,000 mbarn/atom ^{10}B, 19.9 % ^{10}B in B_{nat}).[a] These values, however, are low since they do not account for the water or air content absorbed into the graphite. Table 1.1-7 with its accompanying text provides some insight into the evaluated water content. Pulsed neutron source measurements were performed to obtain global impurity measurements for the entire core that included moisture content and intergranular nitrogen from the air. These measurements were performed in the empty PROTEUS graphite reflectors and were initially evaluated using diffusion theory.[b] Later Monte Carlo methods were used to evaluate the measured data to provide a nominal ^{10}B concentration of 2.69 ± 0.16 (assumed units of mbarn/atom), which corresponds to 0.2696 and 0.2591 ppma in the radial and axial reflectors, respectively.[c] The average EBC is 1.33 ppm (by at.%). The uncertainty in the initial reported concentration (±0.16 mbarn/atom) is propagated to obtain an uncertainty in the EBC of ±0.08 ppma (1σ). All graphite (excluding pebbles) used in the HTR-PROTEUS experiments are assumed to have the same impurity content and uncertainty unless otherwise specified.

The impurity content of the radial reflector surrounding the core and the thermal column was 1.33 ppm (EBC by atom percent). The uncertainty in the impurity content was 0.08 ppma (1σ). A double-sided perturbation was performed in which the impurity content was perturbed by ±0.24 ppma to estimate the uncertainty in k_{eff} due to the uncertainty in the impurity content of the radial reflector. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-5.

Table 2.1-5. Effect of Uncertainty in Graphite Impurity Content.

Case (Core)	**Deviation**	Δk_p	±	$\sigma_{\Delta kp}$	**Scaling Factor**	Δk_{eff} **(1σ)**	±	$\sigma_{\Delta keff}$
1 (9)	±0.24 ppma	-0.00340	±	0.00005	3	-0.00113	±	0.00002
2 (10)	±0.24 ppma	-0.00240	±	0.00004	3	-0.00080	±	0.00001

[a] E. M. Baum, H. D. Knox, and T. R. Miller, *Nuclides and Isotopes: 16th Edition*, Knolls Atomic Power Laboratory (2002).
[b] Williams, T., Mathews, D., and Yamane, T., "Measurement of the Absorption Properties of the HTR-PROTEUS Reflector Graphite by Means of a Pulsed-Neutron Technique," TM-41-93-34, Paul Scherrer Institut, Villigen, October 3, 1995.
[c] Difilippo, F. C., "Applications of Monte Carlo Simulations of Thermalization Processes to the Nondestructive Assay of Graphite," *Nucl. Sci. Eng.*, **133**, 163-177 (1999).

2.1.2.3 Safety Ring Composition

The composition specifications for Peraluman-300 is provided in Table 1.1-8. The composition values listed as less than a given value are taken at half this maximum value in the nominal material composition. The aluminum content is adjusted such that the total composition adds up to 100%. The nominal composition used for evaluation of the uncertainty in the composition of the safety ring is in Table 2.1-6.

A double-sided perturbation was performed in which the plate composition was perturbed by minimizing and maximizing the aluminum content in the Peraluman, while simultaneously maximizing or minimizing the other elemental constituents within the specified limits, to estimate the uncertainty in k_{eff} due to the uncertainty in the safety ring composition. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty assuming a bounding limit with uniform probability distribution. Results are shown in Table 2.1-7.

Table 2.1-6. Composition of the Peraluman-300.

Element	Minimum wt.%	Maximum wt.%	Nominal wt.%	Nominal Atoms/barn-cm
B	--	0.001	0.0005	7.3807E-07
Mg	--	3.1	1.55	1.0177E-03
Al	Balance		97.344	5.7575E-02
Si	0.4	0.4	0.4	2.2729E-04
Mn	--	0.5	0.25	7.2621E-05
Fe	0.3	0.3	0.3	8.5730E-05
Cu	0.05	0.05	0.05	1.2557E-05
Zn	0.1	0.1	0.1	2.4398E-05
Ga	--	0.01	0.005	1.1444E-06
Cd	--	0.001	0.0005	7.0983E-08
Total	--	--	100	5.9018E-02

Table 2.1-7. Effect of Uncertainty in Safety Ring Composition.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	Min/Max Al	0.00021	±	0.00005	√3	0.00012	±	0.00003
2 (10)	Min/Max Al	0.00004	±	0.00004	√3	0.00002	±	0.00002

2.1.2.4 C-Driver Plug Density

The C-Driver plugs were reported in Table 1.1-6 to have a density of 1.75 ± 0.007 g/cm^3 in ~50 % of the channels (inner rings) and 1.78 g/cm^3 in ~50% of the channels (outer rings). There is no clear designation how a 50:50 split is managed for an odd number of rings. Therefore an average density of 1.765 g/cm^3 is used for all 311 C-Driver plugs. A total of 308 plugs were reported as being placed in the reflector since some were removed for core instrumentation; however, the exact location of the removed plugs is unknown. Additional uncertainty due to the evaluation of the density of three additional plugs is assumed to be negligible. It is assumed that the measured density uncertainty of 0.012 g/cm^3 (1σ), discussed in Section 2.1.2.1, sufficiently encompasses the uncertainty in the new graphite density. The reported density range of 1.75 to 1.78 g/cm^3 for the new graphite is reported to be consistent with the old graphite. This range is encompassed by the 3σ uncertainty.

The density of the C-Driver plugs within the radial reflector surrounding the core was 1.765 g/cm^3. The uncertainty in the density was 0.012 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.036 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in the density of the C-Driver plugs. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-8. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-8. Effect of Uncertainty in C-Driver Plug Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	±0.036 g/cm^3	0.00028	±	0.00005	3	0.00009	±	0.00002
2 (10)	±0.036 g/cm^3	0.00023	±	0.00004	3	0.00008	±	0.00001

2.1.3 Upper Axial Reflector

2.1.3.1 Location above Core

The bottom surface of the graphite in the upper axial reflector is located 1893 mm above the top surface of the lower axial reflector, creating a core cavity with a height of 1893 mm. This value is obtained by calculating the difference between reported heights in Figure 1.1-1. Elsewhere it has been reported that this height is 1863 mm.[a] It is believed that this latter value was reported incorrectly. The suspended position of the upper axial reflector was measured to within 3 to 5 mm.[b]

The location of the upper axial reflector above the inside bottom of the core cavity is 1893 mm. The uncertainty in this location was assumed to be 5 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the location was perturbed by ±15 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the location of the upper axial reflector. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-9.

Table 2.1-9. Effect of Uncertainty in the Location of the Upper Axial Reflector.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	±15 mm	-0.00078	±	0.00005	$3\sqrt{3}$	-0.00015	±	0.00001
2 (10)	±15 mm	-0.00040	±	0.00004	$3\sqrt{3}$	-0.00008	±	0.00001

[a] Difilippo, F. C., “Monte Carlo Calculations of Pebble Bed Benchmark Configurations of the PROTEUS Facility,” *Nucl. Sci. Eng.*, **143**, 240-253 (2003).
[b] Personal communication with Oliver Köberl at PSI (October 26, 2011).

2.1.3.2 Aluminum Dimensions

A detailed model was prepared (see Appendix C) where the aluminum support structure for the upper axial reflector (see Figures 1.1-4 and 1.1-6) was included with the geometry and dimensions modeled as identical as possible to those provided in the figures. Components of the aluminum support structure were included below the upper surface of the upper axial reflector. Uncertainty in the exact geometry is assumed to be negligible since the effective bias for compacting the curved surface below the graphite components of the reflector was negligible (see Section 3.1.1.1). An uncertainty was assumed of 1 mm in the thickness of all aluminum sheet material used to manufacture the structural support for the upper axial reflector. Due to the difficulty in exactly modeling the dimensions of all aluminum components, this uncertainty is treated as systematic and total aluminum mass was not conserved.

The uncertainty in dimensions of the aluminum support structure was assumed to be 1 mm (bounding limit with uniform probability distribution). A single-sided perturbation was performed in which all thicknesses were simultaneously decreased by 2 mm (material replaced by void) to estimate the uncertainty in k_{eff} due to the uncertainty in the dimensions of the aluminum support structure. The calculated results were then scaled to obtain the 1σ uncertainty. The total mass of the aluminum was not conserved. Results are shown in Table 2.1-10.

Table 2.1-10. Effect of Uncertainty in Aluminum Dimensions.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	-2 mm	-0.00250	±	0.00010	2√3	-0.00072	±	0.00003
2 (10)	-2 mm	-0.00159	±	0.00008	2√3	-0.00046	±	0.00002

2.1.3.3 Aluminum Composition

The composition specifications for Peraluman-300 is provided in Table 1.1-8. The composition values listed as less than a given value are taken at half this maximum value in the nominal material composition. The aluminum content is adjusted such that the total composition adds up to 100 %. The nominal composition used for evaluation of the uncertainty in the composition of the safety ring is in Table 2.1-6.

A double-sided perturbation was performed in which the plate composition was perturbed by minimizing and maximizing the aluminum content in the Peraluman, while simultaneously maximizing or minimizing the other elemental constituents within the specified limits, to estimate the uncertainty in k_{eff} due to the uncertainty in the composition of the aluminum support structure for the upper axial reflector. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty assuming a bounding limit with uniform probability distribution. Results are shown in Table 2.1-11.

Table 2.1-11. Effect of Uncertainty in Support Structure Composition.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	Min/Max Al	0.00067	±	0.00005	√3	0.00039	±	0.00003
2 (10)	Min/Max Al	0.00042	±	0.00004	√3	0.00024	±	0.00002

2.1.4 Lower Axial Reflector

2.1.4.1 Central Cylinder Diameter

The diameter of the central graphite cylinder of the lower axial reflector was 495 mm. The uncertainty in the diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A one-sided perturbation was performed in which the diameter was perturbed by -2 mm to estimate the uncertainty in k_{eff} due to the uncertainty in diameter of the graphite cylinder. The calculated results were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-12. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-12. Effect of Uncertainty in Central Cylinder Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	-2 mm	0.00017	±	0.00010	2√3	0.00005	±	0.00003
2 (10)	-2 mm	-0.00005	±	0.00008	2√3	-0.00001	±	0.00002

2.1.4.2 Height

The lower axial reflector (see Figure 1.1-7) has penetrations, many of which filled with graphite plugs, that penetrate axially the full length of the graphite. All holes and associated plugs are perturbed along with the perturbation in the total height of the radial reflector. Any additional uncertainty or correlation effects are assumed to be negligible.

The height of the lower axial reflector was 780 mm. The uncertainty in the height was assumed to be 1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the height was perturbed by ±3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the height of the lower axial reflector. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-13. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-13. Effect of Uncertainty in Height.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	±3 mm	-0.00001	±	0.00005	3√3	<0.00001	±	0.00001
2 (10)	±3 mm	0.00007	±	0.00004	3√3	0.00001	±	0.00001

2.1.4.3 Annulus Density

Old graphite was used for the annulus of the lower axial reflector (Table 1.1-6) with a reported density of 1.76 ± 0.01 g/cm^3. It is assumed that the measured density uncertainty of 0.012 g/cm^3 (1σ), discussed in Section 2.1.2.1, sufficiently describes the uncertainty in the graphite density of the lower axial reflector.

The density of the annulus of the lower axial reflector was 1.76 g/cm^3. The uncertainty in the density was 0.012 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.036 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in the density of the annulus of the lower axial reflector. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-14.

Table 2.1-14. Effect of Uncertainty in Annulus Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	±0.036 g/cm^3	0.00038	±	0.00005	3	0.00013	±	0.00002
2 (10)	±0.036 g/cm^3	0.00028	±	0.00004	3	0.00009	±	0.00001

2.1.4.4 Annulus Impurities

It is assumed that the EBC of 1.33 ± 0.08 ppm (by wt.%), discussed in Section 2.1.2.2, sufficiently described the impurity content in the central annulus of the lower axial reflector.

The impurity content of the annulus of the lower axial reflector was 1.33 ppm (EBC by atom percent). The uncertainty in the impurity content was 0.08 ppma (1σ). A double-sided perturbation was performed in which the impurity content was perturbed by ±0.24 ppma to estimate the uncertainty in k_{eff} due to the uncertainty in the impurity content of the annulus. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-15.

Table 2.1-15. Effect of Uncertainty in Annulus Impurity Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	±0.24 ppma	-0.00038	±	0.00005	3	-0.00013	±	0.00002
2 (10)	±0.24 ppma	-0.00032	±	0.00004	3	-0.00011	±	0.00001

2.1.5 Autorod

2.1.5.1 Copper Thickness

The thickness of the copper was 3 mm (Figure 1.1-10). The uncertainty in the thickness was assumed to be 1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the thickness was perturbed by ±3 mm (where -3mm would represent the condition of no autorod copper being present in the core) to estimate the uncertainty in k_{eff} due to the uncertainty in the thickness of the copper. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-16. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-16. Effect of Uncertainty in Copper Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	±3 mm	-0.00048	±	0.00005	$3\sqrt{3}$	-0.00009	±	0.00001
2 (10)	±3 mm	-0.00034	±	0.00004	$3\sqrt{3}$	-0.00006	±	0.00001

2.1.5.2 Orientation

The orientation of the copper wedge in the autorod compared to the core center was not reported. It is assumed to be parallel to the y-axis in the benchmark model. A single-sided perturbation was performed in which the orientation of the autorod was rotated by 90° (parallel to the x-axis) to estimate the uncertainty in k_{eff} due to the uncertainty in the orientation of the copper. The calculated results were then scaled to obtain the 1σ uncertainty assuming a bounding limit with uniform probability distribution. Results are shown in Table 2.1-17.

Table 2.1-17. Effect of Uncertainty in Copper Orientation.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	Rotate 90°	0.00019	±	0.00010	√3	0.00011	±	0.00006
2 (10)	Rotate 90°	-0.00003	±	0.00008	√3	-0.00002	±	0.00005

2.1.6 Fuel Pebbles

2.1.6.1 Quantity of Pebbles

Exact quantities of fuel and moderator pebbles were placed in the cores. There is no associated uncertainty. The number of fuel pebbles reported for each core configuration is summarized in Table 2.1-18.

Table 2.1-18. Number of Fuel Pebbles.

Case (Core)	# Fuel Pebbles
1 (9)	4870
2 (10)	4332

2.1.6.2 Pebble Packing Fraction

The theoretical packing fraction for an infinite columnar hexagonal point-on-point (CHPOP) packed configuration is 0.6046.[a] The packing fraction for each core configuration was computed by taking the total volume of pebbles within the core cavity (assumed diameter of 6.000 cm apiece) and dividing by the total core volume within the 12-sided region of the cavity and the pebble stack height. The packing fraction is approximately 58 vol.%, due to additional void space at the core/reflector interface. The pebbles were placed in exact positions, there is small uncertainty in the packing fraction due to the small uncertainties in the diameters of the pebbles and dimensions of the graphite reflector. This uncertainty is evaluated as part of Section 2.1.10.1.

[a] Difilippo, F. C., "Monte Carlo Calculations of Pebble Bed Benchmark Configurations of the PROTEUS Facility," *Nucl. Sci. Eng.*, **143**, 240-253 (2003).

Table 2.1-19. Pebble Packing Fraction.

Case (Core)	Total # Pebbles	Pebble Volume (m^3)	Pebble Stack Height (m)	Core Volume (m^3)	Packing Fraction (vol.%)[(a)]
1 (9)	9747	~1.1024	1.62	~1.8893	~58.35
2 (10)	8664	~0.9799	1.44	~1.6793	~58.35

(a) An infinite columnar hexagonal point-on-point packed lattice has a theoretical filling factor of 0.6046.

2.1.6.3 TRISO Random Packing

Each fuel pebble was reported to contain 9394 TRISO particles (Figure 1.1-14); this value was most probably derived from knowledge of the total mass of uranium per fuel pebble. The exact quantity of TRISO particles may vary between pebbles; however, the uncertainty in the exact quantity of TRISO particles is directly correlated with the uncertainty in fuel mass per pebble, and evaluated in Section 2.1.6.7.

The TRISO particles are randomly located within the fueled zone of each fuel pebble. To investigate the effective uncertainty in TRISO particle placement within the fuel pebbles, TRISO particles were modeled within a lattice structure (see Figure 4.1-1 with associated textual discussion) and the URAN card in MCNP5 was used to simulate the random particle displacement.[a] Care was taken to ensure that the fuel kernels of the TRISO particles (but not the graphite layers) were not truncated by the boundary of the fueled region. The resultant k_{eff} value calculated in this manner was compared against a similar case in which the random positioning of particles was not enabled. Results are shown in Table 2.1-20. The uncertainty is small and approximately at the 2σ statistical uncertainty for Core 10 and negligible in Core 9.

Table 2.1-20. Effect of Uncertainty in TRISO Random Packing.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	Random Particle Placement	-0.00002	±	0.00010	1	-0.00002	±	0.00010
2 (10)	Random Particle Placement	-0.00015	±	0.00008	1	-0.00015	±	0.00008

2.1.6.4 Kernel Radius

The radius of the TRISO kernel was 0.02510 cm (Table 1.1-1). The uncertainty in the radius was 0.0006 cm (1σ). A double-sided perturbation was performed in which the radius was perturbed by ±0.0015 cm to estimate the uncertainty in k_{eff} due to the uncertainty in the radius of the TRISO kernel. Uranium mass was conserved. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-21.

The calculated Δk_{eff} uncertainty was adjusted to account for random and systematic components of the total uncertainty. The systematic component is assumed to represent 15 % of the total uncertainty; the random component is negligible due to the perturbation of a large quantity of objects. The final adjusted Δk_{eff} uncertainty is therefore only the preserved systematic uncertainty. The calculated uncertainty is negligible (≤0.00010).

[a] X-5 Monte Carlo Team, "MCNP – a General Monte Carlo n-Particle Transport Code, version 5, Volume II: User's Guide" LA-CP-03-0245, Los Alamos National Laboratory (2003).

Table 2.1-21. Effect of Uncertainty in UO_2 Kernel Radius.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (9)	±0.0015 cm	-0.00079	±	0.00005	2.5	-0.00032	±	0.00002	-0.00005
2 (10)	±0.0015 cm	0.00030	±	0.00004	2.5	0.00012	±	0.00002	0.00002

2.1.6.5 Isotopic Content (Mass) ^{234}U

The mass and uncertainty of each uranium isotope in a fuel pebble was reported in Table 1.1-1. The isotopic content of the fuel would have been measured and the mass of each isotope calculated based upon the total uranium mass within each pebble. The isotopic content (in wt.%) of each isotope was computed for both the uranium metal and UO_2 fuel kernel (see Table 2.1-22).

The mass of ^{234}U reported was 0.008 g per pebble (Table 1.1-1). The uncertainty in the ^{234}U mass was 0.001 g (~0.017 wt.%, 1σ). A double-sided perturbation was performed in which the ^{234}U mass was perturbed by ±0.003 g (~0.050 wt.%) to estimate the uncertainty in k_{eff} due to the uncertainty in the isotopic content of ^{234}U. To conserve total uranium mass, the ^{238}U mass was adjusted. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-23.

Table 2.1-22. Isotopic Composition of Uranium.

Isotope/Element	Mass (g)	Uranium Metal Composition (wt.%)	UO_2 Composition (wt.%)
^{234}U	0.008	0.134	0.118
^{235}U	1.000	16.762	14.77
^{236}U	0.005	0.084	0.074
^{238}U	4.953	83.020	73.155
O	--	--	11.87
Impurities	--	--	0.013
Total	5.966	100.000	100.000

Table 2.1-23. Effect of Uncertainty in the ^{234}U content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	±0.003 g (~0.050 wt.%)	-0.00056	±	0.00005	3	-0.00019	±	0.00002
2 (10)	±0.003 g (~0.050 wt.%)	-0.00041	±	0.00004	3	-0.00014	±	0.00001

2.1.6.6 Isotopic Content (Mass) ^{235}U

See discussion in Section 2.1.6.5 regarding the isotopic content of the uranium fuel.

The mass of ^{235}U reported was 1.000 g per pebble (Table 1.1-1). The uncertainty in the ^{235}U mass was 0.010 g (~0.17 wt.%, 1σ). A double-sided perturbation was performed in which the ^{235}U mass was perturbed by ±0.030 g (~0.50 wt.%) to estimate the uncertainty in k_{eff} due to the uncertainty in the isotopic content of ^{235}U. To conserve total uranium mass, the ^{238}U mass was adjusted. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-24.

Table 2.1-24. Effect of Uncertainty in the ^{235}U Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	±0.030 g (~0.50 wt.%)	0.00786	±	0.00005	3	0.00262	±	0.00002
2 (10)	±0.030 g (~0.50 wt.%)	0.00937	±	0.00004	3	0.00312	±	0.00001

2.1.6.7 Uranium Mass

Table 1.1-1 reports a mass uncertainty in the fuel of ±0.060 g, which appears to be a sum of the uncertainties in the ^{235}U and ^{238}U masses and equates to a mass density uncertainty in the UO_2 fuel of approximately 0.11 g/cm^3. However, this table also reports the uncertainty in the UO_2 density as ±0.04 g/cm^3, almost a factor of 3 smaller. The table has footnotes for some of the uncertainties to explain the confidence level of the measured parameters; however, no additional information is provided for the uranium fuel mass or UO_2 density. A fuel mass of 5.966 g (UO_2 density of 10.88 g/cm^3) was selected for the fuel kernels and the larger uncertainty of 0.060 g (0.11 g/cm^3) selected to represent the 1σ uncertainty in the uranium mass.

The total mass of uranium per fuel pebble was 5.966 g (Table 1.1-1). The uncertainty in the mass was 0.060 g (0.068 g UO_2, 0.11 g/cm^3, 1σ). A double-sided perturbation was performed in which the uranium dioxide density was perturbed by ±0.12 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in the uranium mass per fuel pebble. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. The radius of the UO_2 kernels and the oxygen-to-uranium ratio was held constant. Results are shown in Table 2.1-25.

The calculated Δk_{eff} uncertainty was adjusted to account for random and systematic components of the total uncertainty. The systematic component is assumed to represent 15 % of the total uncertainty; the random component is negligible due to the perturbation of a large quantity of objects. The final adjusted Δk_{eff} uncertainty is therefore only the preserved systematic uncertainty.

Table 2.1-25. Effect of Uncertainty in the Fuel Pebble Uranium Mass.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor(a)	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (9)	±0.065 g (0.12 g/cm^3)	0.00245	±	0.00005	12/11	0.00225	±	0.00005	0.00034
2 (10)	±0.065 g (0.12 g/cm^3)	0.00308	±	0.00004	12/11	0.00282	±	0.00004	0.00042

(a) The scaling factor converts the perturbation uncertainty of 0.12 g/cm^3, which represents the reported 3σ uncertainty in the UO_2 mass density to the 0.11 g/cm^3 1σ uncertainty in the mass density based upon the reported uncertainty in the uranium mass measurements.

2.1.6.8 Fueled Zone Impurities

The reported impurity content for the fuel pebbles is listed in Table 1.1-13. The composition values listed as less than a given value are taken at half this maximum value in the nominal material composition. The fueled zone composition (graphite region within the pebble surrounding the TRISO particles) is adjusted such that the total composition adds up to 100 %. The nominal impurity content used for evaluation of the uncertainty in the fueled zone impurities is in Table 2.1-26.

The nominal fueled zone impurity content is shown in Table 2.1-26. The selected uncertainty in each impurity was 50 % of the nominal value (1σ). A double-sided perturbation was performed in which all impurities were simultaneously perturbed by ±50 % to estimate the uncertainty in k_{eff} due to the uncertainty in the fueled zone impurity content. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty.

The scaling factor was obtained by first determining the equivalent boron content (EBC) of each impurity based upon their concentration in the graphite and their respective ASTM EBC factor.[a] The ratio of the equivalent boron content for each individual impurity to the total EBC was calculated; most ratios were small compared to the dominant impurities of boron (~41 %) and lithium (~30 %). Sample perturbations were performed to confirm that perturbations of the dominant impurities produced uncertainties in k_{eff}, divided by the total uncertainty obtained by perturbing all impurities simultaneously, would produce ratios approximately equal to the EBC ratios. The EBC ratios for all the graphite impurities were combined taking the square root of the sum of the squares to obtain a scaling factor of 53 %, which is needed to convert the additive perturbation of impurity content into one representing the quadrative summation expected for perturbing each impurity individually by 50 %. Results are shown in Table 2.1-27.

[a] ASTM C1233-03, "Standard Practice for Determining Equivalent Boron Contents of Nuclear Materials," ASTM International, West Conshohocken, PA (2009).

Table 2.1-26. Fuel Pebble Impurities.

Element	Minimum ppm (wt.%)	Maximum ppm (wt.%)	Nominal ppm (wt.%)
Ag	--	0.2	0.1
B	0.101	0.101	0.101
Ca	9.28	9.28	9.28
Cd	--	0.103	0.0515
Cl	--	3	1.5
Co	--	0.13	0.065
Cr	1.81	1.81	1.81
Dy	--	0.01	0.005
Eu	--	0.01	0.005
Fe	2.95	2.95	2.95
Gd	--	0.01	0.005
Li	--	1	0.5
Mn	0.43	0.43	0.43
Ni	--	1	0.5
S	--	0.011	0.0055
Ti	0.497	0.497	0.497
V	--	0.433	0.2165
Total	--	--	18.0215

Table 2.1-27. Effect of Uncertainty in the Fueled Zone Impurities.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	±50 %	-0.00023	±	0.00005	1/0.53	-0.00012	±	0.00003
2 (10)	±50 %	-0.00017	±	0.00004	1/0.53	-0.00009	±	0.00002

2.1.6.9 Unfueled Zone Impurities

The reported impurity content for the fuel pebbles is listed in Table 1.1-13. It is assumed that the unfueled zone impurities are the same as the fueled zone impurities in Section 2.1.6.8. The composition values listed as less than a given value are taken at half this maximum value in the nominal material composition. The unfueled zone composition (graphite shell surrounding the fueled zone of the pebble) is adjusted such that the total composition adds up to 100 %. The nominal impurity content used for evaluation of the uncertainty in the unfueled zone impurities is in Table 2.1-26.

The nominal unfueled zone impurity content is shown in Table 2.1-26. The selected uncertainty in each impurity was 50 % of the nominal value (1σ). A double-sided perturbation was performed in which all impurities were simultaneously perturbed by ±50 % to estimate the uncertainty in k_{eff} due to the uncertainty in the unfueled zone impurity content. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty.

The scaling factor was obtained by first determining the equivalent boron content (EBC) of each impurity based upon their concentration in the graphite and their respective ASTM EBC factor.[a] The ratio of the equivalent boron content for each individual impurity to the total EBC was calculated; most ratios were small compared to the dominant impurities of boron (~41 %) and lithium (~30 %). Sample perturbations were performed to confirm that perturbations of the dominant impurities produced uncertainties in k_{eff}, divided by the total uncertainty obtained by perturbing all impurities simultaneously, would produce ratios approximately equal to the EBC ratios. The EBC ratios for all the graphite impurities were combined taking the square root of the sum of the squares to obtain a scaling factor of 53 %, which is needed to convert the additive perturbation of impurity content into one representing the quadrative summation expected for perturbing each impurity individually by 50 %. Results are shown in Table 2.1-28.

Table 2.1-28. Effect of Uncertainty in the Unfueled Zone Impurities.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	±50 %	-0.00023	±	0.00005	1/0.53	-0.00012	±	0.00003
2 (10)	±50 %	-0.00032	±	0.00004	1/0.53	-0.00017	±	0.00002

2.1.6.10 Water Content

The water content of the moderator pebbles was reported to be 0.01 wt.%. It is assumed that the water content of the fuel pebbles was also 0.01 wt.%. The uncertainty in the water content is also assumed to be 0.01 wt.% (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the water content was perturbed by ±0.01 wt.% to estimate the uncertainty in k_{eff} due to the uncertainty in the fuel pebble water content. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-29.

A second perturbation analysis was performed in PROTEUS-GCR-EXP-001 assessing the uncertainty in the fuel pebble water content if the water was absorbed only within the outer surface of the pebble (depth of 3.5 mm) because dry graphite will obtain water from the surrounding atmosphere. The results from that perturbation analysis were negligible and is assumed to also be negligible for other HTR-PROTEUS core configurations. Because it is unclear how or when water was retained within the pebbles, the larger

[a] ASTM C1233-03, “Standard Practice for Determining Equivalent Boron Contents of Nuclear Materials,” ASTM International, West Conshohocken, PA (2009).

uncertainty, obtained using uniform distribution of water content throughout the pebble, is utilized to represent the total uncertainty in the fuel pebble water content.

Table 2.1-29. Effect of Uncertainty in the Water Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	±0.01 wt.%	0.00018	±	0.00005	√3	0.00011	±	0.00003
2 (10)	±0.01 wt.%	0.00003	±	0.00004	√3	0.00001	±	0.00002

2.1.6.11 Oxygen-to-Uranium Ratio

A nominal oxygen-to-uranium ratio is 2.00. The uncertainty in the ratio was assumed to be 0.01 (1σ). A double-sided perturbation was performed in which the ratio was perturbed by ±0.03 to estimate the uncertainty in k_{eff} due to the uncertainty in the oxygen-to-uranium ratio. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-30.

Table 2.1-30. Effect of Uncertainty in the Oxygen-to-Uranium Ratio.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	±0.03	-0.00039	±	0.00005	3	-0.00013	±	0.00002
2 (10)	±0.03	-0.00048	±	0.00004	3	-0.00016	±	0.00001

2.1.7 Moderator Pebbles

2.1.7.1 Quantity of Pebbles

Exact quantities of fuel and moderator pebbles were placed in the cores. There is no associated uncertainty. The number of moderator pebbles reported for each core configuration is given in Table 2.1-31.

Table 2.1-31. Number of Moderator Pebbles.

Case (Core)	# Moderator Pebbles
1 (9)	4877
2 (10)	4332

2.1.7.2 Mass

The total mass per moderator pebble was 190.54 g (Table 1.1-2). The uncertainty in the mass was 1.44 g (0.013 g/cm^3, 1σ). A double-sided perturbation was performed in which the mass was perturbed by ±4.32 g (0.038 g/cm^3) to estimate the uncertainty in k_{eff} due to the uncertainty in the mass per moderator pebble. The radius of the moderator pebbles was conserved. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-32.

The calculated Δk_{eff} uncertainty was adjusted to account for random and systematic components of the total uncertainty. The systematic component is assumed to represent 15 % of the total uncertainty; the random component is negligible due to the perturbation of a large quantity of objects. The final adjusted Δk_{eff} uncertainty is therefore only the preserved systematic uncertainty.

Table 2.1-32. Effect of Uncertainty in the Moderator Pebble Mass.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (9)	±4.32 g (0.038 g/cm^3)	0.00309	±	0.00005	3	0.00103	±	0.00002	0.00015
2 (10)	±4.32 g (0.038 g/cm^3)	0.00200	±	0.00004	3	0.00067	±	0.00001	0.00010

2.1.7.3 Impurities

The reported impurity content for the moderator pebbles is listed in Table 1.1-14. The composition values listed as less than a given value are taken at half this maximum value in the nominal material composition. The moderator pebble composition is adjusted such that the total composition adds up to 100 %. The nominal impurity content used for evaluation of the uncertainty in the unfueled zone impurities is in Table 2.1-33.

The nominal moderator pebble impurity content is shown in Table 2.1-33. The selected uncertainty in each impurity was 50 % of the nominal value (1σ). A double-sided perturbation was performed in which all impurities were simultaneously perturbed by ±50 % to estimate the uncertainty in k_{eff} due to the uncertainty in the moderator pebble impurity content. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty.

The scaling factor was obtained by first determining the equivalent boron content (EBC) of each impurity based upon their concentration in the graphite and their respective ASTM EBC factor.[a] The ratio of the equivalent boron content for each individual impurity to the total EBC was calculated; most ratios were small compared to the dominant impurities of boron (~47 %), chlorine (~16 %) and gadolinium (~11 %). Sample perturbations were performed to confirm that perturbations of the dominant impurities produced uncertainties in k_{eff}, divided by the total uncertainty obtained by perturbing all impurities simultaneously, would produce ratios approximately equal to the EBC ratios. The EBC ratios for all the graphite impurities were combined taking the square root of the sum of the squares to obtain a scaling factor of 52 %, which is needed to convert the additive perturbation of impurity content into one representing the quadrative summation expected for perturbing each impurity individually by 50 %. Results are shown in Table 2.1-34.

[a] ASTM C1233-03, "Standard Practice for Determining Equivalent Boron Contents of Nuclear Materials," ASTM International, West Conshohocken, PA (2009).

Table 2.1-33. Moderator Pebble Impurities.

Element	Minimum ppm (wt.%)	Maximum ppm (wt.%)	Nominal ppm (wt.%)
B	0.76	0.76	0.76
Ca	129	129	129
Cd	--	0.6	0.3
Cl	18.64	18.64	18.64
Dy	0.065	0.065	0.065
Eu	0.13	0.13	0.13
Fe	5.9	5.9	5.9
Gd	0.040	0.040	0.040
Li	0.88	0.88	0.88
Ni	0.78	0.78	0.78
S	140	140	140
Si	35	35	35
Sm	0.086	0.086	0.086
Ti	10	10	10
V	13	13	13
Total	--	--	354.581

Table 2.1-34. Effect of Uncertainty in the Moderator Pebble Impurities.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	50 %	-0.00318	±	0.00005	1/0.52	-0.00166	±	0.00003
2 (10)	50 %	-0.00296	±	0.00004	1/0.52	-0.00154	±	0.00002

2.1.7.4 Water Content

The water content of the moderator pebbles was reported to be 0.01 wt.%. The uncertainty in the water content was assumed to be 0.01 wt.% (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the water content was perturbed by ±0.01 wt.% to estimate the uncertainty in k_{eff} due to the uncertainty in the moderator pebble water content. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-35. The calculated uncertainty is negligible (≤0.00010).

A second perturbation analysis was performed in PROTEUS-GCR-EXP-001 assessing the uncertainty in the moderator pebble water content if the water was absorbed only within the outer surface of the pebble (depth of 3.5 mm) because dry graphite will obtain water from the surrounding atmosphere. The results from that perturbation analysis were negligible and is assumed to also be negligible for other HTR-PROTEUS core configurations.

Table 2.1-35. Effect of Uncertainty in the Water Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	±0.01 wt.%	0.00012	±	0.00005	√3	0.00007	±	0.00003
2 (10)	±0.01 wt.%	-0.00002	±	0.00004	√3	-0.00001	±	0.00002

2.1.8 Withdrawable Control Rods

2.1.8.1 Outer Tube Composition

The end plugs of the stainless steel control rods are assumed to be manufactured from the same material as the outer tube (St1.4541). There is no significant difference between using this material or the composition of the inner tube (St1.4301).

The composition of the outer steel tube and end plugs was stainless steel Type St1.4541 (see Table 2.1-36). A double-sided perturbation was performed in which the composition was perturbed by minimizing and maximizing the iron content in the steel, while simultaneously maximizing or minimizing the other elemental constituents within the specified limits, to estimate the uncertainty in k_{eff} due to the uncertainty in steel tube composition. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty assuming a bounding limit with uniform probability distribution. Results are shown in Table 2.1-37. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-36. Composition of Stainless Steel St1.4541.

Element	Minimum wt.%	Maximum wt.%	Nominal wt.%
C	--	0.1	0.05
Si	--	1	0.5
Mn	--	2	1
Cr	17	19	18
Ni	9	11.5	10.25
Ti	--	≥wt.%C	0.05
Fe	Balance		70.15
Total	--	--	100

Table 2.1-37. Effect of Uncertainty in Outer Steel Tube Composition.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	Min/Max Fe	-0.00005	±	0.00005	√3	-0.00003	±	0.00003
2 (10)	Min/Max Fe	0.00003	±	0.00004	√3	0.00001	±	0.00002

2.1.9 Polyethylene Rods

2.1.9.1 Diameter

The diameter of the polyethylene rods was 6.5 mm (Figure 1.1-18). The uncertainty in diameter was assumed to be 0.1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the diameter was perturbed by ±0.3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the diameter of the polyethylene rods. Linear density, which is the unit mass per length of rod, was conserved. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-38. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-38. Effect of Uncertainty in the Polyethylene Rod Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	NA	NA			NA	NA		
2 (10)	±0.3 mm	0.00045	±	0.00004	3√3	0.00009	±	0.00001

2.1.9.2 Length

The length of the polyethylene rods was 1450 mm. The uncertainty in length was reported to be 5 mm (assumed to be 1σ). A double-sided perturbation was performed in which the length was perturbed by ±15 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the length of the polyethylene rods. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-39. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-39. Effect of Uncertainty in the Polyethylene Rod Length.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	NA	NA			NA	NA		
2 (10)	±15 mm	-0.00007	±	0.00004	3	-0.00002	±	0.00001

2.1.9.3 Density

The linear density of the polyethylene rods was 0.3161 g/cm (mass density: 0.9526 g/cm^3, Figure 1.1-21). The uncertainty in the linear density was 0.0001 g/cm (0.0003 g/cm^3, 1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.0003 g/cm (0.0009 g/cm^3) to estimate the uncertainty in k_{eff} due to the uncertainty in the density of the polyethylene rods. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-40. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-40. Effect of Uncertainty in the Polyethylene Rod Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	NA	NA			NA	NA		
2 (10)	±0.0003 g/cm (0.0009 g/cm^3)	-0.00001	±	0.00004	3	<0.00001	±	0.00001

2.1.9.4 Hydrogen-to-Carbon Ratio

The hydrogen-to-carbon ratio of the polyethylene rods was 2.03. The uncertainty in the ratio was 0.03 (1σ). A double-sided perturbation was performed in which the ratio was perturbed by ±0.09 to estimate the uncertainty in k_{eff} due to the uncertainty in the hydrogen-to-carbon ratio of the polyethylene rods. The bulk density of the polyethylene rods was conserved. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-41.

Table 2.1-41. Effect of Uncertainty in the Hydrogen-to-Carbon Ratio.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	NA	NA			NA	NA		
2 (10)	±0.09	-0.00037	±	0.00004	3	-0.00012	±	0.00001

2.1.9.5 Impurities

The impurity content of the polyethylene rods was not reported. An EBC of 0.5 ± 0.5 ppm (by wt.%) was assumed to represent a reasonable estimate for the impurity content with its respective uncertainty, and is included in the composition of the polyethylene rods. The effect of impurities in these rods are insignificant compared to the impurity content of the graphite blocks and pebbles, therefore larger contents and uncertainties were not investigated further.

The impurity content of the polyethylene rods was 0.5 ppm (EBC by weight). The uncertainty in the impurity content was 0.5 ppm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the impurity content was perturbed by ±0.5 ppm to estimate the uncertainty in k_{eff} due to the uncertainty in the impurity content of the polyethylene rods. Half of the differences between the calculated upper and lower perturbed values were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-42. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-42. Effect of Uncertainty in the Polyethylene Impurities.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (9)	NA	NA			NA	NA		
2 (10)	±0.5 ppm	0.00001	±	0.00004	1	0.00001	±	0.00004

2.1.10 Experimental Measurements

2.1.10.1 Stacked Pebble Height

The pebbles in Cores 9 and 10 were stacked in CHPOP cells (see Figure 1.0-3) and thus the core height is determined by calculating the height of pebbles stacked directly on top of each other (as reported in Tables 1.1-3 and 1.1-5). The total stack height for each core configuration is provided in Table 2.1-43.

Table 2.1-43. Stacked Pebble Height.

Case (Core)	# Pebble Layers	Stack Height (m)
1 (9)	27	1.62
2 (10)	24	1.44

The uncertainty in the core height is a function of the uncertainty in the diameter of the individual pebbles. The uncertainty in the pebble radii were evaluated separately (see Section 2.1.9.11 and 2.1.10.2 of PROTEUS-GCR-EXP-001) while maintaining the total pebble stack height, effectively increasing or decreasing the packing fraction of each core. The uncertainty in diameter of the pebbles was determined to be negligible. A separate uncertainty analysis was performed in which the core stack height was allowed to vary with the perturbation in pebble diameter to investigate the effect of perturbing the pebble packing fraction.

The uncertainty in core height was ~0.06 % (based on a pebble radius uncertainty of 0.00175 cm). A single-sided perturbation was performed in which the height was increased by ±0.06 % (pebble radii increased by 0.00175 cm) to estimate the uncertainty in k_{eff} due to the uncertainty in the stacked pebble height. Results are shown in Table 2.1-44.

The calculated Δk_{eff} uncertainty was adjusted to account for random and systematic components of the total uncertainty. The systematic component is assumed to represent 15 % of the total uncertainty; the random component is negligible due to the perturbation of a large quantity of objects. The final adjusted Δk_{eff} uncertainty is therefore only the preserved systematic uncertainty. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-44. Effect of Uncertainty in the Stacked Pebble Height.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (9)	±0.06 % (pebble radii increased by 0.00175 cm)	-0.00006	±	0.00005	1	-0.00006	±	0.00005	-0.00001
2 (10)	±0.06 % (pebble radii increased by 0.00175 cm)	-0.00007	±	0.00004	1	-0.00007	±	0.00004	-0.00001

2.1.11 Total Experimental Uncertainty

A compilation of the total evaluated uncertainty in the critical configurations of Cores 9 and 10 (Cases 1 and 2, respectively) of the HTR-PROTEUS experiments is provided in Tables 2.1-45 and 2.1-46, respectively. As discussed earlier, uncertainties that are not treated as 100 % systematic, because perturbation analyses were simultaneously applied to multiple components are treated as 15 % systematic (to preserve some uncertainty due to possible, yet unknown, systematic effects) and 85 % random. The random portion of the uncertainty is then divided by the square root of the number of perturbed components, and is negligible for most uncertainties. The total evaluated uncertainty is the root-sum square of all individual uncertainties. A graphical representation of the primary sources of uncertainty is shown in Figure 2.1-1.

Uncertainties ≤0.00010 are reported as negligible (neg) and those that do not apply to a given configuration because they are not used or included as part of the evaluation of a different uncertainty are marked as not applicable (NA). The most significant contribution to the overall uncertainty is the fuel enrichment and the impurity content of the moderator pebbles. All uncertainties providing at least 0.05 $\%\Delta k_{eff}$ are highlighted in Tables 2.1-45 and 2.1-46. The uncertainties in the experimental critical configurations for Cores 9 and 10 were evaluated and determined to be acceptable.

Table 2.1-45. Summary of Evaluated Uncertainties in HTR-PROTEUS Case 1 (Core 9).

Perturbed Parameter	**Parameter Value**	**1σ Uncertainty**	**Δk_{eff} (1σ)**
Radial Reflector Density (g/cm^3)	1.76	0.012	0.00102
Radial Reflector Impurities (ppma EBC)	1.33	0.08	0.00113
Safety Ring Composition (wt.%)	Table 2.1-6	1 / √3	0.00012
C-Driver Plug Density (g/cm^3)	1.765	0.012	neg
Location of Upper Axial Reflector (mm)	1893	5 / √3	0.00015
Upper Axial Aluminum Dimensions (mm)	Figure 1.1-4	1 / √3	0.00072
Upper Axial Aluminum Composition	Table 2.1-6	1 / √3	0.00039
Lower Axial Cylinder Diameter (mm)	495	1 / √3	neg
Lower Axial Reflector Height (mm)	780	1 / √3	neg
Lower Axial Annulus Density (g/cm^3)	1.76	0.012	0.00013
Lower Axial Annulus Impurities (ppma EBC)	1.33	0.08	0.00013
Autorod Copper Wedge Thickness (mm)	3	1 / √3	neg
Orientation of Autorod Copper Wedge (°)	Unknown	90° / √3	0.00011
TRISO Random Packing	See Section 2.1.6.3		neg
Kernel Radius (cm)	0.02510	0.0006	neg
^{234}U Isotopic Content (wt.%)	~0.134	~0.017	0.00019
^{235}U Isotopic Content (wt.%)	~16.762	~0.17	0.00262
Fuel Pebble Uranium Mass (g)	5.966	0.060	0.00034
Fueled Zone Impurities (ppm)	Table 2.1-26	50 %	0.00012
Unfueled Zone Impurities (ppm)	Table 2.1-26	50 %	0.00012
Fuel Pebble Water Content (wt.%)	0.01	0.01 / √3	0.00011
Oxygen-to-Uranium Ratio	2.00	0.01	0.00013
Moderator Pebble Mass (g)	190.54	1.44	0.00015
Moderator Pebble Impurities (ppm)	Table 2.1-33	50 %	0.00166
Moderator Pebble Water Content (wt.%)	0.01	0.01 / √3	neg
Control Rod Outer Tube Composition (wt.%)	Table 2.1-36	1 / √3	neg
Polyethylene Rod Diameter (mm)	--	--	NA
Polyethylene Rod Length (mm)	--	--	NA
Polyethylene Rod Linear Density (g/cm)	--	--	NA
Polyethylene Rod H:C Ratio	--	--	NA
Polyethylene Rod Impurities (ppm EBC)	--	--	NA
Stacked Pebble Height (mm)	1.62	0.06 %	neg
Total Experimental Uncertainty	**--**	**--**	**0.00359**

Table 2.1-46. Summary of Evaluated Uncertainties in HTR-PROTEUS Case 2 (Core 10).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Radial Reflector Density (g/cm^3)	1.76	0.012	0.00081
Radial Reflector Impurities (ppma EBC)	1.33	0.08	0.00080
Safety Ring Composition (wt.%)	Table 2.1-6	1 / √3	neg
C-Driver Plug Density (g/cm^3)	1.765	0.012	neg
Location of Upper Axial Reflector (mm)	1893	5 / √3	neg
Upper Axial Aluminum Dimensions (mm)	Figure 1.1-4	1 / √3	0.00046
Upper Axial Aluminum Composition	Table 2.1-6	1 / √3	0.00024
Lower Axial Cylinder Diameter (mm)	495	1 / √3	neg
Lower Axial Reflector Height (mm)	780	1 / √3	neg
Lower Axial Annulus Density (g/cm^3)	1.76	0.012	neg
Lower Axial Cylinder Impurities (ppma EBC)	1.33	0.08	0.00011
Autorod Copper Wedge Thickness (mm)	3	1 / √3	neg
Orientation of Autorod Copper Wedge (°)	Unknown	90° / √3	neg
TRISO Random Packing	See Section 2.1.6.3		0.00015
Kernel Radius (cm)	0.02510	0.0006	neg
^{234}U Isotopic Content (wt.%)	~0.134	~0.017	0.00014
^{235}U Isotopic Content (wt.%)	~16.762	~0.17	0.00312
Fuel Pebble Uranium Mass (g)	5.966	0.060	0.00042
Fueled Zone Impurities (ppm)	Table 2.1-26	50 %	neg
Unfueled Zone Impurities (ppm)	Table 2.1-26	50 %	0.00017
Fuel Pebble Water Content (wt.%)	0.01	0.01 / √3	neg
Oxygen-to-Uranium Ratio	2.00	0.01	0.00016
Moderator Pebble Mass (g)	190.54	1.44	neg
Moderator Pebble Impurities (ppm)	Table 2.1-33	50 %	0.00154
Moderator Pebble Water Content (wt.%)	0.01	0.01 / √3	neg
Control Rod Outer Tube Composition (wt.%)	Table 2.1-36	1 / √3	neg
Polyethylene Rod Diameter (mm)	6.5	0.1 / √3	neg
Polyethylene Rod Length (mm)	1450	10 / √3	neg
Polyethylene Rod Linear Density (g/cm)	0.3161	0.0019	neg
Polyethylene Rod H:C Ratio	2.03	0.03	0.00012
Polyethylene Rod Impurities (ppm EBC)	0.5	0.5	neg
Stacked Pebble Height (mm)	1.44	0.06 %	neg
Total Experimental Uncertainty	**--**	**--**	**0.00374**

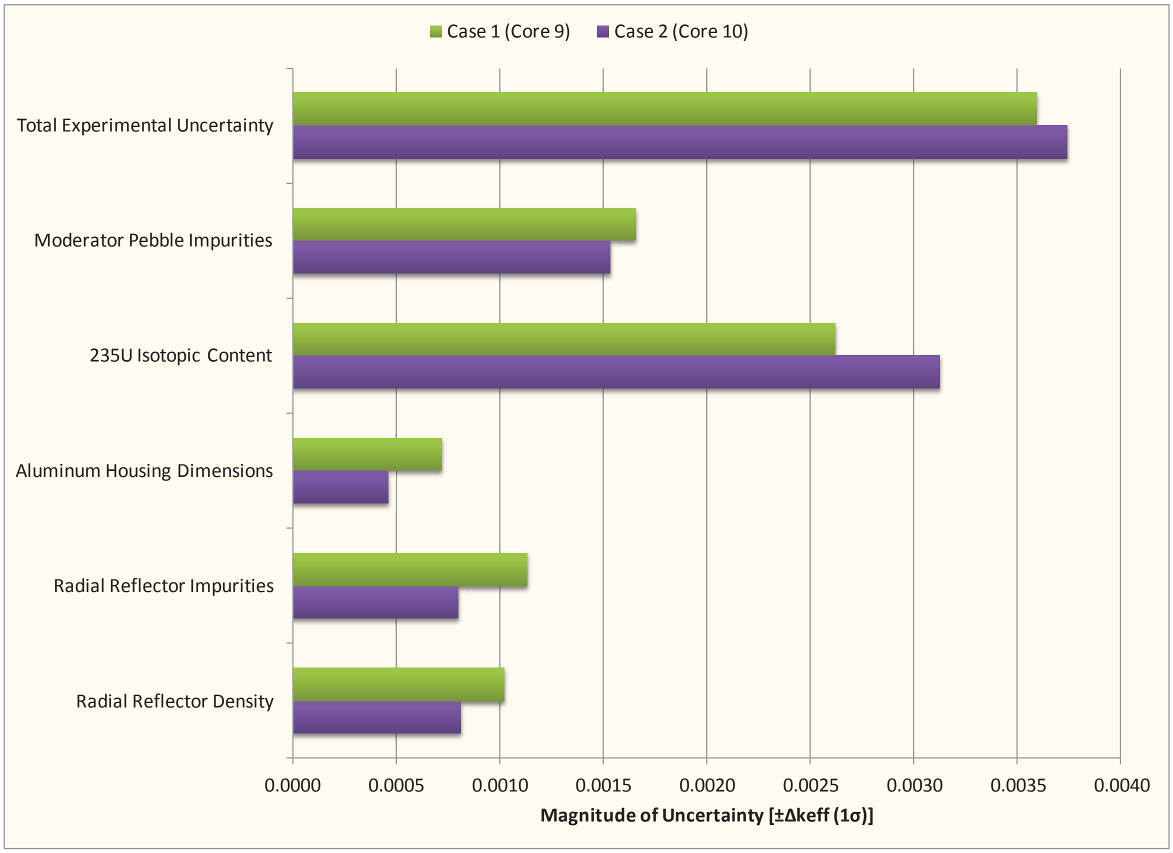

Figure 2.1-1. Graphical Representation of Primary Uncertainties in HTR-PROTEUS.

2.2 Evaluation of Buckling and Extrapolation Length Data

Buckling and extrapolation length measurements were performed but have not yet been evaluated.

2.3 Evaluation of Spectral Characteristics Data

Spectral characteristics measurements were performed but have not yet been evaluated.

2.4 Evaluation of Reactivity Effects Data

Models based upon the benchmark description provided in Section 3.1, for Cores 9 and 10, were utilized with model perturbations simulating control rod movements, as discussed in Section 3.4, to calculate the worths reported in Section 1.4.

Reactivity effects measurements for Cores 9 and 10 include the following:

- Control Rods
  - Individual Rod Worths (4)
  - Full Bank Worth (i.e. worth of inserting all four control rods simultaneously)
  - Partial Bank Worth
- Autorod
  - *Rest Worth [Appendix F]*
  - Rod Worth
  - *Partial Rod Worth*
- Safety/Shutdown Rods
  - Individual Rod Worths (4)
  - Combined Rod Worths (4)
  - Bank Worth of Four Rods
- *Graphite Plugs*
  - *Worth of Control Rod Channels [Appendix F]*
  - *Worth of Autorod Channel*
  - *Worth of Three Empty Channels in Radial Reflector [Appendix F]*
  - *Worth of Empty Channels in Upper Reflector (34, Core 10 only)*
- *Source/Instrumentation*
  - *Startup Sources (Core 9 only)*
  - *Startup Source Penetrations*
  - *Nuclear Instrumentation (Ionization)*
  - *Nuclear Instrumentation (Fission)*

The reactivity measurements were evaluated and found to be acceptable as benchmark experiment measurements except for those indicated in *italics* in the above list. Some of the rejected measurements include reported worth measurements obtained by scaling measured parameters on other HTR-PROTEUS core configuration using the ratio of control rod bank worths. Because these scaled measurements were not directly performed on the current core, they were rejected as benchmark measurements. However, as sufficient information was available to evaluate them, an evaluation is provided in this section of the report with modeling specifications provided in Appendix F. Further discussion of the evaluation process and unacceptability of some of the measurements is discussed in this section. A total of 32 reactivity effects measurements were determined to be acceptable benchmark experiments for both Cores 9 and 10 (16 apiece).

2.4.1 Delayed Neutron Fraction, β_{eff}

Reactivity worths for HTR-PROTEUS measurements were typically reported in \$ or ¢. Staff typically used TWODANT to calculate a β_{eff} value for each of the core configurations, which was approximately 720 pcm for most measurements, especially in Cores 9 and 10, which was then used to convert reactivity measurements to and from Δk.

Calculations were performed using the adjoint-weighted point kinetics capabilities of MCNP5[a,b] with ENDF/B-VII.0 nuclear data to determine a β_{eff} for Cores 9 and 10. The calculated β_{eff} for Core 9, using

[a] B. C. Kiedrowski, T. E. Booth, F. B. Brown, J. S. Bull, J. A. Favorite, R. A. Forster, and R. L. Martz, "MCNP5-1.60 Feature Enhancements & Manual Clarifications," LA-UR-10-06217, Los Alamos National Laboratory (2010).
[b] R. K. Meulekamp and S. C. van der Marck, "Calculating the Effective Delayed Neutron Fraction with Monte Carlo," *Nucl. Sci. Eng.*, **152**, 142-148 (2006).

the benchmark model in Section 3.1 and sample input deck in Appendix A, is 693 pcm. An uncertainty of 5 %, which is typically applied to account for the uncertainty in nuclear data, was applied, providing an uncertainty in β_{eff} of 35 pcm. Core 10 was calculated to have a β_{eff} of 685 ± 34 pcm. Because all reported reactivity measurement worths were reported in units of ρ($) using a β_{eff} value of 0.00720 for both Cores 9 and 10 (except for the safety/shutdown rods in Core 9, which had a reported β_{eff} value of 0.00717), they were adjusted to new calculated β_{eff} values to enable direct comparison between the calculated and benchmark worths. While the statistical uncertainty calculated by MCNP in β_{eff} is < 10 pcm, the larger uncertainty of 5 % is utilized to address the uncertainty in β_{eff} due to the nuclear data parameters themselves; this was evaluated in more detail for a TRIGA-type reactor in NRAD-FUND-RESR-001 (Appendix I), has been similarly seen when evaluating other reactor types using different nuclear data libraries, and is assumed to apply herein as well.

It is assumed that use of the MCNP5-calculated values for β_{eff} are more appropriate since they were generated using a 3D representation of the core. The difference between the MCNP5-generated values and those reported in the references as being obtained using TWODANT r-Θ models is approximately 1σ. Original HTR-PROTEUS experimentalists found that 2D calculations were limited in applications requiring axial positioning of detectors and anomalous sensitivities for some measurement configurations. Both the JEF-1.1 and ENDF/B-VII.0 delayed neutron data for ^{235}U are based upon the original Keepin data;[a] the JEF-1.1 data was reported with a slightly greater uncertainty in the individual parameters (Ref. 10).

2.4.2 Uncertainties in Rod Worth Measurements

Typically the uncertainty in the measurement method is much greater than any uncertainties obtained via computational analysis of geometry and composition perturbations in the benchmark models, such as the comprehensive evaluation performed in Section 2.1 for the critical configurations.

Information is limited regarding a comprehensive analysis of the uncertainties in the HTR-PROTEUS absorber rod worth measurements, where often the reported uncertainty pertains to the statistical uncertainty in the measurements and not the additional uncertainties introduced due to techniques, methods, and rod shadowing effects. These uncertainties have been addressed in other thermal research reactors, such as TRIGA® (Training, Research, Isotopes, General Atomics) reactors,[b,c] and have been utilized in this evaluation to supplement evaluation of the uncertainty in absorber worth measurements performed in the HTR-PROTEUS.

To evaluate the uncertainty in the methods utilized to measure reactivity worth, a literature survey was performed regarding other types of research reactors. While the fundamental physics behind each reactor type is different and impacts typical operations and characteristic uncertainties, the uncertainty in the measurement methods, as discussed below, are relatively similar. Therefore, it is judged to be acceptable to utilize method uncertainties for the measurement of reactivity effects from different research reactors to estimate an uncertainty in the methods utilized to measure the control rod worths in the PROTEUS reactor.

In the evaluation herein, methods and their respective uncertainties in TRIGA-type reactors have been applied to the HTR-PROTEUS experimental measurements. The HTR-PROTEUS operates in a more epithermal spectra than a TRIGA reactor, which is highly moderated by ZrH and water; therefore, the diffusion length is much longer in the HTR-PROTEUS. Control rod movement in a TRIGA reactor core tend to cause shadowing effects, effectively reducing the effective worth of an adjacent control rod. The PROTEUS absorber rods are located in the radial graphite reflector; hence control rod movement create

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[a] G. R. Keepin, T. F. Wimett, R. K. Zeigler, "Delayed Neutrons from Fissionable Isotopes of Uranium, Plutonium and Thorium," *J. Nucl. Energy*, **6**, 1-21 (1957).
[b] TRIGA® Nuclear Reactors, General Atomics, http://triga.ga.com/ (Accessed October 15, 2009).
[c] D. M. Fouquet, J. Razvi, W. L. Whittemore, "TRIGA Research Reactors: A Pathway to the Peaceful Applications of Nuclear Energy," *Nuclear News*, **46**(12), 46-56 (2003).

anti-shadowing effects (i.e. control rod worth is increased because to localized neutron flux has increased) when the neutron flux is redistributed.

As evaluated in Section 2.1.19 of PROTEUS-GCR-EXP-001, and discussed elsewhere in a separate analysis of a TRIGA research reactor,[a] the slight vertical movements and changes in position of the control rods is minor for most worth calculations, < 1 ¢. The uncertainty in the control rod positions is assumed to be included within the uncertainty in the method.

Comparison of the measurements for the safety/shutdown rods (see Section 1.4.2.4) indicates that the 1σ standard deviation of the mean value of multiple rod worth measurements is ≤ 11 ¢, or 5 % of a single rod worth. The standard deviation of the mean increases to < 6 % for measurements of combined rod drop worths. However, no direct repeatability measurements were performed. In NRAD-FUND-RESR-001, the repeatability in a rod worth measurement was shown to be < 1 ¢.

Insufficient reactivity effects measurements were performed to support qualitative assignation of a systematic and random component to each measurement. All evaluated uncertainty components contributing to the total uncertainty in the reactivity effects measurements are assumed to be systematic and combined in quadrature to obtain the total estimated uncertainty in each experimental value.

Expert judgment was used to assign uncertainty. In the evaluation of rod worths measurements and their respective uncertainties, static conditions are utilized to simulate these dynamic measurements.

2.4.2.1 Rod Drop Method and Rod Shadowing Effects

The excitation of a multiplying system, such as a critical reactor, by a rapid change of state, such as a rod drop, will generate short-lived flux modes that are not characteristic of the fundamental mode of the system. However, on the time scales of minutes, the typical period over which rod drop measurements are performed and measured, these harmonics are generally negligible (Ref. 3).

The prompt rod drop method is the easiest way to estimate the reactivity change in a reactor core; this method is based on the prompt flux adjustment that occurs directly after a perturbation, and assumes that the delayed neutron source is constant compared to the initial state. This method is sensitive to spatial effects and less accurate than other methods. Typical uncertainties are on the order of 5-6 % for a TRIGA research reactor.[b],[c] The dominant systematic uncertainty is in the kinetic constants and flux perturbations with the statistical component of the uncertainty < 1 %.

Common uncertainties for rod insertion methods include uncertainties in the delayed neutron data, which is systematic and common to all measuring methods. Another uncertainty source is in the flux redistribution in the subcritical core. As mentioned previously, the changes in flux are dominated by the long-lived delayed neutron precursors, whose distribution closely resembled that of the critical reactor shortly after the perturbation of the core. The most significant uncertainty source is the flux redistribution in the presence of control rods, i.e., rod shadowing effects. The positions of the control rods in the reactor impact the worth of the rod being measured. The uncertainty in this method is reported to be 3 % - 5 % for individual control rod worths in a TRIGA research reactor, with a statistical

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[a] I. Mele, M. Ravnik, and A. Trkov, "TRIGA Mark II Benchmark Experiment, Part I: Steady-State Operation," *Nucl. Technol.*, **105**, 37-51 (1994).
[b] C. Jammes, B. Geslot, R. Rosa, G. Imel, and P. Fougeras, "Comparison of Reactivity Estimations Obtained from Rod-Drop and Pulsed Neutron Source Experiments," *Ann. Nucl. Energy*, **32**, 1131-1145 (2005).
[c] G. Perret, C. Jammes, G. Imel, C. Destouches, P. Chaussonnet, J. M. Laurens, R. Soule, G. M. Thomas, W. Assal, P. Fougeras, P. Blaise, J-P. Hudelot, H. Philibert, and G. Bignan, "Determination of Reactivity by a Revised Rod-Drop Technique in the MUSE-4 Programme – Comparison with Dynamic Measurements," *7th Information Exchange Meeting on Actinide and Fission Product Partitioning and Transmutation*, Juja, Korea, October 14-16 (2002).

error of < 0.2 %. However, the impact of the interference due to the presence of other control rods increases the estimated uncertainty to ~10 %.[a]

The rod insertion method is very similar to the rod drop method, except that the control rods are driven into the core instead of dropped. It has been shown that flux perturbation effects due to control rods present in the core (rod shadowing) can impact the measured worth of a control rod by more than 30 %. On average, however, the reported values for this analysis of a TRIGA research reactor varied ~8 % and the core operated with most of the control rods partially inserted into the core.[b]

Insufficient information is available regarding the exact positions, sizes, and compositions of the various detectors utilized throughout the HTR-PROTEUS experimental program. Should sufficient information have been available, calculation of flux form factors to account for the redistribution of the flux could be performed to very accurately assess the uncertainty contribution from rod shadowing effects.[a,c] As such, this uncertainty was estimated as discussed in the next paragraph.

Comparison of the difference between the sum of the individual control rod worths (see Table 1.4-2) with the measured control rod bank worth (see Section 1.4.2.2), indicates a difference of ~4 % in Core 9 and ~2 % in Core 10. Then comparison of the sum of the average measured worth of Shutdown Rods 5 through 8 and the measured worth for dropping all rods together (see Tables 1.4-8 and 1.4-9 for Cores 9 and 10, respectively) indicates a difference of ~11 % in Core 9 and ~13 % in Core 10. It is assumed that these differences can be utilized to approximate an additional bounding uncertainty (i.e. $\div \sqrt{3}$) that can be applied to the method uncertainty to account for shadowing effects in the HTR-PROTEUS absorber rod measurements.

2.4.2.2 Stable Period Method

The positive period method is also referred to as the rod exchange method or stable period method, where the rod worth is measured relative to another, calibrated, control rod, or stepwise movements of the rod are measured with a reactivity meter. Calibration curve measurements in a TRIGA research reactor have shown that the uncertainty in rod exchange measurements are slightly < 10 %. The uncertainty includes uncertainties in control rod positions, interference effects from other control rods during the measurement (rod shadowing), and statistical errors from reactivity calculated by the reactivity meter; the latter of which are negligible.[d]

Due to the severe local flux distribution deformation in rod exchange measurements, simulations need to model the effects correctly for each measurement step. An uncertainty of 10 % is typical for this type of measurement,[e] and has become the standard for treating the uncertainty in reactivity measurements in other TRIGA research reactors.[f]

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[a] I. Mele, M. Ravnik, and A. Trkov, "TRIGA Mark II Benchmark Experiment, Part II: Pulse Operation," *Nucl. Technol.*, **105**, 52-58 (1994).
[b] A. Trkov, M. Ravnik, H. Wimmer, B. Glumac, and H. Böck, "Application of the Rod-Insertion Method for Control Rod Worth Measurements in Research Reactors," *Kerntechnik*, **60**, 255-261 (1995).
[c] M. Pdvratnik, L. Snoj, A. Trkov, G. Žerovnik, "Calculations to Support Absolute Thermal Power Calibration of the Slovenian TRIGA Mark II Reactor," 20th Int. Conf. Nuclear Energy for New Europe 2011, Bovec, Slovenia, September 12-15, 2011.
[d] I. Mele, M. Ravnik, and A. Trkov, "TRIGA Mark II Benchmark Experiment, Part II: Pulse Operation," *Nucl. Technol.*, **105**, 52-58 (1994).
[e] R. Jeraj, B. Glumac, and M. Maučec, "Monte Carlo Simulation of the TRIGA Mark II Benchmark Experiment," *Nucl. Technol.*, **120**, 179-187 (1997).
[f] T. Matsumoto and N. Hayakawa, "Benchmark Analysis of TRIGA Mark II Reactivity Experiment Using a Continuous Energy Monte Carlo Code MCNP," *J. Nucl. Sci. Technol.*, **37**, 1082-1087 (2000).

2.4.2.3 Pulsed Neutron Source Method

Uncertainties have been reported for pulse neutron source measurements as low as 1 %.[a] However, the typical uncertainties are reported in Table 1.4-1 for the three PNS techniques. The Sjöstrand and Gozani techniques are utilized in the HTR-PROTEUS safety/shutdown rod worth measurements. As the worth of those rods (individually or in combination) is > 1 $, the uncertainty in the measurement technique is between 3 % and 4 %.

2.4.2.4 Uncertainties Applied to Worth Measurements in HTR-PROTEUS

An uncertainty of 6 % is selected to represent the uncertainty in the inverse kinetics and stable period techniques utilized to obtain a single experimental worth measurement pertaining to the control rods, autorod, and graphite plugs; this uncertainty includes the small contributions due to statistical and repeatability uncertainties (< 1 %), some minor contribution due to rod shadowing effects (~1 % - 2 %), and the dominant contribution from the measurement techniques (~5 % - 6 %). The statistical and repeatability uncertainties are known to be small, as discussed in Sections 2.4.2 and 2.4.2.1. The rod shadowing effect uncertainty was derived for these HTR-PROTEUS control rod measurements at the end of Section 2.4.2.1. The uncertainties in rod drop measurements were derived from the uncertainty inverse kinetics methods of TRIGA reactors, also discussed in Section 2.4.2.1. The reported uncertainty of a typical stable period measurement of < 10 % (see Section 2.4.2.2) included rod shadowing effects; it is assumed that the estimated total uncertainty of 6 % adequately represents a 1σ uncertainty in the control rod worth measurements for HTR-PROTEUS Cores 9 and 10.

An uncertainty of 8 % is selected to represent the uncertainty in the pulsed neutron source techniques utilized to obtain a single experimental worth measurement pertaining to safety/shutdown rods; this uncertainty includes the small contributions due to statistical and repeatability uncertainties (<1 %), some minor contribution due to the measurement techniques (~3 % - 4 %), and the dominant contribution due to rod shadowing effects (~ 6 % - 8 %). Although safety/shutdown rod measurements were performed using IK and/or PNS measurements, the larger uncertainty of 8 % was selected instead of 6 % as there is possibly a trade off between technique uncertainty and the uncertainty in shadowing effects impacting the measurement technique. The statistical and repeatability uncertainties are known to be small, as discussed in Sections 2.4.2 and 2.4.2.1. The rod shadowing effect uncertainty was derived for these HTR-PROTEUS safety/shutdown rod measurements at the end of Section 2.4.2.1. The uncertainty in PNS measurements were discussed in Section 2.4.2.3. It is assumed that the estimated total uncertainty of 8 % adequately represents a 1σ uncertainty in the safey/shutdown rod worth measurements for HTR-PROTEUS Cores 9 and 10.

The worths of the graphite plugs were estimated based on measurements performed on similar HTR-PROTEUS core configurations; the reported uncertainties for Cores 9 and 10 are greater than the estimated 6 %. The larger reported uncertainties will be utilized as the uncertainties in the graphite plug worths.

2.4.3 Control Rod Worth Measurements

Individual and bank worth measurements were performed for the four withdrawable stainless steel control rods. Radial positions in the core are shown in Figure 1.1-2 (outermost radial positions). The individual rod worths are found in Table 1.4-2. Due to rod shadowing effects, the summation of the individual rod worths incorrectly reflects the worth of the control rod bank. Measured control rod bank insertions (partial and full) are recorded in Section 1.4.2.2. The reported values were adjusted to use the same β_{eff} value (see Section 2.4.1) as used in the MCNP calculations. The evaluated experimental values are provided in Tables 2.4-1 and 2.4-2 for Cores 9 and 10, respectively.

[a] C. Jammes, B. Geslot, R. Rosa, G. Imel, and P. Fougeras, "Comparison of Reactivity Estimations Obtained from Rod-Drop and Pulsed Neutron Source Experiments," *Ann. Nucl. Energy*, **32**, 1131-1145 (2005).

Table 2.4-1. Evaluated Control Rod Worth Measurements (Core 9).

Rod(s) Inserted	Measurement Technique(a)	Measured Worth			Adjusted Worth(b)		
		ρ($)	±	σ	ρ($)	±	σ(c)
1	IK	-0.3969	±	0.0009	-0.41	±	0.02
2	IK	-0.3904	±	0.0009	-0.41	±	0.02
3	IK	-0.3907	±	0.0009	-0.41	±	0.02
4	IK	-0.3961	±	0.0009	-0.41	±	0.02
Full Bank	SP	-1.52	±	0.02	-1.58	±	0.09
Partial Bank(d)	SP	-0.704	±	0.01	-0.73	±	0.04

(a) IK = Inverse Kinetics; SP = Stable Period
(b) The measured worth is adjusted per the discussion in Section 2.4.1 from the reported calculated β_{eff} of 720 pcm to the currently calculated value of 693 pcm. The number of significant digits is reduced due to the increased uncertainty in the adjusted worths.
(c) The uncertainty in the measured worth is increased to at least 6 % when the reported uncertainty in the measurement is less than this minimum uncertainty value.
(d) Partial insertion was performed from a control rod bank position of 1620 mm.

Table 2.4-2. Evaluated Control Rod Worth Measurements (Core 10).

Rod(s) Inserted	Measurement Technique(a)	Measured Worth			Adjusted Worth(b)		
		ρ($)	±	σ	ρ($)	±	σ(c)
1	IK	-0.2819	±	0.0007	-0.30	±	0.02
2	IK	-0.2785	±	0.00084	-0.29	±	0.02
3	IK	-0.2764	±	0.00074	-0.29	±	0.02
4	IK	-0.2815	±	0.00071	-0.30	±	0.02
Full Bank	SP	-1.096	±	--	-1.15	±	0.07
Partial Bank(d)	SP	-0.368	±	0.01	-0.39	±	0.02

(a) IK = Inverse Kinetics; SP = Stable Period
(b) The measured worth is adjusted per the discussion in Section 2.4.1 from the reported calculated β_{eff} of 720 pcm to the currently calculated value of 685 pcm. The number of significant digits is reduced due to the increased uncertainty in the adjusted worths.
(c) The uncertainty in the measured worth is increased to at least 6 % when the reported uncertainty in the measurement is less than this minimum uncertainty value.
(d) Partial insertion was performed from a control rod bank position of 1540 mm.

2.4.4 Autorod Worth Measurements

Worth measurements were performed for the single autorod. The radial position of the autorod is shown in Figure 1.1-2. The rest worth (i.e. the worth of removing the absorber rod after it has been fully withdrawn), the full rod insertion worth, and partial rod insertion worths are reported for both Cores 9 and 10 in Section 1.4.2.3. For Core 9, the total insertion worth of the autorod (reported in Table 1.4-3) was selected over the worth reported to scaling Core 5 worth measurements because the former was physically measured. Partial autorod worth measurements were not evaluated as their respective worths were almost identical to the full insertion worth of the autorod within experimental measurements uncertainty. The reported values were adjusted to use the same β_{eff} value (see Section 2.4.1) as used in the MCNP calculations. The evaluated experimental values are provided in Tables 2.4-3 and 2.4-4 for Cores 9 and 10, respectively.

The autorod rest worth measurements were scaled measurements and not considered as a benchmark measurements.

Table 2.4-3. Evaluated Autorod Worth Measurements (Core 9).

Measured Value	**Measurement Technique**[a]	**Measured Worth**			**Adjusted Worth**[b]		
		ρ($)	**±**	**σ**	**ρ($)**	**±**	**σ**[c]
Rest Worth	Scaled from Core 5 Value	-0.125	±	0.005	-0.13	±	0.01
Insertion Worth	IK	-0.0918	±	0.0006	-0.10	±	0.01

(a) IK = Inverse Kinetics
(b) The measured worth is adjusted per the discussion in Section 2.4.1 from the reported calculated β_{eff} of 720 pcm to the currently calculated value of 693 pcm. The number of significant digits is reduced due to the increased uncertainty in the adjusted worths.
(c) The uncertainty in the measured worth is increased to at least 6 % when the reported uncertainty in the measurement is less than this minimum uncertainty value.

Table 2.4-4. Evaluated Autorod Worth Measurements (Core 10).

Measured Value	**Measurement Technique**[a]	**Measured Worth**			**Adjusted Worth**[b]		
		ρ($)	**±**	**σ**	**ρ($)**	**±**	**σ**[c]
Rest Worth	Core 1A Value	-0.077	±	0.005	-0.081	±	0.005
Insertion Worth	IK	-0.0696	±	0.00044	-0.073	±	0.004

(a) IK = Inverse Kinetics
(b) The measured worth is adjusted per the discussion in Section 2.4.1 from the reported calculated β_{eff} of 720 pcm to the currently calculated value of 685 pcm.
(c) The uncertainty in the measured worth is increased to at least 6 % when the reported uncertainty in the measurement is less than this minimum uncertainty value.

2.4.5 Safety/Shutdown Rod Worth Measurements

2.4.5.1 Tube Compositions

The information provided in this section is necessary to develop the benchmark model atom densities in Section 3.4.3 for the safety/shutdown absorber rods, whereas insufficient information was provided in Section 1.4.3.

The safety/shutdown absorber rods consisted of borated steel rod section (~5 wt.% boron) enclosed within 18/8 stainless steel tubes. The borated steel was reported to have a density of 6.878 g/cm^3 and 7.92 g/cm^3 for the stainless steel. The borated steel composition, as reported, is in Table 1.1-9. The stainless steel composition, as reported, is in Table 1.1-10. Because the borated steel composition does not total to 100 wt.%, it was renormalized, as provided in Table 2.4-5.

Table 2.4-5. Composition of Borated Steel.

Element	Reported Composition (wt.%)	Renormalized Composition (wt.%)
^{10}B	0.94	0.94902
^{11}B	3.76	3.79606
Si	1.02	1.02978
Cr	40.4	40.78748
Mn	1.30	1.31247
Fe	41.8	42.20091
Ni	9.83	9.92428
Total	99.05	100.00000

The 18/8 stainless steel has a comparable composition to Type 301/302/304 stainless steel, which include the additional constituents carbon, silicon, and manganese.[a] The iron content in the 18/8 stainless steel composition was slightly reduced to include these additional elements. The revised stainless steel tube composition for the safety/shutdown rods is provide in Table 2.4-6.

Table 2.4-6. Composition of 18/8 Stainless Steel.

Element	Reported Composition (wt.%)	Revised Composition (wt.%)
Cr	18	18
Fe	74	72.425
Ni	8	8
C	--	0.075
Si	--	0.5
Mn	--	1
Total	100	100

The aluminum shock dampers were not included in this analysis; the impact of their removal on reactivity measurements is negligible.

[a] R. H. Perry and Don W. Green, *Perry's Chemical Engineers' Handbook*, 7th edition, McGraw-Hill, New York, NY (1997).

2.4.5.2 Consolidation of Worth Measurements

Worth measurements were performed for four of the safety/shutdown absorber rods (identified as Rods 5, 6, 7, and 8). The radial positions in the core are shown in Figure 1.1-2. Various individual rod worths and combined rod drop worths were measured, including a bank worth with all four rods, as provided in Section 1.4.2.4. An average worth for each measurement was determined after removing repetitive measurements from the literature and "bad measurements", as indicated by the experimenters. A summary of the various measurements reported in Tables 1.4-4 through 1.4-13 is provided below in Tables 2.4-7 and 2.4-8 for Cores 9 and 10, respectively. The summary tables indicate which measurements were included in determination of the benchmark experiment absorber rod worths.

Mean values were computed using the non-excluded measurements by computing a non-weighted average and standard deviation for each set of worth measurements. The average values were then adjusted to use the same β_{eff} value (see Section 2.4.1) as used in the MCNP calculations. The standard deviation in each average value was less than 8 %; therefore, the uncertainty was increased to 8 % for each measurement. Finally the uncertainty was divided by the square-root of the number of individual measurements performed for each mean worth value to obtain the uncertainty for each experimental worth. The evaluated experimental values are provided in Tables 2.4-9 and 2.4-10 for Cores 9 and 10, respectively.

Table 2.4-7. Summary of Safety/Shutdown Rod Worth Measurements (Core 9).

Rods(s) Inserted	Table	Reported Worth ρ($)	Reason for Exclusion
?	1.4-11	-3.64	Unclear which single rod was inserted
		-3.70	Unclear which single rod was inserted
		-3.62	Unclear which single rod was inserted
5	1.4-8	-3.69	
		-3.61	
	1.4-12	-3.558	
		-4.880	Reported as a bad detector
6	1.4-4	-3.73	
		-3.63	
		-3.69	
		-3.77	
		-3.73	
		-3.74	Average of previous measurements
	1.4-6	-3.73	Average of previous measurements
		-3.68	Average of previous measurements
	1.4-8	-3.72	
		-3.73	
		-3.63	
	1.4-10	-3.68	Same average value as found in Table 1.4-6
	1.4-12	-3.594	
		-4.185	Reported as a bad detector
7	1.4-12	-3.578	
		-4.040	Reported as a bad detector
8	1.4-12	-3.482	

Table 2.4-7. (cont'd.) Summary of Safety/Shutdown Rod Worth Measurements (Core 9).

Rods(s) Inserted	Table	Reported Worth ρ($)	Reason for Exclusion
5+6	1.4-4	-7.71	
		-7.74	
		-7.88	
		-7.85	
		-7.82	Average of previous measurements
	1.4-6	-7.78	Average of previous measurements
		-7.85	Average of previous measurements
	1.4-8	-7.69	
		-7.72	
	1.4-10	-7.85	Same average value as found in Table 1.4-6
	1.4-11[(a)]	-7.74	
		-7.83	
		-7.89	
	1.4-12	-7.48	
		-8.71	Reported as a bad detector
5+7	1.4-12	-7.19	
5+8	1.4-12	-7.15	
5+6+7	1.4-4	-11.69	
		-11.36	
		-11.63	
		-12.25	
		-11.85	
		-11.83	Average of previous measurements
	1.4-6	-11.86	Average of previous measurements
		-11.61	Average of previous measurements
	1.4-8	-11.61	
		-11.76	
		-11.23	
		-11.49	
	1.4-10	-11.61	Same average value as found in Table 1.4-6
	1.4-11[(b)]	-11.63	
		-11.91	
		-12.03	
5+6+7+8	1.4-4	-16.00	
		-15.63	
		-16.39	
		-16.43	
		-16.17	Average of previous measurements
	1.4-6	-16.01	Average of previous measurements
		-16.43	Average of previous measurements
	1.4-8	-16.10	
		-15.89	
	1.4-10	-16.43	Same average value as found in Table 1.4-6
	1.4-11[(b)]	-15.63	
		-15.52	
		-16.81	
	1.4-12	-15.25	

(a) Due to the similarity in worth measurement magnitudes for Table 1.4-11 dual-rod insertions, and the typical insertion of both Rods 5 and 6 concurrently, these three measurements are assumed to pertain to this measurement.
(b) Similar argument for footnote (a) also applies for the triple- and quad-rod insertions in Table 1.4-11.

Table 2.4-8. Summary of Safety/Shutdown Rod Worth Measurements (Core 10).

Rods(s) Inserted	Table	Reported Worth ρ($)	Reason for Exclusion
5	1.4-9	-2.75	
		-2.63	
	1.4-13	-2.72	
		-3.10	Reported as a bad detector
		-2.63	
		-2.75	Average of previous measurements
6	1.4-5	-2.75	Rejected by experimenter
		-2.63	
		-2.65	
		-2.69	
		-2.59	
		-2.66	Average of previous measurements
	1.4-7	-2.70	Average of previous measurements
		-2.61	Average of previous measurements
	1.4-9	-2.79	
	1.4-13	-2.74	
		-2.92	Reported as a bad detector
		-2.71	
		-2.77	Average of previous measurements
7	1.4-13	-2.73	
		-2.92	Reported as a bad detector
		-2.60	
		-2.74	Average of previous measurements
8	1.4-13	-2.67	
		-2.56	Reported as a bad detector
		-2.51	
		-2.62	Average of previous measurements

Table 2.4-8. (cont'd.) Summary of Safety/Shutdown Rod Worth Measurements (Core 10).

Rods(s) Inserted	Table	Reported Worth ρ($)	Reason for Exclusion
5+6	1.4-5	-6.17	Rejected by experimenter
		-5.56	
		-5.48	
		-5.72	
		-5.47	
		-5.54	Average of previous measurements
	1.4-7	-5.79	Average of previous measurements
		-5.52	Average of previous measurements
	1.4-9	-6.17	
		-5.56	
	1.4-13	-5.79	
		-6.43	Reported as a bad detector
		-5.52	
		-5.76	Average of previous measurements
5+7	1.4-13	-5.65	
		-6.17	Reported as a bad detector
		-5.26	
		-5.54	Average of previous measurements
5+8	1.4-13	-5.59	
		-6.25	Reported as a bad detector
		-5.35	
		-5.64	Average of previous measurements
5+6+7	1.4-5	-9.38	Rejected by experimenter
		-8.61	
		-8.42	
		-9.38	
		-8.64	
		-8.91	Average of previous measurements
	1.4-7	-9.06	Average of previous measurements
		-8.63	Average of previous measurements
	1.4-9	-8.72	
		-9.60	
		-9.83	
		-8.26	
		-8.99	
		-8.68	
		-8.18	
		-8.94	
		-8.60	
5+6+7+8	1.4-5	-12.99	Rejected by experimenter
		-11.80	
		-11.42	
		-12.12	
		-11.71	
		-11.74	Average of previous measurements
	1.4-7	-12.18	Average of previous measurements
		-11.76	Average of previous measurements
	1.4-9	-12.04	
		-13.94	
		-11.70	
		-11.71	
		-11.98	
	1.4-13	-12.63	
		-12.93	Reported as a bad detector
		-11.57	
		-12.43	Average of previous measurements

Table 2.4-9. Evaluated Safety/Shutdown Rod Worth Measurements (Core 9).

Rod(s) Inserted	Number Unique Values (N)	Measurement Technique(s)(a)	Average Worth			Adjusted Worth(b)	Adjusted Uncertainty(b)
			ρ($)	±	σ(c)	ρ($)(d)	±σ / √N(d,e)
5	3	IK	-3.62	±	0.07	-3.74	0.17
6	9	IK, PNS	-3.69	±	0.06	-3.82	0.10
7	1	IK	-3.58	±	0.01	-3.70	0.30
8	1	IK	-3.48	±	0.01	-3.60	0.29
5+6	10	IK, PNS	-7.75	±	0.12	-8.02	0.20
5+7	1	IK	-7.19	±	0.02	-7.44	0.60
5+8	1	IK	-7.15	±	0.02	-7.40	0.59
5+6+7	12	IK, PNS	-11.70	±	0.28	-12.11	0.28
5+6+7+8	10	IK, PNS	-15.97	±	0.48	-16.52	0.42

(a) IK = Inverse Kinetics; PNS = Pulsed Neutron Source
(b) The measured worth is adjusted per the discussion in Section 2.4.1 from the reported calculated β_{eff} of 717 pcm to the currently calculated value of 693 pcm.
(c) This uncertainty is the standard deviation of the average when multiple measurements are combined. For a single measurement, it is the reported uncertainty in that measurement.
(d) The uncertainty in the adjusted worth is increased to 8 %.
(e) The uncertainty in the adjusted worth is adjusted according to the number of unique measurements incorporated in determining the mean adjusted worth.

Table 2.4-10. Evaluated Safety/Shutdown Rod Worth Measurements (Core 10).

Rod(s) Inserted	Number Unique Values (N)	Measurement Technique(s)[(a)]	Average Worth			Adjusted Worth[(b)]	Adjusted Uncertainty[(b)]
			ρ($)	±	σ[(c)]	ρ($)	±σ / √N[(d,e)]
5	4	IK	-2.68	±	0.06	-2.82	0.11
6	7	IK, PNS	-2.69	±	0.07	-2.82	0.09
7	2	IK	-2.67	±	0.09	-2.80	0.16
8	2	IK	-2.59	±	0.11	-2.72	0.15
5+6	8	IK, PNS	-5.66	±	0.24	-5.95	0.17
5+7	2	IK	-5.46	±	0.28	-5.73	0.32
5+8	2	IK	-5.47	±	0.17	-5.75	0.33
5+6+7	13	IK, PNS	-8.83	±	0.50	-9.29	0.21
5+6+7+8	11	IK, PNS	-12.06	±	0.70	-12.67	0.31

(a) IK = Inverse Kinetics; PNS = Pulsed Neutron Source
(b) The measured worth is adjusted per the discussion in Section 2.4.1 from the reported calculated β_{eff} of 720 pcm to the currently calculated value of 685 pcm.
(c) This uncertainty is the standard deviation of the average when multiple measurements are combined. For a single measurement, it is the reported uncertainty in that measurement.
(d) The uncertainty in the adjusted worth is increased to 8 %.
(e) The uncertainty in the adjusted worth is adjusted according to the number of unique measurements incorporated in determining the mean adjusted worth.

2.4.6 Graphite Plug Worth Measurements

Graphite plug worth measurements were reported for Cores 9 and 10 (see Tables 1.4-14 and 1.4-15, respectively) and include the worth of graphite in the control rod channels, autorod channel, empty channels in three R2 positions of the radial reflector, and 34 channels in the upper reflector. Calculations of the worth of the autorod channel are more than three times greater than the reported "measured" worth obtained by scaling measurements from other core configurations. It is unclear why there is such a large discrepancy. The small estimated uncertainty of the "measured" worth with a large estimated experimental uncertainty contributes to this discrepancy. The worth of the autorod channel was determined to not represent an acceptable benchmark experiment. A similar discrepancy is seen for calculations of the worth of the 34 graphite plugs in the upper axial reflector for Core 10; in this instance, however, calculations are approximately three times smaller than the reported "measured" worth obtained by scaling measurements from another core configuration. The uncertainty in this measurement is also large. The worth of the empty channels in the upper axial reflector for Core 10 was also determined to not represent an acceptable benchmark experiment. The reported values were adjusted to use the same β_{eff} value (see Section 2.4.1) as used in the MCNP calculations. The evaluated experimental values are provided in Tables 2.4-11 and 2.4-12 for Cores 9 and 10, respectively.

The graphite plug worths are evaluated simply by filling the voided channel volume with the graphite plug composition. The plugs were designed to minimize air channel volume in the radial and axial graphite reflectors. Minor variation in the diameter of the simulated plug material is assumed to introduce a negligible computational bias or uncertainty due to the large experimental uncertainty associated with these measurements. The locations of the control rod channels and empty R2 channels are shown in Figure 3.4-4.

The material properties and dimensions of the graphite plugs, as well as their respective uncertainties, are discussed in detail in Section 2.1 of PROTEUS-GCR-EXP-001 for both the radial and axial reflectors. Uncertainties in the graphite plug properties are assumed to be negligible compared to the uncertainty in the total experiment uncertainty, which is dominated by the uncertainty in the measurement techniques employed in evaluating the worth of the graphite plugs.

The graphite plug worth measurements were scaled measurements and not considered as a benchmark measurements.

Table 2.4-11. Evaluated Graphite Plug Worth Measurements (Core 9).

Measured Value	**Measurement Technique**	**Measured Worth**			**Adjusted Worth[(a)]**		
		ρ($)	**±**	**σ**	**ρ($)**	**±**	**σ**
Control Rod Channels	Scaled from Core 5 Value	-0.025	±	0.003	-0.026	±	0.003
Autorod Channel[(b)]	Scaled from Core 5 Value	-0.007	±	0.003	-0.007	±	0.003
Empty Channels: R2-15, -47, & -63	Scaled from Core 5 Value	-0.05	±	0.01	-0.05	±	0.01

(a) The measured worth is adjusted per the discussion in Section 2.4.1 from the reported calculated β_{eff} of 720 pcm to the currently calculated value of 693 pcm.
(b) This worth value is calculated to be -0.024 ± 0.014 ρ($) using MCNP5 and ENDF/B-VII.0 neutron data. The (C-E)/E values is 232 % ± 240 %. This experimental measurement is judged to be unacceptable.

Table 2.4-12. Evaluated Graphite Plug Worth Measurements (Core 10).

Measured Value	**Measurement Technique**	**Measured Worth**			**Adjusted Worth[(a)]**		
		ρ($)	**±**	**σ**	**ρ($)**	**±**	**σ**
Control Rod Channels	Core 1A Value	-0.02	±	0.002	-0.021	±	0.002
Autorod Channel[(b)]	Core 1A Value	-0.005	±	0.003	-0.022	±	0.012
Empty Channels: R2-15, -47, & -63	Core 1A Value	-0.04	±	0.01	-0.04	±	0.01
Upper Reflector Channels (34)[(c)]	Scaled from Core 1A Value	-0.036	±	0.02	-0.038	±	0.38

(a) The measured worth is adjusted per the discussion in Section 2.4.1 from the reported calculated β_{eff} of 720 pcm to the currently calculated value of 685 pcm.
(b) This worth value is calculated to be -0.022 ± 0.014 ρ($) using MCNP5 and ENDF/B-VII.0 neutron data. The (C-E)/E values is 310 % ± 340 %. This experimental measurement is judged to be unacceptable.
(c) This worth value is calculated to be -0.014 ± 0.012 ρ($) using MCNP5 and ENDF/B-VII.0 neutron data. The (C-E)/E values is -62 % ± 39 %. This experimental measurement is judged to be unacceptable.

2.4.7 Source/Instrumentation Worth Measurements

Worths were reported in Tables 1.4-16 and 1.4-17 for the removal of the start-up sources, start-up source penetrations, nuclear instrumentation (ionization), and nuclear instrumentation (fission), for Cores 9 and 10, respectively. However, there was insufficient information available to sufficiently model and evaluate these measurements. Therefore, all measurements pertaining to the worth of the sources and instrumentation were deemed unacceptable for use as benchmark experiments.

2.4.8 Summary of Reactivity Effects Measurements

A summary of the adjusted worth measurements, as described and evaluated in Section 2.4, is provided in Tables 2.4-13 and 2.4-14 for Cores 9 and 10, respectively. Measurements scaled from another core configuration were evaluated but deemed not acceptable as benchmark data; further information for modeling these data is provided in Appendix F. Case numbers are assigned as follows, X.Y-Z, where X represents the critical core case number, Y indicates the measurement type (in this case 4 for reactivity effect measurement), and Z represents the ordering of individual measurements for the main core configuration, X.

Table 2.4-13. Adjusted Experimental Reactivity Effects Measurements (Core 9).

Case	Measured Parameter	Benchmark Measurement?	Experimental Worth		
			ρ($)	±	σ
1.4-1	Control Rod 1	Yes	-0.41	±	0.02
1.4-2	Control Rod 2	Yes	-0.41	±	0.02
1.4-3	Control Rod 3	Yes	-0.41	±	0.02
1.4-4	Control Rod 4	Yes	-0.41	±	0.02
1.4-5	Control Rod Bank Full Insertion	Yes	-1.58	±	0.09
1.4-6	Control Rod Bank Partial Insertion	Yes	-0.73	±	0.04
--	Autorod Rest Worth	No	-0.13	±	0.01
1.4-7	Autorod Insertion	Yes	-0.10	±	0.01
1.4-8	Safety/Shutdown Rod 5	Yes	-3.74	±	0.17
1.4-9	Safety/Shutdown Rod 6	Yes	-3.82	±	0.10
1.4-10	Safety/Shutdown Rod 7	Yes	-3.70	±	0.30
1.4-11	Safety/Shutdown Rod 8	Yes	-3.60	±	0.29
1.4-12	Safety/Shutdown Rods 5+6	Yes	-8.02	±	0.20
1.4-13	Safety/Shutdown Rods 5+7	Yes	-7.44	±	0.60
1.4-14	Safety/Shutdown Rods 5+8	Yes	-7.40	±	0.59
1.4-15	Safety/Shutdown Rods 5+6+7	Yes	-12.11	±	0.28
1.4-16	Safety/Shutdown Rods 5+6+7+8	Yes	-16.52	±	0.42
--	Graphite in Control Rod Channels	No	-0.026	±	0.003
--	Graphite in Empty Channels: R2-15, -47, & -63	No	-0.05	±	0.01

Table 2.4-14. Adjusted Experimental Reactivity Effects Measurements (Core 10).

Case	Measured Parameter	Benchmark Measurement?	Experimental Worth		
			ρ($)	**±**	**σ**
2.4-1	Control Rod 1	Yes	-0.30	±	0.02
2.4-2	Control Rod 2	Yes	-0.29	±	0.02
2.4-3	Control Rod 3	Yes	-0.29	±	0.02
2.4-4	Control Rod 4	Yes	-0.30	±	0.02
2.4-5	Control Rod Bank Full Insertion	Yes	-1.15	±	0.07
2.4-6	Control Rod Bank Partial Insertion	Yes	-0.39	±	0.02
--	Autorod Rest Worth	No	-0.081	±	0.005
2.4-7	Autorod Insertion	Yes	-0.073	±	0.004
2.4-8	Safety/Shutdown Rod 5	Yes	-2.82	±	0.11
2.4-9	Safety/Shutdown Rod 6	Yes	-2.82	±	0.09
2.4-10	Safety/Shutdown Rod 7	Yes	-2.80	±	0.16
2.4-11	Safety/Shutdown Rod 8	Yes	-2.72	±	0.15
2.4-12	Safety/Shutdown Rods 5+6	Yes	-5.95	±	0.17
2.4-13	Safety/Shutdown Rods 5+7	Yes	-5.73	±	0.32
2.4-14	Safety/Shutdown Rods 5+8	Yes	-5.75	±	0.33
2.4-15	Safety/Shutdown Rods 5+6+7	Yes	-9.29	±	0.21
2.4-16	Safety/Shutdown Rods 5+6+7+8	Yes	-12.67	±	0.31
--	Graphite in Control Rod Channels	No	-0.021	±	0.002
--	Graphite in Empty Channels: R2-15, -47, & -63	No	-0.04	±	0.01

2.5 Evaluation of Reactivity Coefficient Data

Reactivity coefficient measurements were performed but have not yet been evaluated.

2.6 Evaluation of Kinetics Measurements Data

Kinetics measurements were performed but have not yet been evaluated.

2.7 Evaluation of Reaction-Rate Distributions

Reaction-rate distribution measurements were performed but have not yet been evaluated.

2.8 Evaluation of Power Distribution Data

Power distribution measurements were not performed.

2.9 Evaluation of Isotopic Measurements

Isotopic measurements were not performed.

2.10 Evaluation of Other Miscellaneous Types of Measurements

Other miscellaneous types of measurements were not performed.

3.0 BENCHMARK SPECIFICATIONS

Two benchmark experiments were evaluated in this report: Cores 9 and 10. These core configurations represent the columnar hexagonal point-on-point (CHPOP) configurations of the HTR-PROTEUS experiment with a moderator-to-fuel pebble ratio of 1:1. Cores 9 and 10 use withdrawable, hollow, stainless steel control rods. Core 9 has 27 pebble layers; a second configuration, or state, of Core 9 that included a 28th layer of just moderator pebbles was not evaluated as it was very similar in core design and implemented to perform core operations after initial criticality was attained. Core 10 retains the same pebble loading as Core 9, but to a height of 24 layers. It has polyethylene rods inserted between pebbles to simulate water ingress.

3.1 Benchmark-Model Specifications for Critical and / or Subcritical Measurements

The benchmark critical configurations for Cores 9 and 10 will be referred to as Cases 1 and 2, respectively. Both methods of identification are utilized throughout the rest of this report to facilitate users with differing familiarities with HTR-PROTEUS and IRPhEP benchmark format.

The HTR-PROTEUS configurations consist of a thick annular graphite reflector surrounding a pair of thick axial graphite reflectors that sandwich a core cavity region containing fuel and moderator pebbles (see Figures 3.1-16 and 3.1-23). Most core configurations in the HTR-PROTEUS experimental series included exact placement of the pebbles, as is the case with Cases 1 and 2 evaluated in this benchmark report. Penetrations in the graphite reflectors were provided for control rods and instrumentation; typically these holes were filled with graphite plugs or filler pieces when not in use.

Case 1 (Core 9) represented the initial critical experiment, or "base case", against which Case 2 (Core 10), which included polyethylene rods placed in channels between the pebbles, was constructed to simulate water ingress effects within pebble bed systems. Both cores could be compared with the randomly stacked core configuration (Core 4) with the same moderator to fuel pebble ratio of 1:1 (see PROTEUS-GCR-EXP-002).

3.1.1 Description of the Benchmark Model Simplifications

Various simplifications were necessary to prepare benchmark model specifications for the critical core configurations. Experimental measurements were performed or estimated based on experimental measurements for a variety of simplifications (see Section 1.1.5), since the original intent of this experimental series was to provide benchmark quality experiments that could be easily modeled. Only a selection of the measured simplifications was retained as biases to be applied to the benchmark models (see Tables 3.1-1 and 3.1-2). Some of the core features were retained in the models to reduce the total effective bias, since they could be modeled easily. The retained measured biases generally represent simplifications of the benchmark models where insufficient information existed to reproduce the measurement with a calculation or reverse the simplification by adding more detail to the benchmark model. Simplifications that were simulated in the original reference reports (also reported in Section 1.1.5) were not retained, but instead recalculated.

Significant simplifications in assembly geometries and compositions were investigated for the first HTR-PROTEUS cores: 1, 1A, 2, and 3 (PROTEUS-GCR-EXP-001). Those simplifications that yielded small ($\leq$0.00100 Δk) or negligible ($\leq$0.00010 Δk) biases that were incorporated into the other benchmark models are now also included in these benchmark models (see Table 3.1-3). Biases calculated for the removal of control rods, coolant channels in the axial reflectors, removal of upper axial reflector aluminum support structure, and voiding of air were large and considered unacceptable for the benchmark models of Cores 1, 1A, 2, and 3. Therefore, these simplifications were not performed and the features were retained in the benchmark models of Cores 9 and 10.

3.1.1.1 Evaluation of Benchmark Model Biases

A summary of the experimentally measured reactivity corrections utilized for the benchmark models is provided in Tables 3.1-1 and 3.1-2 for Cases 1 and 2, respectively. The values for Cases 1 and 2 were obtained from Tables 1.1-17 and 1.1-19, respectively. The reported β_{eff} values were used to convert the reactivity corrections and their associated uncertainties from their original measured reactivities in units of ¢ into Δk; it was assumed that there was an additional bias uncertainty due to the use of the reported β_{eff} values of 5% (1σ) of the reported value (~0.00036 $\Delta\beta_{eff}$). Many of the measurement biases were used directly, since sufficient information was not available to include most of them in the models.

Some of the C-Driver channels in the 2nd and 3rd rings of the radial reflector contained instrumentation instead of graphite rods. The effect of filling these empty positions with graphite rods was measured.

Start-up sources with associated penetrations were used in HTR-PROTEUS. The effect of removing these sources and filling the penetrations with graphite was measured.

Instrumentation and detectors in the core were removed and the effect was measured.

Typically 33 coolant channels in the lower axial reflector and 34 coolant channels in the upper axial reflector were empty during many of the HTR-PROTEUS experiments. However, for Cores 9 and 10, the channels in the lower axial reflector were filled. Both core configurations were modeled with the open coolant channels in the upper reflector and filled coolant channels in the lower reflector.

Table 3.1-1. Experimentally Determined Reactivity Corrections for Case 1 (Core 9).

	Reactivity Correction			**Reactivity Correction**		
Measured Effect	**ρ¢**	**±**	**σ**	**Δk**	**±**	**σ**
Empty Channels in Ring 2 of Radial Reflector	5	±	1	0.00036	±	0.00007
Start-Up Sources	4	±	1	0.00029	±	0.00007
Start-Up Source Penetrations	1	±	0.2	0.00007	±	0.00001
Nuclear Instrumentation (Ionization)	9	±	1.5	0.00065	±	0.00011
Nuclear Instrumentation (Fission)	1	±	0.7	0.00007	±	0.00005
Total (Reported β_{eff} = 0.00720)[(a)]	20	±	2.19	0.00144	±	0.00016

(a) Assumed uncertainty in β_{eff} of 5% (1σ).

Table 3.1-2. Experimentally Determined Reactivity Corrections for Case 2 (Core 10).

	Reactivity Correction			**Reactivity Correction**		
Measured Effect	**ρ¢**	**±**	**σ**	**Δk**	**±**	**σ**
Empty Channels in Ring 2 of Radial Reflector	4	±	1	0.00029	±	0.00007
Start-Up Sources	--	±	--	--	±	--
Start-Up Source Penetrations	1	±	0.2	0.00007	±	0.00001
Nuclear Instrumentation (Ionization)	8.4	±	1.2	0.00060	±	0.00009
Nuclear Instrumentation (Fission)	0.8	±	0.6	0.00006	±	0.00004
Total (Reported β_{eff} = 0.00723)[(a)]	14.2	±	1.69	0.00102	±	0.00013

(a) Assumed uncertainty in β_{eff} of 5% (1σ).

Additional biases were evaluated for the benchmark simplifications of Cores 1, 1A, 2, and 3 (PROTEUS-GCR-EXP-001); a summary of the biases is listed in Table 3.1-3. The effective bias for most of the individually calculated biases were negligible compared to the statistical uncertainty for Cores 1, 1A, 2, and 3, except for the bias for homogenizing the radial reflector; therefore, individual calculations were not performed for Cores 9 and 10 and only a summary of the simplifications is provided with the total effective bias for incorporation of these simplifications in the benchmark models. The effective simplification bias was computed by comparing calculated eigenvalues obtained with MCNP5 input decks (Appendix A) of the benchmark models described in Section 3 and detailed models (Appendix C).

Simplifications to the benchmark models include the removal of many of the assembly components external to the large radial reflector, such as the concrete walls, steel support pedestal, and thermal column (Figures 1.1-1, 1.1-3, and 1.1-9). Experimental measurements confirmed that room return effects were negligible for this series of experiments and therefore deemed unnecessary in the benchmark models.

The safety/shutdown rods and the aluminum shock dampers (Figure 1.1-9) were removed from the benchmark models. The eight channels for these rods were retained in the models (Figure 1.1-2b). Since the safety/shutdown rods were fully withdrawn from the core, their removal from the benchmark models was effectively negligible.

The radial reflector was homogenized with the axial modifiers in the core cavity, C-Driver channels, and graphite plugs in the C-Driver channels (Figures 1.1-2 and 1.1-3). Only penetrations for control rod use were retained: withdrawable control rods, safety/shutdown rods, and autorod. The withdrawable control rods were placed in four of the C-Driver channels in ring 5 of the radial reflector. The ZEBRA rod channels from the initial core, Core 1, were filled with graphite plugs. Radial reflector simplifications facilitate ease of modeling these benchmark configurations. The outer and inner 22-sided polygon surfaces of the radial reflector were converted to cylindrical surfaces; the core cavity region retained its 12-sided polygon surface.

The safety ring (Figure 1.1-4) is removed from the benchmark model and the aluminum support structure of the upper axial reflector was simplified such that the aluminum spherical surfaces (Figures 1.1-4 and 1.1-6) are modeled as an aluminum disc, 1-cm-thick, retaining the outer diameter of the aluminum structure (104.2 cm). The aluminum support structure was a complex entity and very difficult to model with exact detail.

The lower axial reflector was simplified by cylinderizing the graphite annulus and filling the small source gap with graphite (Figure 1.1-7). As with simplification of the radial reflector, removal of the exact location of vertices for the multifaceted polygons used to generate this core by using cylindrical representations greatly simplifies modeling of these benchmark configurations.

All pebbles in the models have a radius of 3.000 cm. The mass of the pebbles was conserved and the resultant bias is negligible.

Impurities in the TRISO particles are removed from the models.

A standard air composition was used for all models with a temperature of 20°C, pressure of 980 mbar, and 50 % humidity. Neon, helium, and krypton are not included in the benchmark model; the bias for their removal is negligible.

Table 3.1-3. Calculated Simplification Biases.

- Removal of Concrete Walls
- Removal of Steel Support Pedestal
- Removal of Thermal Column
- Removal of Safety/Shutdown Rods
  - Includes Shock Dampers
- Cylinderization of Radial Reflector
  - Outer and inner 22-sided polygon surfaces converted to cylindrical surfaces; the core cavity region retained its 12-sided polygon surface
- Removal of Safety Ring
- Homogenization of Radial Reflector
  - Remove All Penetrations Except Those for Control Rods
- Simplify Aluminum Support Structure of Upper Axial Reflector
- Cylinderize Lower Axial Reflector Annulus
- Fill Source Gap with Graphite
- Model All Pebbles with a Radius of 3.000 cm
- Remove UO_2 Impurities in the TRISO Kernels
- Remove Impurities in the TRISO Layers
- Use a Standard Air Composition for All Models
  - Remove Ne, He, and Kr from Air Composition

Case (Core)	1 (9)	2 (10)
Bias (Δk)	0.00147 ± 0.00010	0.00096 ± 0.00008

The total bias for each benchmark configuration (Table 3.1-4) is obtained by summation of the experimentally measured corrections (Tables 3.1-1 and 3.1-2) with the computed simplification bias (Table 3.1-3). The total bias uncertainties are obtained by summing under quadrature the individual bias uncertainties. For example, for Case 1 (Core 9), the measured correction of 0.00144 ± 0.00016 Δk (Table 3.1-1) is added to the calculated simplification bias of 0.00147 ± 0.00010 Δk (Table 3.1-3) to obtain a total simplification bias for the benchmark model of 0.00291 ± 0.00019 Δk (3.1-4).

Table 3.1-4. Total Benchmark Biases (Δk).

Case (Core)	1 (9)	2 (10)
Measured Corrections	0.00144 ± 0.00016	0.00102 ± 0.00013
Calculated Simplifications	0.00147 ± 0.00010	0.00096 ± 0.00008
Total Bias	**0.00291 ± 0.00019**	**0.00198 ± 0.00015**

3.1.2 Dimensions

3.1.2.1 Radial Reflector

The graphite radial reflector (Figure 3.1-1) is an annulus with an equivalent inner radius of 62.83398 cm, an equivalent outer radius of 163.76986 cm, and a height of 330.4 cm. The portion of the radial reflector surrounding the core cavity region can be described as a cylinder with a dodecagon (12-sided polygon) cross section; the distance between the midpoint of each side alternates between 60.15 and 60.3 cm from the core center. This region of the radial reflector extends 172.9 cm upward from the base of the cavity region, located 78.0 cm above the bottom of the radial reflector. Penetrations in the radial reflector are provided for eight safety/shutdown rods, an autorod, and four withdrawable control rods. These holes axially penetrate completely through the radial reflector with the x,y positions provided in Table 3.1-5 and shown in Figures 3.1-2. While the penetrations for the safety/shutdown rods are preserved in the benchmark model, the rods themselves are not included.

Table 3.1-5. Penetrations in Radial Reflector (dimensions in cm).

Penetration Purpose	x-Coordinate	y-Coordinate	Hole Diameter
Safety/Shutdown Rod Hole 1	-38.45	56.57	4.5
Safety/Shutdown Rod Hole 2	32.74	-60.05	4.5
Safety/Shutdown Rod Hole 3	57.17	37.55	4.5
Safety/Shutdown Rod Hole 4	-53.23	-42.95	4.5
Safety/Shutdown Rod Hole 5	67.19	-12.82	4.5
Safety/Shutdown Rod Hole 6	-66.98	13.87	4.5
Safety/Shutdown Rod Hole 7	19.31	65.62	4.5
Safety/Shutdown Rod Hole 8	-13.87	-66.98	4.5
Autorod Hole	17.36	-87.29	5.5
Withdrawable Control Rod Hole 1	-83.70	34.67	2.743
Withdrawable Control Rod Hole 2	34.67	83.70	2.743
Withdrawable Control Rod Hole 3	83.70	-34.67	2.743
Withdrawable Control Rod Hole 4	-34.67	-83.70	2.743

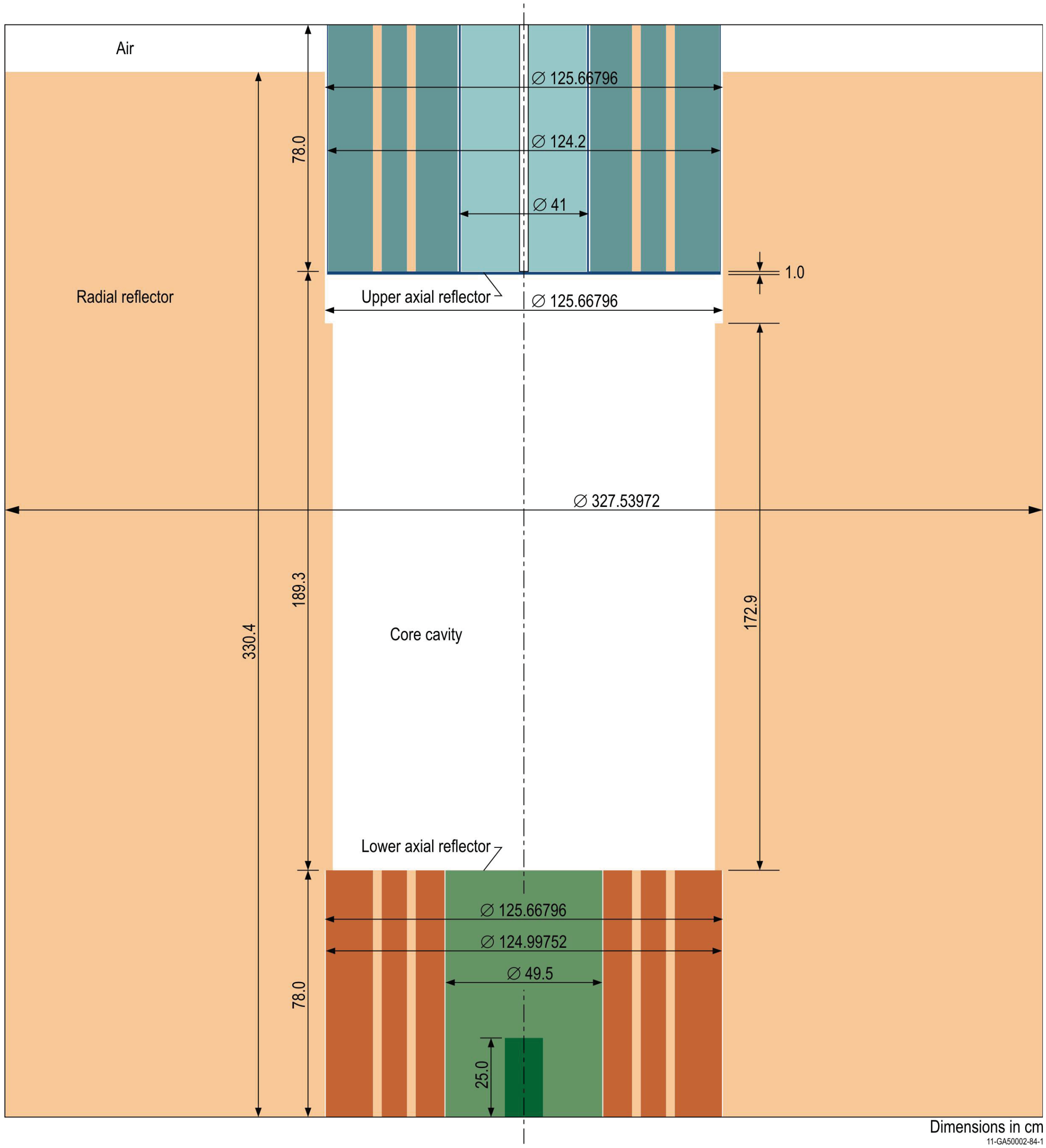

Figure 3.1-1. Radial and Axial Reflectors Surrounding Core Cavity Region.

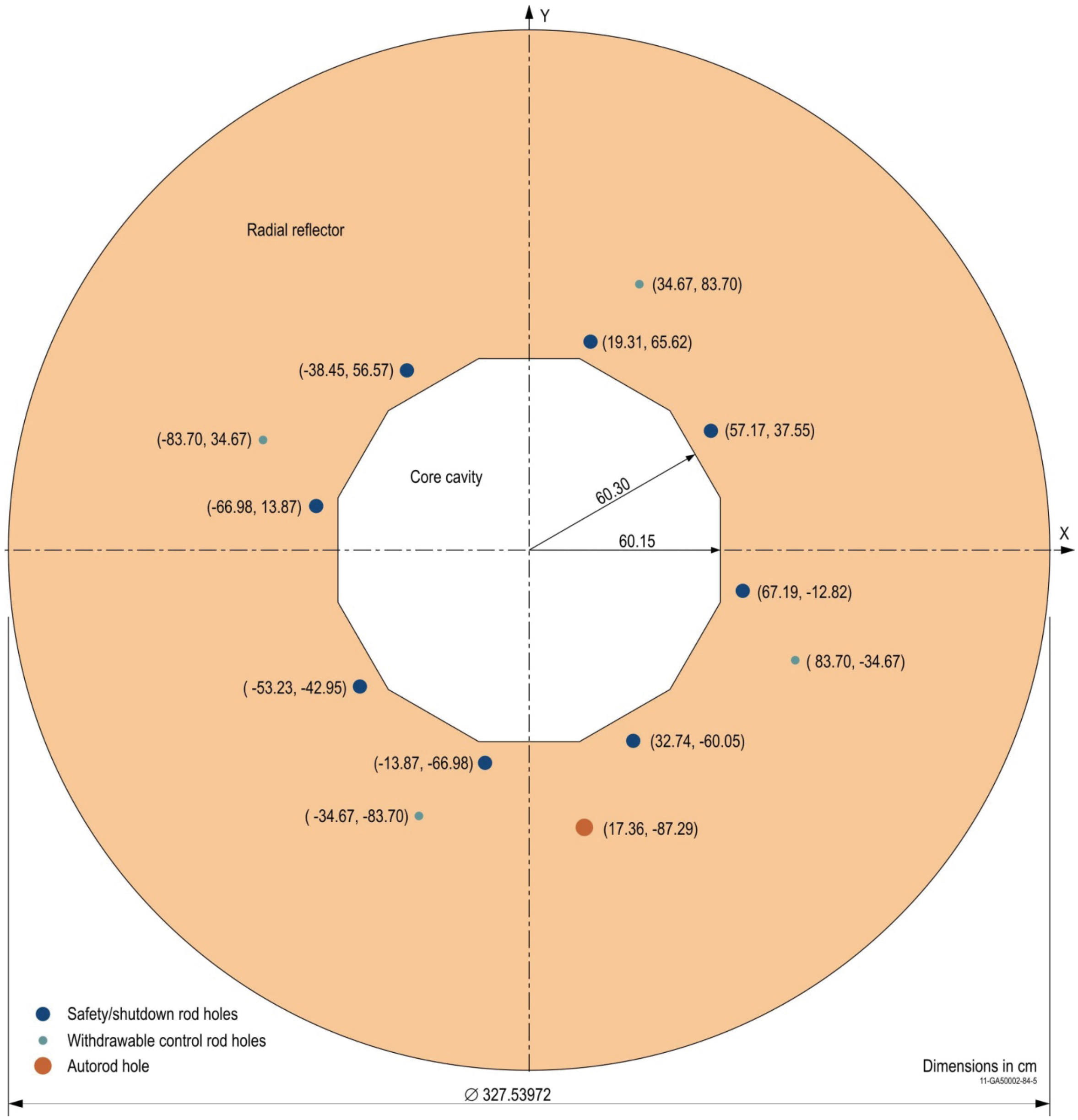

Figure 3.1-2. Radial Reflector Surrounding Core Cavity Region.

3.1.2.2 Upper Axial Reflector

The upper axial reflector consists of a graphite cylinder (radius of 19.7 cm) with a single coolant channel (diameter of 2.743 cm) and a graphite annulus (inner radius of 20.93 cm and outer radius of 61.7 cm) with 160 coolant channels (diameters of 2.743 cm) distributed equally and uniformly spaced within 5 annular locations with distances of 30.0, 35.5, 41.0, 46.25, and 51.5 cm radially from the center of the reflector (see Figure 3.1-4 and Table 3.1-6). Of the 161 channels, 127 are filled with graphite plugs (diameter of 2.65 cm), as noted in Table 3.1-6 with a "Y". The height of all graphite components is 78.0 cm. An aluminum structure supports the graphite components of the upper axial reflector with an inner annular sheet (19.8 cm inner radius and 20.5 cm outer radius) separating the graphite annulus and cylinder and another outer annular sheet (61.8 cm inner radius and 62.1 cm outer radius) surrounding the entire axial reflector. Air gaps exist between the graphite and aluminum portions of the reflector. The thickness of the aluminum structure below the graphite is 1.0 cm. The bottom of the graphite in the upper axial reflector rests 189.3 cm above the top of the lower axial reflector. The inside radius of the radial reflector surrounding the upper axial reflector is 62.83398 cm.

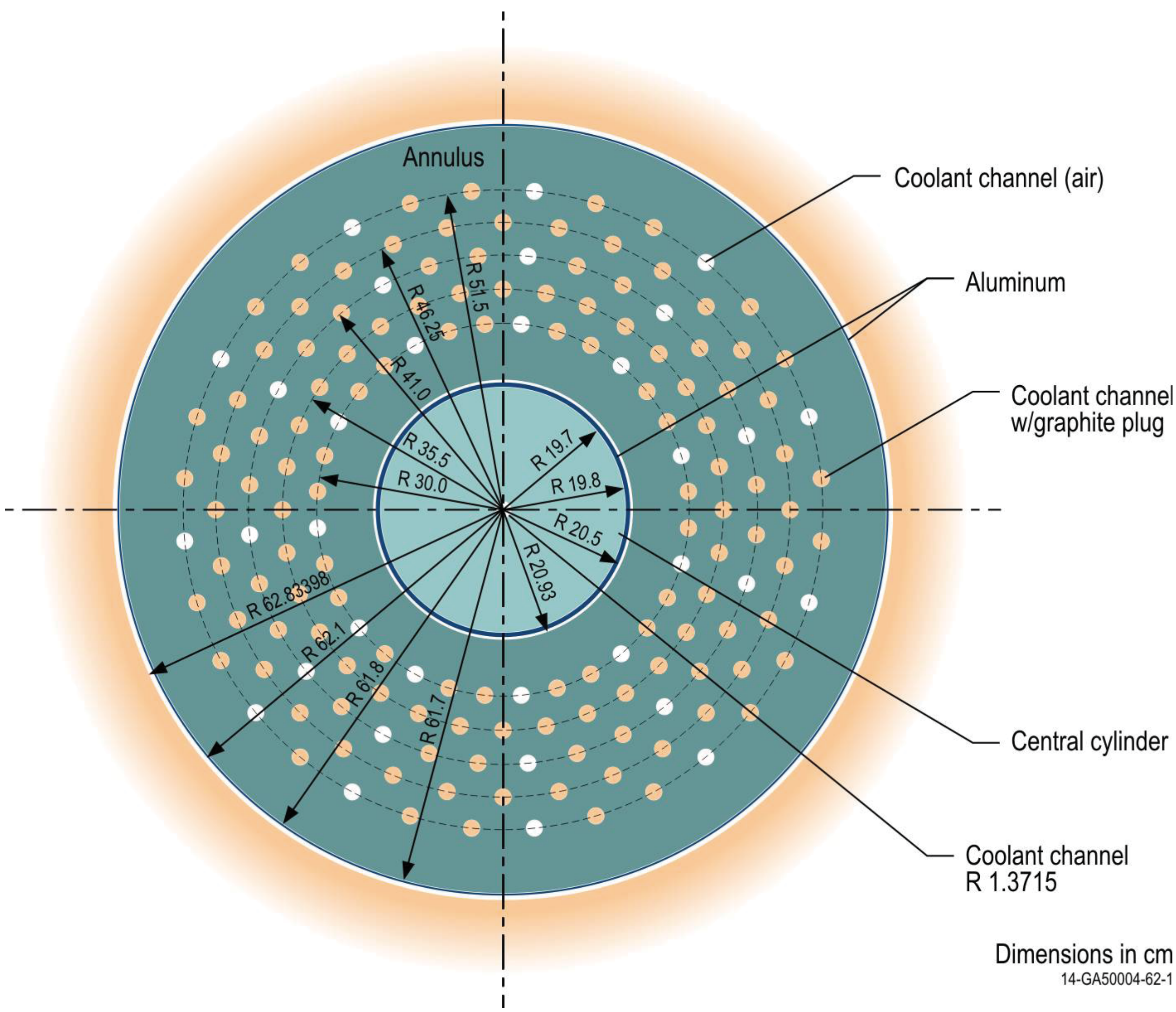

Figure 3.1-4. Upper Axial Reflector.

Table 3.1-6. Penetration Coordinates in the Axial Reflectors (dimensions in cm).

Ring	1			2			3		
Position	**x**	**y**	**Plug?[(a)]**	**x**	**y**	**Plug?[(a)]**	**x**	**y**	**Plug?[(a)]**
1	-29.86	2.94	Y	-34.82	6.93	Y	-39.23	11.90	Y
2	-28.71	8.71	Y	-32.80	13.59	Y	-36.16	19.33	N
3	-26.46	14.14	N	-29.52	19.72	Y	-31.69	26.01	Y
4	-23.19	19.03	Y	-25.10	25.10	Y	-26.01	31.69	Y
5	-19.03	23.19	Y	-19.72	29.52	Y	-19.33	36.16	N
6	-14.14	26.46	N	-13.59	32.80	Y	-11.90	39.23	Y
7	-8.71	28.71	Y	-6.93	34.82	Y	-4.02	40.80	Y
8	-2.94	29.86	Y	0.00	35.50	Y	4.02	40.80	N
9	2.94	29.86	N	6.93	34.82	Y	11.90	39.23	Y
10	8.71	28.71	Y	13.59	32.80	Y	19.33	36.16	Y
11	14.14	26.46	Y	19.72	29.52	Y	26.01	31.69	N
12	19.03	23.19	N	25.10	25.10	Y	31.69	26.01	Y
13	23.19	19.03	Y	29.52	19.72	Y	36.16	19.33	Y
14	26.46	14.14	Y	32.80	13.59	Y	39.23	11.90	N
15	28.71	8.71	N	34.82	6.93	Y	40.80	4.02	Y
16	29.86	2.94	Y	35.50	0.00	Y	40.80	-4.02	Y
17	29.86	-2.94	Y	34.82	-6.93	Y	39.23	-11.90	N
18	28.71	-8.71	N	32.80	-13.59	Y	36.16	-19.33	Y
19	26.46	-14.14	Y	29.52	-19.72	Y	31.69	-26.01	Y
20	23.19	-19.03	Y	25.10	-25.10	Y	26.01	-31.69	N
21	19.03	-23.19	N	19.72	-29.52	Y	19.33	-36.16	Y
22	14.14	-26.46	Y	13.59	-32.80	Y	11.90	-39.23	Y
23	8.71	-28.71	Y	6.93	-34.82	Y	4.02	-40.80	N
24	2.94	-29.86	N	0.00	-35.50	Y	-4.02	-40.80	Y
25	-2.94	-29.86	Y	-6.93	-34.82	Y	-11.90	-39.23	Y
26	-8.71	-28.71	Y	-13.59	-32.80	Y	-19.33	-36.16	N
27	-14.14	-26.46	N	-19.72	-29.52	Y	-26.01	-31.69	Y
28	-19.03	-23.19	Y	-25.10	-25.10	Y	-31.69	-26.01	N
29	-23.19	-19.03	N	-29.52	-19.72	Y	-36.16	-19.33	Y
30	-26.46	-14.14	Y	-32.80	-13.59	Y	-39.23	-11.90	Y
31	-28.71	-8.71	Y	-34.82	-6.93	Y	-40.80	-4.02	N
32	-29.86	-2.94	N	-35.50	0.00	Y	-40.80	4.02	Y

Table 3.1-6. (cont'd.). Penetration Coordinates in the Axial Reflectors (dimensions in cm).

Ring	4			5		
Position	**x**	**y**	**Plug?**[(a)]	**x**	**y**	**Plug?**[(a)]
1	-42.73	17.70	Y	-45.42	24.28	N
2	-38.46	25.70	Y	-39.81	32.67	Y
3	-32.70	32.70	Y	-32.67	39.81	Y
4	-25.70	38.46	Y	-24.28	45.42	N
5	-17.70	42.73	Y	-14.95	49.28	Y
6	-9.02	45.36	Y	-5.05	51.25	Y
7	0.00	46.25	Y	5.05	51.25	N
8	9.02	45.36	Y	14.95	49.28	Y
9	17.70	42.73	Y	24.28	45.42	Y
10	25.70	38.46	Y	32.67	39.81	N
11	32.70	32.70	Y	39.81	32.67	Y
12	38.46	25.70	Y	45.42	24.28	Y
13	42.73	17.70	Y	49.28	14.95	N
14	45.36	9.02	Y	51.25	5.05	Y
15	46.25	0.00	Y	51.25	-5.05	Y
16	45.36	-9.02	Y	49.28	-14.95	N
17	42.73	-17.70	Y	45.42	-24.28	Y
18	38.46	-25.70	Y	39.81	-32.67	Y
19	32.70	-32.70	Y	32.67	-39.81	N
20	25.70	-38.46	Y	24.28	-45.42	Y
21	17.70	-42.73	Y	14.95	-49.28	Y
22	9.02	-45.36	Y	5.05	-51.25	N
23	0.00	-46.25	Y	-5.05	-51.25	Y
24	-9.02	-45.36	Y	-14.95	-49.28	Y
25	-17.70	-42.73	Y	-24.28	-45.42	N
26	-25.70	-38.46	Y	-32.67	-39.81	Y
27	-32.70	-32.70	Y	-39.81	-32.67	N
28	-38.46	-25.70	Y	-45.42	-24.28	Y
29	-42.73	-17.70	Y	-49.28	-14.95	Y
30	-45.36	-9.02	Y	-51.25	-5.05	N
31	-46.25	0.00	Y	-51.25	5.05	Y
32	-45.36	9.02	Y	-49.28	14.95	Y

(a) This column notes whether a graphite plug is (marked by "Y") or is not (marked by "N") located within the coolant channel.

3.1.2.3 Lower Axial Reflector

The lower axial reflector consists of a graphite cylinder (radius of 24.75 cm) containing a removable source plug and a graphite annulus (equivalent inner radius of 25.05171 cm and equivalent outer radius of 62.71754 cm) with 160 coolant channels (diameter of 2.742 cm) with the same XY positions as the upper axial reflector (see Figure 3.1-5 and Table 3.1-6). Graphite plugs (diameter of 2.65 cm) fill all 160 coolant channel positions. The height of all graphite components, except the source plug, is 78.0 cm. The source plug is located at the bottom of the graphite cylinder along its axis and has a radius of 6.0 cm and height of 25.0 cm, located within a hole in the graphite cylinder with the same dimensions. The inside radius of the radial reflector surrounding the lower axial reflector is 62.83398 cm.

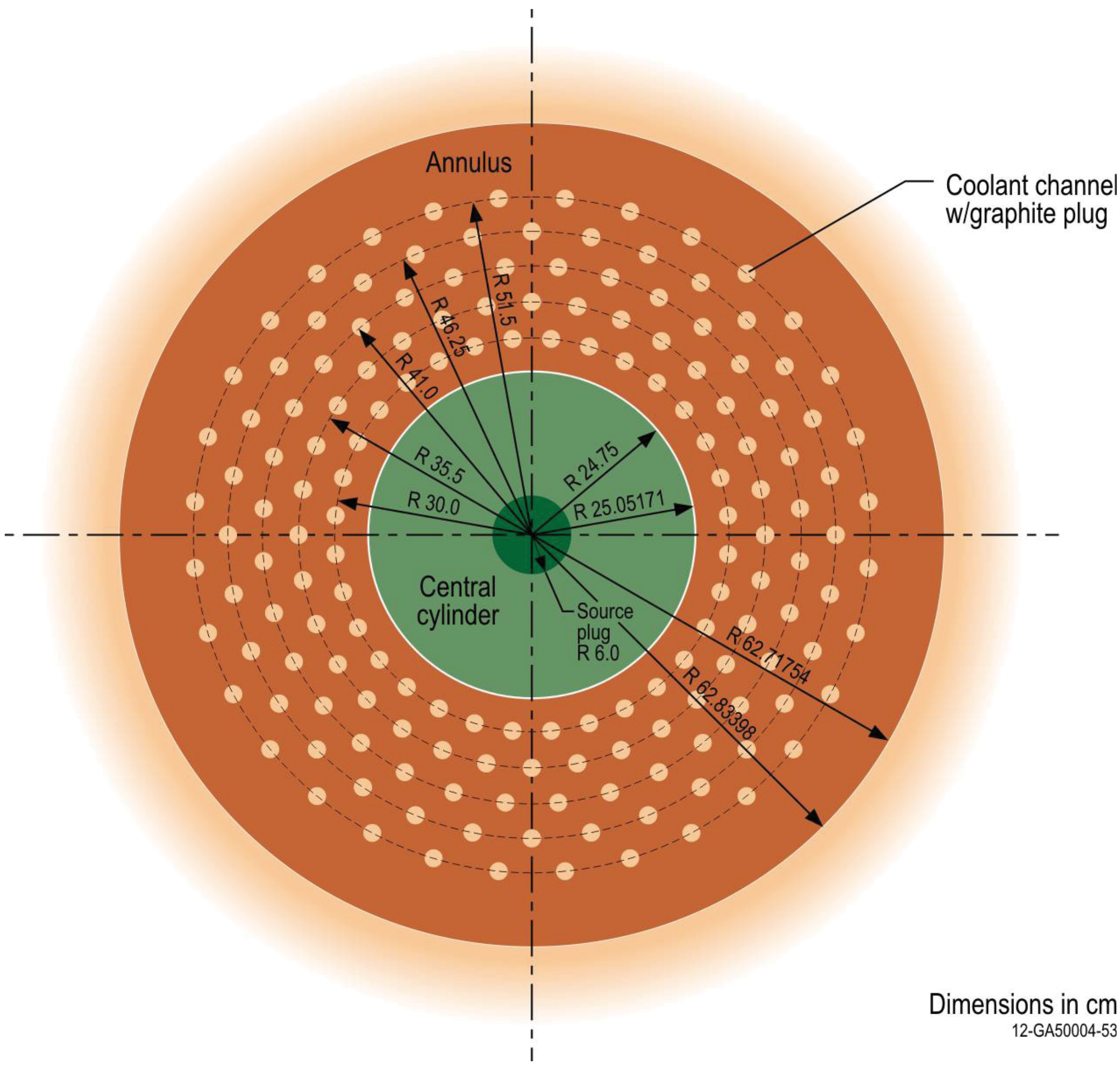

Figure 3.1-5. Lower Axial Reflector.

3.1.2.4 Autorod

The autorod (Figures 3.1-6 and 3.1-7) consists of an aluminum guide tube (inner diameter of 4 cm and outer diameter of 4.4 cm) running the full length of its penetration in the radial reflector. A copper wedge can be raised or lowered within the tube for fine reactivity control of the assembly. The copper wedge has a thickness of 0.3 cm and a length of 230 cm. The top of the wedge has a width of 3.9 cm and tapers to a point at the bottom of the wedge. The XY position of the autorod compared to the core is shown in Figure 3.1-2 with the orientation shown in Figure 3.1-6. When fully inserted, the tip of the autorod is located 7.5 cm below the bottom of the radial reflector. The autorod is considered fully "withdrawn" in its uppermost position of 100.0 cm above its fully inserted position (see Figure 3.1-7). The distance the autorod is withdrawn from the fully inserted position for each core configuration is provided in Table 3.1-7.

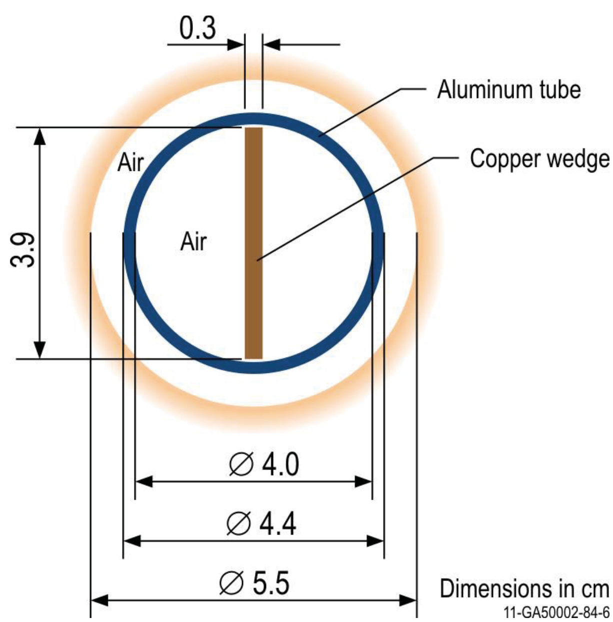

Figure 3.1-6. Top View of Autorod.

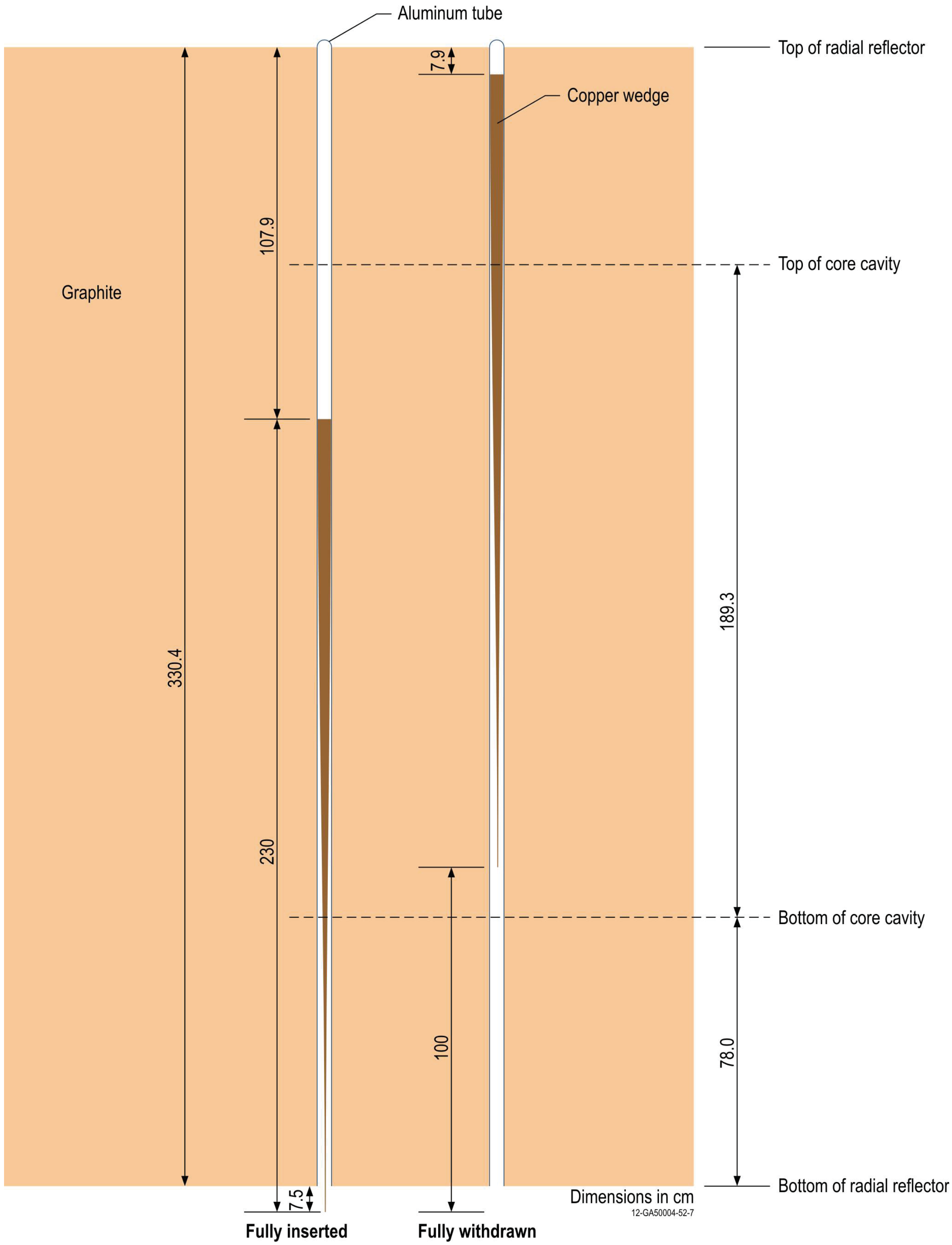

Figure 3.1-7. Autorod Vertical Position within Radial Reflector.

Table 3.1-7. Control Rod Positions (distance in cm).

Case (Core)	1 (9)	2 (10)
Control Rod	**Withdrawn Distance**	**Withdrawn Distance**
Safety/Shutdown Rod 1	NA	NA
Safety/Shutdown Rod 2	NA	NA
Safety/Shutdown Rod 3	NA	NA
Safety/Shutdown Rod 4	NA	NA
Safety/Shutdown Rod 5	NA	NA
Safety/Shutdown Rod 6	NA	NA
Safety/Shutdown Rod 7	NA	NA
Safety/Shutdown Rod 8	NA	NA
Autorod	25.8	1.5
Withdrawable Control Rod 1	249.4	96.0
Withdrawable Control Rod 2	249.4	96.0
Withdrawable Control Rod 3	249.4	96.0
Withdrawable Control Rod 4	249.4	96.0

3.1.2.5 Fuel Pebbles

The graphite fuel pebbles have a diameter of 6.000 cm. A total of 9394 TRISO particles are randomly distributed within the graphite matrix of the fueled zone (diameter of 4.700 cm) of each fuel pebble (Figure 3.1-8). The fuel pebbles are located in the core cavity; their positions in each core configuration are described in more detail in Section 3.1.2.10. Each TRISO particle consists of four layers surrounding a UO_2 kernel. The fuel kernel has a diameter of 0.0502 cm. A graphite buffer layer (thickness of 0.00915 cm) surrounds the fuel kernel. An inner pyrolytic carbon (IPyC) layer (thickness of 0.00399 cm), SiC layer (thickness of 0.00353 cm), and outer pyrolytic carbon (OPyC) layer (thickness of 0.00400 cm) then each, in succession, surround the growing TRISO particle, as shown in Figure 3.1-8.

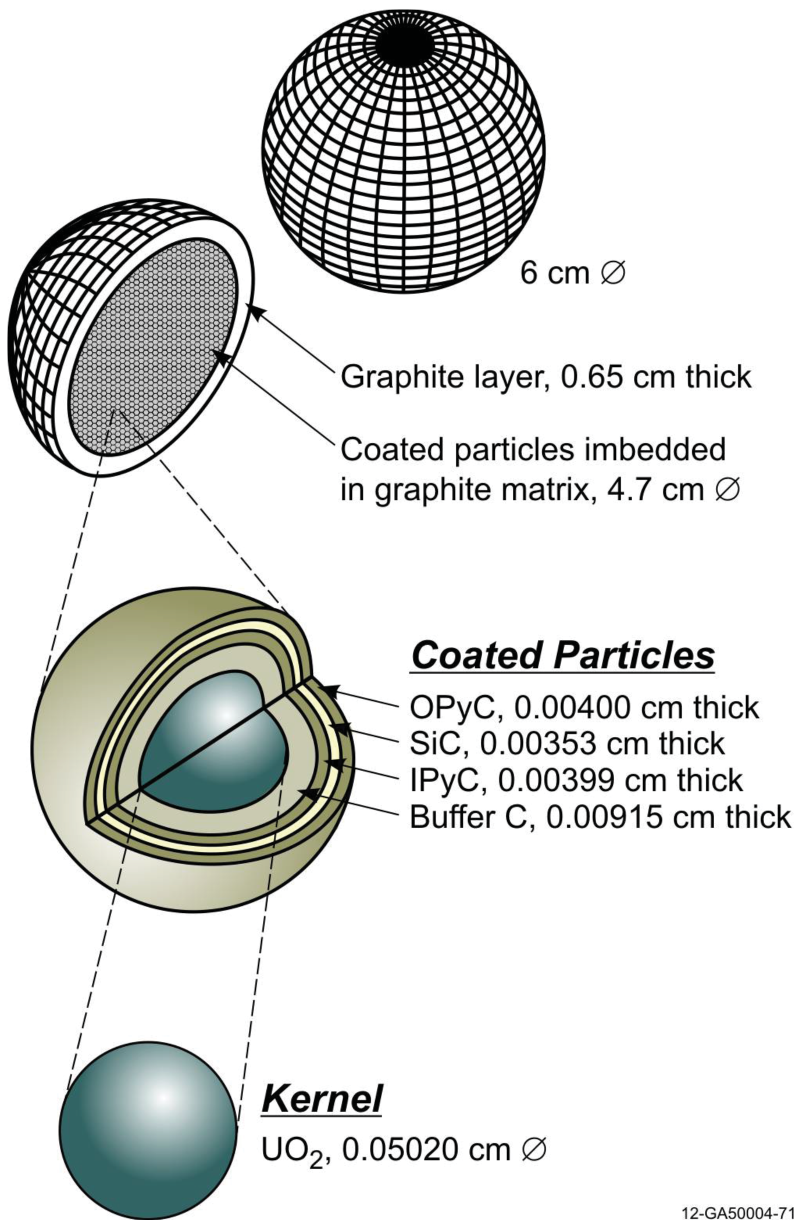

Figure 3.1-8. Fuel Pebble and TRISO Particle.

3.1.2.6 Moderator Pebbles

The graphite moderator pebbles have a diameter of 6.000 cm. They are located in the core cavity; their positions in each core configuration are described in more detail in Section 3.1.2.10.

3.1.2.7 Withdrawable Stainless Steel Control Rods

The withdrawable control rods (Figures 3.1-9 through 3.1-11) are comprised of two concentric stainless steel tubes with end plugs. The inner tube has an inner diameter of 0.95 cm and an outer diameter of 1.35 cm. The outer tube has an inner diameter of 1.4 cm and an outer diameter of 2.2 cm. Both tubes have a total length of 215.0 cm. The dimensions for the end plugs are shown in Figure 3.1-10. The stainless steel control rods are completely inserted into the core when the bottom surface of the bottom end plug is located 75.5 cm above the bottom of the radial reflector; they are completely withdrawn when raised 249.4 cm from the fully inserted position (see Figure 3.1-11). A graphite plug (diameter of 2.65 cm and height of 73.0 cm) is located in the bottom of each penetration for the withdrawable control rods. The withdrawn positions of the withdrawable control rods are provided in Table 3.1-7.

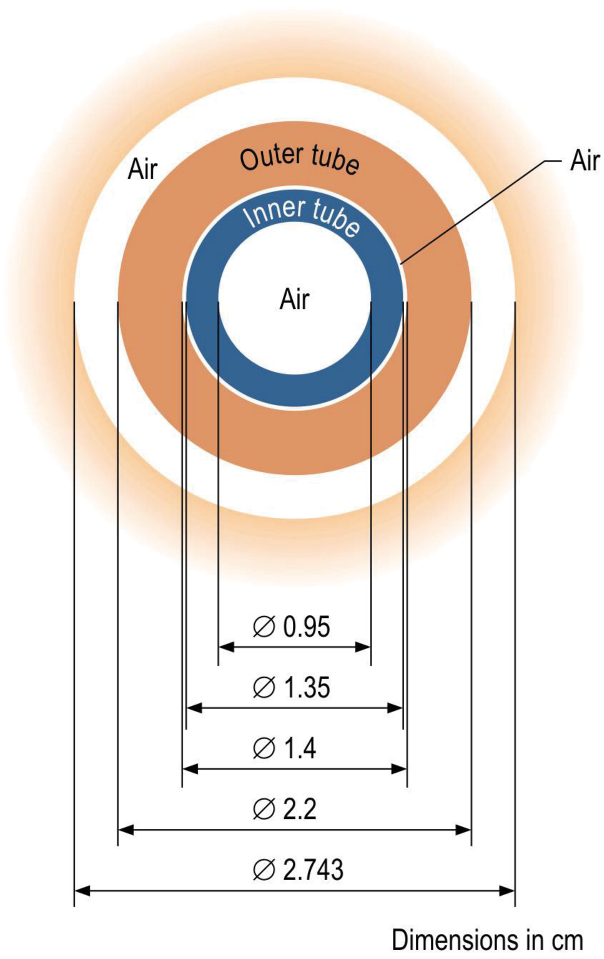

Figure 3.1-9. Top View of Withdrawable Control Rod.

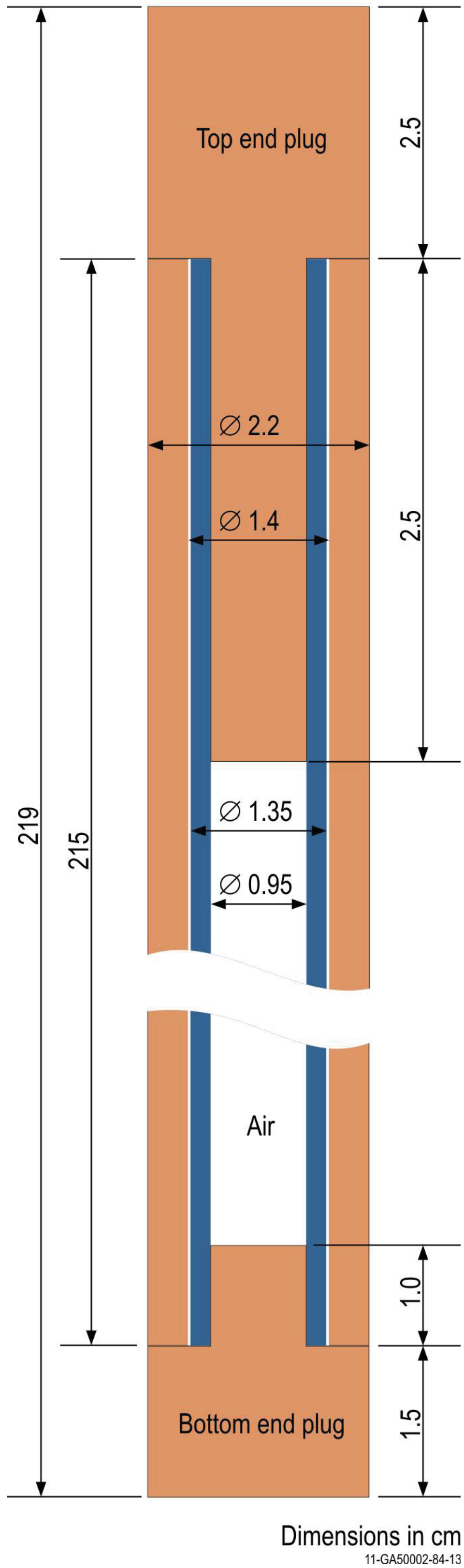

Figure 3.1-10. Axial View of Withdrawable Control Rod.

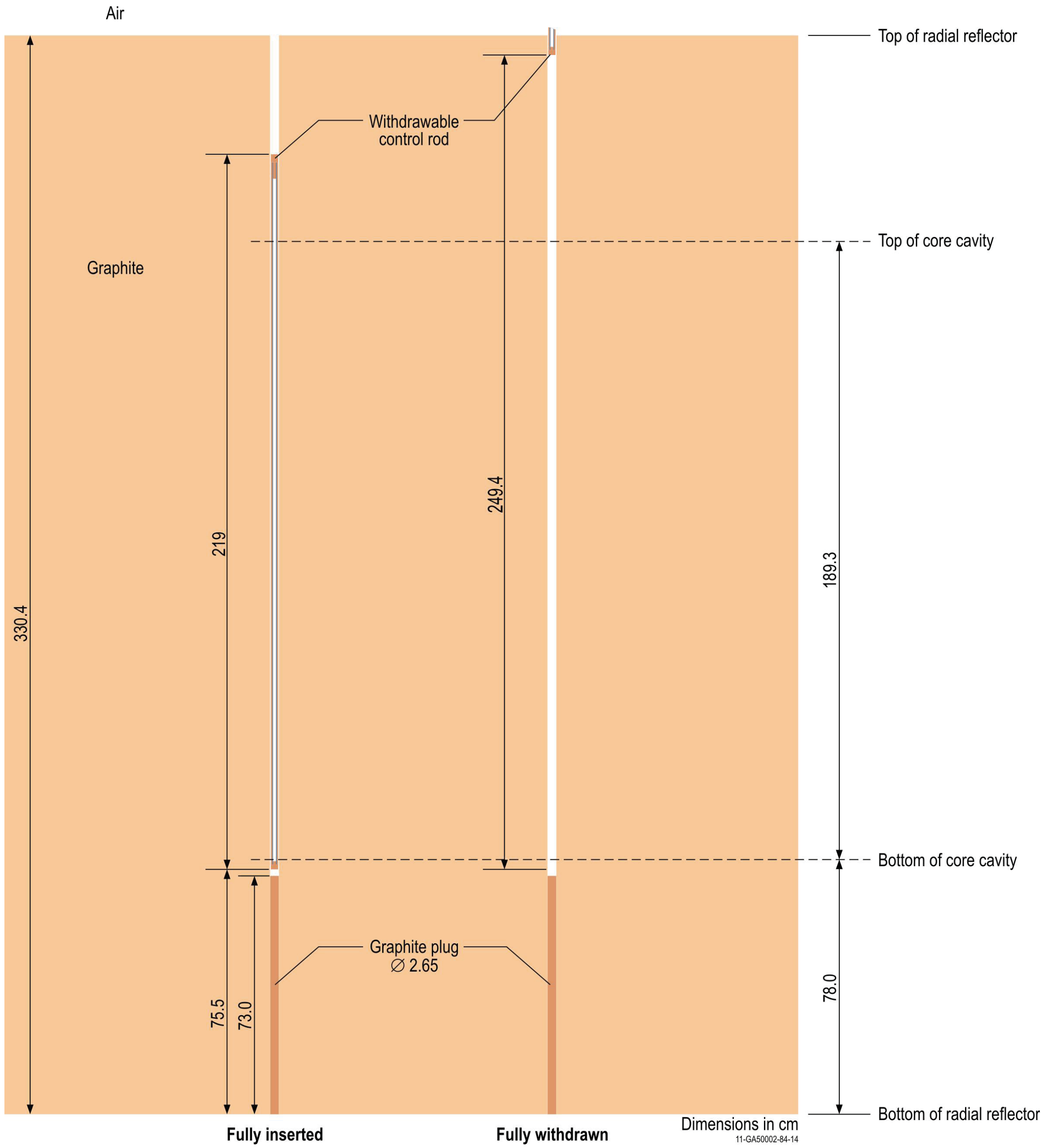

Figure 3.1-11. Withdrawable Control Rod Vertical Position within Radial Reflector.

3.1.2.8 Polyethylene Rods

Polyethylene (sometimes referred to as plastic) rods are used to simulate water ingress in Case 2 (Core 10) only. Each rod has a diameter of 0.65 cm and length of 145.0 cm. There are a total of 654 rods located in the core; they are placed vertically in interstitial pebble channels (see Figures 3.1-21 and 3.1-26).

3.1.2.9 Ambient Air

Air is located in any gaps, holes, or penetrations within the benchmark model that does not contain the graphite reflectors, graphite plugs, aluminum support structure, pebbles, lattice supports, or control rods.

3.1.2.10 Core Configurations

Each core has a unique configuration of fuel and moderator pebbles stacked within the core cavity. The position of each pebble is known since the pebbles are deterministically placed in columnar hexagonal point-on-point packed lattices, as shown in Figure 3.1-12. Information corresponding to the loading of each configuration is provided in Table 3.1-8 with additional visualization of the core descriptions in Figures 3.1-13 through 3.1-26.

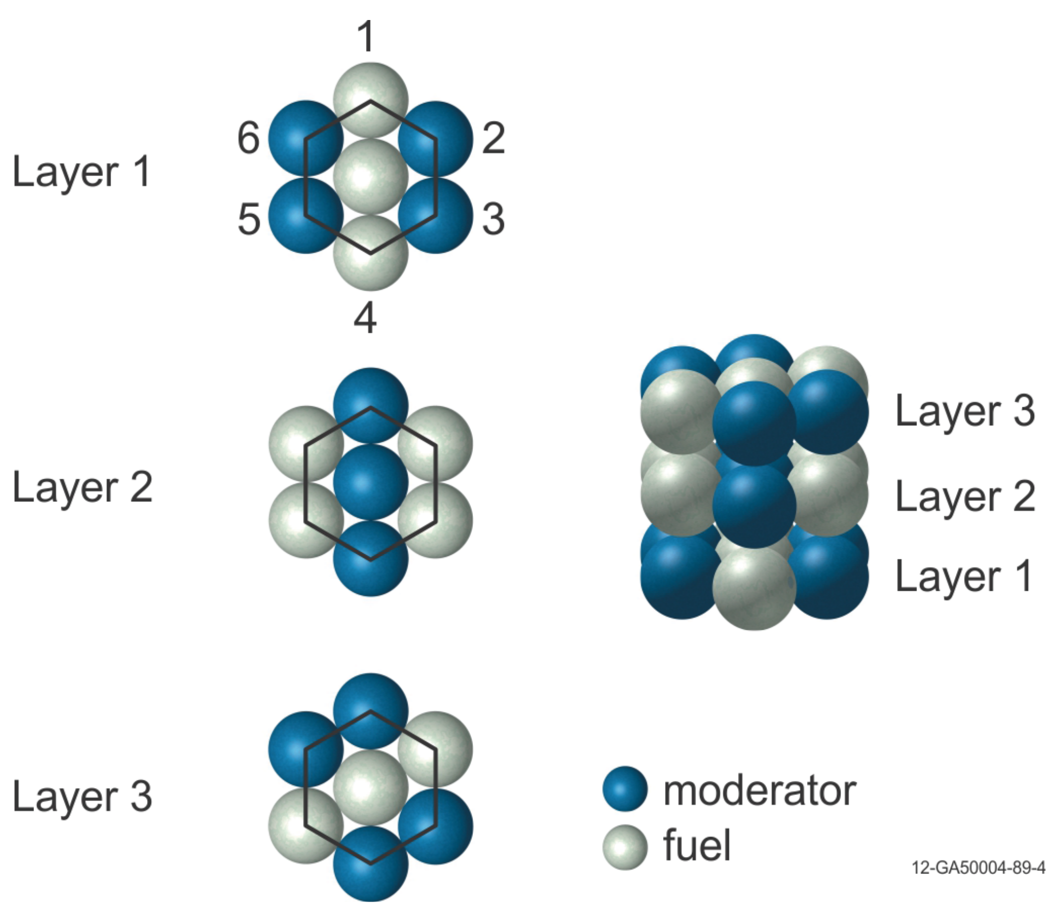

Figure 3.1-12. Subunit for Construction of the Columnar Hexagonal Point-On-Point (CHPOP) Cell.

Table 3.1-8. Additional Core Configuration Parameters.

Case	Core	# Fuel Pebbles	# Moderator Pebbles	# Pebble Layers	Core Height (m)	# Polyethylene Rods	Associated Figures
1	9	4870	4877	27	1.62	0	3.1-13 to 3.1-19
2	10	4332	4332	24	1.44	654	3.1-20 to 3.1-26

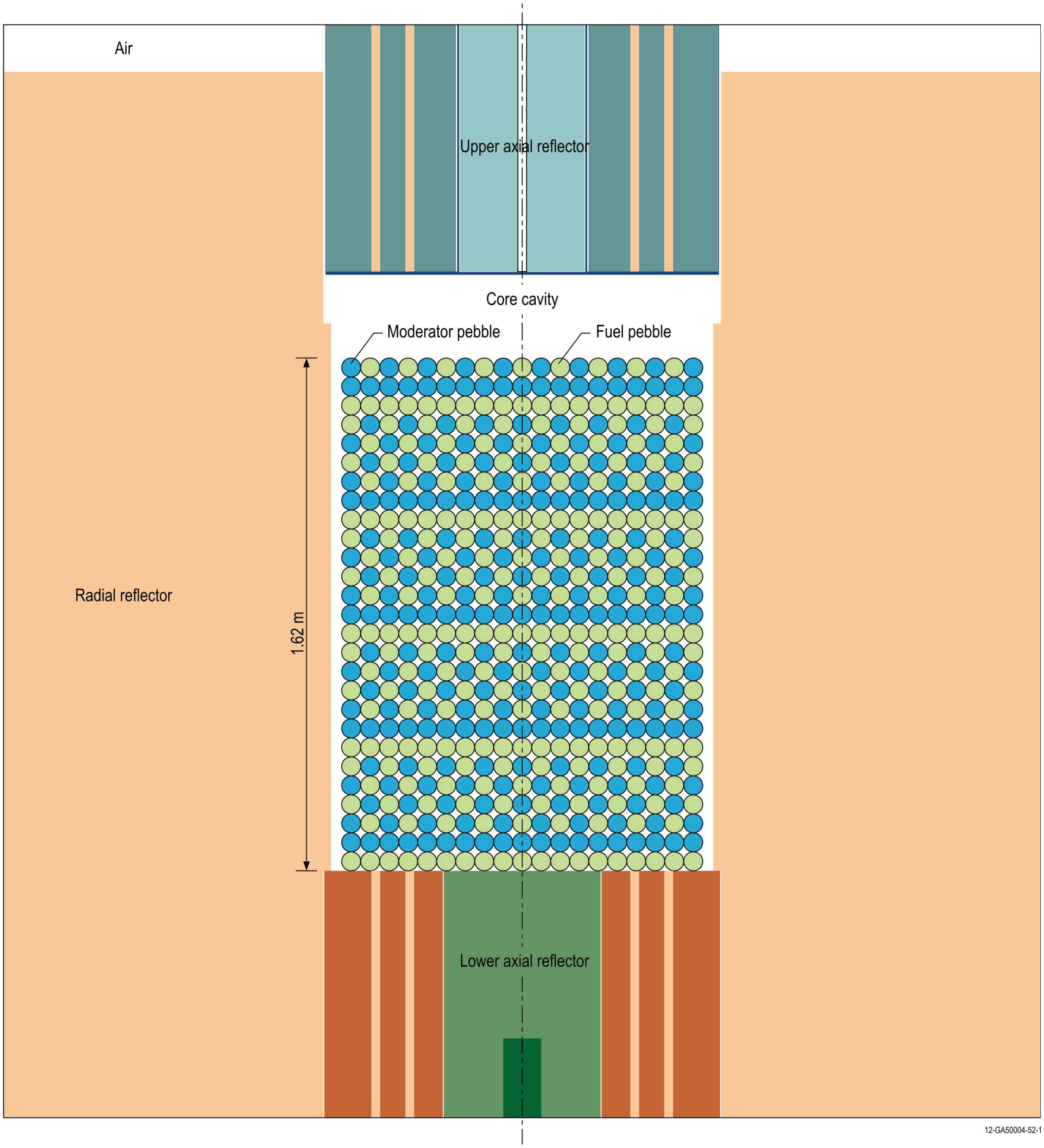

Figure 3.1-13. Vertical Profile of Case 1 (Core 9).

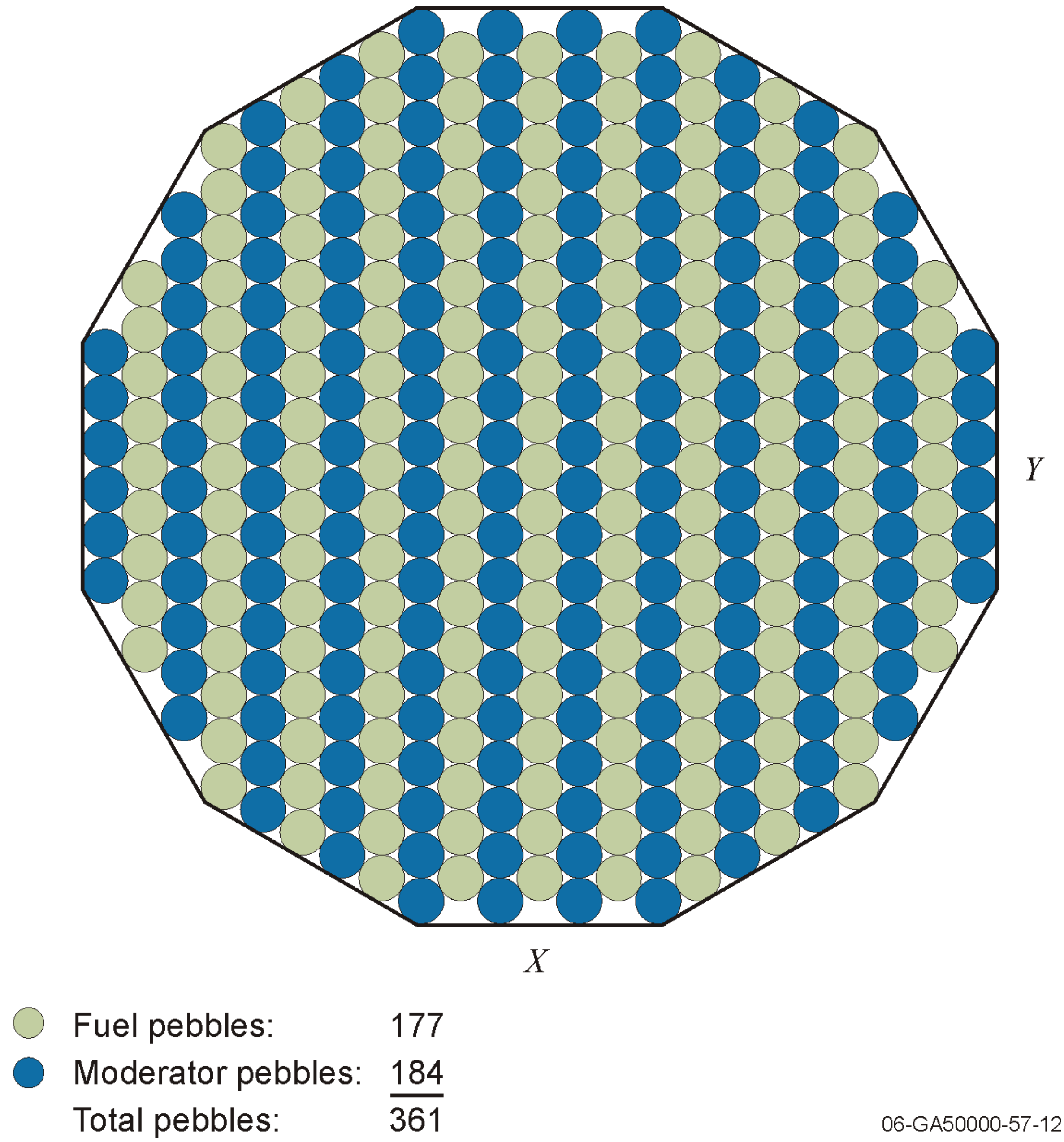

Figure 3.1-14. Layers 1, 7, 13, 19, and 25 of Case 1 (Core 9).

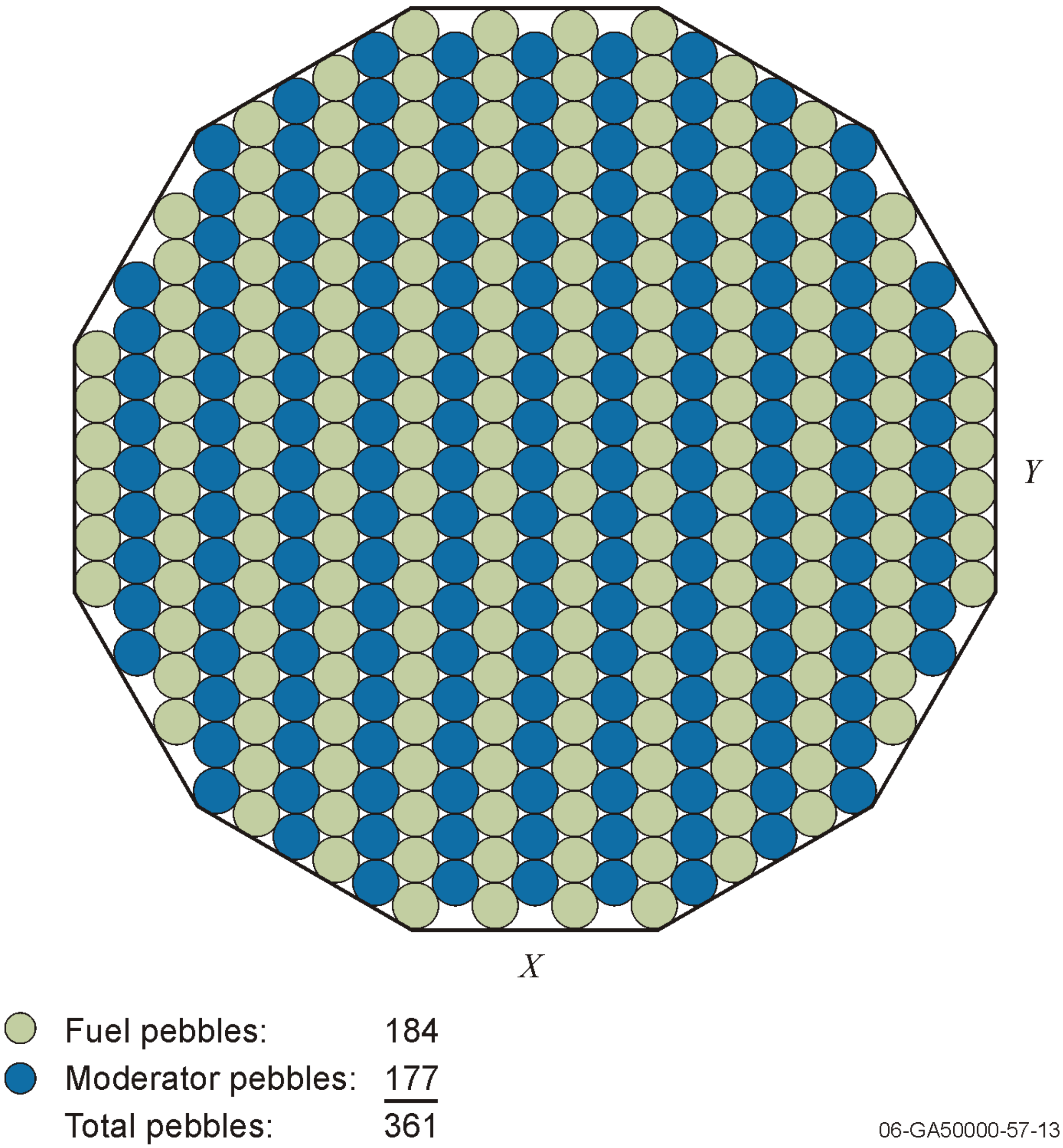

Figure 3.1-15. Layers 2, 8, 14, 20, and 26 of Case 1 (Core 9).

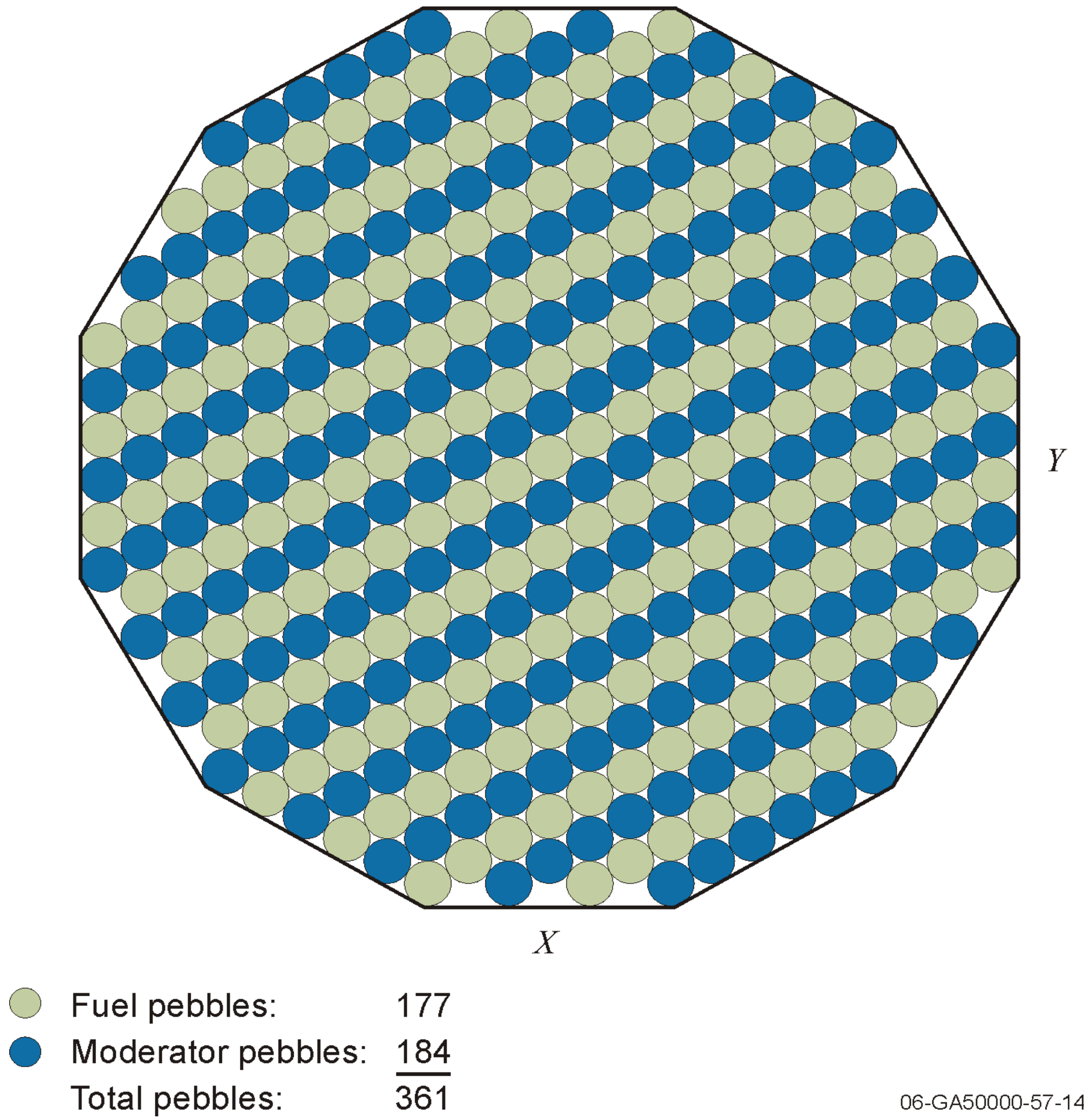

Figure 3.1-16. Layers 3, 9, 15, 21, and 27 of Case 1 (Core 9).

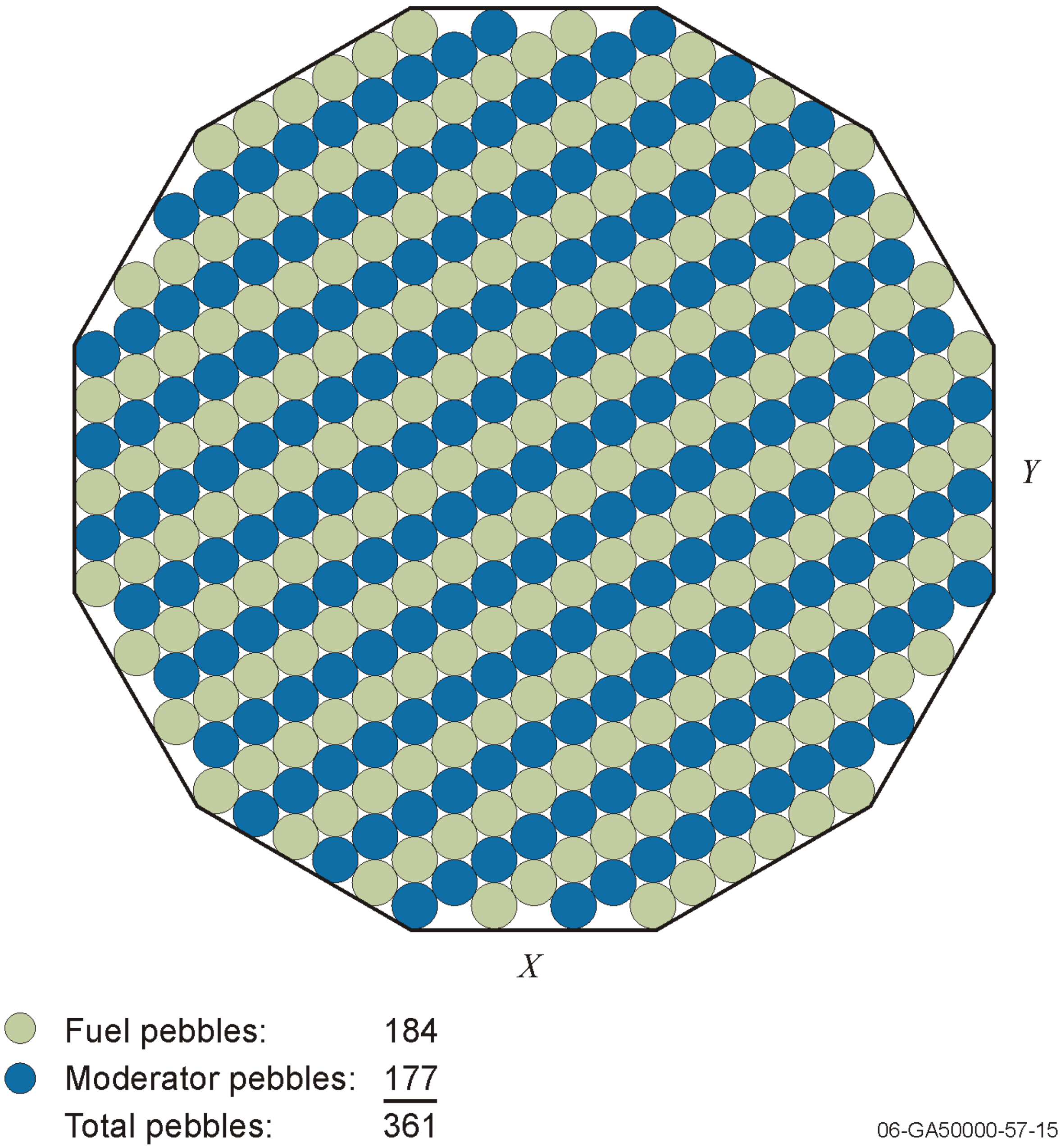

Figure 3.1-17. Layers 4, 10, 16, and 22 of Case 1 (Core 9).

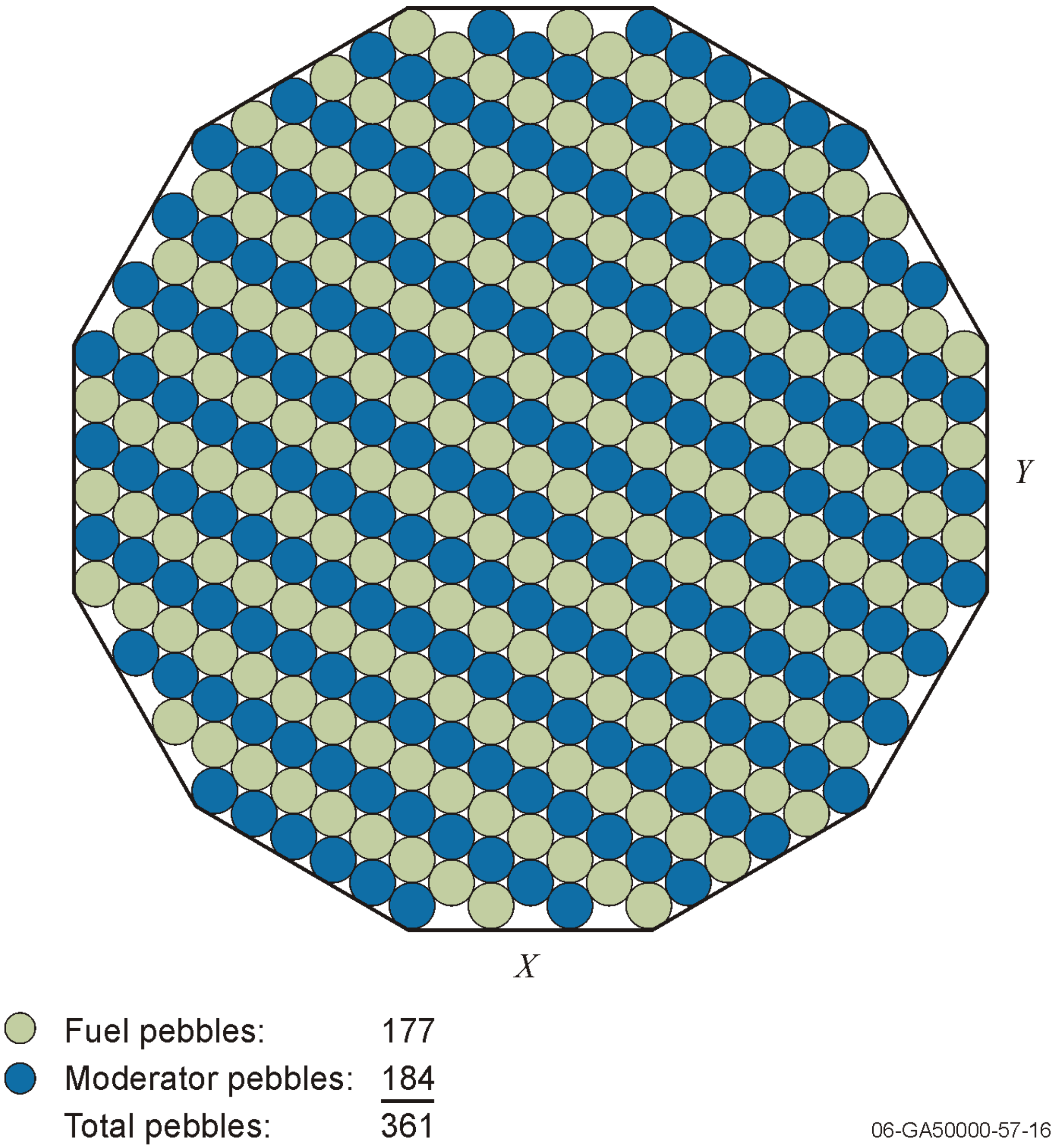

Figure 3.1-18. Layers 5, 11, 17, and 23 of Case 1 (Core 9).

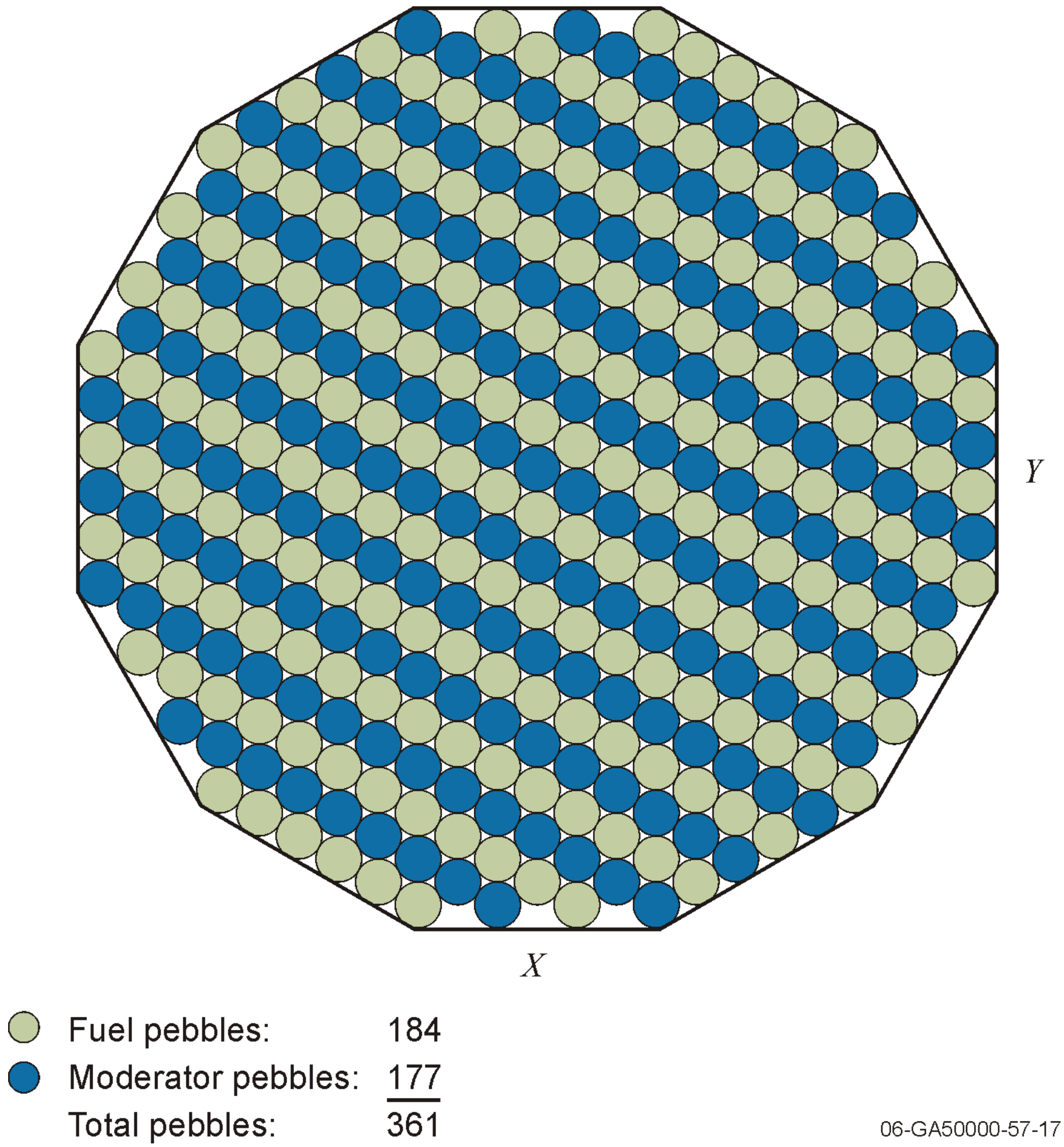

Figure 3.1-19. Layers 6, 12, 18, and 24 of Case 1 (Core 9).

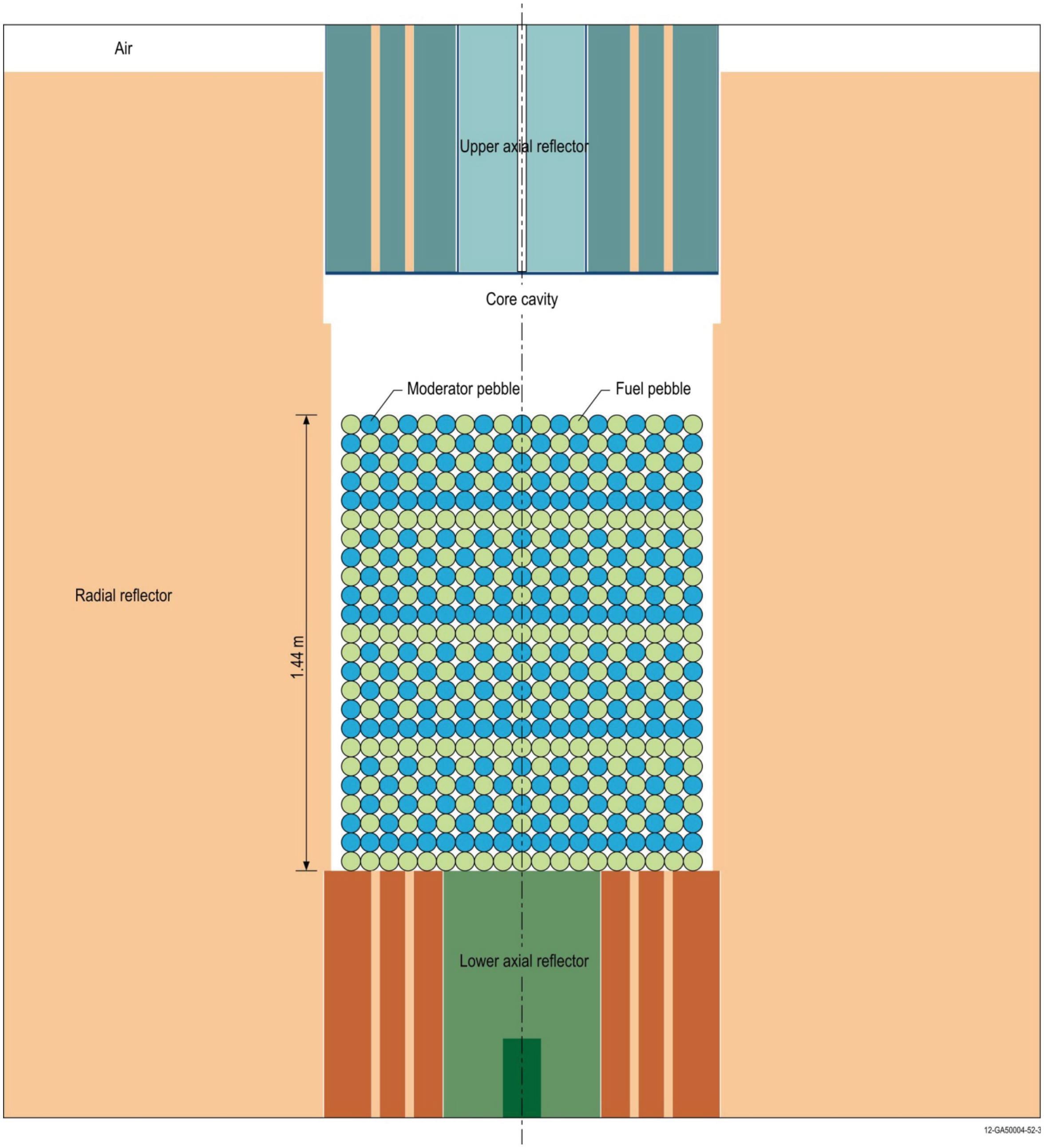

Figure 3.1-20. Vertical Profile of Case 2 (Core 10).

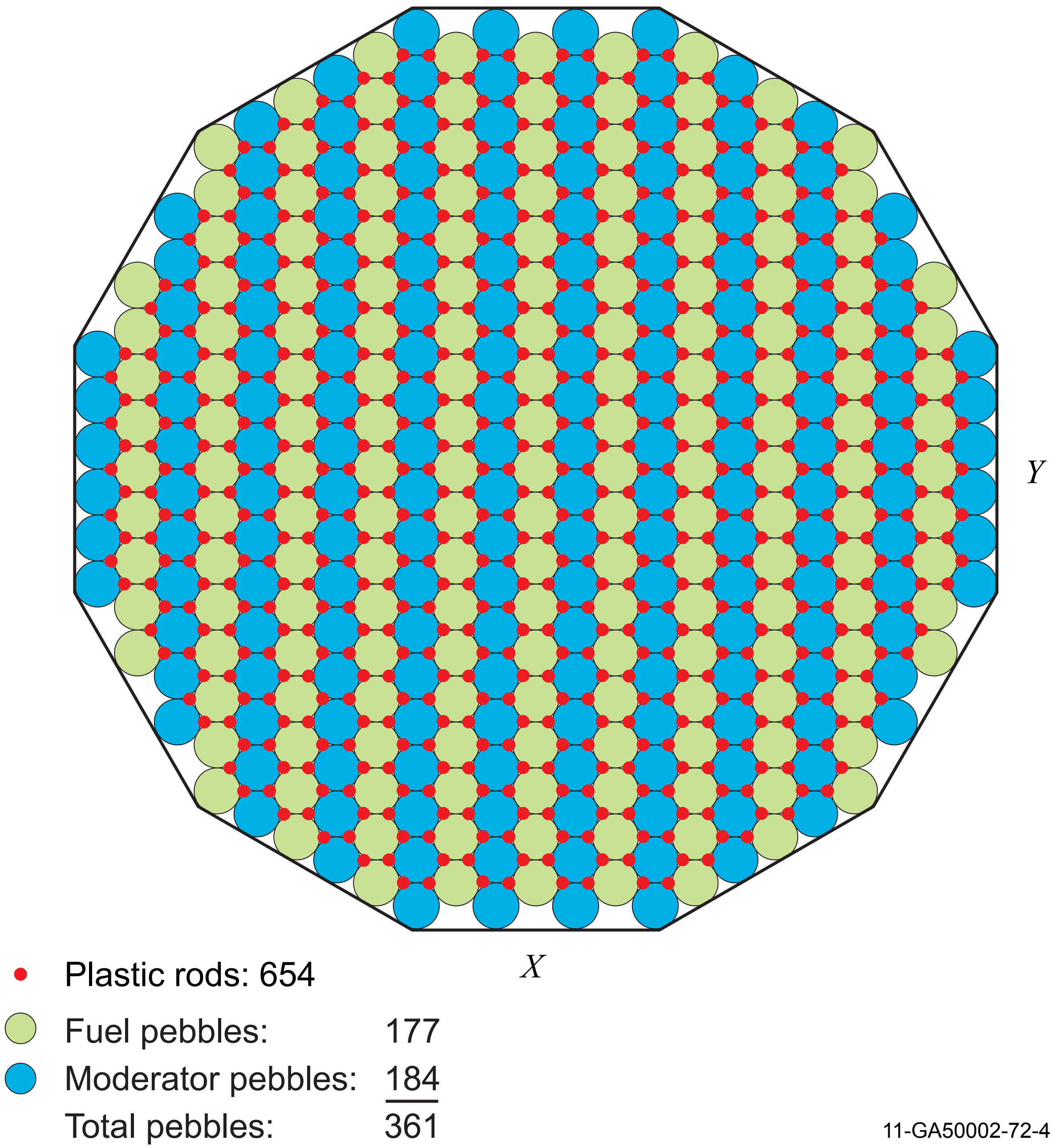

Figure 3.1-21. Layers 1, 7, 13, 19, and 25 of Case 2 (Core 10).

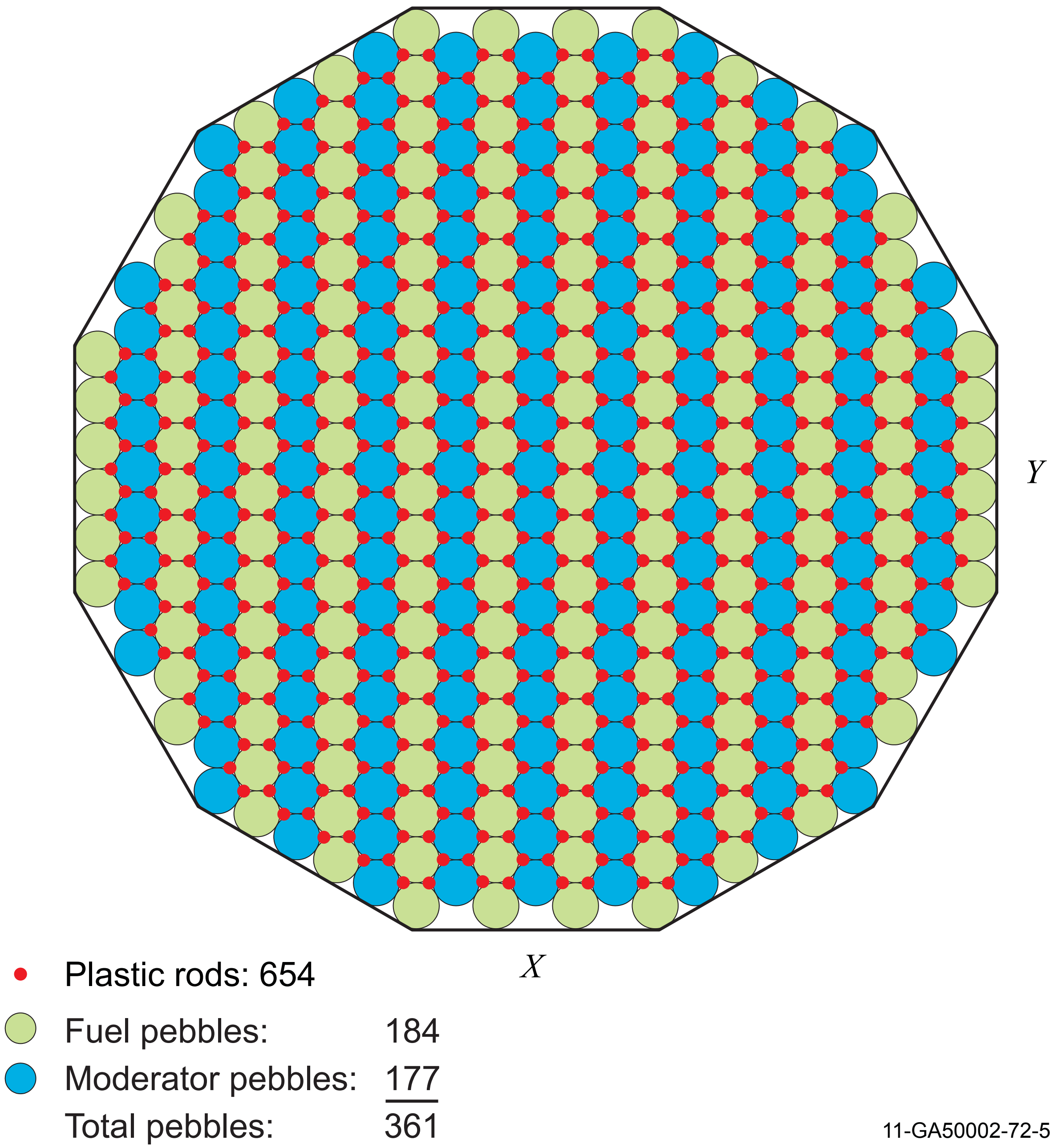

Figure 3.1-22. Layers 2, 8, 14, 20, and 26 of Case 2 (Core 10).

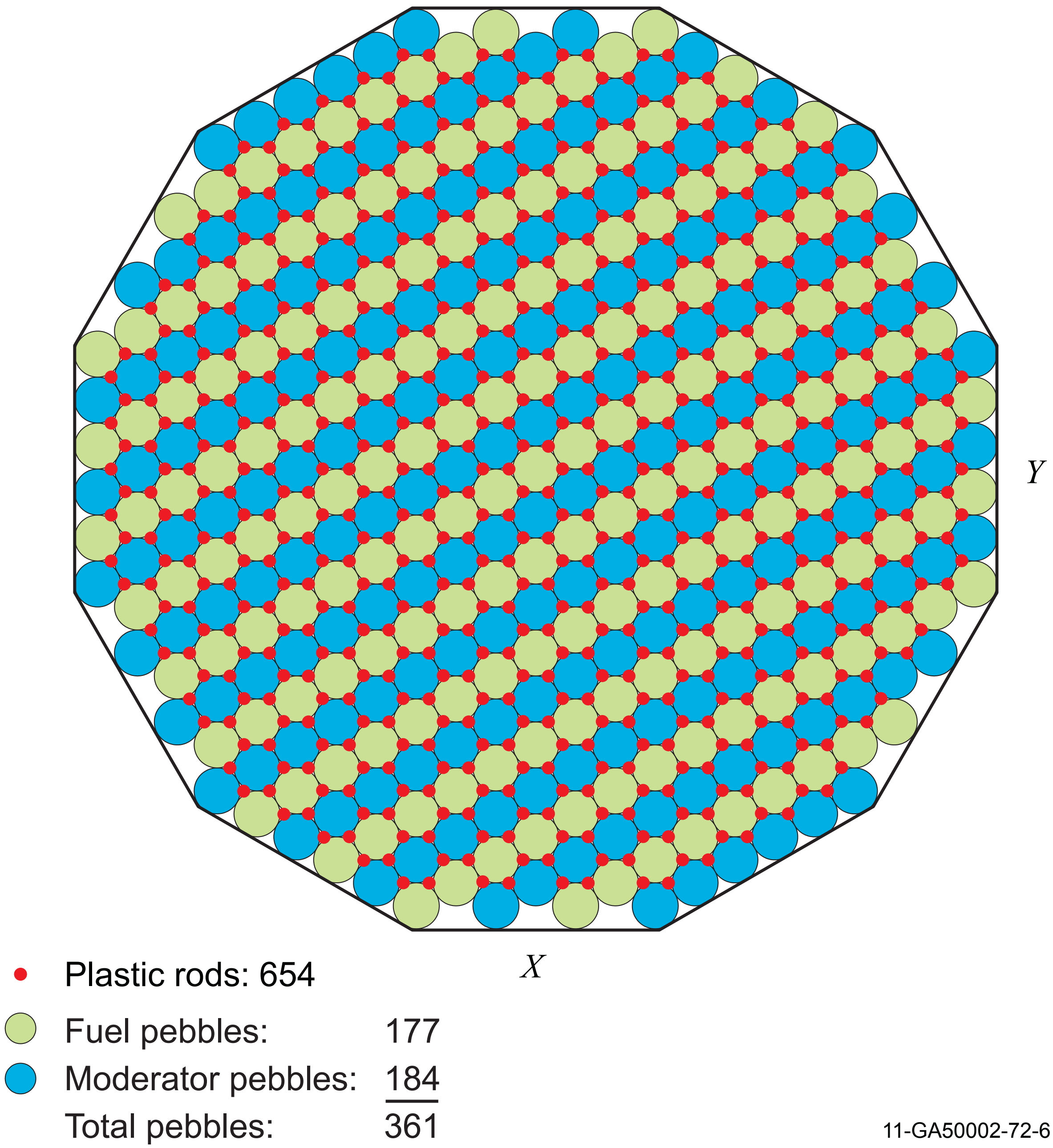

Figure 3.1-23. Layers 3, 9, 15, 21, and 27 of Case 2 (Core 10).

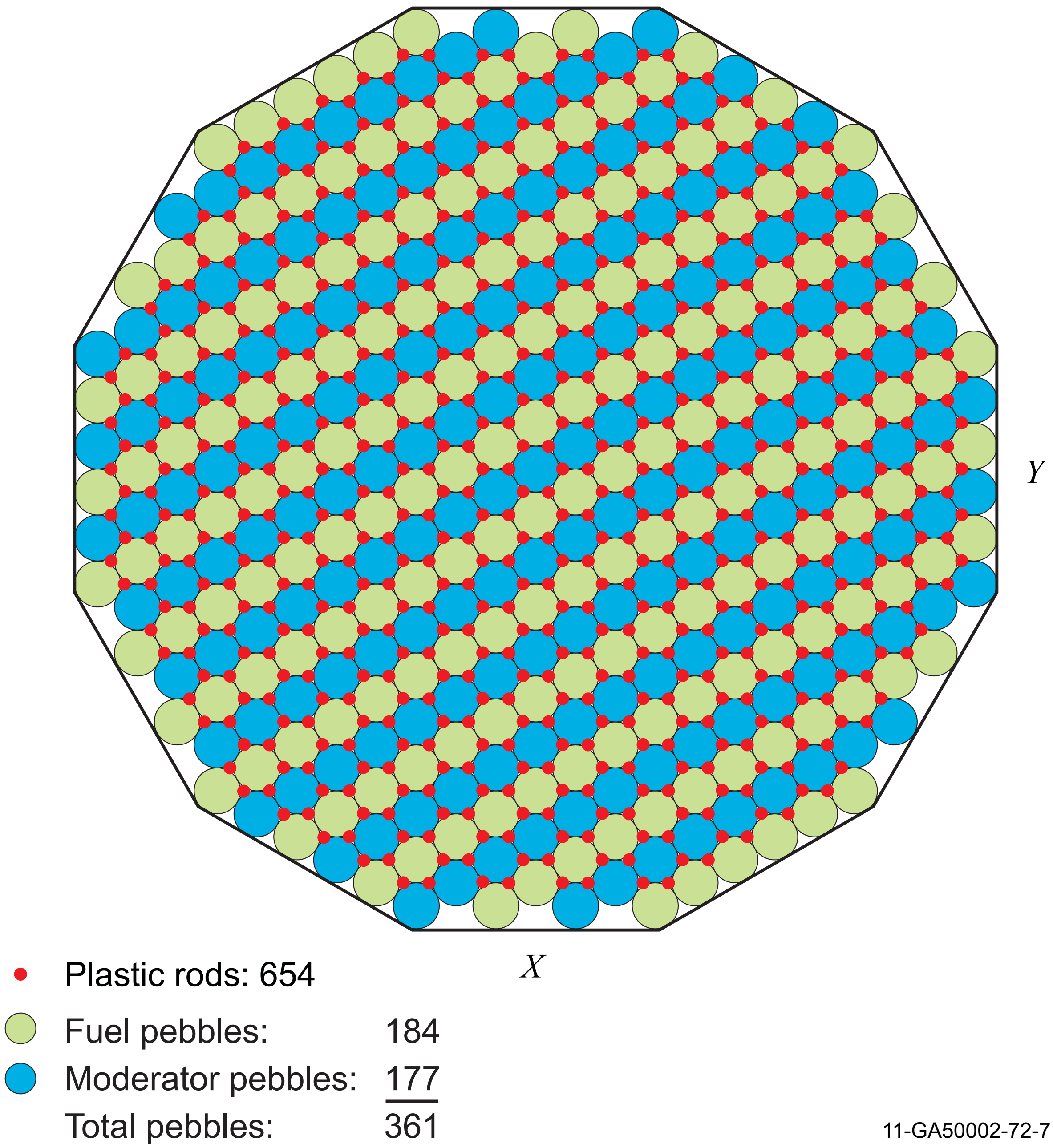

Figure 3.1-24. Layers 4, 10, 16, and 22 of Case 2 (Core 10).

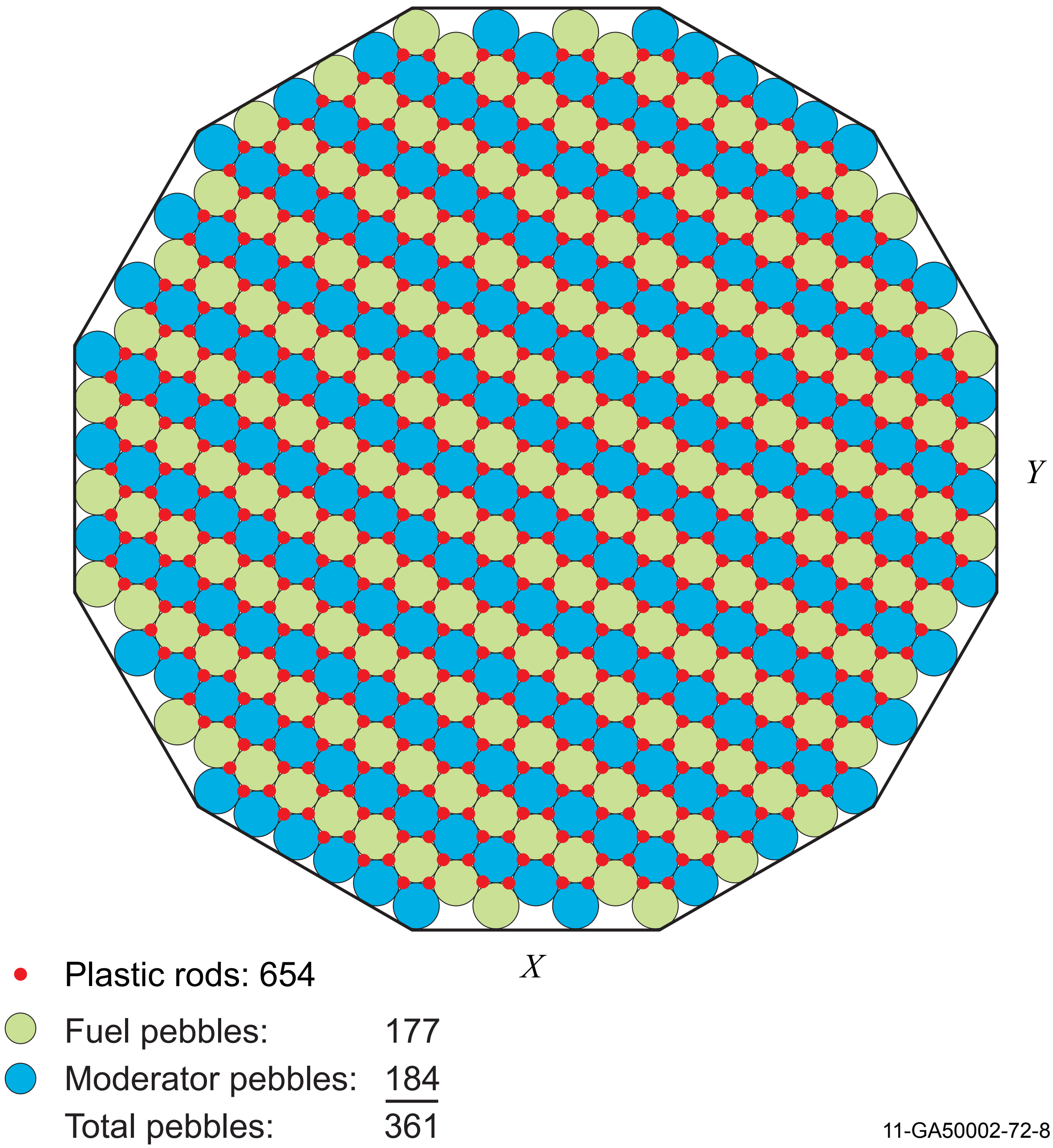

Figure 3.1-25. Layers 5, 11, 17, and 23 of Case 2 (Core 10).

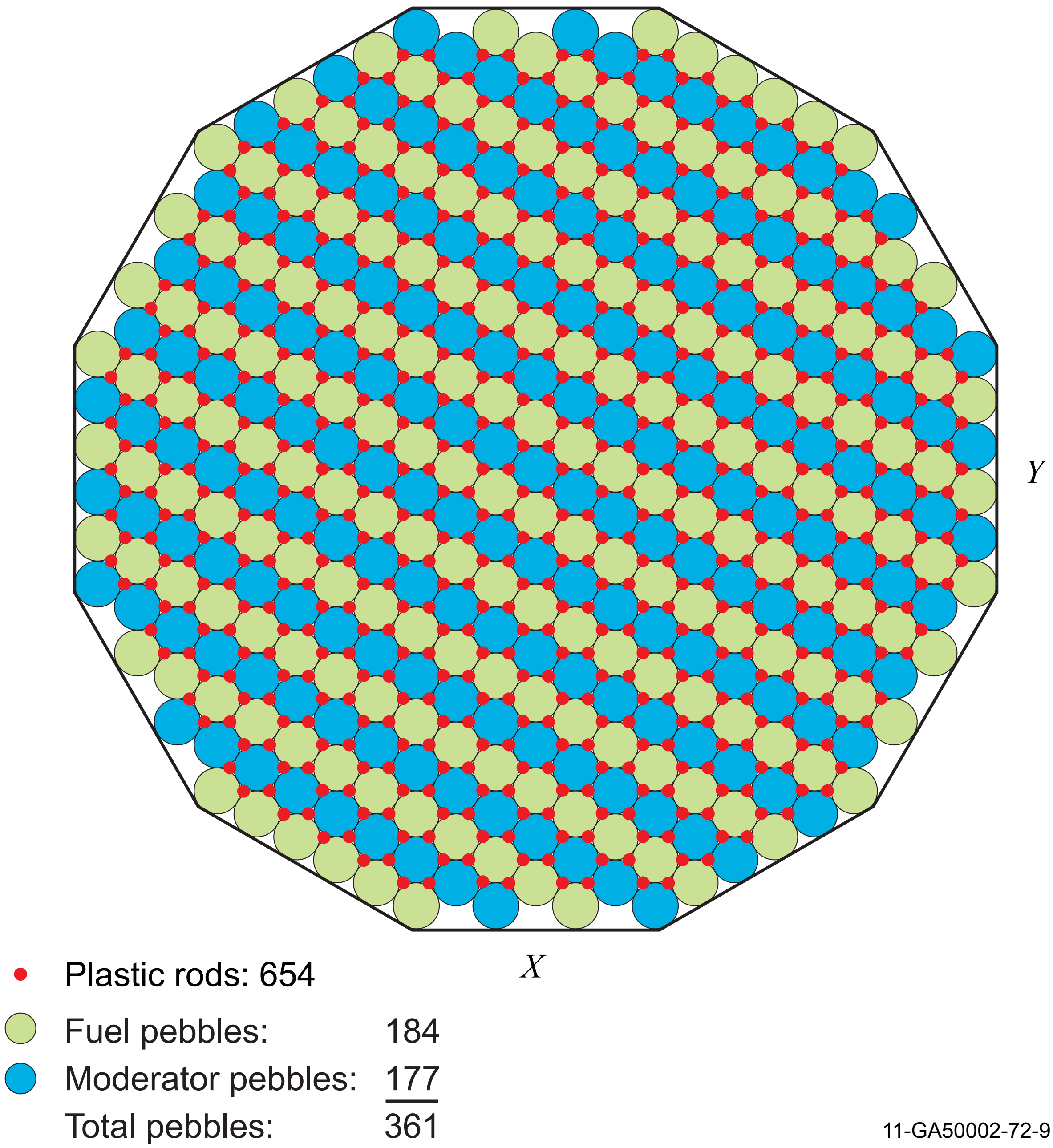

Figure 3.1-26. Layers 6, 12, 18, and 24 of Case 2 (Core 10).

3.1.3 Material Data

3.1.3.1 Radial Reflector

The homogenized (see Section 3.1.1.1) graphite radial reflector has the compositions in Table 3.1-9. The graphite in the radial reflector has 1.33 ppm EBC (by at.%), which equates to a nominal ^{10}B concentration of 2.69 mbarn/atom.

Table 3.1-9. Radial Reflector Graphite Composition.

Isotope/Element	Atoms/barn-cm
^{10}B	2.3253E-08
^{11}B	9.3597E-08
C	8.7857E-02
Total	8.7857E-02
Mass Density (g/cm^3)	1.752264

3.1.3.2 Upper Axial Reflector

The upper axial reflector graphite is comprised of three compositions, depending on the component of the assembly (see Table 3.1-10). The support structure into which the graphite material is placed is Peraluman-300 (Table 3.1-11).

Table 3.1-10. Upper Axial Reflector Graphite Composition (see Figure 3.1-4).

Component	Cylinder	Annulus	Plugs
Isotope/Element	**Atoms/barn-cm**	**Atoms/barn-cm**	**Atoms/barn-cm**
^{10}B	2.3235E-08	2.3368E-08	2.3356E-08
^{11}B	9.3524E-08	9.4059E-08	9.4011E-08
C	8.7789E-02	8.8291E-02	8.8245E-02
Total	8.7789E-02	8.8291E-02	8.8245E-02
Mass Density (g/cm^3)	1.750896	1.760901	1.76

Table 3.1-11. Upper Axial Reflector Peraluman-300 Support Structure Composition.

Isotope/Element	Atoms/barn-cm
^{10}B	1.4688E-07
^{11}B	5.9119E-07
Mg	1.0177E-03
Al	5.7575E-02
Si	2.2729E-04
Mn	7.2621E-05
Fe	8.5730E-05
Cu	1.2557E-05
Zn	2.4398E-05
Ga	1.1444E-06
Cd	7.0983E-08
Total	5.9018E-02
Mass Density (g/cm^3)	2.65

3.1.3.3 Lower Axial Reflector

The lower axial reflector graphite is comprised of two compositions, depending on the component of the assembly (see Table 3.1-12).

Table 3.1-12. Lower Axial Reflector Graphite Composition.

Component	Cylinder	Annulus / Source Plug
Isotope/Element	**Atoms/barn-cm**	**Atoms/barn-cm**
^{10}B	2.3223E-08	2.3356E-08
^{11}B	9.3476E-08	9.4011E-08
C	8.7744E-02	8.8245E-02
Total	8.7744E-02	8.8245E-02
Mass Density (g/cm^3)	1.75	1.76

3.1.3.4 Autorod

The autorod consists of copper wedge (Table 3.1-13) within an aluminum guide tube (Table 3.1-14).

Table 3.1-13. Autorod Copper (Type C110) Wedge Composition.

Element	Atoms/barn-cm
Cu	8.4206E-02
O	6.6923E-05
Ag	3.7224E-06
S	1.2522E-05
Ni	6.8410E-06
Fe	7.1900E-06
Total	8.4303E-02
Mass Density (g/cm^3)	8.89

Table 3.1-14. Autorod Aluminum (Type 1100) Tube Composition.

Element	Atoms/barn-cm
Si	2.8947E-04
Fe	1.4558E-04
Cu	3.1984E-05
Mn	7..661E-06
Zn	1.2429E-05
Co	6.8975E-05
Ni	6.9257E-05
Sn	3.4242E-05
Al	5.9087E-02
Total	5.9746E-02
Mass Density (g/cm^3)	2.70

3.1.3.5 Fuel Pebbles

The UO_2 fuel used for the TRISO kernels has the composition provided in Table 3.1-15. The compositions of the additional SiC and graphite layers surrounding the kernel to form the TRISO particle are in Table 3.1-16. The fuel pebble graphite matrix surrounding the TRISO particles in the fueled zone and forming the outer unfueled layer has the composition shown in Table 3.1-17.

Table 3.1-15. UO_2 Fuel Kernel Composition.

Isotope/Element	**Atoms/barn-cm**
O	4.8612E-02
^{234}U	3.3079E-05
^{235}U	4.1172E-03
^{236}U	2.0499E-05
^{238}U	2.0135E-02
Total	7.2917E-02
Mass Density (g/cm^3)	10.88

Table 3.1-16. TRISO SiC and Graphite Layer Compositions.

Layer	**Buffer**	**IPyC**	**SiC**	**OPyC**
Isotope/Element	**Atoms/barn-cm**	**Atoms/barn-cm**	**Atoms/barn-cm**	**Atoms/barn-cm**
C	5.2640E-02	9.5254E-02	4.8055E-02	9.4752E-02
Si	--	--	4.8055E-02	--
Total	5.2640E-02	9.5254E-02	9.6110E-02	9.4752E-02
Mass Density (g/cm^3)	1.05	1.90	3.20	1.89

Table 3.1-17. Fuel Pebble Graphite Composition.

Isotope/Element	Atoms/barn-cm
C	8.6842E-02
Ag	9.6706E-10
^{10}B	1.9393E-09
^{11}B	7.8061E-09
Ca	2.4154E-07
Cd	4.7791E-10
Cl	4.4135E-08
Co	1.1505E-09
Cr	3.6312E-08
Dy	3.2097E-11
Eu	3.4322E-11
Fe	5.5104E-08
Gd	3.3169E-11
^{6}Li	5.7034E-09
^{7}Li	6.9441E-08
Mn	8.1647E-09
Ni	8.8864E-09
S	1.7893E-10
Ti	1.0831E-08
V	4.4334E-09
H	1.1581E-05
O	5.7904E-06
Total	8.6859E-02
Mass Density (g/cm^3)	1.732204

3.1.3.6 Moderator Pebbles

The composition of the graphite moderator pebbles is in Table 3.1-18.

Table 3.1-18. Moderator Pebble Graphite Composition.

Isotope/Element	Atoms/barn-cm
C	8.4434E-02
^{10}B	1.4193E-08
^{11}B	5.7130E-08
Ca	3.2656E-06
Cd	2.7077E-09
Cl	5.3343E-07
Dy	4.0583E-10
Eu	8.6793E-10
Fe	1.0719E-07
Gd	2.5808E-10
^{6}Li	9.7630E-09
^{7}Li	1.1887E-07
Ni	1.3483E-08
S	4.4297E-06
Si	1.2644E-06
Sm	5.8029E-10
Ti	2.1196E-07
V	2.5891E-07
H	1.1263E-05
O	5.6317E-06
Total	8.4461E-02
Mass Density (g/cm^3)	1.684743

3.1.3.7 Withdrawable Control Rods

The withdrawable control rods consist of an inner stainless steel tube (Table 3.1-19) held within an outer stainless steel tube with end plugs (Table 3.1-20).

Table 3.1-19. Control Rod Stainless Steel (Type St1.4301) Tube Composition.

Element	Atoms/barn-cm
C	1.3864E-04
Si	8.4696E-04
Mn	8.6597E-04
Cr	1.6927E-02
Ni	8.3083E-03
Fe	5.9391E-02
Total	8.6477E-02
Mass Density (g/cm^3)	7.9

Table 3.1-20. Control Rod Stainless Steel (Type St1.4541) Tube and End Plug Composition.

Element	Atoms/barn-cm
C	1.9805E-04
Si	8.4696E-04
Mn	8.6597E-04
Cr	1.6469E-02
Ni	8.3083E-03
Ti	4.9695E-05
Fe	5.9761E-02
Total	8.6499E-02
Mass Density (g/cm^3)	7.9

3.1.3.8 Polyethylene Rods

The composition of the polyethylene (sometimes referred to as plastic) rods is in Table 3.1-21.

Table 3.1-21. Polyethylene Rod Composition.

Isotope/Element	**Atoms/barn-cm**
^{10}B	5.2797E-09
^{11}B	2.1252E-08
H	8.2845E-02
C	4.0810E-02
Total	1.2365E-01
Mass Density (g/cm^3)	0.95259

3.1.3.9 Ambient Air

The composition of the ambient air is in Table 3.1-22. The air has a temperature of 293 K, pressure of 980 mbar, and 50 % humidity.

Table 3.1-22. Ambient Air Composition.

Element	**Atoms/barn-cm**
H	5.7098E-07
N	3.7362E-05
O	1.0326E-05
Ar	2.2345E-07
C	9.1319E-09
Total	4.8492E-05
Mass Density (g/cm^3)	0.00115932

3.1.4 Temperature Data

The benchmark model temperature is 293 K.

3.1.5 Experimental and Benchmark-Model k_{eff} and / or Subcritical Parameters

The experimental k_{eff} was approximately at unity, maintained at delayed critical with the 1σ uncertainty summarized in Section 2.1.11 for each of the two configurations. Simplification biases and uncertainties, as discussed in Section 3.1.1.1 were applied to the benchmark model. The benchmark k_{eff} is shown in Table 3.1-23 for each of the two cases. The uncertainty in the benchmark k_{eff} value is obtained by summing under quadrature the total experimental uncertainty (Tables 2.1-45 and 2.1-46) and the total bias uncertainty (Table 3.1-4).

Table 3.1-23. Experimental and Benchmark Eigenvalues, Biases, and Uncertainties.

Case	Core (state)	Experimental			Bias			Benchmark		
		k_{eff}	±	σ	Δk	±	σ	k_{eff}	±	σ
1	9 (#1)	1.0000	±	0.0036	0.0029	±	0.0002	1.0029	±	0.0036
2	10	1.0000	±	0.0037	0.0020	±	0.0002	1.0020	±	0.0037

3.2 Benchmark-Model Specifications for Buckling and Extrapolation-Length Measurements

Buckling and extrapolation length measurements were performed but have not yet been evaluated.

3.3 Benchmark-Model Specifications for Spectral Characteristics Measurements

Spectral characteristics measurements were performed but have not yet been evaluated.

3.4 Benchmark-Model Specifications for Reactivity Effects Measurements

A total of 32 reactivity effects measurements were determined to be acceptable benchmark experiments for both Cores 9 and 10 (16 apiece).

3.4.1 Description of the Benchmark Model Simplifications

Detailed models (see Appendix C) of the PROTEUS reactor core configurations were prepared to evaluate biases in the benchmark models for the critical configurations. Sample calculations performed using the benchmark models provided in Section 3.1 with the model simplifications described in Section 3.1.1.1 yielded results similar to, within the statistical uncertainty, results calculated using the detailed models. Therefore, no bias is applied to the benchmark values.

The reactivity effects measurements were reported in units of $ using the reported, calculated β_{eff} values of 0.00720 for both Cores 9 and 10 (except for the safety/shutdown rods in Core 9, which had a reported β_{eff} value of 0.00717); they were adjusted to the MCNP-calculated β_{eff} values of 0.00693 for Core 9 and 0.00685 for Core 10 for comparison with calculations and for use as benchmark measurements. For further discussion regarding the selection of β_{eff}, see Section 2.4.1.

3.4.2 Dimensions

The dimensions of the benchmark models for determination of the reactivity effects measurements in the HTR-PROTEUS Cores 9 and 10 are identical to those of the critical core configurations described in Section 3.1.2, with exceptions discussed below.

3.4.2.1 Control Rod Worths

The radial positions of the control rods are shown in Figure 3.1-2 with the maximum and minimum range of vertical placement shown in Figure 3.1-11. The x-y positions of the four control rods are listed in Table 3.4-1. The individual control rod worth is obtained taking the benchmark critical configurations (Section 3.1) and comparing the condition with a single control rod fully withdrawn and then fully inserted. The control rod bank worth is obtained by comparison of the condition with all control rods fully withdrawn and then fully inserted. The partial bank insertion worth is obtained by comparison of the cores with the control rod bank partially withdrawn and then fully inserted. The distance the control rod bank is withdrawn upward from full insertion is 88.0 cm for Core 9 and 96.0 cm for Core 10. The geometric description of the control rods is provided in Section 3.1.2.7.

Table 3.4-1. Absorber Rod x-y Positions (distance in cm).

Absorber Rod	X	Y
Safety/Shutdown Rod 1	-38.45	56.57
Safety/Shutdown Rod 2	32.74	-60.05
Safety/Shutdown Rod 3	57.17	37.55
Safety/Shutdown Rod 4	-53.23	-42.95
Safety/Shutdown Rod 5	67.19	-12.82
Safety/Shutdown Rod 6	-66.98	13.87
Safety/Shutdown Rod 7	19.31	65.62
Safety/Shutdown Rod 8	-13.87	-66.98
Autorod	17.36	-87.29
Withdrawable Control Rod 1	34.67	83.70
Withdrawable Control Rod 2	83.70	-34.67
Withdrawable Control Rod 3	-34.67	-83.70
Withdrawable Control Rod 4	-83.70	34.67

3.4.2.2 Autorod Worths

The radial location of the autorod is shown in Figure 3.1-2 with the maximum and minimum range of vertical placement shown in Figure 3.1-7. The x-y position of the autorod is listed in Table 3.4-1. The autorod worth is obtained taking the benchmark critical configurations (Section 3.1) and comparing the condition with the autorod fully withdrawn and then fully inserted. The geometric description of the autorod is provided in Section 3.1.2.4.

3.4.2.3 Safety/Shutdown Rod Worths

The radial positions of the safety/shutdown rods are shown in Figure 3.1-2. The safety/shutdown rods (Figures 3.4-1 through 3.4-3) are comprised of borated steel rod contained within a stainless steel tube with end plugs. The borated steel rod has a diameter of 3.5 cm and length of 210 cm. The stainless steel tube has an inner diameter of 3.6 cm and outer diameter of 4.0 cm. The dimensions for the end plugs are shown in Figure 3.4-2. The safety/shutdown rods are completely inserted into the core when the bottom surface of the borated steel is located 35 cm below the floor of the core cavity; they are completely withdrawn when raised 290 cm from the fully inserted position (see Figure 3.4-3). The x-y positions of the eight safety/shutdown rods is listed in Table 3.4-1.

The individual or combined safety/shutdown rod worths are obtained taking the benchmark critical configurations (Section 3.1), modifying them to include the safety/shutdown rods as described in this section, and comparing the condition with a the safety/shutdown rods fully withdrawn and then fully inserted.

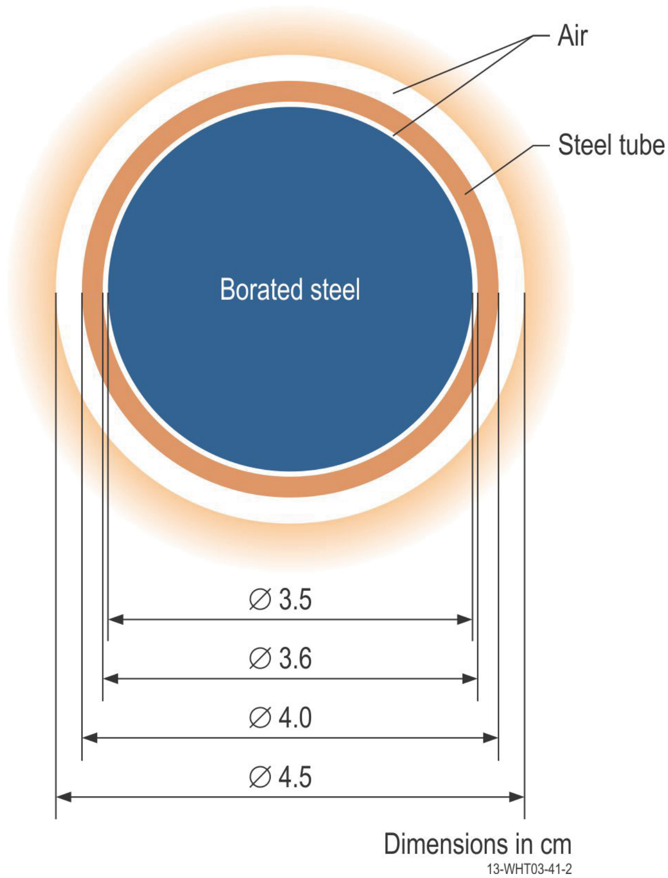

Figure 3.4-1. Top View of Safety/Shutdown Rod.

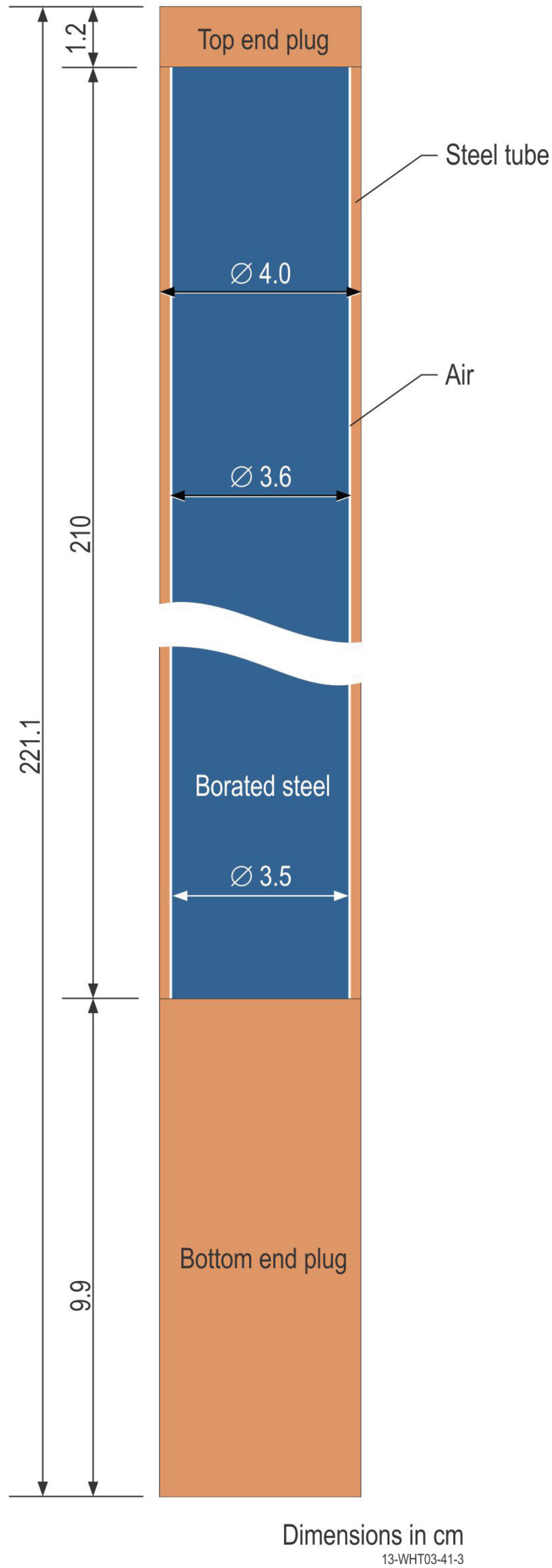

Figure 3.4-2. Axial View of Safety/Shutdown Rod.

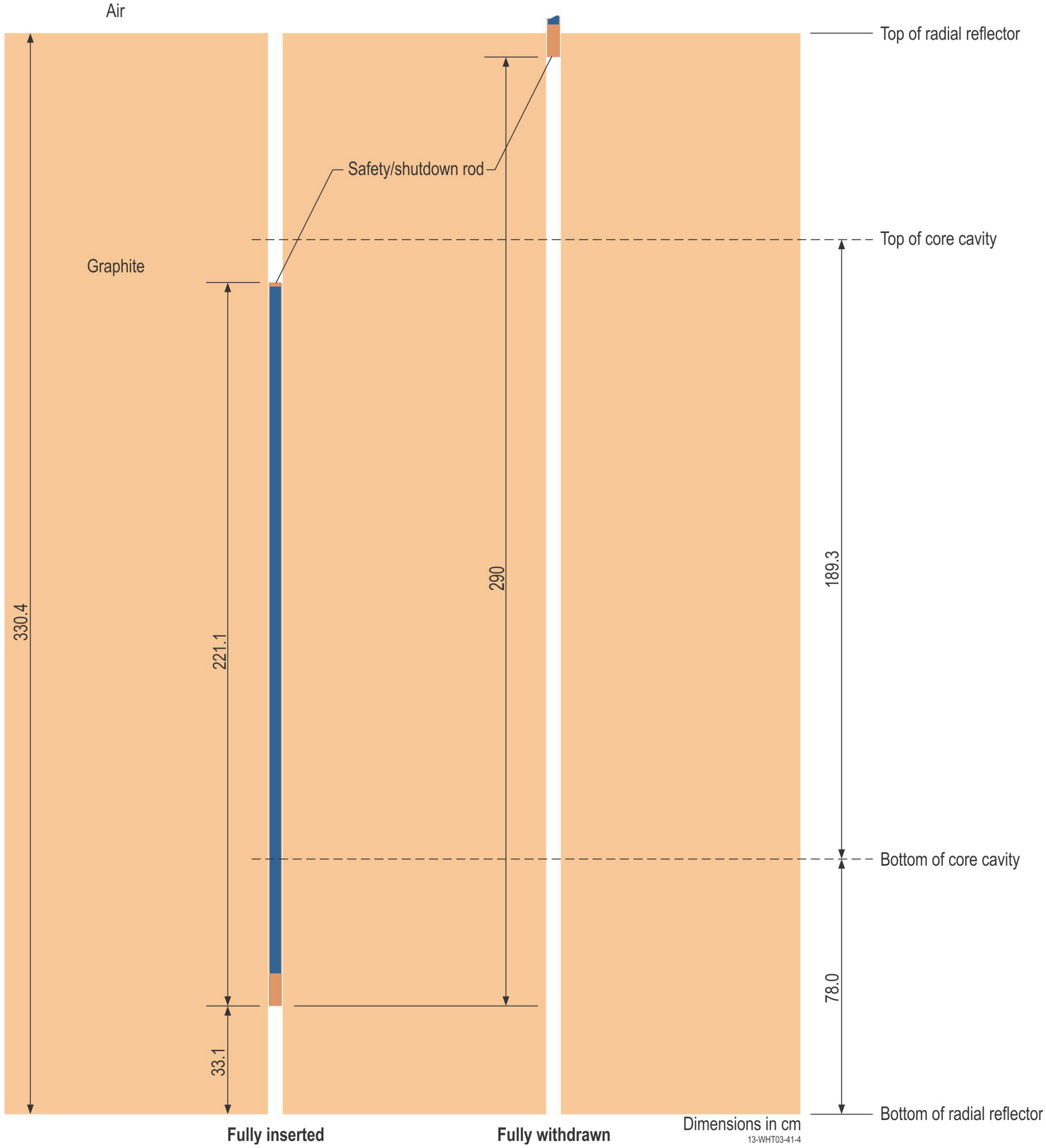

Figure 3.4-3. Safety/Shutdown Rod Vertical Position within Radial Reflector.

3.4.3 Material Data

The materials of the benchmark models for determination of the reactivity effects measurements in the HTR-PROTEUS Cores 9 and 10 are identical to those of the critical core configurations described in Section 3.1.3.

3.4.3.1 Control Rod Worths

No additional information is necessary for these benchmark measurements. The material description of the control rods is provided in Section 3.1.3.7.

3.4.3.2 Autorod Worths

No additional information is necessary for these benchmark measurements. The material description of the autorod is provided in Section 3.1.3.4.

3.4.3.3 Safety/Shutdown Rod Worths

The safety/shutdown rods consist of an inner borated steel rod (Table 3.4-2) held within an outer stainless steel tube with end plugs (Table 3.4-3).

Table 3.4-2. Safety/Shutdown Rod Borated Steel (~5 wt.%) Rod Composition.

Element	Atoms/barn-cm
^{10}B	3.9257E-03
^{11}B	1.4282E-02
Si	1.5187E-03
Cr	3.2491E-02
Mn	9.8952E-04
Fe	3.1300E-02
Ni	7.0036E-03
Total	9.1511E-02
Mass Density (g/cm^3)	6.878

Table 3.4-3. Safety/Shutdown Rod Stainless Steel (Type 18/8) Tube and End Plug Composition.

Element	Atoms/barn-cm
Cr	1.6511E-02
Fe	6.1855E-02
Ni	6.5009E-03
C	2.9783E-04
Si	8.4910E-04
Mn	8.6816E-04
Total	8.6882E-02
Mass Density (g/cm^3)	7.92

3.4.4 Temperature Data

The benchmark model temperature is 300 K.

3.4.5 Benchmark-Model Specification for Reactivity Effects Parameters

The experimental measurements are evaluated in Section 2.4 and summarized in Tables 2.4-13 and 2.4-14. These values represent the benchmark experiment worths, and are repeated in Table 3.4-4 for Core 9 and Table 3.4-5 for Core 10.

Table 3.4-4. Benchmark Reactivity Effects Measurements (Core 9).

Case	**Measured Parameter**	**Benchmark Worth**		
		ρ($)	**±**	**σ**
1.4-1	Control Rod 1	-0.41	±	0.02
1.4-2	Control Rod 2	-0.41	±	0.02
1.4-3	Control Rod 3	-0.41	±	0.02
1.4-4	Control Rod 4	-0.41	±	0.02
1.4-5	Control Rod Bank Full Insertion	-1.58	±	0.09
1.4-6	Control Rod Bank Partial Insertion	-0.73	±	0.04
1.4-8	Autorod Insertion	-0.10	±	0.01
1.4-8	Safety/Shutdown Rod 5	-3.75	±	0.17
1.4-9	Safety/Shutdown Rod 6	-3.82	±	0.10
1.4-10	Safety/Shutdown Rod 7	-3.70	±	0.30
1.4-11	Safety/Shutdown Rod 8	-3.60	±	0.29
1.4-12	Safety/Shutdown Rods 5+6	-8.02	±	0.20
1.4-13	Safety/Shutdown Rods 5+7	-7.44	±	0.60
1.4-14	Safety/Shutdown Rods 5+8	-7.40	±	0.59
1.4-15	Safety/Shutdown Rods 5+6+7	-12.11	±	0.28
1.4-16	Safety/Shutdown Rods 5+6+7+8	-16.52	±	0.47

Table 3.4-5. Benchmark Reactivity Effects Measurements (Core 10).

Case	Measured Parameter	Benchmark Worth		
		ρ($)	±	σ
2.4-1	Control Rod 1	-0.30	±	0.02
2.4-2	Control Rod 2	-0.29	±	0.02
2.4-3	Control Rod 3	-0.29	±	0.02
2.4-4	Control Rod 4	-0.30	±	0.02
2.4-5	Control Rod Bank Full Insertion	-1.15	±	0.07
2.4-6	Control Rod Bank Partial Insertion	-0.39	±	0.02
2.4-7	Autorod Insertion	-0.073	±	0.004
2.4-8	Safety/Shutdown Rod 5	-2.82	±	0.11
2.4-9	Safety/Shutdown Rod 6	-2.82	±	0.09
2.4-10	Safety/Shutdown Rod 7	-2.80	±	0.16
2.4-11	Safety/Shutdown Rod 8	-2.72	±	0.15
2.4-12	Safety/Shutdown Rods 5+6	-5.95	±	0.17
2.4-13	Safety/Shutdown Rods 5+7	-5.73	±	0.32
2.4-14	Safety/Shutdown Rods 5+8	-5.75	±	0.33
2.4-15	Safety/Shutdown Rods 5+6+7	-9.29	±	0.21
2.4-16	Safety/Shutdown Rods 5+6+7+8	-12.67	±	0.31

3.5 Benchmark-Model Specifications for Reactivity Coefficient Measurements

Reactivity coefficient measurements were performed but have not yet been evaluated.

3.6 Benchmark-Model Specifications for Kinetics Measurements

Kinetics measurements were performed but have not yet been evaluated.

3.7 Benchmark-Model Specifications for Reaction-Rate Distribution Measurements

Reaction-rate distribution measurements were performed but have not yet been evaluated.

3.8 Benchmark-Model Specifications for Power Distribution Measurements

Power distribution measurements were not performed.

3.9 Benchmark-Model Specifications for Isotopic Measurements

Isotopic measurements were not performed.

3.10 Benchmark-Model Specifications for Other Miscellaneous Types of Measurements

Other miscellaneous types of measurements were not performed.

4.0 RESULTS OF SAMPLE CALCULATIONS

4.1 Results of Calculations of the Critical or Subcritical Configurations

The benchmark models described in Section 3.1 were used with MCNP5 (see Appendix A.1 for sample input deck for Case 1) and ENDF/B-VII.0 neutron cross section data. Random particles are not easily modeled in MCNP, therefore all 9394 TRISO particles were modeled within a cubic lattice with sides 0.1758 cm in length. All TRISO particles are completely contained within the fueled region of the fuel pebbles (see Figure 4.1-1); this was verified by visually inspecting each layer in a visual editor. The effect of random particle placement was determined to be essentially negligible relative to a regular array of particles in a fuel pebble (see Section 2.1.9.4 of PROTEUS-GCR-EXP-001).[a]

Monte Carlo calculations were performed with 1,650 generations with 100,000 neutrons per generation. The k_{eff} estimates are based on 150 skipped generations and a total of 150,000,000 neutron histories each. Calculated eigenvalues are shown in Table 4.1-1. All calculated eigenvalues are greater than the benchmark value but within 1 % and within the 2σ uncertainty. Models developed by Difilippo using MCNP4C with ENDF/B-VI (DLC-189) neutron cross sections did not include Cases 1 and 2 (Cores 9 and 10).[b] As noted in PROTEUS-GCR-EXP-001, the models by Difilippo include water content within the graphite reflectors. Evaluation of the water content indicates that the small quantity has a negligible impact on the neutron scattering and only provides additional negative reactivity (~100 pcm) to the system. However, the addition of water absorption seems to be incorrect as the analysis of the equivalent boron content in the graphite reflectors should have already included absorption from water contained within the graphite blocks. Another difference exists for the density of the polyethylene rods; Difilippo reports polyethylene with a mass density of ~0.77 g/cm^3, which is suspiciously low, when the density calculated for the benchmark models is ~0.94 g/cm^3. This latter difference only impacts those models containing polyethylene rods.

Monte Carlo calculations with ENDF/B-VII0.0 of k_{eff} for graphite-moderated reactors and assemblies typically compute greater than the benchmark values, as seen for the High Temperature Engineering Test Reactor (HTTR-GCR-RESR-001, -002, and -003), the HTR-10 Pebble-Bed Reactor (HTR10-GCR-RESR-001), and the other HTR-PROTEUS configurations (PROTEUS-GCR-EXP-001, -002, and -003). Computations of the ASTRA critical facility with the MCU-REA1 code agree well with the benchmark k_{eff} (ASTRA-GCR-EXP-001) but calculate high when using MCNP.[c] The MCU computer program was developed to include a special feature to evaluate systems with double-heterogeneity, such as TRISO particles in a HTGR.[d] The computational bias using MCNP is on the order of 1-2 % greater than the benchmark values. The HTTR configurations are closer to 2 % and it has been previously discussed that the bias is possibly due to uncertainties in the impurity content of the graphite blocks[e,f] and a need to increase the thermal neutron capture cross section of carbon in both JENDL-3.3 and ENDF/B-VII.0 nuclear data libraries.[g]

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[a] Colak, U. and Seker, V., "Monte Carlo Criticality Calculations for a Pebble Bed Reactor with MCNP," *Nucl. Sci. Eng.*, **149**, 131-137 (2005).
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[d] N. N. Ponomarev-Stepnoi, et al., "Using the MCU Computer Program to Analyze the Results of Critical Experiments with HTGR Fuel Pellets on ASTRA Testing Stand," *Atomic Energy*, **97**, pp. 669-677 (2004).
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[f] N. Fujimoto, et al., "Startup Core Physics Tests of High Temperature Engineering Test Reactor (HTTR) (II)," *J. At. Energy Soc. Jpn.*, **42**, pp. 458-464 (2000) [in Japanese].
[g] S. Shimakawa, M. Goto, S. Nakagawa, and Y. Tachibana, "Impact of Capture Cross-Section of Carbon on Nuclear Design for HTGRs," *Proc. HTR 2010*, Prague, Czech Republic, October 18-20, 2010.

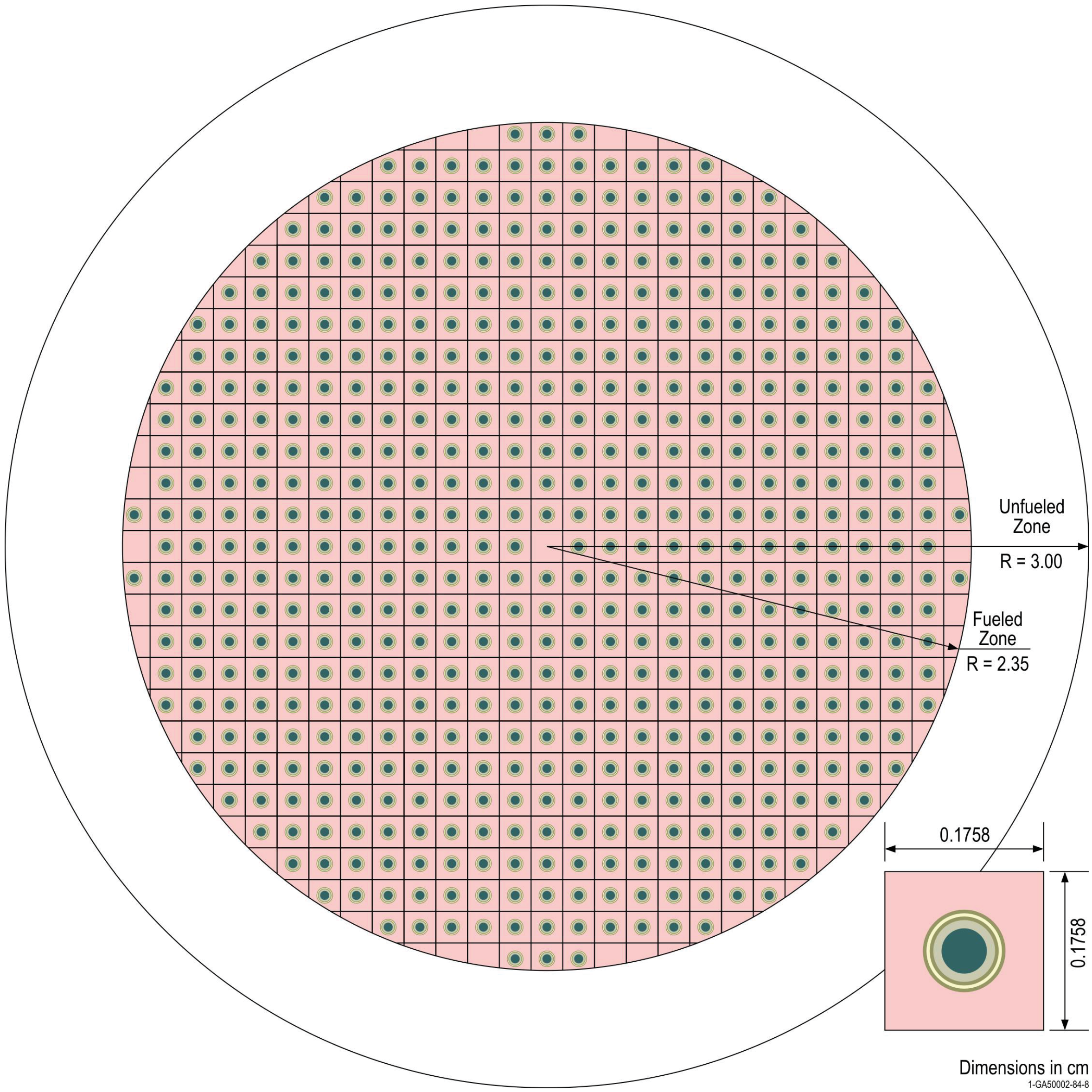

Figure 4.1-1. Regular TRISO Lattice Used in MCNP Calculations of the Benchmark Models.

Table 4.1-1. Comparison of Benchmark Eigenvalues (MCNP5).

Case	Core (state)	Neutron Cross Section Library	Calculated (MCNP5)			Benchmark			$\frac{C-E}{E}(\%)$	Difference (pcm)
			k_{eff}	±	σ	k_{eff}	±	σ		
1	9 (#1)	ENDF/B-VII.0	1.00581	±	0.00007	1.0029	±	0.0036	0.38	377
2	10		1.00667	±	0.00006	1.0020	±	0.0037	0.54	543

Additional sample calculations were obtained using the sample input decks provided in Appendix A for the benchmark model provided in Section 3.1 and updating them with ENDF/B-VII.1 neutron cross section data;[a] the revised input decks were run using MCNP6.1.[b] Results are provided in Table 4.1-2. The calculated eigenvalues are now lower than the benchmark values. The result for Case 1 is greater than 1 % from the benchmark value and within a 4σ uncertainty. Case 2 results are within the 3σ uncertainty. Note that the observed difference between the results shown in Tables 4.1-1 and 4.1-2 is mostly due to the change in the absorption cross section for carbon adopted in ENDF/B-VII.1 from the JENDL-4.0 nuclear data library. The delayed neutron data for ^{235}U in ENDF/B-VII.1 was reverted back to their ENDF/B-VI.8 values instead of the original Keepin data.[a]

Table 4.1-2. Comparison of Benchmark Eigenvalues (MCNP6).

Case	Core (state)	Neutron Cross Section Library	Calculated (MCNP6)			Benchmark			$\frac{C-E}{E}(\%)$	Difference (pcm)
			k_{eff}	±	σ	k_{eff}	±	σ		
1	9 (#1)	ENDF/B-VII.1	0.99098	±	0.00007	1.0029	±	0.0036	-1.19	-1192
2	10		0.99486	±	0.00006	1.0020	±	0.0037	-0.71	-714

4.2 Results of Buckling and Extrapolation Length Calculations

Buckling and extrapolation length measurements were performed but have not yet been evaluated.

4.3 Results of Spectral-Characteristics Calculations

Spectral characteristics measurements were performed but have not yet been evaluated.

[a] M. B. Chadwick, et al., "ENDF/B-VII.1: Nuclear Data for Science and Technology: Cross Sections, Covariances, Fission Product Yields and Decay Data," *Nucl. Data Sheets*, **112**: 2887-2996 (2011).
[b] J. T. Goorley, et al., "Initial MCNP6 Release Overview – MCNP6 version 1.0," LA-UR-13-22934, Los Alamos National Laboratory (2013).

4.4 Results of Reactivity-Effects Calculations

The benchmark models described in Section 3.4 were used with MCNP5-1.60 (see Appendix A.1 and A.4 for input decks) and ENDF/B-VII.0 neutron cross section data. For additional details regarding how the TRISO particles were modeled, see Section 4.1. Monte Carlo calculations were performed with 1,650 generations with 100,000 neutrons per generation. The k_{eff} estimates are based on 150 skipped generations and a total of 150,000,000 neutron histories each.

The difference between various configurations, as described in Section 3.4.2, were simulated to calculate reactivity worths (Δk/k). These worths were then converted into units of ρ($) using a β_{eff} value of 0.00693 ± 0.00035 (5 %, 1σ) for Core 9 and 0.00685 ± 0.00034 (5 %, 1σ) for Core 10. The Monte Carlo statistical uncertainty is approximately $0.01. The uncertainty in the calculated values provided in this section also include the uncertainty in β_{eff}; therefore, calculations using additional neutron cross section libraries were not performed.

Results for the 32 cases are provided in Table 4.4-1 for Core 9 and Table 4.4-2 for Core 10 (16 apiece). There is generally good agreement between calculated and benchmark worths. Most calculations are within 1σ to 2σ of the benchmark values. At the time of this evaluation the statistical uncertainty in MCNP calculations of the HTR-PROTEUS benchmark models is ~1 ¢; it is not practical to further reduce this uncertainty with currently available computing resources.

The worth of a control rod is calculated using the following equation:

$$\rho(\$) = \frac{k_{inserted} - k_{withdrawn}}{k_{inserted} \times k_{withdrawn}} \times \frac{1}{\beta_{eff}}.$$

Measurements scaled from another core configuration were evaluated but deemed not acceptable as benchmark data; further information for modeling these data is provided in Appendix F.

Table 4.4-1. Sample Calculations for Reactivity Effects Measurements (Core 9).

Case	Measured Parameter	Benchmark Worth			Calculated Worth			$\frac{C-E}{E}(\%)$	±	σ(a)
		ρ($)	±	σ	ρ($)	±	σ			
1.4-1	Control Rod 1	-0.41	±	0.02	-0.38	±	0.02	-7	±	7
1.4-2	Control Rod 2	-0.41	±	0.02	-0.37	±	0.02	-10	±	7
1.4-3	Control Rod 3	-0.41	±	0.02	-0.38	±	0.02	-7	±	7
1.4-4	Control Rod 4	-0.41	±	0.02	-0.38	±	0.02	-7	±	7
1.4-5	Control Rod Bank Full Insertion	-1.58	±	0.09	-1.55	±	0.08	-2	±	8
1.4-6	Control Rod Bank Partial Insertion	-0.73	±	0.04	-0.70	±	0.04	-4	±	8
1.4-7	Autorod Insertion	-0.10	±	0.01	-0.12	±	0.02	20	±	23
1.4-8	Safety/Shutdown Rod 5	-3.74	±	0.17	-3.78	±	0.19	1	±	7
1.4-9	Safety/Shutdown Rod 6	-3.82	±	0.10	-3.82	±	0.19	0	±	6
1.4-10	Safety/Shutdown Rod 7	-3.70	±	0.30	-3.82	±	0.19	3	±	10
1.4-11	Safety/Shutdown Rod 8	-3.60	±	0.29	-3.70	±	0.19	3	±	10
1.4-12	Safety/Shutdown Rods 5+6	-8.02	±	0.20	-8.03	±	0.40	0	±	6
1.4-13	Safety/Shutdown Rods 5+7	-7.44	±	0.60	-7.76	±	0.39	4	±	10
1.4-14	Safety/Shutdown Rods 5+8	-7.40	±	0.59	-7.69	±	0.38	4	±	10
1.4-15	Safety/Shutdown Rods 5+6+7	-12.11	±	0.28	-12.30	±	0.61	2	±	6
1.4-16	Safety/Shutdown Rods 5+6+7+8	-16.52	±	0.42	-16.98	±	0.85	3	±	6

(a) The uncertainty in $\frac{C-E}{E}(\%)$ is calculated by propagating the uncertainties in both the calculated and benchmark experiment eigenvalues using the following equation: $\sigma = 100\% \times \sqrt{\left(\frac{\sigma_C}{E}\right)^2 + \left(\frac{\sigma_E C}{E^2}\right)^2}$.

Table 4.4-2. Sample Calculations for Reactivity Effects Measurements (Core 10).

Case	Measured Parameter	Benchmark Worth			Calculated Worth			$\frac{C-E}{E}(\%)$	±	σ(a)
		ρ($)	±	σ	ρ($)	±	σ			
2.4-1	Control Rod 1	-0.30	±	0.02	-0.29	±	0.02	-3	±	9
2.4-2	Control Rod 2	-0.29	±	0.02	-0.28	±	0.02	-3	±	10
2.4-3	Control Rod 3	-0.29	±	0.02	-0.25	±	0.02	-14	±	9
2.4-4	Control Rod 4	-0.30	±	0.02	-0.28	±	0.02	-7	±	9
2.4-5	Control Rod Bank Full Insertion	-1.15	±	0.07	-1.11	±	0.06	-3	±	8
2.4-6	Control Rod Bank Partial Insertion	-0.39	±	0.02	-0.37	±	0.02	-5	±	7
2.4-7	Autorod Insertion	-0.073	±	0.004	-0.08	±	0.01	10	±	15
2.4-8	Safety/Shutdown Rod 5	-2.82	±	0.11	-2.73	±	0.14	-3	±	6
2.4-9	Safety/Shutdown Rod 6	-2.82	±	0.09	-2.75	±	0.14	-2	±	6
2.4-10	Safety/Shutdown Rod 7	-2.80	±	0.16	-2.73	±	0.14	-2	±	7
2.4-11	Safety/Shutdown Rod 8	-2.72	±	0.15	-2.66	±	0.13	-2	±	7
2.4-12	Safety/Shutdown Rods 5+6	-5.95	±	0.17	-5.70	±	0.29	-4	±	6
2.4-13	Safety/Shutdown Rods 5+7	-5.73	±	0.32	-5.54	±	0.28	-3	±	7
2.4-14	Safety/Shutdown Rods 5+8	-5.75	±	0.33	-5.49	±	0.27	-5	±	7
2.4-15	Safety/Shutdown Rods 5+6+7	-9.29	±	0.21	-8.65	±	0.43	-7	±	5
2.4-16	Safety/Shutdown Rods 5+6+7+8	-12.67	±	0.31	-11.81	±	0.59	-7	±	5

(a) The uncertainty in $\frac{C-E}{E}(\%)$ is calculated by propagating the uncertainties in both the calculated and benchmark experiment eigenvalues using the following equation: $\sigma = 100\% \times \sqrt{\left(\frac{\sigma_C}{E}\right)^2 + \left(\frac{\sigma_E C}{E^2}\right)^2}$.

4.5 Results of Reactivity Coefficient Calculations

Reactivity coefficient measurements were performed but have not yet been evaluated.

4.6 Results of Kinetics Parameter Calculations

Kinetics measurements were performed but have not yet been evaluated.

4.7 Results of Reaction-Rate Distribution Calculations

Reaction-rate distribution measurements were performed but have not yet been evaluated.

4.8 Results of Power Distribution Calculations

Power distribution measurements were not performed.

4.9 Results of Isotopic Calculations

Isotopic measurements were not performed.

4.10 Results of Calculations for Other Miscellaneous Types of Measurements

Other miscellaneous types of measurements were not performed.

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7. Rosselet, M., Chawla, R., and Williams, T., "Epithermal Inverse Kinetic Measurements and Their Interpretation Using a Two-Group Point-Kinetic Model," *Nucl. Sci. Eng.*, **135**, 33-47 (2000).
8. Rosselet, M., Williams, T., and Chawla, R., "Subcriticality Measurements Using an Epithermal Pulsed-Neutron-Source Technique in Pebble-Bed HTR Configurations," *Ann. Nucl. Energy*, **25**, 285-294 (1998).
9. Rosselet, M., Chawla, R., Joneja, O. P., Williams, T., "Measurement and Analysis of Shutdown Rod Worths in LEU-HTR Configurations," *Proc. The 10th International Conference on Emerging Nuclear Energy Systems (ICENES 2000)*, Petten, The Netherlands, September 25-28, 2000.
10. Rosselet, M., "Reactivity Measurements and their Interpretation in Systems with Large Spatial Effects," Ph.D. Dissertation, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland (1999).

APPENDIX A: COMPUTER CODES, CROSS SECTIONS, AND TYPICAL INPUT LISTINGS

A.1 Critical/Subcritical Configurations

A.1.1 Name(s) of code system(s) used.

Monte Carlo n-Particle, version 5.1.60 (MCNP5).

A.1.2 Bibliographic references for the codes used.

X-5 Monte Carlo Team, "MCNP – a General Monte Carlo n-Particle Transport Code, version 5," LA-UR-03-1987, Los Alamos National Laboratory (2003).

A.1.3 Origin of cross-section data.

The Evaluated Neutron Data File library, ENDF/B-VII.0[a] was utilized in the benchmark model analysis.

A.1.4 Spectral calculations and data reduction methods used.

Not applicable.

A.1.5 Number of energy groups or if continuous-energy cross sections are used in the different phases of calculation.

Continuous-energy cross sections.

A.1.6 Component calculations.

- Type of cell calculation – Reactor core, reflectors, and moderator
- Geometry – TRISO particles in graphite pebbles
- Theory used – Not applicable
- Method used – Monte Carlo
- Calculation characteristics
  - MCNP5 – histories/cycles/cycles skipped = 100,000/1,650/150
    continuous-energy cross sections

A.1.7 Other assumptions and characteristics.

Not applicable.

[a] M. B. Chadwick, et al., "ENDF/B-VII.0: Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology," *Nucl. Data Sheets*, **107**: 2931-3060 (2006).

A.1.8 Typical input listings for each code system type.

The input deck provided below is for core configuration 9 (Case 1). The following portions of the code need reconfigured for core configuration 10 (Case 2):

- Autorod position,
- Withdrawable control rod positions, and
- Core cavity filled with correct pebble configuration (including polyethylene rods).

MCNP5 Input Deck for Case 1 (Core 9) [can be modified for Case 2 (Core 10)]:

```
HTR-PROTEUS :: Cores 9 & 10
c Pebble Bed Experimental Program
c Columnar Hexagonal Point-On-Point Packing with a 1:1 Moderator to Fuel Pebble Ratio
c
c John Darrell Bess - Idaho National Laboratory
c Last Updated: July 23, 2012
c
c Cell Cards ******************************************************************
c ------ Air Above Reflector ------
5    10 4.8492E-05  32 -1202 33 -34
          (1101 1102 1103 1104 1105 1106 1107 1108)
          (503 519 535 551 1113) imp:n=1
c
c ------ Radial Reflector ------
11   3 8.7858E-02  (33 -34 31 -32
          (1101 1102 1103 1104 1105 1106 1107 1108)
          (503 519 535 551 1113)):((7001:7002) 1811 -7003 -33) imp:n=1
c
c ------ Air Gap Above Core ------
22   10 4.8492E-05  7003 -1801 -33
          imp:n=1
c
c --- Control Rod Channels ----------------------------------------------------
c ------ Safety/Shutdown Rod Holes ------
1101 10 4.8492E-05  -1101 31 -1202 imp:n=1  $ Rod 1
1102 10 4.8492E-05  -1102 31 -1202 imp:n=1  $ Rod 2
1103 10 4.8492E-05  -1103 31 -1202 imp:n=1  $ Rod 3
1104 10 4.8492E-05  -1104 31 -1202 imp:n=1  $ Rod 4
1105 10 4.8492E-05  -1105 31 -1202 imp:n=1  $ Rod 5
1106 10 4.8492E-05  -1106 31 -1202 imp:n=1  $ Rod 6
1107 10 4.8492E-05  -1107 31 -1202 imp:n=1  $ Rod 7
1108 10 4.8492E-05  -1108 31 -1202 imp:n=1  $ Rod 8
c
c ------ Withdrawable Control Rod Holes ------
503  10 4.8492E-05   -503 1003 31 -3091 imp:n=1  $ Position 3 Hole
1003 29 8.8245E-02  -1003 31 -3091 imp:n=1  $ Position 3 Plug
3105 0    -503 3091 -1202 imp:n=1 fill=21 (-83.70  34.67 0)  $ Control Rod 4
519  10 4.8492E-05   -519 1019 31 -3091 imp:n=1  $ Position 19 Hole
1019 29 8.8245E-02  -1019 31 -3091 imp:n=1  $ Position 19 Plug
3102 0    -519 3091 -1202 imp:n=1 fill=18 ( 34.67  83.70 0)  $ Control Rod 1
535  10 4.8492E-05   -535 1035 31 -3091 imp:n=1  $ Position 35 Hole
1035 29 8.8245E-02  -1035 31 -3091 imp:n=1  $ Position 35 Plug
3103 0    -535 3091 -1202 imp:n=1 fill=19 ( 83.70 -34.67 0)  $ Control Rod 2
551  10 4.8492E-05   -551 1051 31 -3091 imp:n=1  $ Position 51 Hole
1051 29 8.8245E-02  -1051 31 -3091 imp:n=1  $ Position 51 Plug
3104 0    -551 3091 -1202 imp:n=1 fill=20 (-34.67 -83.70 0)  $ Control Rod 3
c
c ------ Autorod Hole ------
1113 0  -1113 31 -1202 imp:n=1 fill=11 (17.36 -87.29 0)
c
c --- Upper Axial Reflector ---------------------------------------------------
c ------ Central Cylinder ------
1201 10 4.8492E-05  1201 -1202 -1203 imp:n=1  $ Central Coolant Channel
1202 6 8.7789E-02  1201 -1202 1203 -1204 imp:n=1  $ Graphite
c
c ------ Graphite Annulus ------
1211 7 8.8291E-02  1201 -1202 1211 -1333
          (1301 1302 1303 1304 1305 1306 1307 1308 1309 1310 1311 1312 1313
           1314 1315 1316 1317 1318 1319 1320 1321 1322 1323 1324 1325 1326
           1327 1328 1329 1330 1331 1332)
           imp:n=1  $ Ring 1 Region
```

```
1212 7 8.8291E-02  1201 -1202 1333 -1433
          (1401 1402 1403 1404 1405 1406 1407 1408 1409 1410 1411 1412 1413
           1414 1415 1416 1417 1418 1419 1420 1421 1422 1423 1424 1425 1426
           1427 1428 1429 1430 1431 1432)
           imp:n=1  $ Ring 2 Region
1213 7 8.8291E-02  1201 -1202 1433 -1533
          (1501 1502 1503 1504 1505 1506 1507 1508 1509 1510 1511 1512 1513
           1514 1515 1516 1517 1518 1519 1520 1521 1522 1523 1524 1525 1526
           1527 1528 1529 1530 1531 1532)
           imp:n=1  $ Ring 3 Region
1214 7 8.8291E-02  1201 -1202 1533 -1633
          (1601 1602 1603 1604 1605 1606 1607 1608 1609 1610 1611 1612 1613
           1614 1615 1616 1617 1618 1619 1620 1621 1622 1623 1624 1625 1626
           1627 1628 1629 1630 1631 1632)
           imp:n=1  $ Ring 4 Region
1215 7 8.8291E-02  1201 -1202 1633 -1212
          (1701 1702 1703 1704 1705 1706 1707 1708 1709 1710 1711 1712 1713
           1714 1715 1716 1717 1718 1719 1720 1721 1722 1723 1724 1725 1726
           1727 1728 1729 1730 1731 1732)
           imp:n=1  $ Ring 5 Region
c
c ------ Coolant Channels ------
c --------- Ring 1 ---------
1301 10 4.8492E-05  2401 -1301 1201 -1202 imp:n=1  $ Position 1
1302 10 4.8492E-05  2402 -1302 1201 -1202 imp:n=1  $ Position 2
1303 10 4.8492E-05       -1303 1201 -1202 imp:n=1  $ Position 3
1304 10 4.8492E-05  2404 -1304 1201 -1202 imp:n=1  $ Position 4
1305 10 4.8492E-05  2405 -1305 1201 -1202 imp:n=1  $ Position 5
1306 10 4.8492E-05       -1306 1201 -1202 imp:n=1  $ Position 6
1307 10 4.8492E-05  2407 -1307 1201 -1202 imp:n=1  $ Position 7
1308 10 4.8492E-05  2408 -1308 1201 -1202 imp:n=1  $ Position 8
1309 10 4.8492E-05       -1309 1201 -1202 imp:n=1  $ Position 9
1310 10 4.8492E-05  2410 -1310 1201 -1202 imp:n=1  $ Position 10
1311 10 4.8492E-05  2411 -1311 1201 -1202 imp:n=1  $ Position 11
1312 10 4.8492E-05       -1312 1201 -1202 imp:n=1  $ Position 12
1313 10 4.8492E-05  2413 -1313 1201 -1202 imp:n=1  $ Position 13
1314 10 4.8492E-05  2414 -1314 1201 -1202 imp:n=1  $ Position 14
1315 10 4.8492E-05       -1315 1201 -1202 imp:n=1  $ Position 15
1316 10 4.8492E-05  2416 -1316 1201 -1202 imp:n=1  $ Position 16
1317 10 4.8492E-05  2417 -1317 1201 -1202 imp:n=1  $ Position 17
1318 10 4.8492E-05       -1318 1201 -1202 imp:n=1  $ Position 18
1319 10 4.8492E-05  2419 -1319 1201 -1202 imp:n=1  $ Position 19
1320 10 4.8492E-05  2420 -1320 1201 -1202 imp:n=1  $ Position 20
1321 10 4.8492E-05       -1321 1201 -1202 imp:n=1  $ Position 21
1322 10 4.8492E-05  2422 -1322 1201 -1202 imp:n=1  $ Position 22
1323 10 4.8492E-05  2423 -1323 1201 -1202 imp:n=1  $ Position 23
1324 10 4.8492E-05       -1324 1201 -1202 imp:n=1  $ Position 24
1325 10 4.8492E-05  2425 -1325 1201 -1202 imp:n=1  $ Position 25
1326 10 4.8492E-05  2426 -1326 1201 -1202 imp:n=1  $ Position 26
1327 10 4.8492E-05       -1327 1201 -1202 imp:n=1  $ Position 27
1328 10 4.8492E-05  2428 -1328 1201 -1202 imp:n=1  $ Position 28
1329 10 4.8492E-05       -1329 1201 -1202 imp:n=1  $ Position 29
1330 10 4.8492E-05  2430 -1330 1201 -1202 imp:n=1  $ Position 30
1331 10 4.8492E-05  2431 -1331 1201 -1202 imp:n=1  $ Position 31
1332 10 4.8492E-05       -1332 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 2 ---------
1401 10 4.8492E-05  2501 -1401 1201 -1202 imp:n=1  $ Position 1
1402 10 4.8492E-05  2502 -1402 1201 -1202 imp:n=1  $ Position 2
1403 10 4.8492E-05  2503 -1403 1201 -1202 imp:n=1  $ Position 3
1404 10 4.8492E-05  2504 -1404 1201 -1202 imp:n=1  $ Position 4
1405 10 4.8492E-05  2505 -1405 1201 -1202 imp:n=1  $ Position 5
1406 10 4.8492E-05  2506 -1406 1201 -1202 imp:n=1  $ Position 6
1407 10 4.8492E-05  2507 -1407 1201 -1202 imp:n=1  $ Position 7
1408 10 4.8492E-05  2508 -1408 1201 -1202 imp:n=1  $ Position 8
1409 10 4.8492E-05  2509 -1409 1201 -1202 imp:n=1  $ Position 9
1410 10 4.8492E-05  2510 -1410 1201 -1202 imp:n=1  $ Position 10
1411 10 4.8492E-05  2511 -1411 1201 -1202 imp:n=1  $ Position 11
1412 10 4.8492E-05  2512 -1412 1201 -1202 imp:n=1  $ Position 12
1413 10 4.8492E-05  2513 -1413 1201 -1202 imp:n=1  $ Position 13
1414 10 4.8492E-05  2514 -1414 1201 -1202 imp:n=1  $ Position 14
1415 10 4.8492E-05  2515 -1415 1201 -1202 imp:n=1  $ Position 15
1416 10 4.8492E-05  2516 -1416 1201 -1202 imp:n=1  $ Position 16
1417 10 4.8492E-05  2517 -1417 1201 -1202 imp:n=1  $ Position 17
1418 10 4.8492E-05  2518 -1418 1201 -1202 imp:n=1  $ Position 18
1419 10 4.8492E-05  2519 -1419 1201 -1202 imp:n=1  $ Position 19
```

```
1420 10 4.8492E-05  2520 -1420 1201 -1202 imp:n=1  $ Position 20
1421 10 4.8492E-05  2521 -1421 1201 -1202 imp:n=1  $ Position 21
1422 10 4.8492E-05  2522 -1422 1201 -1202 imp:n=1  $ Position 22
1423 10 4.8492E-05  2523 -1423 1201 -1202 imp:n=1  $ Position 23
1424 10 4.8492E-05  2524 -1424 1201 -1202 imp:n=1  $ Position 24
1425 10 4.8492E-05  2525 -1425 1201 -1202 imp:n=1  $ Position 25
1426 10 4.8492E-05  2526 -1426 1201 -1202 imp:n=1  $ Position 26
1427 10 4.8492E-05  2527 -1427 1201 -1202 imp:n=1  $ Position 27
1428 10 4.8492E-05  2528 -1428 1201 -1202 imp:n=1  $ Position 28
1429 10 4.8492E-05  2529 -1429 1201 -1202 imp:n=1  $ Position 29
1430 10 4.8492E-05  2530 -1430 1201 -1202 imp:n=1  $ Position 30
1431 10 4.8492E-05  2531 -1431 1201 -1202 imp:n=1  $ Position 31
1432 10 4.8492E-05  2532 -1432 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 3 ---------
1501 10 4.8492E-05  2601 -1501 1201 -1202 imp:n=1  $ Position 1
1502 10 4.8492E-05       -1502 1201 -1202 imp:n=1  $ Position 2
1503 10 4.8492E-05  2603 -1503 1201 -1202 imp:n=1  $ Position 3
1504 10 4.8492E-05  2604 -1504 1201 -1202 imp:n=1  $ Position 4
1505 10 4.8492E-05       -1505 1201 -1202 imp:n=1  $ Position 5
1506 10 4.8492E-05  2606 -1506 1201 -1202 imp:n=1  $ Position 6
1507 10 4.8492E-05  2607 -1507 1201 -1202 imp:n=1  $ Position 7
1508 10 4.8492E-05       -1508 1201 -1202 imp:n=1  $ Position 8
1509 10 4.8492E-05  2609 -1509 1201 -1202 imp:n=1  $ Position 9
1510 10 4.8492E-05  2610 -1510 1201 -1202 imp:n=1  $ Position 10
1511 10 4.8492E-05       -1511 1201 -1202 imp:n=1  $ Position 11
1512 10 4.8492E-05  2612 -1512 1201 -1202 imp:n=1  $ Position 12
1513 10 4.8492E-05  2613 -1513 1201 -1202 imp:n=1  $ Position 13
1514 10 4.8492E-05       -1514 1201 -1202 imp:n=1  $ Position 14
1515 10 4.8492E-05  2615 -1515 1201 -1202 imp:n=1  $ Position 15
1516 10 4.8492E-05  2616 -1516 1201 -1202 imp:n=1  $ Position 16
1517 10 4.8492E-05       -1517 1201 -1202 imp:n=1  $ Position 17
1518 10 4.8492E-05  2618 -1518 1201 -1202 imp:n=1  $ Position 18
1519 10 4.8492E-05  2619 -1519 1201 -1202 imp:n=1  $ Position 19
1520 10 4.8492E-05       -1520 1201 -1202 imp:n=1  $ Position 20
1521 10 4.8492E-05  2621 -1521 1201 -1202 imp:n=1  $ Position 21
1522 10 4.8492E-05  2622 -1522 1201 -1202 imp:n=1  $ Position 22
1523 10 4.8492E-05       -1523 1201 -1202 imp:n=1  $ Position 23
1524 10 4.8492E-05  2624 -1524 1201 -1202 imp:n=1  $ Position 24
1525 10 4.8492E-05  2625 -1525 1201 -1202 imp:n=1  $ Position 25
1526 10 4.8492E-05       -1526 1201 -1202 imp:n=1  $ Position 26
1527 10 4.8492E-05  2627 -1527 1201 -1202 imp:n=1  $ Position 27
1528 10 4.8492E-05       -1528 1201 -1202 imp:n=1  $ Position 28
1529 10 4.8492E-05  2629 -1529 1201 -1202 imp:n=1  $ Position 29
1530 10 4.8492E-05  2630 -1530 1201 -1202 imp:n=1  $ Position 30
1531 10 4.8492E-05       -1531 1201 -1202 imp:n=1  $ Position 31
1532 10 4.8492E-05  2632 -1532 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 4 ---------
1601 10 4.8492E-05  2701 -1601 1201 -1202 imp:n=1  $ Position 1
1602 10 4.8492E-05  2702 -1602 1201 -1202 imp:n=1  $ Position 2
1603 10 4.8492E-05  2703 -1603 1201 -1202 imp:n=1  $ Position 3
1604 10 4.8492E-05  2704 -1604 1201 -1202 imp:n=1  $ Position 4
1605 10 4.8492E-05  2705 -1605 1201 -1202 imp:n=1  $ Position 5
1606 10 4.8492E-05  2706 -1606 1201 -1202 imp:n=1  $ Position 6
1607 10 4.8492E-05  2707 -1607 1201 -1202 imp:n=1  $ Position 7
1608 10 4.8492E-05  2708 -1608 1201 -1202 imp:n=1  $ Position 8
1609 10 4.8492E-05  2709 -1609 1201 -1202 imp:n=1  $ Position 9
1610 10 4.8492E-05  2710 -1610 1201 -1202 imp:n=1  $ Position 10
1611 10 4.8492E-05  2711 -1611 1201 -1202 imp:n=1  $ Position 11
1612 10 4.8492E-05  2712 -1612 1201 -1202 imp:n=1  $ Position 12
1613 10 4.8492E-05  2713 -1613 1201 -1202 imp:n=1  $ Position 13
1614 10 4.8492E-05  2714 -1614 1201 -1202 imp:n=1  $ Position 14
1615 10 4.8492E-05  2715 -1615 1201 -1202 imp:n=1  $ Position 15
1616 10 4.8492E-05  2716 -1616 1201 -1202 imp:n=1  $ Position 16
1617 10 4.8492E-05  2717 -1617 1201 -1202 imp:n=1  $ Position 17
1618 10 4.8492E-05  2718 -1618 1201 -1202 imp:n=1  $ Position 18
1619 10 4.8492E-05  2719 -1619 1201 -1202 imp:n=1  $ Position 19
1620 10 4.8492E-05  2720 -1620 1201 -1202 imp:n=1  $ Position 20
1621 10 4.8492E-05  2721 -1621 1201 -1202 imp:n=1  $ Position 21
1622 10 4.8492E-05  2722 -1622 1201 -1202 imp:n=1  $ Position 22
1623 10 4.8492E-05  2723 -1623 1201 -1202 imp:n=1  $ Position 23
1624 10 4.8492E-05  2724 -1624 1201 -1202 imp:n=1  $ Position 24
1625 10 4.8492E-05  2725 -1625 1201 -1202 imp:n=1  $ Position 25
1626 10 4.8492E-05  2726 -1626 1201 -1202 imp:n=1  $ Position 26
1627 10 4.8492E-05  2727 -1627 1201 -1202 imp:n=1  $ Position 27
```

```
1628 10 4.8492E-05  2728 -1628 1201 -1202 imp:n=1  $ Position 28
1629 10 4.8492E-05  2729 -1629 1201 -1202 imp:n=1  $ Position 29
1630 10 4.8492E-05  2730 -1630 1201 -1202 imp:n=1  $ Position 30
1631 10 4.8492E-05  2731 -1631 1201 -1202 imp:n=1  $ Position 31
1632 10 4.8492E-05  2732 -1632 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 5 ---------
1701 10 4.8492E-05       -1701 1201 -1202 imp:n=1  $ Position 1
1702 10 4.8492E-05  2802 -1702 1201 -1202 imp:n=1  $ Position 2
1703 10 4.8492E-05  2803 -1703 1201 -1202 imp:n=1  $ Position 3
1704 10 4.8492E-05       -1704 1201 -1202 imp:n=1  $ Position 4
1705 10 4.8492E-05  2805 -1705 1201 -1202 imp:n=1  $ Position 5
1706 10 4.8492E-05  2806 -1706 1201 -1202 imp:n=1  $ Position 6
1707 10 4.8492E-05       -1707 1201 -1202 imp:n=1  $ Position 7
1708 10 4.8492E-05  2808 -1708 1201 -1202 imp:n=1  $ Position 8
1709 10 4.8492E-05  2809 -1709 1201 -1202 imp:n=1  $ Position 9
1710 10 4.8492E-05       -1710 1201 -1202 imp:n=1  $ Position 10
1711 10 4.8492E-05  2811 -1711 1201 -1202 imp:n=1  $ Position 11
1712 10 4.8492E-05  2812 -1712 1201 -1202 imp:n=1  $ Position 12
1713 10 4.8492E-05       -1713 1201 -1202 imp:n=1  $ Position 13
1714 10 4.8492E-05  2814 -1714 1201 -1202 imp:n=1  $ Position 14
1715 10 4.8492E-05  2815 -1715 1201 -1202 imp:n=1  $ Position 15
1716 10 4.8492E-05       -1716 1201 -1202 imp:n=1  $ Position 16
1717 10 4.8492E-05  2817 -1717 1201 -1202 imp:n=1  $ Position 17
1718 10 4.8492E-05  2818 -1718 1201 -1202 imp:n=1  $ Position 18
1719 10 4.8492E-05       -1719 1201 -1202 imp:n=1  $ Position 19
1720 10 4.8492E-05  2820 -1720 1201 -1202 imp:n=1  $ Position 20
1721 10 4.8492E-05  2821 -1721 1201 -1202 imp:n=1  $ Position 21
1722 10 4.8492E-05       -1722 1201 -1202 imp:n=1  $ Position 22
1723 10 4.8492E-05  2823 -1723 1201 -1202 imp:n=1  $ Position 23
1724 10 4.8492E-05  2824 -1724 1201 -1202 imp:n=1  $ Position 24
1725 10 4.8492E-05       -1725 1201 -1202 imp:n=1  $ Position 25
1726 10 4.8492E-05  2826 -1726 1201 -1202 imp:n=1  $ Position 26
1727 10 4.8492E-05       -1727 1201 -1202 imp:n=1  $ Position 27
1728 10 4.8492E-05  2828 -1728 1201 -1202 imp:n=1  $ Position 28
1729 10 4.8492E-05  2829 -1729 1201 -1202 imp:n=1  $ Position 29
1730 10 4.8492E-05       -1730 1201 -1202 imp:n=1  $ Position 30
1731 10 4.8492E-05  2831 -1731 1201 -1202 imp:n=1  $ Position 31
1732 10 4.8492E-05  2832 -1732 1201 -1202 imp:n=1  $ Position 32
c
c ------ Graphite Plugs ------
c --------- Ring 1 ---------
12401 29 8.8245E-02  -2401 1201 -1202 imp:n=1  $ Position 1
12402 29 8.8245E-02  -2402 1201 -1202 imp:n=1  $ Position 2
c    *Coolant Channel (No Plug)   $ Position 3
12404 29 8.8245E-02  -2404 1201 -1202 imp:n=1  $ Position 4
12405 29 8.8245E-02  -2405 1201 -1202 imp:n=1  $ Position 5
c    *Coolant Channel (No Plug)   $ Position 6
12407 29 8.8245E-02  -2407 1201 -1202 imp:n=1  $ Position 7
12408 29 8.8245E-02  -2408 1201 -1202 imp:n=1  $ Position 8
c    *Coolant Channel (No Plug)   $ Position 9
12410 29 8.8245E-02  -2410 1201 -1202 imp:n=1  $ Position 10
12411 29 8.8245E-02  -2411 1201 -1202 imp:n=1  $ Position 11
c    *Coolant Channel (No Plug)   $ Position 12
12413 29 8.8245E-02  -2413 1201 -1202 imp:n=1  $ Position 13
12414 29 8.8245E-02  -2414 1201 -1202 imp:n=1  $ Position 14
c    *Coolant Channel (No Plug)   $ Position 15
12416 29 8.8245E-02  -2416 1201 -1202 imp:n=1  $ Position 16
12417 29 8.8245E-02  -2417 1201 -1202 imp:n=1  $ Position 17
c    *Coolant Channel (No Plug)   $ Position 18
12419 29 8.8245E-02  -2419 1201 -1202 imp:n=1  $ Position 19
12420 29 8.8245E-02  -2420 1201 -1202 imp:n=1  $ Position 20
c    *Coolant Channel (No Plug)   $ Position 21
12422 29 8.8245E-02  -2422 1201 -1202 imp:n=1  $ Position 22
12423 29 8.8245E-02  -2423 1201 -1202 imp:n=1  $ Position 23
c    *Coolant Channel (No Plug)   $ Position 24
12425 29 8.8245E-02  -2425 1201 -1202 imp:n=1  $ Position 25
12426 29 8.8245E-02  -2426 1201 -1202 imp:n=1  $ Position 26
c    *Coolant Channel (No Plug)   $ Position 27
12428 29 8.8245E-02  -2428 1201 -1202 imp:n=1  $ Position 28
c    *Coolant Channel (No Plug)   $ Position 29
12430 29 8.8245E-02  -2430 1201 -1202 imp:n=1  $ Position 30
12431 29 8.8245E-02  -2431 1201 -1202 imp:n=1  $ Position 31
c    *Coolant Channel (No Plug)   $ Position 32
c
c --------- Ring 2 ---------
```

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12501 29 8.8245E-02  -2501 1201 -1202 imp:n=1  $ Position 1
12502 29 8.8245E-02  -2502 1201 -1202 imp:n=1  $ Position 2
12503 29 8.8245E-02  -2503 1201 -1202 imp:n=1  $ Position 3
12504 29 8.8245E-02  -2504 1201 -1202 imp:n=1  $ Position 4
12505 29 8.8245E-02  -2505 1201 -1202 imp:n=1  $ Position 5
12506 29 8.8245E-02  -2506 1201 -1202 imp:n=1  $ Position 6
12507 29 8.8245E-02  -2507 1201 -1202 imp:n=1  $ Position 7
12508 29 8.8245E-02  -2508 1201 -1202 imp:n=1  $ Position 8
12509 29 8.8245E-02  -2509 1201 -1202 imp:n=1  $ Position 9
12510 29 8.8245E-02  -2510 1201 -1202 imp:n=1  $ Position 10
12511 29 8.8245E-02  -2511 1201 -1202 imp:n=1  $ Position 11
12512 29 8.8245E-02  -2512 1201 -1202 imp:n=1  $ Position 12
12513 29 8.8245E-02  -2513 1201 -1202 imp:n=1  $ Position 13
12514 29 8.8245E-02  -2514 1201 -1202 imp:n=1  $ Position 14
12515 29 8.8245E-02  -2515 1201 -1202 imp:n=1  $ Position 15
12516 29 8.8245E-02  -2516 1201 -1202 imp:n=1  $ Position 16
12517 29 8.8245E-02  -2517 1201 -1202 imp:n=1  $ Position 17
12518 29 8.8245E-02  -2518 1201 -1202 imp:n=1  $ Position 18
12519 29 8.8245E-02  -2519 1201 -1202 imp:n=1  $ Position 19
12520 29 8.8245E-02  -2520 1201 -1202 imp:n=1  $ Position 20
12521 29 8.8245E-02  -2521 1201 -1202 imp:n=1  $ Position 21
12522 29 8.8245E-02  -2522 1201 -1202 imp:n=1  $ Position 22
12523 29 8.8245E-02  -2523 1201 -1202 imp:n=1  $ Position 23
12524 29 8.8245E-02  -2524 1201 -1202 imp:n=1  $ Position 24
12525 29 8.8245E-02  -2525 1201 -1202 imp:n=1  $ Position 25
12526 29 8.8245E-02  -2526 1201 -1202 imp:n=1  $ Position 26
12527 29 8.8245E-02  -2527 1201 -1202 imp:n=1  $ Position 27
12528 29 8.8245E-02  -2528 1201 -1202 imp:n=1  $ Position 28
12529 29 8.8245E-02  -2529 1201 -1202 imp:n=1  $ Position 29
12530 29 8.8245E-02  -2530 1201 -1202 imp:n=1  $ Position 30
12531 29 8.8245E-02  -2531 1201 -1202 imp:n=1  $ Position 31
12532 29 8.8245E-02  -2532 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 3 ---------
12601 29 8.8245E-02  -2601 1201 -1202 imp:n=1  $ Position 1
c    *Coolant Channel (No Plug)   $ Position 2
12603 29 8.8245E-02  -2603 1201 -1202 imp:n=1  $ Position 3
12604 29 8.8245E-02  -2604 1201 -1202 imp:n=1  $ Position 4
c    *Coolant Channel (No Plug)   $ Position 5
12606 29 8.8245E-02  -2606 1201 -1202 imp:n=1  $ Position 6
12607 29 8.8245E-02  -2607 1201 -1202 imp:n=1  $ Position 7
c    *Coolant Channel (No Plug)   $ Position 8
12609 29 8.8245E-02  -2609 1201 -1202 imp:n=1  $ Position 9
12610 29 8.8245E-02  -2610 1201 -1202 imp:n=1  $ Position 10
c    *Coolant Channel (No Plug)   $ Position 11
12612 29 8.8245E-02  -2612 1201 -1202 imp:n=1  $ Position 12
12613 29 8.8245E-02  -2613 1201 -1202 imp:n=1  $ Position 13
c    *Coolant Channel (No Plug)   $ Position 14
12615 29 8.8245E-02  -2615 1201 -1202 imp:n=1  $ Position 15
12616 29 8.8245E-02  -2616 1201 -1202 imp:n=1  $ Position 16
c    *Coolant Channel (No Plug)   $ Position 17
12618 29 8.8245E-02  -2618 1201 -1202 imp:n=1  $ Position 18
12619 29 8.8245E-02  -2619 1201 -1202 imp:n=1  $ Position 19
c    *Coolant Channel (No Plug)   $ Position 20
12621 29 8.8245E-02  -2621 1201 -1202 imp:n=1  $ Position 21
12622 29 8.8245E-02  -2622 1201 -1202 imp:n=1  $ Position 22
c    *Coolant Channel (No Plug)   $ Position 23
12624 29 8.8245E-02  -2624 1201 -1202 imp:n=1  $ Position 24
12625 29 8.8245E-02  -2625 1201 -1202 imp:n=1  $ Position 25
c    *Coolant Channel (No Plug)   $ Position 26
12627 29 8.8245E-02  -2627 1201 -1202 imp:n=1  $ Position 27
c    *Coolant Channel (No Plug)   $ Position 28
12629 29 8.8245E-02  -2629 1201 -1202 imp:n=1  $ Position 29
12630 29 8.8245E-02  -2630 1201 -1202 imp:n=1  $ Position 30
c    *Coolant Channel (No Plug)   $ Position 31
12632 29 8.8245E-02  -2632 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 4 ---------
12701 29 8.8245E-02  -2701 1201 -1202 imp:n=1  $ Position 1
12702 29 8.8245E-02  -2702 1201 -1202 imp:n=1  $ Position 2
12703 29 8.8245E-02  -2703 1201 -1202 imp:n=1  $ Position 3
12704 29 8.8245E-02  -2704 1201 -1202 imp:n=1  $ Position 4
12705 29 8.8245E-02  -2705 1201 -1202 imp:n=1  $ Position 5
12706 29 8.8245E-02  -2706 1201 -1202 imp:n=1  $ Position 6
12707 29 8.8245E-02  -2707 1201 -1202 imp:n=1  $ Position 7
12708 29 8.8245E-02  -2708 1201 -1202 imp:n=1  $ Position 8
```

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12709 29 8.8245E-02  -2709 1201 -1202 imp:n=1  $ Position 9
12710 29 8.8245E-02  -2710 1201 -1202 imp:n=1  $ Position 10
12711 29 8.8245E-02  -2711 1201 -1202 imp:n=1  $ Position 11
12712 29 8.8245E-02  -2712 1201 -1202 imp:n=1  $ Position 12
12713 29 8.8245E-02  -2713 1201 -1202 imp:n=1  $ Position 13
12714 29 8.8245E-02  -2714 1201 -1202 imp:n=1  $ Position 14
12715 29 8.8245E-02  -2715 1201 -1202 imp:n=1  $ Position 15
12716 29 8.8245E-02  -2716 1201 -1202 imp:n=1  $ Position 16
12717 29 8.8245E-02  -2717 1201 -1202 imp:n=1  $ Position 17
12718 29 8.8245E-02  -2718 1201 -1202 imp:n=1  $ Position 18
12719 29 8.8245E-02  -2719 1201 -1202 imp:n=1  $ Position 19
12720 29 8.8245E-02  -2720 1201 -1202 imp:n=1  $ Position 20
12721 29 8.8245E-02  -2721 1201 -1202 imp:n=1  $ Position 21
12722 29 8.8245E-02  -2722 1201 -1202 imp:n=1  $ Position 22
12723 29 8.8245E-02  -2723 1201 -1202 imp:n=1  $ Position 23
12724 29 8.8245E-02  -2724 1201 -1202 imp:n=1  $ Position 24
12725 29 8.8245E-02  -2725 1201 -1202 imp:n=1  $ Position 25
12726 29 8.8245E-02  -2726 1201 -1202 imp:n=1  $ Position 26
12727 29 8.8245E-02  -2727 1201 -1202 imp:n=1  $ Position 27
12728 29 8.8245E-02  -2728 1201 -1202 imp:n=1  $ Position 28
12729 29 8.8245E-02  -2729 1201 -1202 imp:n=1  $ Position 29
12730 29 8.8245E-02  -2730 1201 -1202 imp:n=1  $ Position 30
12731 29 8.8245E-02  -2731 1201 -1202 imp:n=1  $ Position 31
12732 29 8.8245E-02  -2732 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 5 ---------
c    *Coolant Channel (No Plug)   $ Position 1
12802 29 8.8245E-02  -2802 1201 -1202 imp:n=1  $ Position 2
12803 29 8.8245E-02  -2803 1201 -1202 imp:n=1  $ Position 3
c    *Coolant Channel (No Plug)   $ Position 4
12805 29 8.8245E-02  -2805 1201 -1202 imp:n=1  $ Position 5
12806 29 8.8245E-02  -2806 1201 -1202 imp:n=1  $ Position 6
c    *Coolant Channel (No Plug)   $ Position 7
12808 29 8.8245E-02  -2808 1201 -1202 imp:n=1  $ Position 8
12809 29 8.8245E-02  -2809 1201 -1202 imp:n=1  $ Position 9
c    *Coolant Channel (No Plug)   $ Position 10
12811 29 8.8245E-02  -2811 1201 -1202 imp:n=1  $ Position 11
12812 29 8.8245E-02  -2812 1201 -1202 imp:n=1  $ Position 12
c    *Coolant Channel (No Plug)   $ Position 13
12814 29 8.8245E-02  -2814 1201 -1202 imp:n=1  $ Position 14
12815 29 8.8245E-02  -2815 1201 -1202 imp:n=1  $ Position 15
c    *Coolant Channel (No Plug)   $ Position 16
12817 29 8.8245E-02  -2817 1201 -1202 imp:n=1  $ Position 17
12818 29 8.8245E-02  -2818 1201 -1202 imp:n=1  $ Position 18
c    *Coolant Channel (No Plug)   $ Position 19
12820 29 8.8245E-02  -2820 1201 -1202 imp:n=1  $ Position 20
12821 29 8.8245E-02  -2821 1201 -1202 imp:n=1  $ Position 21
c    *Coolant Channel (No Plug)   $ Position 22
12823 29 8.8245E-02  -2823 1201 -1202 imp:n=1  $ Position 23
12824 29 8.8245E-02  -2824 1201 -1202 imp:n=1  $ Position 24
c    *Coolant Channel (No Plug)   $ Position 25
12826 29 8.8245E-02  -2826 1201 -1202 imp:n=1  $ Position 26
c    *Coolant Channel (No Plug)   $ Position 27
12828 29 8.8245E-02  -2828 1201 -1202 imp:n=1  $ Position 28
12829 29 8.8245E-02  -2829 1201 -1202 imp:n=1  $ Position 29
c    *Coolant Channel (No Plug)   $ Position 30
12831 29 8.8245E-02  -2831 1201 -1202 imp:n=1  $ Position 31
12832 29 8.8245E-02  -2832 1201 -1202 imp:n=1  $ Position 32
c
c ------ Aluminum Tank ------
1800   9 5.9018E-02  1801 -1201 -1221       imp:n=1  $ Bottom Center
1803   9 5.9018E-02  1801 -1201  1222 -1223 imp:n=1  $ Bottom Annulus
1804  10 4.8492E-05  1201 -1202  1204 -1221 imp:n=1  $ Air Gap
1805   9 5.9018E-02  1801 -1202  1221 -1222 imp:n=1  $ Inner Vertical Liner
1806  10 4.8492E-05  1201 -1202  1222 -1211 imp:n=1  $ Air Gap
1807  10 4.8492E-05  1201 -1202  1212 -1223 imp:n=1  $ Air Gap
1808   9 5.9018E-02  1801 -1202  1223 -1802 imp:n=1  $ Outer Vertical Liner
1819  10 4.8492E-05  1801 -1202  1802 -33 imp:n=1  $ Air Gap
c
c --- Lower Axial Reflector ---------------------------------------------------
1820  4 8.7744E-02  31 -1811 -1812 (1821:1823) imp:n=1  $ Inner Cylinder
1821  30 8.8245E-02  31 -1821 -1823 imp:n=1  $ Graphite Plug
c
c ------ Graphite Annulus ------
1831  10 4.8492E-05  31 -1811 1812 -1831 imp:n=1  $ Air Gap
1832  5 8.8245E-02  31 -1811 -1333 1831
```

```
          (1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913
           1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926
           1927 1928 1929 1930 1931 1932)
           imp:n=1  $ Ring 1 Region
1833  5 8.8245E-02  31 -1811 1333 -1433
          (2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
           2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026
           2027 2028 2029 2030 2031 2032)
           imp:n=1  $ Ring 2 Region
1834  5 8.8245E-02  31 -1811 1433 -1533
          (2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113
           2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126
           2127 2128 2129 2130 2131 2132)
           imp:n=1  $ Ring 3 Region
1835  5 8.8245E-02  31 -1811 1533 -1633
          (2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213
           2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226
           2227 2228 2229 2230 2231 2232)
           imp:n=1  $ Ring 4 Region
1836  5 8.8245E-02  31 -1811 1633 -1832
           (2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313
           2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326
           2327 2328 2329 2330 2331 2332)
           imp:n=1  $ Ring 5 Region
1837  10 4.8492E-05  31 -1811 1832 -33 imp:n=1  $ Air Gap
c
c ------ Coolant Channels ------
c --------- Ring 1 ---------
1901 10 4.8492E-05  2401 -1901 31 -1811 imp:n=1  $ Position 1
1902 10 4.8492E-05  2402 -1902 31 -1811 imp:n=1  $ Position 2
1903 10 4.8492E-05  2403 -1903 31 -1811 imp:n=1  $ Position 3
1904 10 4.8492E-05  2404 -1904 31 -1811 imp:n=1  $ Position 4
1905 10 4.8492E-05  2405 -1905 31 -1811 imp:n=1  $ Position 5
1906 10 4.8492E-05  2406 -1906 31 -1811 imp:n=1  $ Position 6
1907 10 4.8492E-05  2407 -1907 31 -1811 imp:n=1  $ Position 7
1908 10 4.8492E-05  2408 -1908 31 -1811 imp:n=1  $ Position 8
1909 10 4.8492E-05  2409 -1909 31 -1811 imp:n=1  $ Position 9
1910 10 4.8492E-05  2410 -1910 31 -1811 imp:n=1  $ Position 10
1911 10 4.8492E-05  2411 -1911 31 -1811 imp:n=1  $ Position 11
1912 10 4.8492E-05  2412 -1912 31 -1811 imp:n=1  $ Position 12
1913 10 4.8492E-05  2413 -1913 31 -1811 imp:n=1  $ Position 13
1914 10 4.8492E-05  2414 -1914 31 -1811 imp:n=1  $ Position 14
1915 10 4.8492E-05  2415 -1915 31 -1811 imp:n=1  $ Position 15
1916 10 4.8492E-05  2416 -1916 31 -1811 imp:n=1  $ Position 16
1917 10 4.8492E-05  2417 -1917 31 -1811 imp:n=1  $ Position 17
1918 10 4.8492E-05  2418 -1918 31 -1811 imp:n=1  $ Position 18
1919 10 4.8492E-05  2419 -1919 31 -1811 imp:n=1  $ Position 19
1920 10 4.8492E-05  2420 -1920 31 -1811 imp:n=1  $ Position 20
1921 10 4.8492E-05  2421 -1921 31 -1811 imp:n=1  $ Position 21
1922 10 4.8492E-05  2422 -1922 31 -1811 imp:n=1  $ Position 22
1923 10 4.8492E-05  2423 -1923 31 -1811 imp:n=1  $ Position 23
1924 10 4.8492E-05  2424 -1924 31 -1811 imp:n=1  $ Position 24
1925 10 4.8492E-05  2425 -1925 31 -1811 imp:n=1  $ Position 25
1926 10 4.8492E-05  2426 -1926 31 -1811 imp:n=1  $ Position 26
1927 10 4.8492E-05  2427 -1927 31 -1811 imp:n=1  $ Position 27
1928 10 4.8492E-05  2428 -1928 31 -1811 imp:n=1  $ Position 28
1929 10 4.8492E-05  2429 -1929 31 -1811 imp:n=1  $ Position 29
1930 10 4.8492E-05  2430 -1930 31 -1811 imp:n=1  $ Position 30
1931 10 4.8492E-05  2431 -1931 31 -1811 imp:n=1  $ Position 31
1932 10 4.8492E-05  2432 -1932 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 2 ---------
2001 10 4.8492E-05  2501 -2001 31 -1811 imp:n=1  $ Position 1
2002 10 4.8492E-05  2502 -2002 31 -1811 imp:n=1  $ Position 2
2003 10 4.8492E-05  2503 -2003 31 -1811 imp:n=1  $ Position 3
2004 10 4.8492E-05  2504 -2004 31 -1811 imp:n=1  $ Position 4
2005 10 4.8492E-05  2505 -2005 31 -1811 imp:n=1  $ Position 5
2006 10 4.8492E-05  2506 -2006 31 -1811 imp:n=1  $ Position 6
2007 10 4.8492E-05  2507 -2007 31 -1811 imp:n=1  $ Position 7
2008 10 4.8492E-05  2508 -2008 31 -1811 imp:n=1  $ Position 8
2009 10 4.8492E-05  2509 -2009 31 -1811 imp:n=1  $ Position 9
2010 10 4.8492E-05  2510 -2010 31 -1811 imp:n=1  $ Position 10
2011 10 4.8492E-05  2511 -2011 31 -1811 imp:n=1  $ Position 11
2012 10 4.8492E-05  2512 -2012 31 -1811 imp:n=1  $ Position 12
2013 10 4.8492E-05  2513 -2013 31 -1811 imp:n=1  $ Position 13
2014 10 4.8492E-05  2514 -2014 31 -1811 imp:n=1  $ Position 14
```

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2015 10 4.8492E-05  2515 -2015 31 -1811 imp:n=1  $ Position 15
2016 10 4.8492E-05  2516 -2016 31 -1811 imp:n=1  $ Position 16
2017 10 4.8492E-05  2517 -2017 31 -1811 imp:n=1  $ Position 17
2018 10 4.8492E-05  2518 -2018 31 -1811 imp:n=1  $ Position 18
2019 10 4.8492E-05  2519 -2019 31 -1811 imp:n=1  $ Position 19
2020 10 4.8492E-05  2520 -2020 31 -1811 imp:n=1  $ Position 20
2021 10 4.8492E-05  2521 -2021 31 -1811 imp:n=1  $ Position 21
2022 10 4.8492E-05  2522 -2022 31 -1811 imp:n=1  $ Position 22
2023 10 4.8492E-05  2523 -2023 31 -1811 imp:n=1  $ Position 23
2024 10 4.8492E-05  2524 -2024 31 -1811 imp:n=1  $ Position 24
2025 10 4.8492E-05  2525 -2025 31 -1811 imp:n=1  $ Position 25
2026 10 4.8492E-05  2526 -2026 31 -1811 imp:n=1  $ Position 26
2027 10 4.8492E-05  2527 -2027 31 -1811 imp:n=1  $ Position 27
2028 10 4.8492E-05  2528 -2028 31 -1811 imp:n=1  $ Position 28
2029 10 4.8492E-05  2529 -2029 31 -1811 imp:n=1  $ Position 29
2030 10 4.8492E-05  2530 -2030 31 -1811 imp:n=1  $ Position 30
2031 10 4.8492E-05  2531 -2031 31 -1811 imp:n=1  $ Position 31
2032 10 4.8492E-05  2532 -2032 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 3 ---------
2101 10 4.8492E-05  2601 -2101 31 -1811 imp:n=1  $ Position 1
2102 10 4.8492E-05  2602 -2102 31 -1811 imp:n=1  $ Position 2
2103 10 4.8492E-05  2603 -2103 31 -1811 imp:n=1  $ Position 3
2104 10 4.8492E-05  2604 -2104 31 -1811 imp:n=1  $ Position 4
2105 10 4.8492E-05  2605 -2105 31 -1811 imp:n=1  $ Position 5
2106 10 4.8492E-05  2606 -2106 31 -1811 imp:n=1  $ Position 6
2107 10 4.8492E-05  2607 -2107 31 -1811 imp:n=1  $ Position 7
2108 10 4.8492E-05  2608 -2108 31 -1811 imp:n=1  $ Position 8
2109 10 4.8492E-05  2609 -2109 31 -1811 imp:n=1  $ Position 9
2110 10 4.8492E-05  2610 -2110 31 -1811 imp:n=1  $ Position 10
2111 10 4.8492E-05  2611 -2111 31 -1811 imp:n=1  $ Position 11
2112 10 4.8492E-05  2612 -2112 31 -1811 imp:n=1  $ Position 12
2113 10 4.8492E-05  2613 -2113 31 -1811 imp:n=1  $ Position 13
2114 10 4.8492E-05  2614 -2114 31 -1811 imp:n=1  $ Position 14
2115 10 4.8492E-05  2615 -2115 31 -1811 imp:n=1  $ Position 15
2116 10 4.8492E-05  2616 -2116 31 -1811 imp:n=1  $ Position 16
2117 10 4.8492E-05  2617 -2117 31 -1811 imp:n=1  $ Position 17
2118 10 4.8492E-05  2618 -2118 31 -1811 imp:n=1  $ Position 18
2119 10 4.8492E-05  2619 -2119 31 -1811 imp:n=1  $ Position 19
2120 10 4.8492E-05  2620 -2120 31 -1811 imp:n=1  $ Position 20
2121 10 4.8492E-05  2621 -2121 31 -1811 imp:n=1  $ Position 21
2122 10 4.8492E-05  2622 -2122 31 -1811 imp:n=1  $ Position 22
2123 10 4.8492E-05  2623 -2123 31 -1811 imp:n=1  $ Position 23
2124 10 4.8492E-05  2624 -2124 31 -1811 imp:n=1  $ Position 24
2125 10 4.8492E-05  2625 -2125 31 -1811 imp:n=1  $ Position 25
2126 10 4.8492E-05  2626 -2126 31 -1811 imp:n=1  $ Position 26
2127 10 4.8492E-05  2627 -2127 31 -1811 imp:n=1  $ Position 27
2128 10 4.8492E-05  2628 -2128 31 -1811 imp:n=1  $ Position 28
2129 10 4.8492E-05  2629 -2129 31 -1811 imp:n=1  $ Position 29
2130 10 4.8492E-05  2630 -2130 31 -1811 imp:n=1  $ Position 30
2131 10 4.8492E-05  2631 -2131 31 -1811 imp:n=1  $ Position 31
2132 10 4.8492E-05  2632 -2132 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 4 ---------
2201 10 4.8492E-05  2701 -2201 31 -1811 imp:n=1  $ Position 1
2202 10 4.8492E-05  2702 -2202 31 -1811 imp:n=1  $ Position 2
2203 10 4.8492E-05  2703 -2203 31 -1811 imp:n=1  $ Position 3
2204 10 4.8492E-05  2704 -2204 31 -1811 imp:n=1  $ Position 4
2205 10 4.8492E-05  2705 -2205 31 -1811 imp:n=1  $ Position 5
2206 10 4.8492E-05  2706 -2206 31 -1811 imp:n=1  $ Position 6
2207 10 4.8492E-05  2707 -2207 31 -1811 imp:n=1  $ Position 7
2208 10 4.8492E-05  2708 -2208 31 -1811 imp:n=1  $ Position 8
2209 10 4.8492E-05  2709 -2209 31 -1811 imp:n=1  $ Position 9
2210 10 4.8492E-05  2710 -2210 31 -1811 imp:n=1  $ Position 10
2211 10 4.8492E-05  2711 -2211 31 -1811 imp:n=1  $ Position 11
2212 10 4.8492E-05  2712 -2212 31 -1811 imp:n=1  $ Position 12
2213 10 4.8492E-05  2713 -2213 31 -1811 imp:n=1  $ Position 13
2214 10 4.8492E-05  2714 -2214 31 -1811 imp:n=1  $ Position 14
2215 10 4.8492E-05  2715 -2215 31 -1811 imp:n=1  $ Position 15
2216 10 4.8492E-05  2716 -2216 31 -1811 imp:n=1  $ Position 16
2217 10 4.8492E-05  2717 -2217 31 -1811 imp:n=1  $ Position 17
2218 10 4.8492E-05  2718 -2218 31 -1811 imp:n=1  $ Position 18
2219 10 4.8492E-05  2719 -2219 31 -1811 imp:n=1  $ Position 19
2220 10 4.8492E-05  2720 -2220 31 -1811 imp:n=1  $ Position 20
2221 10 4.8492E-05  2721 -2221 31 -1811 imp:n=1  $ Position 21
2222 10 4.8492E-05  2722 -2222 31 -1811 imp:n=1  $ Position 22
```

```
2223 10 4.8492E-05  2723 -2223 31 -1811 imp:n=1  $ Position 23
2224 10 4.8492E-05  2724 -2224 31 -1811 imp:n=1  $ Position 24
2225 10 4.8492E-05  2725 -2225 31 -1811 imp:n=1  $ Position 25
2226 10 4.8492E-05  2726 -2226 31 -1811 imp:n=1  $ Position 26
2227 10 4.8492E-05  2727 -2227 31 -1811 imp:n=1  $ Position 27
2228 10 4.8492E-05  2728 -2228 31 -1811 imp:n=1  $ Position 28
2229 10 4.8492E-05  2729 -2229 31 -1811 imp:n=1  $ Position 29
2230 10 4.8492E-05  2730 -2230 31 -1811 imp:n=1  $ Position 30
2231 10 4.8492E-05  2731 -2231 31 -1811 imp:n=1  $ Position 31
2232 10 4.8492E-05  2732 -2232 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 5 ---------
2301 10 4.8492E-05  2801 -2301 31 -1811 imp:n=1  $ Position 1
2302 10 4.8492E-05  2802 -2302 31 -1811 imp:n=1  $ Position 2
2303 10 4.8492E-05  2803 -2303 31 -1811 imp:n=1  $ Position 3
2304 10 4.8492E-05  2804 -2304 31 -1811 imp:n=1  $ Position 4
2305 10 4.8492E-05  2805 -2305 31 -1811 imp:n=1  $ Position 5
2306 10 4.8492E-05  2806 -2306 31 -1811 imp:n=1  $ Position 6
2307 10 4.8492E-05  2807 -2307 31 -1811 imp:n=1  $ Position 7
2308 10 4.8492E-05  2808 -2308 31 -1811 imp:n=1  $ Position 8
2309 10 4.8492E-05  2809 -2309 31 -1811 imp:n=1  $ Position 9
2310 10 4.8492E-05  2810 -2310 31 -1811 imp:n=1  $ Position 10
2311 10 4.8492E-05  2811 -2311 31 -1811 imp:n=1  $ Position 11
2312 10 4.8492E-05  2812 -2312 31 -1811 imp:n=1  $ Position 12
2313 10 4.8492E-05  2813 -2313 31 -1811 imp:n=1  $ Position 13
2314 10 4.8492E-05  2814 -2314 31 -1811 imp:n=1  $ Position 14
2315 10 4.8492E-05  2815 -2315 31 -1811 imp:n=1  $ Position 15
2316 10 4.8492E-05  2816 -2316 31 -1811 imp:n=1  $ Position 16
2317 10 4.8492E-05  2817 -2317 31 -1811 imp:n=1  $ Position 17
2318 10 4.8492E-05  2818 -2318 31 -1811 imp:n=1  $ Position 18
2319 10 4.8492E-05  2819 -2319 31 -1811 imp:n=1  $ Position 19
2320 10 4.8492E-05  2820 -2320 31 -1811 imp:n=1  $ Position 20
2321 10 4.8492E-05  2821 -2321 31 -1811 imp:n=1  $ Position 21
2322 10 4.8492E-05  2822 -2322 31 -1811 imp:n=1  $ Position 22
2323 10 4.8492E-05  2823 -2323 31 -1811 imp:n=1  $ Position 23
2324 10 4.8492E-05  2824 -2324 31 -1811 imp:n=1  $ Position 24
2325 10 4.8492E-05  2825 -2325 31 -1811 imp:n=1  $ Position 25
2326 10 4.8492E-05  2826 -2326 31 -1811 imp:n=1  $ Position 26
2327 10 4.8492E-05  2827 -2327 31 -1811 imp:n=1  $ Position 27
2328 10 4.8492E-05  2828 -2328 31 -1811 imp:n=1  $ Position 28
2329 10 4.8492E-05  2829 -2329 31 -1811 imp:n=1  $ Position 29
2330 10 4.8492E-05  2830 -2330 31 -1811 imp:n=1  $ Position 30
2331 10 4.8492E-05  2831 -2331 31 -1811 imp:n=1  $ Position 31
2332 10 4.8492E-05  2832 -2332 31 -1811 imp:n=1  $ Position 32
c
c ------ Graphite Plugs ------
c --------- Ring 1 ---------
2401 29 8.8245E-02  -2401 31 -1811 imp:n=1  $ Position 1
2402 29 8.8245E-02  -2402 31 -1811 imp:n=1  $ Position 2
2403 29 8.8245E-02  -2403 31 -1811 imp:n=1  $ Position 3
2404 29 8.8245E-02  -2404 31 -1811 imp:n=1  $ Position 4
2405 29 8.8245E-02  -2405 31 -1811 imp:n=1  $ Position 5
2406 29 8.8245E-02  -2406 31 -1811 imp:n=1  $ Position 6
2407 29 8.8245E-02  -2407 31 -1811 imp:n=1  $ Position 7
2408 29 8.8245E-02  -2408 31 -1811 imp:n=1  $ Position 8
2409 29 8.8245E-02  -2409 31 -1811 imp:n=1  $ Position 9
2410 29 8.8245E-02  -2410 31 -1811 imp:n=1  $ Position 10
2411 29 8.8245E-02  -2411 31 -1811 imp:n=1  $ Position 11
2412 29 8.8245E-02  -2412 31 -1811 imp:n=1  $ Position 12
2413 29 8.8245E-02  -2413 31 -1811 imp:n=1  $ Position 13
2414 29 8.8245E-02  -2414 31 -1811 imp:n=1  $ Position 14
2415 29 8.8245E-02  -2415 31 -1811 imp:n=1  $ Position 15
2416 29 8.8245E-02  -2416 31 -1811 imp:n=1  $ Position 16
2417 29 8.8245E-02  -2417 31 -1811 imp:n=1  $ Position 17
2418 29 8.8245E-02  -2418 31 -1811 imp:n=1  $ Position 18
2419 29 8.8245E-02  -2419 31 -1811 imp:n=1  $ Position 19
2420 29 8.8245E-02  -2420 31 -1811 imp:n=1  $ Position 20
2421 29 8.8245E-02  -2421 31 -1811 imp:n=1  $ Position 21
2422 29 8.8245E-02  -2422 31 -1811 imp:n=1  $ Position 22
2423 29 8.8245E-02  -2423 31 -1811 imp:n=1  $ Position 23
2424 29 8.8245E-02  -2424 31 -1811 imp:n=1  $ Position 24
2425 29 8.8245E-02  -2425 31 -1811 imp:n=1  $ Position 25
2426 29 8.8245E-02  -2426 31 -1811 imp:n=1  $ Position 26
2427 29 8.8245E-02  -2427 31 -1811 imp:n=1  $ Position 27
2428 29 8.8245E-02  -2428 31 -1811 imp:n=1  $ Position 28
2429 29 8.8245E-02  -2429 31 -1811 imp:n=1  $ Position 29
```

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2430 29 8.8245E-02  -2430 31 -1811 imp:n=1  $ Position 30
2431 29 8.8245E-02  -2431 31 -1811 imp:n=1  $ Position 31
2432 29 8.8245E-02  -2432 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 2 ---------
2501 29 8.8245E-02  -2501 31 -1811 imp:n=1  $ Position 1
2502 29 8.8245E-02  -2502 31 -1811 imp:n=1  $ Position 2
2503 29 8.8245E-02  -2503 31 -1811 imp:n=1  $ Position 3
2504 29 8.8245E-02  -2504 31 -1811 imp:n=1  $ Position 4
2505 29 8.8245E-02  -2505 31 -1811 imp:n=1  $ Position 5
2506 29 8.8245E-02  -2506 31 -1811 imp:n=1  $ Position 6
2507 29 8.8245E-02  -2507 31 -1811 imp:n=1  $ Position 7
2508 29 8.8245E-02  -2508 31 -1811 imp:n=1  $ Position 8
2509 29 8.8245E-02  -2509 31 -1811 imp:n=1  $ Position 9
2510 29 8.8245E-02  -2510 31 -1811 imp:n=1  $ Position 10
2511 29 8.8245E-02  -2511 31 -1811 imp:n=1  $ Position 11
2512 29 8.8245E-02  -2512 31 -1811 imp:n=1  $ Position 12
2513 29 8.8245E-02  -2513 31 -1811 imp:n=1  $ Position 13
2514 29 8.8245E-02  -2514 31 -1811 imp:n=1  $ Position 14
2515 29 8.8245E-02  -2515 31 -1811 imp:n=1  $ Position 15
2516 29 8.8245E-02  -2516 31 -1811 imp:n=1  $ Position 16
2517 29 8.8245E-02  -2517 31 -1811 imp:n=1  $ Position 17
2518 29 8.8245E-02  -2518 31 -1811 imp:n=1  $ Position 18
2519 29 8.8245E-02  -2519 31 -1811 imp:n=1  $ Position 19
2520 29 8.8245E-02  -2520 31 -1811 imp:n=1  $ Position 20
2521 29 8.8245E-02  -2521 31 -1811 imp:n=1  $ Position 21
2522 29 8.8245E-02  -2522 31 -1811 imp:n=1  $ Position 22
2523 29 8.8245E-02  -2523 31 -1811 imp:n=1  $ Position 23
2524 29 8.8245E-02  -2524 31 -1811 imp:n=1  $ Position 24
2525 29 8.8245E-02  -2525 31 -1811 imp:n=1  $ Position 25
2526 29 8.8245E-02  -2526 31 -1811 imp:n=1  $ Position 26
2527 29 8.8245E-02  -2527 31 -1811 imp:n=1  $ Position 27
2528 29 8.8245E-02  -2528 31 -1811 imp:n=1  $ Position 28
2529 29 8.8245E-02  -2529 31 -1811 imp:n=1  $ Position 29
2530 29 8.8245E-02  -2530 31 -1811 imp:n=1  $ Position 30
2531 29 8.8245E-02  -2531 31 -1811 imp:n=1  $ Position 31
2532 29 8.8245E-02  -2532 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 3 ---------
2601 29 8.8245E-02  -2601 31 -1811 imp:n=1  $ Position 1
2602 29 8.8245E-02  -2602 31 -1811 imp:n=1  $ Position 2
2603 29 8.8245E-02  -2603 31 -1811 imp:n=1  $ Position 3
2604 29 8.8245E-02  -2604 31 -1811 imp:n=1  $ Position 4
2605 29 8.8245E-02  -2605 31 -1811 imp:n=1  $ Position 5
2606 29 8.8245E-02  -2606 31 -1811 imp:n=1  $ Position 6
2607 29 8.8245E-02  -2607 31 -1811 imp:n=1  $ Position 7
2608 29 8.8245E-02  -2608 31 -1811 imp:n=1  $ Position 8
2609 29 8.8245E-02  -2609 31 -1811 imp:n=1  $ Position 9
2610 29 8.8245E-02  -2610 31 -1811 imp:n=1  $ Position 10
2611 29 8.8245E-02  -2611 31 -1811 imp:n=1  $ Position 11
2612 29 8.8245E-02  -2612 31 -1811 imp:n=1  $ Position 12
2613 29 8.8245E-02  -2613 31 -1811 imp:n=1  $ Position 13
2614 29 8.8245E-02  -2614 31 -1811 imp:n=1  $ Position 14
2615 29 8.8245E-02  -2615 31 -1811 imp:n=1  $ Position 15
2616 29 8.8245E-02  -2616 31 -1811 imp:n=1  $ Position 16
2617 29 8.8245E-02  -2617 31 -1811 imp:n=1  $ Position 17
2618 29 8.8245E-02  -2618 31 -1811 imp:n=1  $ Position 18
2619 29 8.8245E-02  -2619 31 -1811 imp:n=1  $ Position 19
2620 29 8.8245E-02  -2620 31 -1811 imp:n=1  $ Position 20
2621 29 8.8245E-02  -2621 31 -1811 imp:n=1  $ Position 21
2622 29 8.8245E-02  -2622 31 -1811 imp:n=1  $ Position 22
2623 29 8.8245E-02  -2623 31 -1811 imp:n=1  $ Position 23
2624 29 8.8245E-02  -2624 31 -1811 imp:n=1  $ Position 24
2625 29 8.8245E-02  -2625 31 -1811 imp:n=1  $ Position 25
2626 29 8.8245E-02  -2626 31 -1811 imp:n=1  $ Position 26
2627 29 8.8245E-02  -2627 31 -1811 imp:n=1  $ Position 27
2628 29 8.8245E-02  -2628 31 -1811 imp:n=1  $ Position 28
2629 29 8.8245E-02  -2629 31 -1811 imp:n=1  $ Position 29
2630 29 8.8245E-02  -2630 31 -1811 imp:n=1  $ Position 30
2631 29 8.8245E-02  -2631 31 -1811 imp:n=1  $ Position 31
2632 29 8.8245E-02  -2632 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 4 ---------
2701 29 8.8245E-02  -2701 31 -1811 imp:n=1  $ Position 1
2702 29 8.8245E-02  -2702 31 -1811 imp:n=1  $ Position 2
2703 29 8.8245E-02  -2703 31 -1811 imp:n=1  $ Position 3
```

```
2704 29 8.8245E-02  -2704 31 -1811 imp:n=1  $ Position 4
2705 29 8.8245E-02  -2705 31 -1811 imp:n=1  $ Position 5
2706 29 8.8245E-02  -2706 31 -1811 imp:n=1  $ Position 6
2707 29 8.8245E-02  -2707 31 -1811 imp:n=1  $ Position 7
2708 29 8.8245E-02  -2708 31 -1811 imp:n=1  $ Position 8
2709 29 8.8245E-02  -2709 31 -1811 imp:n=1  $ Position 9
2710 29 8.8245E-02  -2710 31 -1811 imp:n=1  $ Position 10
2711 29 8.8245E-02  -2711 31 -1811 imp:n=1  $ Position 11
2712 29 8.8245E-02  -2712 31 -1811 imp:n=1  $ Position 12
2713 29 8.8245E-02  -2713 31 -1811 imp:n=1  $ Position 13
2714 29 8.8245E-02  -2714 31 -1811 imp:n=1  $ Position 14
2715 29 8.8245E-02  -2715 31 -1811 imp:n=1  $ Position 15
2716 29 8.8245E-02  -2716 31 -1811 imp:n=1  $ Position 16
2717 29 8.8245E-02  -2717 31 -1811 imp:n=1  $ Position 17
2718 29 8.8245E-02  -2718 31 -1811 imp:n=1  $ Position 18
2719 29 8.8245E-02  -2719 31 -1811 imp:n=1  $ Position 19
2720 29 8.8245E-02  -2720 31 -1811 imp:n=1  $ Position 20
2721 29 8.8245E-02  -2721 31 -1811 imp:n=1  $ Position 21
2722 29 8.8245E-02  -2722 31 -1811 imp:n=1  $ Position 22
2723 29 8.8245E-02  -2723 31 -1811 imp:n=1  $ Position 23
2724 29 8.8245E-02  -2724 31 -1811 imp:n=1  $ Position 24
2725 29 8.8245E-02  -2725 31 -1811 imp:n=1  $ Position 25
2726 29 8.8245E-02  -2726 31 -1811 imp:n=1  $ Position 26
2727 29 8.8245E-02  -2727 31 -1811 imp:n=1  $ Position 27
2728 29 8.8245E-02  -2728 31 -1811 imp:n=1  $ Position 28
2729 29 8.8245E-02  -2729 31 -1811 imp:n=1  $ Position 29
2730 29 8.8245E-02  -2730 31 -1811 imp:n=1  $ Position 30
2731 29 8.8245E-02  -2731 31 -1811 imp:n=1  $ Position 31
2732 29 8.8245E-02  -2732 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 5 ---------
2801 29 8.8245E-02  -2801 31 -1811 imp:n=1  $ Position 1
2802 29 8.8245E-02  -2802 31 -1811 imp:n=1  $ Position 2
2803 29 8.8245E-02  -2803 31 -1811 imp:n=1  $ Position 3
2804 29 8.8245E-02  -2804 31 -1811 imp:n=1  $ Position 4
2805 29 8.8245E-02  -2805 31 -1811 imp:n=1  $ Position 5
2806 29 8.8245E-02  -2806 31 -1811 imp:n=1  $ Position 6
2807 29 8.8245E-02  -2807 31 -1811 imp:n=1  $ Position 7
2808 29 8.8245E-02  -2808 31 -1811 imp:n=1  $ Position 8
2809 29 8.8245E-02  -2809 31 -1811 imp:n=1  $ Position 9
2810 29 8.8245E-02  -2810 31 -1811 imp:n=1  $ Position 10
2811 29 8.8245E-02  -2811 31 -1811 imp:n=1  $ Position 11
2812 29 8.8245E-02  -2812 31 -1811 imp:n=1  $ Position 12
2813 29 8.8245E-02  -2813 31 -1811 imp:n=1  $ Position 13
2814 29 8.8245E-02  -2814 31 -1811 imp:n=1  $ Position 14
2815 29 8.8245E-02  -2815 31 -1811 imp:n=1  $ Position 15
2816 29 8.8245E-02  -2816 31 -1811 imp:n=1  $ Position 16
2817 29 8.8245E-02  -2817 31 -1811 imp:n=1  $ Position 17
2818 29 8.8245E-02  -2818 31 -1811 imp:n=1  $ Position 18
2819 29 8.8245E-02  -2819 31 -1811 imp:n=1  $ Position 19
2820 29 8.8245E-02  -2820 31 -1811 imp:n=1  $ Position 20
2821 29 8.8245E-02  -2821 31 -1811 imp:n=1  $ Position 21
2822 29 8.8245E-02  -2822 31 -1811 imp:n=1  $ Position 22
2823 29 8.8245E-02  -2823 31 -1811 imp:n=1  $ Position 23
2824 29 8.8245E-02  -2824 31 -1811 imp:n=1  $ Position 24
2825 29 8.8245E-02  -2825 31 -1811 imp:n=1  $ Position 25
2826 29 8.8245E-02  -2826 31 -1811 imp:n=1  $ Position 26
2827 29 8.8245E-02  -2827 31 -1811 imp:n=1  $ Position 27
2828 29 8.8245E-02  -2828 31 -1811 imp:n=1  $ Position 28
2829 29 8.8245E-02  -2829 31 -1811 imp:n=1  $ Position 29
2830 29 8.8245E-02  -2830 31 -1811 imp:n=1  $ Position 30
2831 29 8.8245E-02  -2831 31 -1811 imp:n=1  $ Position 31
2832 29 8.8245E-02  -2832 31 -1811 imp:n=1  $ Position 32
c
c --- Control Rods ------------------------------------------------------------
c ------ Autorod ------
3031 13 8.4303E-02  3031 -3032 -3033 -3034 -3035 imp:n=1 u=10  $ Copper Plate
3032 10 4.8492E-05  -3031:3032:3033:3034:3035 imp:n=1 u=10  $ Air
c
c ****** Autorod Fully Inserted @ z=0 and Withdrawn @ z=100 *************************
c ****** Autorod Withdrawn to z=25.8 for Core 9 &          *************************
c ******                       z= 1.5 for Core 10,         *************************
c
3033 0    -3036 imp:n=1 u=11 fill=10 (0 0 25.8)
3034 113 5.9746E-02  3036 -3037 31 -32 imp:n=1 u=11  $ Aluminum Tube
3035 10 4.8492E-05  3037:(3036 -31):(3036 32) imp:n=1 u=11  $ Air
```

```
c
c ------ Withdrawable Control Rods ------
3091 10 4.8492E-05  3083 -3084 -3087 imp:n=1 u=17  $ Air
3092 17 8.6477E-02  3082 -3085 3087 -3088 imp:n=1 u=17 $ Inner Tube
3093 10 4.8492E-05  3082 -3085 3088 -3089 imp:n=1 u=17 $ Air Gap
3094 18 8.6499E-02  3082 -3085 3089 -3090 imp:n=1 u=17 $ Outer Tube
3095 18 8.6499E-02  (3081 -3082 -3090):(3082 -3083 -3087) imp:n=1 u=17  $ Bottom End Plug
3096 18 8.6499E-02  (3084 -3085 -3087):(3085 -3086 -3090) imp:n=1 u=17  $ Top End Plug
3097 10 4.8492E-05  -3081:3086:3090 imp:n=1 u=17  $ Air
c
c ****** Control Rods Fully Inserted @ z=0 and Withdrawn @ z=249.4          **********
c ****** Opposite of Reported Values Inserted @ z=250 and Withdrawn @ z=0.6 **********
c ****** Control Rods Withdrawn to z=249.4 for Core 9                       **********
c ****** Control Rods Withdrawn to z=96.0  for Core 10                      **********
c
3098 0  -3095 imp:n=1 u=18 fill=17 (0 0 249.4)  $ Rod 1
3099 0  -3095 imp:n=1 u=19 fill=17 (0 0 249.4)  $ Rod 2
3100 0  -3095 imp:n=1 u=20 fill=17 (0 0 249.4)  $ Rod 3
3101 0  -3095 imp:n=1 u=21 fill=17 (0 0 249.4)  $ Rod 4
c
c --- Pebbles -----------------------------------------------------------------
c ------ TRISO ------
3111 19 7.2917E-02  -3111 imp:n=1 u=22  $ UO2 Kernel
3112 20 5.2640E-02  3111 -3112 imp:n=1 u=22  $ Buffer Coating
3113 21 9.5254E-02  3112 -3113 imp:n=1 u=22  $ IPyC Coating
3114 22 9.6110E-02  3113 -3114 imp:n=1 u=22  $ SiC Coating
3115 23 9.4772E-02  3114 -3115 imp:n=1 u=22  $ OPyC Coating
3116 24 8.6859E-02  3115 imp:n=1 u=22  $ Fueled Zone Graphite
c
3117 24 8.6859E-02  -9999 imp:n=1 u=23  $ Fueled Zone Graphite
c
c ------ TRISO Lattice ------
3121 24 8.6859E-02  -3121 imp:n=1 u=98 lat=1 fill=-14:14 -14:14 -14:14
c
     23 840r
c
     23 405r
     23 12r 22 2r 23 12r
     23 405r
c
     23 260r
     23 12r 22 2r 23 12r
     23 10r 22 6r 23 10r
     23 9r 22 8r 23 9r
     23 9r 22 8r 23 9r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 9r 22 8r 23 9r
     23 9r 22 8r 23 9r
     23 10r 22 6r 23 10r
     23 12r 22 2r 23 12r
     23 260r
c
     23 202r
     23 12r 22 2r 23 12r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 12r 22 2r 23 12r
     23 202r
c
     23 173r
     23 11r 22 4r 23 11r
     23 9r 22 8r 23 9r
     23 8r 22 10r 23 8r
```

```
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 9r 22 8r 23 9r
     23 11r 22 4r 23 11r
     23 173r
c
     23 144r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
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     23 8r 22 10r 23 8r
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     23 7r 22 12r 23 7r
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     23 6r 22 14r 23 6r
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     23 5r 22 16r 23 5r
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     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 9r 22 8r 23 9r
     23 11r 22 4r 23 11r
     23 173r
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     23 202r
     23 12r 22 2r 23 12r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
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     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 12r 22 2r 23 12r
     23 202r
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     23 260r
     23 12r 22 2r 23 12r
     23 10r 22 6r 23 10r
     23 9r 22 8r 23 9r
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     23 8r 22 10r 23 8r
     23 9r 22 8r 23 9r
     23 9r 22 8r 23 9r
     23 10r 22 6r 23 10r
     23 12r 22 2r 23 12r
     23 260r
c
     23 405r
     23 12r 22 2r 23 12r
     23 405r
c
     23 840r
c
c ------ Fuel Pebbles ------
3131 24 8.6859E-02  -3131       imp:n=1 u=24 fill=98 $ Fuel Zone
3132 24 8.6859E-02   3131 -3132 imp:n=1 u=24         $ Pebble Shell (Unfueled Zone)
3133 10 4.8413E-05   3132       imp:n=1 u=24         $ Air
c
c ------ Moderator Pebbles ------
4131 26 8.4461E-02  -3132       imp:n=1 u=25  $ Moderator Pebble
4132 10 4.8413E-05   3132       imp:n=1 u=25  $ Air
c
c ------ Air ------
5001 10 4.8413E-05  -9999 imp:n=1 u=26  $ Air
c
c ------ Pebble Stacks ---------------------------------------------------------
c --------- Standard Stacks ---------
c ------------ Stack 1 (Core 9) ------------
6001 10 4.8413E-05  -6001 imp:n=1 u=27 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
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     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
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     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 2 (Core 9) ------------
6002 10 4.8413E-05  -6001 imp:n=1 u=28 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
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     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
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     26 26 26  26 26 26  26 26 26
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     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 3 (Core 9) ------------
6003 10 4.8413E-05  -6001 imp:n=1 u=29 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 4 (Core 9) ------------
6004 10 4.8413E-05  -6001 imp:n=1 u=30 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
```

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     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 1 (Core 10) ------------
6005 10 4.8413E-05  -6001 imp:n=1 u=31 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
```

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     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 2 (Core 10) ------------
6006 10 4.8413E-05  -6001 imp:n=1 u=32 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
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     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 3 (Core 10) ------------
6007 10 4.8413E-05  -6001 imp:n=1 u=33 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 4 (Core 10) ------------
6008 10 4.8413E-05  -6001 imp:n=1 u=34 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
```

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     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------ Stacks with Polyethylene Rods (Full Set) ------
c    *Polyethylene Rods are Only in Core 10
c
c ------------ Stack 1 - NW, N, NE, SE, S, SW ------------
5101 34 1.2365E-01  -7021 -6003 -7027 imp:n=1 u=35  $ NW Rod
5102 34 1.2365E-01  -7022 -6003 -7027 imp:n=1 u=35  $ N Rod
5103 34 1.2365E-01  -7023 -6003 -7027 imp:n=1 u=35  $ NE Rod
5104 34 1.2365E-01  -7024 -6003 -7027 imp:n=1 u=35  $ SE Rod
5105 34 1.2365E-01  -7025 -6003 -7027 imp:n=1 u=35  $ S Rod
5106 34 1.2365E-01  -7026 -6003 -7027 imp:n=1 u=35  $ SW Rod
5107 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=35 fill=31
c
c ------------ Stack 2 - NW, N, NE, SE, S, SW ------------
5111 34 1.2365E-01  -7021 -6003 -7027 imp:n=1 u=36  $ NW Rod
5112 34 1.2365E-01  -7022 -6003 -7027 imp:n=1 u=36  $ N Rod
5113 34 1.2365E-01  -7023 -6003 -7027 imp:n=1 u=36  $ NE Rod
5114 34 1.2365E-01  -7024 -6003 -7027 imp:n=1 u=36  $ SE Rod
5115 34 1.2365E-01  -7025 -6003 -7027 imp:n=1 u=36  $ S Rod
5116 34 1.2365E-01  -7026 -6003 -7027 imp:n=1 u=36  $ SW Rod
5117 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=36 fill=32
c
c ------------ Stack 3 - NW, N, NE, SE, S, SW ------------
5121 34 1.2365E-01  -7021 -6003 -7027 imp:n=1 u=37  $ NW Rod
5122 34 1.2365E-01  -7022 -6003 -7027 imp:n=1 u=37  $ N Rod
5123 34 1.2365E-01  -7023 -6003 -7027 imp:n=1 u=37  $ NE Rod
5124 34 1.2365E-01  -7024 -6003 -7027 imp:n=1 u=37  $ SE Rod
5125 34 1.2365E-01  -7025 -6003 -7027 imp:n=1 u=37  $ S Rod
5126 34 1.2365E-01  -7026 -6003 -7027 imp:n=1 u=37  $ SW Rod
5127 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=37 fill=33
c
c ------------ Stack 4 - NW, N, NE, SE, S, SW ------------
5131 34 1.2365E-01  -7021 -6003 -7027 imp:n=1 u=38  $ NW Rod
5132 34 1.2365E-01  -7022 -6003 -7027 imp:n=1 u=38  $ N Rod
5133 34 1.2365E-01  -7023 -6003 -7027 imp:n=1 u=38  $ NE Rod
5134 34 1.2365E-01  -7024 -6003 -7027 imp:n=1 u=38  $ SE Rod
5135 34 1.2365E-01  -7025 -6003 -7027 imp:n=1 u=38  $ S Rod
5136 34 1.2365E-01  -7026 -6003 -7027 imp:n=1 u=38  $ SW Rod
5137 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=38 fill=34
```

```
c
c ------ Stacks with Polyethylene Rods (Partial Sets) ------
c ------------ Stack 1 - N, NE, SE, S ------------
5202 like 5102 but u=40  $ N Rod
5203 like 5103 but u=40  $ NE Rod
5204 like 5104 but u=40  $ SE Rod
5205 like 5105 but u=40  $ S Rod
5207 10 4.8413E-05  -6003 (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) imp:n=1 u=40 fill=31
c
c ------------ Stack 1 - NE, SE, S ------------
5213 like 5103 but u=41  $ NE Rod
5214 like 5104 but u=41  $ SE Rod
5215 like 5105 but u=41  $ S Rod
5217 10 4.8413E-05  -6003 (7023:7027) (7024:7027)
                          (7025:7027) imp:n=1 u=41 fill=31
c
c ------------ Stack 1 - SE, S ------------
5224 like 5104 but u=42  $ SE Rod
5225 like 5105 but u=42  $ S Rod
5227 10 4.8413E-05  -6003 (7024:7027) (7025:7027) imp:n=1 u=42 fill=31
c
c ------------ Stack 1 - S, SW ------------
5235 like 5105 but u=43  $ S Rod
5236 like 5106 but u=43  $ SW Rod
5237 10 4.8413E-05  -6003 (7025:7027) (7026:7027) imp:n=1 u=43 fill=31
c
c ------------ Stack 1 - NW, S, SW ------------
5241 like 5101 but u=44  $ NW Rod
5245 like 5105 but u=44  $ S Rod
5246 like 5106 but u=44  $ SW Rod
5247 10 4.8413E-05  -6003 (7021:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=44 fill=31
c
c ------------ Stack 1 - NW, N, S, SW ------------
5251 like 5101 but u=45  $ NW Rod
5252 like 5102 but u=45  $ N Rod
5255 like 5105 but u=45  $ S Rod
5256 like 5106 but u=45  $ SW Rod
5257 10 4.8413E-05  -6003 (7021:7027) (7022:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=45 fill=31
c
c ------------ Stack 1 - NW, N, SW ------------
5261 like 5101 but u=46  $ NW Rod
5262 like 5102 but u=46  $ N Rod
5266 like 5106 but u=46  $ SW Rod
5267 10 4.8413E-05  -6003 (7021:7027) (7022:7027)
                          (7026:7027) imp:n=1 u=46 fill=31
c
c ------------ Stack 1 - NW, N ------------
5271 like 5101 but u=47  $ NW Rod
5272 like 5102 but u=47  $ N Rod
5277 10 4.8413E-05  -6003 (7021:7027) (7022:7027) imp:n=1 u=47 fill=31
c
c ------------ Stack 1 - N, NE ------------
5282 like 5102 but u=48  $ N Rod
5283 like 5103 but u=48  $ NE Rod
5287 10 4.8413E-05  -6003 (7022:7027) (7023:7027) imp:n=1 u=48 fill=31
c
c ------------ Stack 1 - N, NE, SE ------------
5292 like 5102 but u=49  $ N Rod
5293 like 5103 but u=49  $ NE Rod
5294 like 5104 but u=49  $ SE Rod
5297 10 4.8413E-05  -6003 (7022:7027) (7023:7027) (7024:7027)
                          imp:n=1 u=49 fill=31
c
c ------------ Stack 2 - N, NE, SE, S ------------
5302 like 5112 but u=50  $ N Rod
5303 like 5113 but u=50  $ NE Rod
5304 like 5114 but u=50  $ SE Rod
5305 like 5115 but u=50  $ S Rod
5307 10 4.8413E-05  -6003 (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) imp:n=1 u=50 fill=32
c
c ------------ Stack 2 - NE, SE, S, SW ------------
5313 like 5113 but u=51  $ NE Rod
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5314 like 5114 but u=51  $ SE Rod
5315 like 5115 but u=51  $ S Rod
5316 like 5116 but u=51  $ SW Rod
5317 10 4.8413E-05  -6003 (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=51 fill=32
c
c ------------ Stack 2 - NW, SE, S, SW ------------
5321 like 5111 but u=52  $ NW Rod
5324 like 5114 but u=52  $ SE Rod
5325 like 5115 but u=52  $ S Rod
5326 like 5116 but u=52  $ SW Rod
5327 10 4.8413E-05  -6003 (7021:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=52 fill=32
c
c ------------ Stack 2 - NW, N, S, SW ------------
5331 like 5111 but u=53  $ NW Rod
5332 like 5112 but u=53  $ N Rod
5335 like 5115 but u=53  $ S Rod
5336 like 5116 but u=53  $ SW Rod
5337 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7025:7027) (7026:7027)
                          imp:n=1 u=53 fill=32
c
c ------------ Stack 2 - NW, N, NE, SW ------------
5341 like 5111 but u=54  $ NW Rod
5342 like 5112 but u=54  $ N Rod
5343 like 5113 but u=54  $ NE Rod
5346 like 5116 but u=54  $ SW Rod
5347 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027)
                          (7026:7027) imp:n=1 u=54 fill=32
c
c ------------ Stack 2 - NW, N, NE, SE ------------
5351 like 5111 but u=55  $ NW Rod
5352 like 5112 but u=55  $ N Rod
5353 like 5113 but u=55  $ NE Rod
5354 like 5114 but u=55  $ SE Rod
5357 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          imp:n=1 u=55 fill=32
c
c ------------ Stack 3 - NE, SE ------------
5403 like 5123 but u=60  $ NE Rod
5404 like 5124 but u=60  $ SE Rod
5407 10 4.8413E-05  -6003 (7023:7027) (7024:7027) imp:n=1 u=60 fill=33
c
c ------------ Stack 3 - NE, SE, S ------------
5413 like 5123 but u=61  $ NE Rod
5414 like 5124 but u=61  $ SE Rod
5415 like 5125 but u=61  $ S Rod
5417 10 4.8413E-05  -6003 (7023:7027) (7024:7027)
                          (7025:7027) imp:n=1 u=61 fill=33
c
c ------------ Stack 3 - NE, SE, S, SW ------------
5423 like 5123 but u=62  $ NE Rod
5424 like 5124 but u=62  $ SE Rod
5425 like 5125 but u=62  $ S Rod
5426 like 5126 but u=62  $ SW Rod
5427 10 4.8413E-05  -6003 (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=62 fill=33
c
c ------------ Stack 3 - SE, S, SW ------------
5434 like 5124 but u=63  $ SE Rod
5435 like 5125 but u=63  $ S Rod
5436 like 5126 but u=63  $ SW Rod
5437 10 4.8413E-05  -6003 (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=63 fill=33
c
c ------------ Stack 3 - S, SW ------------
5445 like 5125 but u=64  $ S Rod
5446 like 5126 but u=64  $ SW Rod
5447 10 4.8413E-05  -6003 (7025:7027) (7026:7027) imp:n=1 u=64 fill=33
c
c ------------ Stack 3 - NW, SW ------------
5451 like 5121 but u=65  $ NW Rod
5456 like 5126 but u=65  $ SW Rod
5457 10 4.8413E-05  -6003 (7021:7027) (7026:7027) imp:n=1 u=65 fill=33
c
c ------------ Stack 3 - NW, N, SW ------------
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5461 like 5121 but u=66  $ NW Rod
5462 like 5122 but u=66  $ N Rod
5466 like 5126 but u=66  $ SW Rod
5467 10 4.8413E-05  -6003 (7021:7027) (7022:7027)
                          (7026:7027) imp:n=1 u=66 fill=33
c
c ------------ Stack 3 - NW, N, NE, SW ------------
5471 like 5121 but u=67  $ NW Rod
5472 like 5122 but u=67  $ N Rod
5473 like 5123 but u=67  $ NE Rod
5476 like 5126 but u=67  $ SW Rod
5477 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027)
                          (7026:7027) imp:n=1 u=67 fill=33
c
c ------------ Stack 3 - NW, N, NE ------------
5481 like 5121 but u=68  $ NW Rod
5482 like 5122 but u=68  $ N Rod
5483 like 5123 but u=68  $ NE Rod
5487 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027)
                          imp:n=1 u=68 fill=33
c
c ------------ Stack 3 - N, NE ------------
5492 like 5122 but u=69  $ N Rod
5493 like 5123 but u=69  $ NE Rod
5497 10 4.8413E-05  -6003 (7022:7027) (7023:7027) imp:n=1 u=69 fill=33
c
c ------------ Stack 4 - NE, SE ------------
5503 like 5133 but u=70  $ NE Rod
5504 like 5134 but u=70  $ SE Rod
5507 10 4.8413E-05  -6003 (7023:7027) (7024:7027) imp:n=1 u=70 fill=34
c
c ------------ Stack 4 - SE, S ------------
5514 like 5134 but u=71  $ SE Rod
5515 like 5135 but u=71  $ S Rod
5517 10 4.8413E-05  -6003 (7024:7027) (7025:7027) imp:n=1 u=71 fill=34
c
c ------------ Stack 4 - SE, S, SW ------------
5524 like 5134 but u=72  $ SE Rod
5525 like 5135 but u=72  $ S Rod
5526 like 5136 but u=72  $ SW Rod
5527 10 4.8413E-05  -6003 (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=72 fill=34
c
c ------------ Stack 4 - NW, SE, S, SW ------------
5531 like 5131 but u=73  $ NW Rod
5534 like 5134 but u=73  $ SE Rod
5535 like 5135 but u=73  $ S Rod
5536 like 5136 but u=73  $ SW Rod
5537 10 4.8413E-05  -6003 (7021:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=73 fill=34
c
c ------------ Stack 4 - NW, S, SW ------------
5541 like 5131 but u=74  $ NW Rod
5545 like 5135 but u=74  $ S Rod
5546 like 5136 but u=74  $ SW Rod
5547 10 4.8413E-05  -6003 (7021:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=74 fill=34
c
c ------------ Stack 4 - NW, SW ------------
5551 like 5131 but u=75  $ NW Rod
5556 like 5136 but u=75  $ SW Rod
5557 10 4.8413E-05  -6003 (7021:7027) (7026:7027) imp:n=1 u=75 fill=34
c
c ------------ Stack 4 - NW, N ------------
5561 like 5131 but u=76  $ NW Rod
5562 like 5132 but u=76  $ N Rod
5567 10 4.8413E-05  -6003 (7021:7027) (7022:7027) imp:n=1 u=76 fill=34
c
c ------------ Stack 4 - NW, N, NE ------------
5571 like 5131 but u=77  $ NW Rod
5572 like 5132 but u=77  $ N Rod
5573 like 5133 but u=77  $ NE Rod
5577 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027)
                          imp:n=1 u=77 fill=34
c
c ------------ Stack 4 - NW, N, NE, SE ------------
```

```
5581 like 5131 but u=78  $ NW Rod
5582 like 5132 but u=78  $ N Rod
5583 like 5133 but u=78  $ NE Rod
5584 like 5134 but u=78  $ SE Rod
5587 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          imp:n=1 u=78 fill=34
c
c ------------ Stack 4 - N, NE, SE ------------
5592 like 5132 but u=79  $ N Rod
5593 like 5133 but u=79  $ NE Rod
5594 like 5134 but u=79  $ SE Rod
5597 10 4.8413E-05  -6003 (7022:7027) (7023:7027) (7024:7027)
                          imp:n=1 u=79 fill=34
c
c ------ Core Arrangement ----------------------------------------------------
c --------- Core 9 Lattice Description ---------
7001 10 4.8413E-05  -6002 imp:n=1 u=100 lat=2 fill=-12:12 -12:12 0:0
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 29 30 29 30 29 30 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 27 28 27 28 27 28 27 28 27 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 29 30 29 30 29 30 29 30 29 30 29 30 26 26
      26 26 26 26 26 26 26 26 26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26
      26 26 26 26 26 26 26 26 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 26
      26 26 26 26 26 26 26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26
      26 26 26 26 26 26 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 26
      26 26 26 26 26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26
      26 26 26 26 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 26
      26 26 26 26 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 26 26
      26 26 26 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 26 26
c
      26 26 26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26 26 26
c
      26 26 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 26 26 26
      26 26 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 26 26 26 26
      26 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 26 26 26 26
      26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26 26 26 26 26
      26 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 26 26 26 26 26 26
      26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26 26 26 26 26 26 26
      26 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 26 26 26 26 26 26 26 26
      26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26 26 26 26 26 26 26 26 26
      26 26 30 29 30 29 30 29 30 29 30 29 30 29 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 27 28 27 28 27 28 27 28 27 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 30 29 30 29 30 29 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
c
c --------- Core 10 Lattice Description ---------
7002 10 4.8413E-05  -6002 imp:n=1 u=101 lat=2 fill=-12:12 -12:12 0:0
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 69 77 68 77 68 76 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 48 55 35 36 35 36 35 54 47 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 69 78 37 38 37 38 37 38 37 38 67 76 26 26
      26 26 26 26 26 26 26 26 26 48 55 35 36 35 36 35 36 35 36 35 36 35 54 47 26
      26 26 26 26 26 26 26 26 79 37 38 37 38 37 38 37 38 37 38 37 38 37 38 66 26
      26 26 26 26 26 26 26 49 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 46 26
      26 26 26 26 26 26 79 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 66 26
      26 26 26 26 26 49 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 46 26
      26 26 26 26 70 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 65 26
      26 26 26 26 50 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 53 26 26
      26 26 26 60 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 75 26 26
c
      26 26 26 40 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 45 26 26 26
c
      26 26 70 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 65 26 26 26
      26 26 50 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 53 26 26 26 26
      26 60 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 75 26 26 26 26
      26 41 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 44 26 26 26 26 26
      26 61 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 74 26 26 26 26 26 26
      26 41 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 44 26 26 26 26 26 26 26
      26 61 38 37 38 37 38 37 38 37 38 37 38 37 38 37 74 26 26 26 26 26 26 26 26
      26 42 51 35 36 35 36 35 36 35 36 35 36 35 52 43 26 26 26 26 26 26 26 26 26
      26 26 71 62 38 37 38 37 38 37 38 37 73 64 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 42 51 35 36 35 36 35 52 43 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 71 63 72 63 72 64 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
c
c --------- Pebble-Filled Core Cavity ---------
```

```
7101 10 4.8413E-05  -7001 -7002 -7003 imp:n=1 fill=100 (0 0 75) $ Core 9
c 7101 10 4.8413E-05  -7001 -7002 -7003 imp:n=1 fill=101 (0 0 75) $ Core 10
c
c --- Model Boundary -----------------------------------------------------------
9999  0  -31:1202:34 imp:n=0  $ The Great Void
c

c Surface Cards ****************************************************************
c --- Radial Reflector ---------------------------------------------------------
c ------ Graphite Annulus ------
31    pz     0.0   $ Bottom of Reflector
32    pz   330.4   $ Top of Reflector
33    cz    62.83398  $ Inside Radial Equivalent-Area Cavity Surface
34    cz   163.76986  $ Outside Radial Equivalent-Area Surface
c
c ------ Safety/Shutdown Rod Holes ------
1101  c/z  -38.45  56.57  2.25  $ Rod 1
1102  c/z   32.74 -60.05  2.25  $ Rod 2
1103  c/z   57.17  37.55  2.25  $ Rod 3
1104  c/z  -53.23 -42.95  2.25  $ Rod 4
1105  c/z   67.19 -12.82  2.25  $ Rod 5
1106  c/z  -66.98  13.87  2.25  $ Rod 6
1107  c/z   19.31  65.62  2.25  $ Rod 7
1108  c/z  -13.87 -66.98  2.25  $ Rod 8
c
c ------ Withdrawable Control Rod Holes ------
503   c/z  -83.70  34.67  1.3715  $ Position 3 Hole
519   c/z   34.67  83.70  1.3715  $ Position 19 Hole
535   c/z   83.70 -34.67  1.3715  $ Position 35 Hole
551   c/z  -34.67 -83.70  1.3715  $ Position 51 Hole
1003  c/z  -83.70  34.67  1.325  $ Position 3 Plug
1019  c/z   34.67  83.70  1.325  $ Position 19 Plug
1035  c/z   83.70 -34.67  1.325  $ Position 35 Plug
1051  c/z  -34.67 -83.70  1.325  $ Position 51 Plug
c
c ------ Autorod Hole ------
1113  c/z   17.36 -87.29  2.75
c
c --- Upper Axial Reflector ----------------------------------------------------
c ------ Central Cylinder ------
1201  pz   267.3     $ Bottom of Graphite
1202  pz   345.3     $ Top of Graphite
1203  cz     1.3715  $ Central Coolant Channel
1204  cz    19.7     $ Outer Radius
c
c ------ Graphite Annulus ------
1211  cz    20.93    $ Inner Radius
1212  cz    61.7     $ Outer Radius
c
c ------ Air Gaps ------
1221  cz    19.8     $ Outside of Central Cylinder
1222  cz    20.5     $ Inside of Annulus
1223  cz    61.8     $ Outside of Annulus
c
c ------ Coolant Channels ------
c --------- Ring 1 ---------
1301  c/z  -29.86   2.94  1.3715  $ Position 1
1302  c/z  -28.71   8.71  1.3715  $ Position 2
1303  c/z  -26.46  14.14  1.3715  $ Position 3
1304  c/z  -23.19  19.03  1.3715  $ Position 4
1305  c/z  -19.03  23.19  1.3715  $ Position 5
1306  c/z  -14.14  26.46  1.3715  $ Position 6
1307  c/z   -8.71  28.71  1.3715  $ Position 7
1308  c/z   -2.94  29.86  1.3715  $ Position 8
1309  c/z    2.94  29.86  1.3715  $ Position 9
1310  c/z    8.71  28.71  1.3715  $ Position 10
1311  c/z   14.14  26.46  1.3715  $ Position 11
1312  c/z   19.03  23.19  1.3715  $ Position 12
1313  c/z   23.19  19.03  1.3715  $ Position 13
1314  c/z   26.46  14.14  1.3715  $ Position 14
1315  c/z   28.71   8.71  1.3715  $ Position 15
1316  c/z   29.86   2.94  1.3715  $ Position 16
1317  c/z   29.86  -2.94  1.3715  $ Position 17
1318  c/z   28.71  -8.71  1.3715  $ Position 18
1319  c/z   26.46 -14.14  1.3715  $ Position 19
1320  c/z   23.19 -19.03  1.3715  $ Position 20
```

```
1321  c/z   19.03 -23.19  1.3715  $ Position 21
1322  c/z   14.14 -26.46  1.3715  $ Position 22
1323  c/z    8.71 -28.71  1.3715  $ Position 23
1324  c/z    2.94 -29.86  1.3715  $ Position 24
1325  c/z   -2.94 -29.86  1.3715  $ Position 25
1326  c/z   -8.71 -28.71  1.3715  $ Position 26
1327  c/z  -14.14 -26.46  1.3715  $ Position 27
1328  c/z  -19.03 -23.19  1.3715  $ Position 28
1329  c/z  -23.19 -19.03  1.3715  $ Position 29
1330  c/z  -26.46 -14.14  1.3715  $ Position 30
1331  c/z  -28.71  -8.71  1.3715  $ Position 31
1332  c/z  -29.86  -2.94  1.3715  $ Position 32
c
1333  cz    32.75  $ Ring Divider for Modeling Simplification
c
c --------- Ring 2 ---------
1401  c/z  -34.82   6.93  1.3715  $ Position 1
1402  c/z  -32.80  13.59  1.3715  $ Position 2
1403  c/z  -29.52  19.72  1.3715  $ Position 3
1404  c/z  -25.10  25.10  1.3715  $ Position 4
1405  c/z  -19.72  29.52  1.3715  $ Position 5
1406  c/z  -13.59  32.80  1.3715  $ Position 6
1407  c/z   -6.93  34.82  1.3715  $ Position 7
1408  c/z    0.00  35.50  1.3715  $ Position 8
1409  c/z    6.93  34.82  1.3715  $ Position 9
1410  c/z   13.59  32.80  1.3715  $ Position 10
1411  c/z   19.72  29.52  1.3715  $ Position 11
1412  c/z   25.10  25.10  1.3715  $ Position 12
1413  c/z   29.52  19.72  1.3715  $ Position 13
1414  c/z   32.80  13.59  1.3715  $ Position 14
1415  c/z   34.82   6.93  1.3715  $ Position 15
1416  c/z   35.50   0.00  1.3715  $ Position 16
1417  c/z   34.82  -6.93  1.3715  $ Position 17
1418  c/z   32.80 -13.59  1.3715  $ Position 18
1419  c/z   29.52 -19.72  1.3715  $ Position 19
1420  c/z   25.10 -25.10  1.3715  $ Position 20
1421  c/z   19.72 -29.52  1.3715  $ Position 21
1422  c/z   13.59 -32.80  1.3715  $ Position 22
1423  c/z    6.93 -34.82  1.3715  $ Position 23
1424  c/z    0.00 -35.50  1.3715  $ Position 24
1425  c/z   -6.93 -34.82  1.3715  $ Position 25
1426  c/z  -13.59 -32.80  1.3715  $ Position 26
1427  c/z  -19.72 -29.52  1.3715  $ Position 27
1428  c/z  -25.10 -25.10  1.3715  $ Position 28
1429  c/z  -29.52 -19.72  1.3715  $ Position 29
1430  c/z  -32.80 -13.59  1.3715  $ Position 30
1431  c/z  -34.82  -6.93  1.3715  $ Position 31
1432  c/z  -35.50   0.00  1.3715  $ Position 32
c
1433  cz    38.25  $ Ring Divider for Modeling Simplification
c
c --------- Ring 3 ---------
1501  c/z  -39.23  11.90  1.3715  $ Position 1
1502  c/z  -36.16  19.33  1.3715  $ Position 2
1503  c/z  -31.69  26.01  1.3715  $ Position 3
1504  c/z  -26.01  31.69  1.3715  $ Position 4
1505  c/z  -19.33  36.16  1.3715  $ Position 5
1506  c/z  -11.90  39.23  1.3715  $ Position 6
1507  c/z   -4.02  40.80  1.3715  $ Position 7
1508  c/z    4.02  40.80  1.3715  $ Position 8
1509  c/z   11.90  39.23  1.3715  $ Position 9
1510  c/z   19.33  36.16  1.3715  $ Position 10
1511  c/z   26.01  31.69  1.3715  $ Position 11
1512  c/z   31.69  26.01  1.3715  $ Position 12
1513  c/z   36.16  19.33  1.3715  $ Position 13
1514  c/z   39.23  11.90  1.3715  $ Position 14
1515  c/z   40.80   4.02  1.3715  $ Position 15
1516  c/z   40.80  -4.02  1.3715  $ Position 16
1517  c/z   39.23 -11.90  1.3715  $ Position 17
1518  c/z   36.16 -19.33  1.3715  $ Position 18
1519  c/z   31.69 -26.01  1.3715  $ Position 19
1520  c/z   26.01 -31.69  1.3715  $ Position 20
1521  c/z   19.33 -36.16  1.3715  $ Position 21
1522  c/z   11.90 -39.23  1.3715  $ Position 22
1523  c/z    4.02 -40.80  1.3715  $ Position 23
1524  c/z   -4.02 -40.80  1.3715  $ Position 24
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1525  c/z  -11.90 -39.23  1.3715  $ Position 25
1526  c/z  -19.33 -36.16  1.3715  $ Position 26
1527  c/z  -26.01 -31.69  1.3715  $ Position 27
1528  c/z  -31.69 -26.01  1.3715  $ Position 28
1529  c/z  -36.16 -19.33  1.3715  $ Position 29
1530  c/z  -39.23 -11.90  1.3715  $ Position 30
1531  c/z  -40.80  -4.02  1.3715  $ Position 31
1532  c/z  -40.80   4.02  1.3715  $ Position 32
c
1533  cz    43.625  $ Ring Divider for Modeling Simplification
c
c --------- Ring 4 ---------
1601  c/z  -42.73  17.70  1.3715  $ Position 1
1602  c/z  -38.46  25.70  1.3715  $ Position 2
1603  c/z  -32.70  32.70  1.3715  $ Position 3
1604  c/z  -25.70  38.46  1.3715  $ Position 4
1605  c/z  -17.70  42.73  1.3715  $ Position 5
1606  c/z   -9.02  45.36  1.3715  $ Position 6
1607  c/z    0.00  46.25  1.3715  $ Position 7
1608  c/z    9.02  45.36  1.3715  $ Position 8
1609  c/z   17.70  42.73  1.3715  $ Position 9
1610  c/z   25.70  38.46  1.3715  $ Position 10
1611  c/z   32.70  32.70  1.3715  $ Position 11
1612  c/z   38.46  25.70  1.3715  $ Position 12
1613  c/z   42.73  17.70  1.3715  $ Position 13
1614  c/z   45.36   9.02  1.3715  $ Position 14
1615  c/z   46.25   0.00  1.3715  $ Position 15
1616  c/z   45.36  -9.02  1.3715  $ Position 16
1617  c/z   42.73 -17.70  1.3715  $ Position 17
1618  c/z   38.46 -25.70  1.3715  $ Position 18
1619  c/z   32.70 -32.70  1.3715  $ Position 19
1620  c/z   25.70 -38.46  1.3715  $ Position 20
1621  c/z   17.70 -42.73  1.3715  $ Position 21
1622  c/z    9.02 -45.36  1.3715  $ Position 22
1623  c/z    0.00 -46.25  1.3715  $ Position 23
1624  c/z   -9.02 -45.36  1.3715  $ Position 24
1625  c/z  -17.70 -42.73  1.3715  $ Position 25
1626  c/z  -25.70 -38.46  1.3715  $ Position 26
1627  c/z  -32.70 -32.70  1.3715  $ Position 27
1628  c/z  -38.46 -25.70  1.3715  $ Position 28
1629  c/z  -42.73 -17.70  1.3715  $ Position 29
1630  c/z  -45.36  -9.02  1.3715  $ Position 30
1631  c/z  -46.25   0.00  1.3715  $ Position 31
1632  c/z  -45.36   9.02  1.3715  $ Position 32
c
1633  cz    48.875  $ Ring Divider for Modeling Simplification
c
c --------- Ring 5 ---------
1701  c/z  -45.42  24.28  1.3715  $ Position 1
1702  c/z  -39.81  32.67  1.3715  $ Position 2
1703  c/z  -32.67  39.81  1.3715  $ Position 3
1704  c/z  -24.28  45.42  1.3715  $ Position 4
1705  c/z  -14.95  49.28  1.3715  $ Position 5
1706  c/z   -5.05  51.25  1.3715  $ Position 6
1707  c/z    5.05  51.25  1.3715  $ Position 7
1708  c/z   14.95  49.28  1.3715  $ Position 8
1709  c/z   24.28  45.42  1.3715  $ Position 9
1710  c/z   32.67  39.81  1.3715  $ Position 10
1711  c/z   39.81  32.67  1.3715  $ Position 11
1712  c/z   45.42  24.28  1.3715  $ Position 12
1713  c/z   49.28  14.95  1.3715  $ Position 13
1714  c/z   51.25   5.05  1.3715  $ Position 14
1715  c/z   51.25  -5.05  1.3715  $ Position 15
1716  c/z   49.28 -14.95  1.3715  $ Position 16
1717  c/z   45.42 -24.28  1.3715  $ Position 17
1718  c/z   39.81 -32.67  1.3715  $ Position 18
1719  c/z   32.67 -39.81  1.3715  $ Position 19
1720  c/z   24.28 -45.42  1.3715  $ Position 20
1721  c/z   14.95 -49.28  1.3715  $ Position 21
1722  c/z    5.05 -51.25  1.3715  $ Position 22
1723  c/z   -5.05 -51.25  1.3715  $ Position 23
1724  c/z  -14.95 -49.28  1.3715  $ Position 24
1725  c/z  -24.28 -45.42  1.3715  $ Position 25
1726  c/z  -32.67 -39.81  1.3715  $ Position 26
1727  c/z  -39.81 -32.67  1.3715  $ Position 27
1728  c/z  -45.42 -24.28  1.3715  $ Position 28
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1729  c/z  -49.28 -14.95  1.3715  $ Position 29
1730  c/z  -51.25  -5.05  1.3715  $ Position 30
1731  c/z  -51.25   5.05  1.3715  $ Position 31
1732  c/z  -49.28  14.95  1.3715  $ Position 32
c
c ------ Aluminum Tank ------
1801  pz   266.3             $ Bottom of Aluminum
1802  cz    62.1             $ Outer Radius
c
c --- Lower Axial Reflector ---------------------------------------------------
c ------ Inner Cylinder ------
1811  pz    78.0   $ Inside Bottom of Cavity
1812  cz    24.75  $ Outer Radius
c
c ------ Graphite Plug ------
1821  pz    25.0
1823  cz     6.0
c
c ------ Graphite Annulus ------
1831  cz    25.05171  $ Inner Radial Equivalent-Area Surface
1832  cz    62.71754  $ Outer Radial Equivalent-Area Surface
c
c ------ Coolant Channels ------
c --------- Ring 1 ---------
1901  c/z  -29.86   2.94  1.371  $ Position 1
1902  c/z  -28.71   8.71  1.371  $ Position 2
1903  c/z  -26.46  14.14  1.371  $ Position 3
1904  c/z  -23.19  19.03  1.371  $ Position 4
1905  c/z  -19.03  23.19  1.371  $ Position 5
1906  c/z  -14.14  26.46  1.371  $ Position 6
1907  c/z   -8.71  28.71  1.371  $ Position 7
1908  c/z   -2.94  29.86  1.371  $ Position 8
1909  c/z    2.94  29.86  1.371  $ Position 9
1910  c/z    8.71  28.71  1.371  $ Position 10
1911  c/z   14.14  26.46  1.371  $ Position 11
1912  c/z   19.03  23.19  1.371  $ Position 12
1913  c/z   23.19  19.03  1.371  $ Position 13
1914  c/z   26.46  14.14  1.371  $ Position 14
1915  c/z   28.71   8.71  1.371  $ Position 15
1916  c/z   29.86   2.94  1.371  $ Position 16
1917  c/z   29.86  -2.94  1.371  $ Position 17
1918  c/z   28.71  -8.71  1.371  $ Position 18
1919  c/z   26.46 -14.14  1.371  $ Position 19
1920  c/z   23.19 -19.03  1.371  $ Position 20
1921  c/z   19.03 -23.19  1.371  $ Position 21
1922  c/z   14.14 -26.46  1.371  $ Position 22
1923  c/z    8.71 -28.71  1.371  $ Position 23
1924  c/z    2.94 -29.86  1.371  $ Position 24
1925  c/z   -2.94 -29.86  1.371  $ Position 25
1926  c/z   -8.71 -28.71  1.371  $ Position 26
1927  c/z  -14.14 -26.46  1.371  $ Position 27
1928  c/z  -19.03 -23.19  1.371  $ Position 28
1929  c/z  -23.19 -19.03  1.371  $ Position 29
1930  c/z  -26.46 -14.14  1.371  $ Position 30
1931  c/z  -28.71 -8.71   1.371  $ Position 31
1932  c/z  -29.86 -2.94   1.371  $ Position 32
c
c --------- Ring 2 ---------
2001  c/z  -34.82   6.93  1.371  $ Position 1
2002  c/z  -32.80  13.59  1.371  $ Position 2
2003  c/z  -29.52  19.72  1.371  $ Position 3
2004  c/z  -25.10  25.10  1.371  $ Position 4
2005  c/z  -19.72  29.52  1.371  $ Position 5
2006  c/z  -13.59  32.80  1.371  $ Position 6
2007  c/z   -6.93  34.82  1.371  $ Position 7
2008  c/z    0.00  35.50  1.371  $ Position 8
2009  c/z    6.93  34.82  1.371  $ Position 9
2010  c/z   13.59  32.80  1.371  $ Position 10
2011  c/z   19.72  29.52  1.371  $ Position 11
2012  c/z   25.10  25.10  1.371  $ Position 12
2013  c/z   29.52  19.72  1.371  $ Position 13
2014  c/z   32.80  13.59  1.371  $ Position 14
2015  c/z   34.82   6.93  1.371  $ Position 15
2016  c/z   35.50   0.00  1.371  $ Position 16
2017  c/z   34.82  -6.93  1.371  $ Position 17
2018  c/z   32.80 -13.59  1.371  $ Position 18
```

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2019  c/z   29.52 -19.72  1.371  $ Position 19
2020  c/z   25.10 -25.10  1.371  $ Position 20
2021  c/z   19.72 -29.52  1.371  $ Position 21
2022  c/z   13.59 -32.80  1.371  $ Position 22
2023  c/z    6.93 -34.82  1.371  $ Position 23
2024  c/z    0.00 -35.50  1.371  $ Position 24
2025  c/z   -6.93 -34.82  1.371  $ Position 25
2026  c/z  -13.59 -32.80  1.371  $ Position 26
2027  c/z  -19.72 -29.52  1.371  $ Position 27
2028  c/z  -25.10 -25.10  1.371  $ Position 28
2029  c/z  -29.52 -19.72  1.371  $ Position 29
2030  c/z  -32.80 -13.59  1.371  $ Position 30
2031  c/z  -34.82  -6.93  1.371  $ Position 31
2032  c/z  -35.50   0.00  1.371  $ Position 32
c
c --------- Ring 3 ---------
2101  c/z  -39.23  11.90  1.371  $ Position 1
2102  c/z  -36.16  19.33  1.371  $ Position 2
2103  c/z  -31.69  26.01  1.371  $ Position 3
2104  c/z  -26.01  31.69  1.371  $ Position 4
2105  c/z  -19.33  36.16  1.371  $ Position 5
2106  c/z  -11.90  39.23  1.371  $ Position 6
2107  c/z   -4.02  40.80  1.371  $ Position 7
2108  c/z    4.02  40.80  1.371  $ Position 8
2109  c/z   11.90  39.23  1.371  $ Position 9
2110  c/z   19.33  36.16  1.371  $ Position 10
2111  c/z   26.01  31.69  1.371  $ Position 11
2112  c/z   31.69  26.01  1.371  $ Position 12
2113  c/z   36.16  19.33  1.371  $ Position 13
2114  c/z   39.23  11.90  1.371  $ Position 14
2115  c/z   40.80   4.02  1.371  $ Position 15
2116  c/z   40.80  -4.02  1.371  $ Position 16
2117  c/z   39.23 -11.90  1.371  $ Position 17
2118  c/z   36.16 -19.33  1.371  $ Position 18
2119  c/z   31.69 -26.01  1.371  $ Position 19
2120  c/z   26.01 -31.69  1.371  $ Position 20
2121  c/z   19.33 -36.16  1.371  $ Position 21
2122  c/z   11.90 -39.23  1.371  $ Position 22
2123  c/z    4.02 -40.80  1.371  $ Position 23
2124  c/z   -4.02 -40.80  1.371  $ Position 24
2125  c/z  -11.90 -39.23  1.371  $ Position 25
2126  c/z  -19.33 -36.16  1.371  $ Position 26
2127  c/z  -26.01 -31.69  1.371  $ Position 27
2128  c/z  -31.69 -26.01  1.371  $ Position 28
2129  c/z  -36.16 -19.33  1.371  $ Position 29
2130  c/z  -39.23 -11.90  1.371  $ Position 30
2131  c/z  -40.80  -4.02  1.371  $ Position 31
2132  c/z  -40.80   4.02  1.371  $ Position 32
c
c --------- Ring 4 ---------
2201  c/z  -42.73  17.70  1.371  $ Position 1
2202  c/z  -38.46  25.70  1.371  $ Position 2
2203  c/z  -32.70  32.70  1.371  $ Position 3
2204  c/z  -25.70  38.46  1.371  $ Position 4
2205  c/z  -17.70  42.73  1.371  $ Position 5
2206  c/z   -9.02  45.36  1.371  $ Position 6
2207  c/z    0.00  46.25  1.371  $ Position 7
2208  c/z    9.02  45.36  1.371  $ Position 8
2209  c/z   17.70  42.73  1.371  $ Position 9
2210  c/z   25.70  38.46  1.371  $ Position 10
2211  c/z   32.70  32.70  1.371  $ Position 11
2212  c/z   38.46  25.70  1.371  $ Position 12
2213  c/z   42.73  17.70  1.371  $ Position 13
2214  c/z   45.36   9.02  1.371  $ Position 14
2215  c/z   46.25   0.00  1.371  $ Position 15
2216  c/z   45.36  -9.02  1.371  $ Position 16
2217  c/z   42.73 -17.70  1.371  $ Position 17
2218  c/z   38.46 -25.70  1.371  $ Position 18
2219  c/z   32.70 -32.70  1.371  $ Position 19
2220  c/z   25.70 -38.46  1.371  $ Position 20
2221  c/z   17.70 -42.73  1.371  $ Position 21
2222  c/z    9.02 -45.36  1.371  $ Position 22
2223  c/z    0.00 -46.25  1.371  $ Position 23
2224  c/z   -9.02 -45.36  1.371  $ Position 24
2225  c/z  -17.70 -42.73  1.371  $ Position 25
2226  c/z  -25.70 -38.46  1.371  $ Position 26
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2227  c/z  -32.70 -32.70  1.371  $ Position 27
2228  c/z  -38.46 -25.70  1.371  $ Position 28
2229  c/z  -42.73 -17.70  1.371  $ Position 29
2230  c/z  -45.36  -9.02  1.371  $ Position 30
2231  c/z  -46.25   0.00  1.371  $ Position 31
2232  c/z  -45.36   9.02  1.371  $ Position 32
c
c --------- Ring 5 ---------
2301  c/z  -45.42  24.28  1.371  $ Position 1
2302  c/z  -39.81  32.67  1.371  $ Position 2
2303  c/z  -32.67  39.81  1.371  $ Position 3
2304  c/z  -24.28  45.42  1.371  $ Position 4
2305  c/z  -14.95  49.28  1.371  $ Position 5
2306  c/z   -5.05  51.25  1.371  $ Position 6
2307  c/z    5.05  51.25  1.371  $ Position 7
2308  c/z   14.95  49.28  1.371  $ Position 8
2309  c/z   24.28  45.42  1.371  $ Position 9
2310  c/z   32.67  39.81  1.371  $ Position 10
2311  c/z   39.81  32.67  1.371  $ Position 11
2312  c/z   45.42  24.28  1.371  $ Position 12
2313  c/z   49.28  14.95  1.371  $ Position 13
2314  c/z   51.25   5.05  1.371  $ Position 14
2315  c/z   51.25  -5.05  1.371  $ Position 15
2316  c/z   49.28 -14.95  1.371  $ Position 16
2317  c/z   45.42 -24.28  1.371  $ Position 17
2318  c/z   39.81 -32.67  1.371  $ Position 18
2319  c/z   32.67 -39.81  1.371  $ Position 19
2320  c/z   24.28 -45.42  1.371  $ Position 20
2321  c/z   14.95 -49.28  1.371  $ Position 21
2322  c/z    5.05 -51.25  1.371  $ Position 22
2323  c/z   -5.05 -51.25  1.371  $ Position 23
2324  c/z  -14.95 -49.28  1.371  $ Position 24
2325  c/z  -24.28 -45.42  1.371  $ Position 25
2326  c/z  -32.67 -39.81  1.371  $ Position 26
2327  c/z  -39.81 -32.67  1.371  $ Position 27
2328  c/z  -45.42 -24.28  1.371  $ Position 28
2329  c/z  -49.28 -14.95  1.371  $ Position 29
2330  c/z  -51.25  -5.05  1.371  $ Position 30
2331  c/z  -51.25   5.05  1.371  $ Position 31
2332  c/z  -49.28  14.95  1.371  $ Position 32
c
c ------ Graphite Plugs ------
c --------- Ring 1 ---------
2401  c/z  -29.86   2.94  1.325  $ Position 1
2402  c/z  -28.71   8.71  1.325  $ Position 2
2403  c/z  -26.46  14.14  1.325  $ Position 3
2404  c/z  -23.19  19.03  1.325  $ Position 4
2405  c/z  -19.03  23.19  1.325  $ Position 5
2406  c/z  -14.14  26.46  1.325  $ Position 6
2407  c/z   -8.71  28.71  1.325  $ Position 7
2408  c/z   -2.94  29.86  1.325  $ Position 8
2409  c/z    2.94  29.86  1.325  $ Position 9
2410  c/z    8.71  28.71  1.325  $ Position 10
2411  c/z   14.14  26.46  1.325  $ Position 11
2412  c/z   19.03  23.19  1.325  $ Position 12
2413  c/z   23.19  19.03  1.325  $ Position 13
2414  c/z   26.46  14.14  1.325  $ Position 14
2415  c/z   28.71   8.71  1.325  $ Position 15
2416  c/z   29.86   2.94  1.325  $ Position 16
2417  c/z   29.86  -2.94  1.325  $ Position 17
2418  c/z   28.71  -8.71  1.325  $ Position 18
2419  c/z   26.46 -14.14  1.325  $ Position 19
2420  c/z   23.19 -19.03  1.325  $ Position 20
2421  c/z   19.03 -23.19  1.325  $ Position 21
2422  c/z   14.14 -26.46  1.325  $ Position 22
2423  c/z    8.71 -28.71  1.325  $ Position 23
2424  c/z    2.94 -29.86  1.325  $ Position 24
2425  c/z   -2.94 -29.86  1.325  $ Position 25
2426  c/z   -8.71 -28.71  1.325  $ Position 26
2427  c/z  -14.14 -26.46  1.325  $ Position 27
2428  c/z  -19.03 -23.19  1.325  $ Position 28
2429  c/z  -23.19 -19.03  1.325  $ Position 29
2430  c/z  -26.46 -14.14  1.325  $ Position 30
2431  c/z  -28.71  -8.71  1.325  $ Position 31
2432  c/z  -29.86  -2.94  1.325  $ Position 32
c
```

```
c --------- Ring 2 ---------
2501  c/z  -34.82   6.93  1.325  $ Position 1
2502  c/z  -32.80  13.59  1.325  $ Position 2
2503  c/z  -29.52  19.72  1.325  $ Position 3
2504  c/z  -25.10  25.10  1.325  $ Position 4
2505  c/z  -19.72  29.52  1.325  $ Position 5
2506  c/z  -13.59  32.80  1.325  $ Position 6
2507  c/z   -6.93  34.82  1.325  $ Position 7
2508  c/z    0.00  35.50  1.325  $ Position 8
2509  c/z    6.93  34.82  1.325  $ Position 9
2510  c/z   13.59  32.80  1.325  $ Position 10
2511  c/z   19.72  29.52  1.325  $ Position 11
2512  c/z   25.10  25.10  1.325  $ Position 12
2513  c/z   29.52  19.72  1.325  $ Position 13
2514  c/z   32.80  13.59  1.325  $ Position 14
2515  c/z   34.82   6.93  1.325  $ Position 15
2516  c/z   35.50   0.00  1.325  $ Position 16
2517  c/z   34.82  -6.93  1.325  $ Position 17
2518  c/z   32.80 -13.59  1.325  $ Position 18
2519  c/z   29.52 -19.72  1.325  $ Position 19
2520  c/z   25.10 -25.10  1.325  $ Position 20
2521  c/z   19.72 -29.52  1.325  $ Position 21
2522  c/z   13.59 -32.80  1.325  $ Position 22
2523  c/z    6.93 -34.82  1.325  $ Position 23
2524  c/z    0.00 -35.50  1.325  $ Position 24
2525  c/z   -6.93 -34.82  1.325  $ Position 25
2526  c/z  -13.59 -32.80  1.325  $ Position 26
2527  c/z  -19.72 -29.52  1.325  $ Position 27
2528  c/z  -25.10 -25.10  1.325  $ Position 28
2529  c/z  -29.52 -19.72  1.325  $ Position 29
2530  c/z  -32.80 -13.59  1.325  $ Position 30
2531  c/z  -34.82  -6.93  1.325  $ Position 31
2532  c/z  -35.50   0.00  1.325  $ Position 32
c
c --------- Ring 3 ---------
2601  c/z  -39.23  11.90  1.325  $ Position 1
2602  c/z  -36.16  19.33  1.325  $ Position 2
2603  c/z  -31.69  26.01  1.325  $ Position 3
2604  c/z  -26.01  31.69  1.325  $ Position 4
2605  c/z  -19.33  36.16  1.325  $ Position 5
2606  c/z  -11.90  39.23  1.325  $ Position 6
2607  c/z   -4.02  40.80  1.325  $ Position 7
2608  c/z    4.02  40.80  1.325  $ Position 8
2609  c/z   11.90  39.23  1.325  $ Position 9
2610  c/z   19.33  36.16  1.325  $ Position 10
2611  c/z   26.01  31.69  1.325  $ Position 11
2612  c/z   31.69  26.01  1.325  $ Position 12
2613  c/z   36.16  19.33  1.325  $ Position 13
2614  c/z   39.23  11.90  1.325  $ Position 14
2615  c/z   40.80   4.02  1.325  $ Position 15
2616  c/z   40.80  -4.02  1.325  $ Position 16
2617  c/z   39.23 -11.90  1.325  $ Position 17
2618  c/z   36.16 -19.33  1.325  $ Position 18
2619  c/z   31.69 -26.01  1.325  $ Position 19
2620  c/z   26.01 -31.69  1.325  $ Position 20
2621  c/z   19.33 -36.16  1.325  $ Position 21
2622  c/z   11.90 -39.23  1.325  $ Position 22
2623  c/z    4.02 -40.80  1.325  $ Position 23
2624  c/z   -4.02 -40.80  1.325  $ Position 24
2625  c/z  -11.90 -39.23  1.325  $ Position 25
2626  c/z  -19.33 -36.16  1.325  $ Position 26
2627  c/z  -26.01 -31.69  1.325  $ Position 27
2628  c/z  -31.69 -26.01  1.325  $ Position 28
2629  c/z  -36.16 -19.33  1.325  $ Position 29
2630  c/z  -39.23 -11.90  1.325  $ Position 30
2631  c/z  -40.80  -4.02  1.325  $ Position 31
2632  c/z  -40.80   4.02  1.325  $ Position 32
c
c --------- Ring 4 ---------
2701  c/z  -42.73  17.70  1.325  $ Position 1
2702  c/z  -38.46  25.70  1.325  $ Position 2
2703  c/z  -32.70  32.70  1.325  $ Position 3
2704  c/z  -25.70  38.46  1.325  $ Position 4
2705  c/z  -17.70  42.73  1.325  $ Position 5
2706  c/z   -9.02  45.36  1.325  $ Position 6
2707  c/z    0.00  46.25  1.325  $ Position 7
```

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2708  c/z    9.02  45.36  1.325  $ Position 8
2709  c/z   17.70  42.73  1.325  $ Position 9
2710  c/z   25.70  38.46  1.325  $ Position 10
2711  c/z   32.70  32.70  1.325  $ Position 11
2712  c/z   38.46  25.70  1.325  $ Position 12
2713  c/z   42.73  17.70  1.325  $ Position 13
2714  c/z   45.36   9.02  1.325  $ Position 14
2715  c/z   46.25   0.00  1.325  $ Position 15
2716  c/z   45.36  -9.02  1.325  $ Position 16
2717  c/z   42.73 -17.70  1.325  $ Position 17
2718  c/z   38.46 -25.70  1.325  $ Position 18
2719  c/z   32.70 -32.70  1.325  $ Position 19
2720  c/z   25.70 -38.46  1.325  $ Position 20
2721  c/z   17.70 -42.73  1.325  $ Position 21
2722  c/z    9.02 -45.36  1.325  $ Position 22
2723  c/z    0.00 -46.25  1.325  $ Position 23
2724  c/z   -9.02 -45.36  1.325  $ Position 24
2725  c/z  -17.70 -42.73  1.325  $ Position 25
2726  c/z  -25.70 -38.46  1.325  $ Position 26
2727  c/z  -32.70 -32.70  1.325  $ Position 27
2728  c/z  -38.46 -25.70  1.325  $ Position 28
2729  c/z  -42.73 -17.70  1.325  $ Position 29
2730  c/z  -45.36  -9.02  1.325  $ Position 30
2731  c/z  -46.25   0.00  1.325  $ Position 31
2732  c/z  -45.36   9.02  1.325  $ Position 32
c
c --------- Ring 5 ---------
2801  c/z  -45.42  24.28  1.325  $ Position 1
2802  c/z  -39.81  32.67  1.325  $ Position 2
2803  c/z  -32.67  39.81  1.325  $ Position 3
2804  c/z  -24.28  45.42  1.325  $ Position 4
2805  c/z  -14.95  49.28  1.325  $ Position 5
2806  c/z   -5.05  51.25  1.325  $ Position 6
2807  c/z    5.05  51.25  1.325  $ Position 7
2808  c/z   14.95  49.28  1.325  $ Position 8
2809  c/z   24.28  45.42  1.325  $ Position 9
2810  c/z   32.67  39.81  1.325  $ Position 10
2811  c/z   39.81  32.67  1.325  $ Position 11
2812  c/z   45.42  24.28  1.325  $ Position 12
2813  c/z   49.28  14.95  1.325  $ Position 13
2814  c/z   51.25   5.05  1.325  $ Position 14
2815  c/z   51.25  -5.05  1.325  $ Position 15
2816  c/z   49.28 -14.95  1.325  $ Position 16
2817  c/z   45.42 -24.28  1.325  $ Position 17
2818  c/z   39.81 -32.67  1.325  $ Position 18
2819  c/z   32.67 -39.81  1.325  $ Position 19
2820  c/z   24.28 -45.42  1.325  $ Position 20
2821  c/z   14.95 -49.28  1.325  $ Position 21
2822  c/z    5.05 -51.25  1.325  $ Position 22
2823  c/z   -5.05 -51.25  1.325  $ Position 23
2824  c/z  -14.95 -49.28  1.325  $ Position 24
2825  c/z  -24.28 -45.42  1.325  $ Position 25
2826  c/z  -32.67 -39.81  1.325  $ Position 26
2827  c/z  -39.81 -32.67  1.325  $ Position 27
2828  c/z  -45.42 -24.28  1.325  $ Position 28
2829  c/z  -49.28 -14.95  1.325  $ Position 29
2830  c/z  -51.25  -5.05  1.325  $ Position 30
2831  c/z  -51.25   5.05  1.325  $ Position 31
2832  c/z  -49.28  14.95  1.325  $ Position 32
c
c --- Control Rods ---------------------------------------------------------------
c ------ Autorod ------
3031  px   -0.15  $ Coreside Copper Plate Face
3032  px    0.15  $ Farside Copper Plate Face
3033  pz  222.5   $ Top Surface of Plate
3034  p    -0.15 0 -7.5  0.15 0 -7.5  -0.15 -1.95 222.5 $ Angled Plate Surface
3035  p    -0.15 0 -7.5  0.15 0 -7.5  -0.15 1.95 222.5  $ Angled Plate Surface
3036  cz    2     $ Aluminum Tube Inner Radius
3037  cz    2.2   $ Aluminum Tube Outer Radius
c
c ------ Withdrawable Control Rods ------
3081  pz   75.5    $ Bottom of Bottom End Plug
3082  pz   77.0    $ Bottom of Tubes
3083  pz   78.0    $ Top of Bottom End Plug
3084  pz  287.0    $ Bottom of Top End Plug
3085  pz  292.0    $ Top of Tubes
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```
3086  pz  294.5    $ Top of Top End Plug
3087  cz    0.475  $ Inner Tube Inner Radius
3088  cz    0.675  $ Inner Tube Outer Radius
3089  cz    0.7    $ Outer Tube Inner Radius
3090  cz    1.1    $ Outer Tube Outer Radius
c
3091  pz   73.0    $ Top of Graphite Plug
3092  cz    1.325  $ Radius of Graphite Plug
c
3095  so 1000      $ A Very Large Sphere
c
c --- Pebbles -----------------------------------------------------------------
c ------ TRISO ------
3111  so  0.0251   $ UO2 Kernel
3112  so  0.03425  $ Buffer Coating
3113  so  0.03824  $ IPyC Coating
3114  so  0.04177  $ SiC Coating
3115  so  0.04577  $ OPyC Coating
c
c ------ TRISO Lattice ------
3121  rpp -0.0879 0.0879 -0.0879 0.0879 -0.0879 0.0879
c
c ------ Fuel Pebble ------
3131  s   0 0 0  2.35  $ Fuel Zone
3132  s   0 0 0  3.00  $ Pebble Shell (Unfueled Zone)
c
c ------ Moderator Pebble ------
c    *Same dimension as Fuel Pebble Shell
c
c ------ CHPOP Pebble Lattice ------
6001  hex  0 0 -3.00  0 0 6.00  3.00 0 0
c
c ------ CHPOP Pebble Stack Lattice ------
6002  hex  0 0 -9.00  0 0 264.  3.00 0 0  $ Core Lattice
6003  hex  0 0 -9.00  0 0 264.  3.4  0 0  $ Adding Poly Rods
c
c --- Graphite Fillers --------------------------------------------------------
c ------ Axial Modifiers ------
7001  hex  0 0 78  0 0 172.9  60.15 0 0
7002  hex  0 0 78  0 0 172.9  0 60.3 0
7003  pz  250.9  $ Top Surface
c
c --- Water Ingress Simulation ------------------------------------------------
c ------ Polyethylene Rods ------
c    *Polyethylene Rods Not Used in Configuration 9
c
7021  c/z  -3.0  1.732050808 0.325  $ NW Rod
7022  c/z   0.0  3.464101615 0.325  $ N Rod
7023  c/z   3.0  1.732050808 0.325  $ NE Rod
7024  c/z   3.0 -1.732050808 0.325  $ SE Rod
7025  c/z   0.0 -3.464101615 0.325  $ S Rod
7026  c/z  -3.0 -1.732050808 0.325  $ SW Rod
7027  pz    148                     $ Top of Rods
c
c ------ Very Large Sphere ------
9999  so  1000  $ For Modeling Purposes Only
c

c Data Cards ******************************************************************
c
c *** Material Cards **********************************************************
c ------ Graphite (Radial Reflector) ------
m3     5010.70c 2.3253E-08   5011.70c 9.3597E-08   6000.70c 8.7858E-02
c         Total 8.7858E-02
mt3   grph.10t
c
c ------ Graphite (Lower Axial Reflector Cylinder) ------
m4     5010.70c 2.3223E-08   5011.70c 9.3476E-08   6000.70c 8.7744E-02
c         Total 8.7744E-02
mt4   grph.10t
c
c ------ Graphite (Lower Axial Reflector Annulus) ------
m5     5010.70c 2.3356E-08   5011.70c 9.4011E-08   6000.70c 8.8245E-02
c         Total 8.8245E-02
mt5   grph.10t
c
```

```
c ------ Graphite (Upper Axial Reflector Cylinder) ------
m6     5010.70c 2.3235E-08   5011.70c 9.3524E-08   6000.70c 8.7789E-02
c         Total 8.7789E-02
mt6   grph.10t
c
c ------ Graphite (Upper Axial Reflector Annulus) ------
m7     5010.70c 2.3368E-08   5011.70c 9.4059E-08   6000.70c 8.8291E-02
c         Total 8.8291E-02
mt7   grph.10t
c
c ------ Peraluman-300 (Upper Axial Reflector) ------
m9     5010.70c 1.4688E-07   5011.70c 5.9119E-07  12024.70c 8.0390E-04
      12025.70c 1.0177E-04  12026.70c 1.1205E-04  13027.70c 5.7575E-02
      14028.70c 2.0962E-04  14029.70c 1.0644E-05  14030.70c 7.0168E-06
      25055.70c 7.2621E-05  26054.70c 5.0109E-06  26056.70c 7.8660E-05
      26057.70c 1.8166E-06  26058.70c 2.4176E-07  29063.70c 8.6855E-06
      29065.70c 3.8712E-06  30000.70c 2.4398E-05  31069.70c 6.8789E-07
      31071.70c 4.5653E-07  48106.70c 8.8729E-10  48108.70c 6.3175E-10
      48110.70c 8.8658E-09  48111.70c 9.0858E-09  48112.70c 1.7128E-08
      48113.70c 8.6741E-09  48114.70c 2.0393E-08  48116.70c 5.3166E-09
c         Total 5.9018E-02
mt9   al27.12t fe56.12t
c
c ------ Air ------
m10    1001.70c 5.7091E-07   1002.70c 6.5663E-11   7014.70c 3.7225E-05
       7015.70c 1.3749E-07   8016.70c 1.0322E-05   8017.70c 3.9239E-09
      18036.70c 7.5192E-10  18038.70c 1.4122E-10  18040.70c 2.2256E-07
       6000.70c 9.1319E-09
c         Total 4.8492E-05
mt10  lwtr.10t hwtr.10t
c
c --- Control Rods -------------------------------------------------------------
c ------ Copper Autorod (i.e. C110) ------
m13   29063.70c 5.8245E-02  29065.70c 2.5961E-02   8016.70c 6.6898E-05
       8017.70c 2.5431E-08  47107.70c 1.9296E-06  47109.70c 1.7927E-06
      16032.70c 1.1887E-05  16033.70c 9.5169E-08  16034.70c 5.3720E-07
      16036.70c 2.5044E-09  28058.70c 4.6572E-06  28060.70c 1.7939E-06
      28061.70c 7.7981E-08  28062.70c 2.4864E-07  28064.70c 6.3321E-08
      26054.70c 4.2025E-07  26056.70c 6.5971E-06  26057.70c 1.5236E-07
      26058.70c 2.0276E-08
c         Total 8.4303E-02
mt13  fe56.12t
c
c ------ Pure Aluminum Autorod Guide Tube (i.e. AL 1100) ------
m113  14028.70c 2.6697E-04  14029.70c 1.3556E-05  14030.70c 8.9364E-06
      26054.70c 8.5091E-06  26056.70c 1.3357E-04  26057.70c 3.0848E-06
      26058.70c 4.1053E-07  29063.70c 2.2123E-05  29065.70c 9.8607E-06
      25055.70c 7.3991E-06  30000.70c 1.2429E-05  27059.70c 6.8975E-05
      28058.70c 4.7148E-05  28060.70c 1.8161E-05  28061.70c 7.8946E-07
      28062.70c 2.5171E-06  28064.70c 6.4104E-07  50112.70c 3.3215E-07
      50114.70c 2.2600E-07  50115.70c 1.1642E-07  50116.70c 4.9788E-06
      50117.70c 2.6298E-06  50118.70c 8.2935E-06  50119.70c 2.9414E-06
      50120.70c 1.1156E-05  50122.70c 1.5854E-06  50124.70c 1.9826E-06
      13027.70c 5.9087E-02
c         Total 5.9746E-02
mt113  al27.12t fe56.12t
c
c ------ St1.4301 Stainless Steel (Inner Tube) ------
m17    6000.70c 1.3864E-04  14028.70c 7.8115E-04  14029.70c 3.9665E-05
      14030.70c 2.6147E-05  25055.70c 8.6597E-04  24050.70c 7.3547E-04
      24052.70c 1.4183E-02  24053.70c 1.6082E-03  24054.70c 4.0032E-04
      28058.70c 5.6560E-03  28060.70c 2.1787E-03  28061.70c 9.4706E-05
      28062.70c 3.0196E-04  28064.70c 7.6901E-05  26054.70c 3.4714E-03
      26056.70c 5.4493E-02  26057.70c 1.2585E-03  26058.70c 1.6748E-04
c         Total 8.6477E-02
mt17  fe56.12t
c
c ------ St1.4541 Stainless Steel (Outer Tube) ------
m18     6000.70c 1.9805E-04  14028.70c 7.8115E-04  14029.70c 3.9665E-05
       14030.70c 2.6147E-05  25055.70c 8.6597E-04  24050.70c 7.1559E-04
       24052.70c 1.3800E-02  24053.70c 1.5648E-03  24054.70c 3.8950E-04
       28058.70c 5.6560E-03  28060.70c 2.1787E-03  28061.70c 9.4706E-05
       28062.70c 3.0196E-04  28064.70c 7.6901E-05  22046.70c 4.0998E-06
       22047.70c 3.6973E-06  22048.70c 3.6635E-05  22049.70c 2.6885E-06
       22050.70c 2.5742E-06  26054.70c 3.4930E-03  26056.70c 5.4833E-02
       26057.70c 1.2663E-03  26058.70c 1.6853E-04
```

```
c         Total 8.6499E-02
mt18  fe56.12t
c
c --- Pebbles ----------------------------------------------------------------
c ------ UO2 ------
m19    8016.70c 4.8593E-02   8017.70c 1.8472E-05  92234.70c 3.3079E-05
      92235.70c 4.1172E-03  92236.70c 2.0499E-05  92238.70c 2.0135E-02
c         Total 7.2917E-02
mt19  o2/u.10t u/o2.10t
c
c ------ Buffer ------
m20    6000.70c 5.2640E-02
c         Total 5.2640E-02
mt20  grph.10t
c
c ------ IPyC ------
m21    6000.70c 9.5254E-02
c         Total 9.5254E-02
mt21  grph.10t
c
c ------ SiC ------
m22   14028.70c 4.4321E-02  14029.70c 2.2505E-03  14030.70c 1.4836E-03
       6000.70c 4.8055E-02
c         Total 9.6110E-02
mt22  grph.10t
c
c ------ OPyC ------
m23    6000.70c 9.4752E-02
c         Total 9.4772E-02
mt23  grph.10t
c
c ------ Fuel Pebbles ------
m24    6000.70c 8.6842E-02  47107.70c 5.0131E-10  47109.70c 4.6575E-10
       5010.70c 1.9393E-09   5011.70c 7.8061E-09  20040.70c 2.3415E-07
      20042.70c 1.5628E-09  20043.70c 3.2608E-10  20044.70c 5.0385E-09
      20046.70c 9.6616E-12  20048.70c 4.5168E-10  48106.70c 5.9739E-12
      48108.70c 4.2534E-12  48110.70c 5.9691E-11  48111.70c 6.1172E-11
      48112.70c 1.1532E-10  48113.70c 5.8401E-11  48114.70c 1.3730E-10
      48116.70c 3.5795E-11  17035.70c 3.3446E-08  17037.70c 1.0690E-08
      27059.70c 1.1505E-09  24050.70c 1.5778E-09  24052.70c 3.0426E-08
      24053.70c 3.4500E-09  24054.70c 8.5879E-10  66156.70c 1.9258E-14
      66158.70c 3.2097E-14  66160.70c 7.5107E-13  66161.70c 6.0695E-12
      66162.70c 8.1879E-12  66163.70c 7.9921E-12  66164.70c 9.0449E-12
      63151.70c 1.6409E-11  63153.70c 1.7913E-11  26054.70c 3.2208E-09
      26056.70c 5.0560E-08  26057.70c 1.1677E-09  26058.70c 1.5539E-10
      64152.70c 6.6337E-14  64154.70c 7.2307E-13  64155.70c 4.9089E-12
      64156.70c 6.7896E-12  64157.70c 5.1909E-12  64158.70c 8.2391E-12
      64160.70c 7.2506E-12   3006.70c 5.7034E-09   3007.70c 6.9441E-08
      25055.70c 8.1647E-09  28058.70c 6.0496E-09  28060.70c 2.3303E-09
      28061.70c 1.0130E-10  28062.70c 3.2298E-10  28064.70c 8.2253E-11
      16032.70c 1.6986E-10  16033.70c 1.3599E-12  16034.70c 7.6760E-12
      16036.70c 3.5786E-14  22046.70c 8.9355E-10  22047.70c 8.0582E-10
      22048.70c 7.9846E-09  22049.70c 5.8596E-10  22050.70c 5.6104E-10
      23000.70c 4.4334E-09   1001.70c 1.1579E-05   1002.70c 1.3318E-09
       8016.70c 5.7882E-06   8017.70c 2.2003E-09
c         Total 8.6859E-02
mt24  grph.10t lwtr.10t hwtr.10t
c
c ------ Moderator Pebbles ------
m26    6000.70c 8.4434E-02   5010.70c 1.4193E-08   5011.70c 5.7130E-08
      20040.70c 3.1657E-06  20042.70c 2.1129E-08  20043.70c 4.4086E-09
      20044.70c 6.8121E-08  20046.70c 1.3062E-10  20048.70c 6.1067E-09
      48106.70c 3.3846E-11  48108.70c 2.4098E-11  48110.70c 3.3819E-10
      48111.70c 3.4658E-10  48112.70c 6.5336E-10  48113.70c 3.3088E-10
      48114.70c 7.7791E-10  48116.70c 2.0280E-10  17035.70c 4.0423E-07
      17037.70c 1.2920E-07  66156.70c 2.4350E-13  66158.70c 4.0583E-13
      66160.70c 9.4964E-12  66161.70c 7.6742E-11  66162.70c 1.0353E-10
      66163.70c 1.0105E-10  66164.70c 1.1436E-10  63151.70c 4.1496E-10
      63153.70c 4.5297E-10  26054.70c 6.2652E-09  26056.70c 9.8350E-08
      26057.70c 2.2713E-09  26058.70c 3.0227E-10  64152.70c 5.1616E-13
      64154.70c 5.6261E-12  64155.70c 3.8196E-11  64156.70c 5.2829E-11
      64157.70c 4.0389E-11  64158.70c 6.4107E-11  64160.70c 5.6416E-11
       3006.70c 9.7630E-09   3007.70c 1.1887E-07  28058.70c 9.1788E-09
      28060.70c 3.5357E-09  28061.70c 1.5369E-10  28062.70c 4.9004E-10
      28064.70c 1.2480E-10  16032.70c 4.2052E-06  16033.70c 3.3666E-08
      16034.70c 1.9004E-07  16036.70c 8.8595E-10  14028.70c 1.1661E-06
```

```
      14029.70c 5.9212E-08  14030.70c 3.9033E-08  62144.70c 1.7815E-11
      62147.70c 8.6986E-11  62148.70c 6.5225E-11  62149.70c 8.0197E-11
      62150.70c 4.2826E-11  62152.70c 1.5523E-10  62154.70c 1.3202E-10
      22046.70c 1.7486E-08  22047.70c 1.5770E-08  22048.70c 1.5625E-07
      22049.70c 1.1467E-08  22050.70c 1.0979E-08  23000.70c 2.5891E-07
       1001.70c 1.1262E-05   1002.70c 1.2953E-09   8016.70c 5.6296E-06
       8017.70c 2.1401E-09
c         Total 8.4461E-02
mt26  grph.10t lwtr.10t hwtr.10t
c
c --- Graphite Fillers -------------------------------------------------------
c ------ Short Plugs/Rods (Axial Reflectors) ------
m29    5010.70c 2.3356E-08   5011.70c 9.4011E-08   6000.70c 8.8245E-02
c         Total 8.8245E-02
mt29  grph.10t
c
c ------ Source Plug (Lower Axial Reflector) ------
m30    5010.70c 2.3356E-08   5011.70c 9.4011E-08   6000.70c 8.8245E-02
c         Total 8.8245E-02
mt30  grph.10t
c
c ------ Lattice Spacers ------
m32    5010.70c 2.3130E-08   5011.70c 9.3099E-08   6000.70c 8.7390E-02
c         Total 8.7390E-02
mt32  grph.10t
c
c --- Water Ingress Simulation -------------------------------------------------
c ------ Polyethylene Rods ------
m34    5010.70c 5.2797E-09   5011.70c 2.1252E-08   1001.70c 8.2835E-02
       1002.70c 9.5271E-06   6000.70c 4.0810E-02
c         Total 1.2365E-01
mt34  poly.10t
c
c *** Control Cards ************************************************************
mode  n
kcode 100000 1 150 1650
ksrc  0 0  80  40 40  80  40 -40  80  -40 -40  80  -40 40  80
      0 0  90  40 40  90  40 -40  90  -40 -40  90  -40 40  90
      0 0 100  40 40 100  40 -40 100  -40 -40 100  -40 40 100
      0 0 110  40 40 110  40 -40 110  -40 -40 110  -40 40 110
      0 0 120  40 40 120  40 -40 120  -40 -40 120  -40 40 120
      0 0 130  40 40 130  40 -40 130  -40 -40 130  -40 40 130
      0 0 140  40 40 140  40 -40 140  -40 -40 140  -40 40 140
      0 0 150  40 40 150  40 -40 150  -40 -40 150  -40 40 150
      0 20  80  20 0  80  -20 0  80  0 -20  80
      0 20  90  20 0  90  -20 0  90  0 -20  90
      0 20 100  20 0 100  -20 0 100  0 -20 100
      0 20 110  20 0 110  -20 0 110  0 -20 110
      0 20 120  20 0 120  -20 0 120  0 -20 120
      0 20 130  20 0 130  -20 0 130  0 -20 130
      0 20 140  20 0 140  -20 0 140  0 -20 140
      0 20 150  20 0 150  -20 0 150  0 -20 150
      0 50  80  50 0  80  -50 0  80  0 -50  80
      0 50  90  50 0  90  -50 0  90  0 -50  90
      0 50 100  50 0 100  -50 0 100  0 -50 100
      0 50 110  50 0 110  -50 0 110  0 -50 110
      0 50 120  50 0 120  -50 0 120  0 -50 120
      0 50 130  50 0 130  -50 0 130  0 -50 130
      0 50 140  50 0 140  -50 0 140  0 -50 140
      0 50 150  50 0 150  -50 0 150  0 -50 150
c
kopts  blocksize=10 kinetics=yes precursor=yes
c print
c
```

A.2 Buckling and Extrapolation Length Configurations

Buckling and extrapolation length measurements were performed but have not yet been evaluated.

A.3 Spectral-Characteristics Configurations

Spectral characteristics measurements were performed but have not yet been evaluated.

A.4 Reactivity-Effects Configurations

The input decks for analysis of most reactivity effects measurements are those of the critical configurations (Appendix A.1 described in Section 3.1) with adjustments discussed in Section 3.4.2.

A sample model that includes the safety/shutdown rods for Core 9 is provided below.

MCNP5 Input Deck for Core 9 with Safety/Shutdown Rods:

```
HTR-PROTEUS :: Cores 9 & 10
c Pebble Bed Experimental Program
c Columnar Hexagonal Point-On-Point Packing with a 1:1 Moderator to Fuel Pebble Ratio
c
c John Darrell Bess - Idaho National Laboratory
c Last Updated: July 23, 2012
c
c Cell Cards ***************************************************************
c ------ Air Above Reflector ------
5    10 4.8492E-05  32 -1202 33 -34
          (1101 1102 1103 1104 1105 1106 1107 1108)
          (503 519 535 551 1113) imp:n=1
c
c ------ Radial Reflector ------
11   3 8.7858E-02  (33 -34 31 -32
          (1101 1102 1103 1104 1105 1106 1107 1108)
          (503 519 535 551 1113)):((7001:7002) 1811 -7003 -33) imp:n=1
c
c ------ Air Gap Above Core ------
22   10 4.8492E-05  7003 -1801 -33
          imp:n=1
c
c --- Control Rod Channels ----------------------------------------------------
c ------ Safety/Shutdown Rod Holes ------
1101 10 4.8492E-05  -1101 31 -1202 imp:n=1 fill=2 (-38.45  56.57 0)  $ Rod 1
1102 10 4.8492E-05  -1102 31 -1202 imp:n=1 fill=3 ( 32.74 -60.05 0)  $ Rod 2
1103 10 4.8492E-05  -1103 31 -1202 imp:n=1 fill=4 ( 57.17  37.55 0)  $ Rod 3
1104 10 4.8492E-05  -1104 31 -1202 imp:n=1 fill=5 (-53.23 -42.95 0)  $ Rod 4
1105 10 4.8492E-05  -1105 31 -1202 imp:n=1 fill=6 ( 67.19 -12.82 0)  $ Rod 5
1106 10 4.8492E-05  -1106 31 -1202 imp:n=1 fill=7 (-66.98  13.87 0)  $ Rod 6
1107 10 4.8492E-05  -1107 31 -1202 imp:n=1 fill=8 ( 19.31  65.62 0)  $ Rod 7
1108 10 4.8492E-05  -1108 31 -1202 imp:n=1 fill=9 (-13.87 -66.98 0)  $ Rod 8
c
c ------ Withdrawable Control Rod Holes ------
503  10 4.8492E-05   -503 1003 31 -3091 imp:n=1  $ Position 3 Hole
1003 29 8.8245E-02  -1003 31 -3091 imp:n=1  $ Position 3 Plug
3105 0    -503 3091 -1202 imp:n=1 fill=21 (-83.70  34.67 0)  $ Control Rod 4
519  10 4.8492E-05   -519 1019 31 -3091 imp:n=1  $ Position 19 Hole
1019 29 8.8245E-02  -1019 31 -3091 imp:n=1  $ Position 19 Plug
3102 0    -519 3091 -1202 imp:n=1 fill=18 ( 34.67  83.70 0)  $ Control Rod 1
535  10 4.8492E-05   -535 1035 31 -3091 imp:n=1  $ Position 35 Hole
1035 29 8.8245E-02  -1035 31 -3091 imp:n=1  $ Position 35 Plug
3103 0    -535 3091 -1202 imp:n=1 fill=19 ( 83.70 -34.67 0)  $ Control Rod 2
551  10 4.8492E-05   -551 1051 31 -3091 imp:n=1  $ Position 51 Hole
1051 29 8.8245E-02  -1051 31 -3091 imp:n=1  $ Position 51 Plug
3104 0    -551 3091 -1202 imp:n=1 fill=20 (-34.67 -83.70 0)  $ Control Rod 3
c
c ------ Autorod Hole ------
1113 0  -1113 31 -1202 imp:n=1 fill=11 (17.36 -87.29 0)
c
c --- Upper Axial Reflector ---------------------------------------------------
c ------ Central Cylinder ------
1201 10 4.8492E-05  1201 -1202 -1203 imp:n=1  $ Central Coolant Channel
1202 6 8.7789E-02  1201 -1202 1203 -1204 imp:n=1  $ Graphite
c
c ------ Graphite Annulus ------
1211 7 8.8291E-02  1201 -1202 1211 -1333
          (1301 1302 1303 1304 1305 1306 1307 1308 1309 1310 1311 1312 1313
           1314 1315 1316 1317 1318 1319 1320 1321 1322 1323 1324 1325 1326
           1327 1328 1329 1330 1331 1332)
           imp:n=1  $ Ring 1 Region
1212 7 8.8291E-02  1201 -1202 1333 -1433
          (1401 1402 1403 1404 1405 1406 1407 1408 1409 1410 1411 1412 1413
           1414 1415 1416 1417 1418 1419 1420 1421 1422 1423 1424 1425 1426
```

```
           1427 1428 1429 1430 1431 1432)
           imp:n=1  $ Ring 2 Region
1213 7 8.8291E-02  1201 -1202 1433 -1533
          (1501 1502 1503 1504 1505 1506 1507 1508 1509 1510 1511 1512 1513
           1514 1515 1516 1517 1518 1519 1520 1521 1522 1523 1524 1525 1526
           1527 1528 1529 1530 1531 1532)
           imp:n=1  $ Ring 3 Region
1214 7 8.8291E-02  1201 -1202 1533 -1633
          (1601 1602 1603 1604 1605 1606 1607 1608 1609 1610 1611 1612 1613
           1614 1615 1616 1617 1618 1619 1620 1621 1622 1623 1624 1625 1626
           1627 1628 1629 1630 1631 1632)
           imp:n=1  $ Ring 4 Region
1215 7 8.8291E-02  1201 -1202 1633 -1212
          (1701 1702 1703 1704 1705 1706 1707 1708 1709 1710 1711 1712 1713
           1714 1715 1716 1717 1718 1719 1720 1721 1722 1723 1724 1725 1726
           1727 1728 1729 1730 1731 1732)
           imp:n=1  $ Ring 5 Region
c
c ------ Coolant Channels ------
c --------- Ring 1 ---------
1301 10 4.8492E-05  2401 -1301 1201 -1202 imp:n=1  $ Position 1
1302 10 4.8492E-05  2402 -1302 1201 -1202 imp:n=1  $ Position 2
1303 10 4.8492E-05       -1303 1201 -1202 imp:n=1  $ Position 3
1304 10 4.8492E-05  2404 -1304 1201 -1202 imp:n=1  $ Position 4
1305 10 4.8492E-05  2405 -1305 1201 -1202 imp:n=1  $ Position 5
1306 10 4.8492E-05       -1306 1201 -1202 imp:n=1  $ Position 6
1307 10 4.8492E-05  2407 -1307 1201 -1202 imp:n=1  $ Position 7
1308 10 4.8492E-05  2408 -1308 1201 -1202 imp:n=1  $ Position 8
1309 10 4.8492E-05       -1309 1201 -1202 imp:n=1  $ Position 9
1310 10 4.8492E-05  2410 -1310 1201 -1202 imp:n=1  $ Position 10
1311 10 4.8492E-05  2411 -1311 1201 -1202 imp:n=1  $ Position 11
1312 10 4.8492E-05       -1312 1201 -1202 imp:n=1  $ Position 12
1313 10 4.8492E-05  2413 -1313 1201 -1202 imp:n=1  $ Position 13
1314 10 4.8492E-05  2414 -1314 1201 -1202 imp:n=1  $ Position 14
1315 10 4.8492E-05       -1315 1201 -1202 imp:n=1  $ Position 15
1316 10 4.8492E-05  2416 -1316 1201 -1202 imp:n=1  $ Position 16
1317 10 4.8492E-05  2417 -1317 1201 -1202 imp:n=1  $ Position 17
1318 10 4.8492E-05       -1318 1201 -1202 imp:n=1  $ Position 18
1319 10 4.8492E-05  2419 -1319 1201 -1202 imp:n=1  $ Position 19
1320 10 4.8492E-05  2420 -1320 1201 -1202 imp:n=1  $ Position 20
1321 10 4.8492E-05       -1321 1201 -1202 imp:n=1  $ Position 21
1322 10 4.8492E-05  2422 -1322 1201 -1202 imp:n=1  $ Position 22
1323 10 4.8492E-05  2423 -1323 1201 -1202 imp:n=1  $ Position 23
1324 10 4.8492E-05       -1324 1201 -1202 imp:n=1  $ Position 24
1325 10 4.8492E-05  2425 -1325 1201 -1202 imp:n=1  $ Position 25
1326 10 4.8492E-05  2426 -1326 1201 -1202 imp:n=1  $ Position 26
1327 10 4.8492E-05       -1327 1201 -1202 imp:n=1  $ Position 27
1328 10 4.8492E-05  2428 -1328 1201 -1202 imp:n=1  $ Position 28
1329 10 4.8492E-05       -1329 1201 -1202 imp:n=1  $ Position 29
1330 10 4.8492E-05  2430 -1330 1201 -1202 imp:n=1  $ Position 30
1331 10 4.8492E-05  2431 -1331 1201 -1202 imp:n=1  $ Position 31
1332 10 4.8492E-05       -1332 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 2 ---------
1401 10 4.8492E-05  2501 -1401 1201 -1202 imp:n=1  $ Position 1
1402 10 4.8492E-05  2502 -1402 1201 -1202 imp:n=1  $ Position 2
1403 10 4.8492E-05  2503 -1403 1201 -1202 imp:n=1  $ Position 3
1404 10 4.8492E-05  2504 -1404 1201 -1202 imp:n=1  $ Position 4
1405 10 4.8492E-05  2505 -1405 1201 -1202 imp:n=1  $ Position 5
1406 10 4.8492E-05  2506 -1406 1201 -1202 imp:n=1  $ Position 6
1407 10 4.8492E-05  2507 -1407 1201 -1202 imp:n=1  $ Position 7
1408 10 4.8492E-05  2508 -1408 1201 -1202 imp:n=1  $ Position 8
1409 10 4.8492E-05  2509 -1409 1201 -1202 imp:n=1  $ Position 9
1410 10 4.8492E-05  2510 -1410 1201 -1202 imp:n=1  $ Position 10
1411 10 4.8492E-05  2511 -1411 1201 -1202 imp:n=1  $ Position 11
1412 10 4.8492E-05  2512 -1412 1201 -1202 imp:n=1  $ Position 12
1413 10 4.8492E-05  2513 -1413 1201 -1202 imp:n=1  $ Position 13
1414 10 4.8492E-05  2514 -1414 1201 -1202 imp:n=1  $ Position 14
1415 10 4.8492E-05  2515 -1415 1201 -1202 imp:n=1  $ Position 15
1416 10 4.8492E-05  2516 -1416 1201 -1202 imp:n=1  $ Position 16
1417 10 4.8492E-05  2517 -1417 1201 -1202 imp:n=1  $ Position 17
1418 10 4.8492E-05  2518 -1418 1201 -1202 imp:n=1  $ Position 18
1419 10 4.8492E-05  2519 -1419 1201 -1202 imp:n=1  $ Position 19
1420 10 4.8492E-05  2520 -1420 1201 -1202 imp:n=1  $ Position 20
1421 10 4.8492E-05  2521 -1421 1201 -1202 imp:n=1  $ Position 21
1422 10 4.8492E-05  2522 -1422 1201 -1202 imp:n=1  $ Position 22
```

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1423 10 4.8492E-05  2523 -1423 1201 -1202 imp:n=1  $ Position 23
1424 10 4.8492E-05  2524 -1424 1201 -1202 imp:n=1  $ Position 24
1425 10 4.8492E-05  2525 -1425 1201 -1202 imp:n=1  $ Position 25
1426 10 4.8492E-05  2526 -1426 1201 -1202 imp:n=1  $ Position 26
1427 10 4.8492E-05  2527 -1427 1201 -1202 imp:n=1  $ Position 27
1428 10 4.8492E-05  2528 -1428 1201 -1202 imp:n=1  $ Position 28
1429 10 4.8492E-05  2529 -1429 1201 -1202 imp:n=1  $ Position 29
1430 10 4.8492E-05  2530 -1430 1201 -1202 imp:n=1  $ Position 30
1431 10 4.8492E-05  2531 -1431 1201 -1202 imp:n=1  $ Position 31
1432 10 4.8492E-05  2532 -1432 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 3 ---------
1501 10 4.8492E-05  2601 -1501 1201 -1202 imp:n=1  $ Position 1
1502 10 4.8492E-05       -1502 1201 -1202 imp:n=1  $ Position 2
1503 10 4.8492E-05  2603 -1503 1201 -1202 imp:n=1  $ Position 3
1504 10 4.8492E-05  2604 -1504 1201 -1202 imp:n=1  $ Position 4
1505 10 4.8492E-05       -1505 1201 -1202 imp:n=1  $ Position 5
1506 10 4.8492E-05  2606 -1506 1201 -1202 imp:n=1  $ Position 6
1507 10 4.8492E-05  2607 -1507 1201 -1202 imp:n=1  $ Position 7
1508 10 4.8492E-05       -1508 1201 -1202 imp:n=1  $ Position 8
1509 10 4.8492E-05  2609 -1509 1201 -1202 imp:n=1  $ Position 9
1510 10 4.8492E-05  2610 -1510 1201 -1202 imp:n=1  $ Position 10
1511 10 4.8492E-05       -1511 1201 -1202 imp:n=1  $ Position 11
1512 10 4.8492E-05  2612 -1512 1201 -1202 imp:n=1  $ Position 12
1513 10 4.8492E-05  2613 -1513 1201 -1202 imp:n=1  $ Position 13
1514 10 4.8492E-05       -1514 1201 -1202 imp:n=1  $ Position 14
1515 10 4.8492E-05  2615 -1515 1201 -1202 imp:n=1  $ Position 15
1516 10 4.8492E-05  2616 -1516 1201 -1202 imp:n=1  $ Position 16
1517 10 4.8492E-05       -1517 1201 -1202 imp:n=1  $ Position 17
1518 10 4.8492E-05  2618 -1518 1201 -1202 imp:n=1  $ Position 18
1519 10 4.8492E-05  2619 -1519 1201 -1202 imp:n=1  $ Position 19
1520 10 4.8492E-05       -1520 1201 -1202 imp:n=1  $ Position 20
1521 10 4.8492E-05  2621 -1521 1201 -1202 imp:n=1  $ Position 21
1522 10 4.8492E-05  2622 -1522 1201 -1202 imp:n=1  $ Position 22
1523 10 4.8492E-05       -1523 1201 -1202 imp:n=1  $ Position 23
1524 10 4.8492E-05  2624 -1524 1201 -1202 imp:n=1  $ Position 24
1525 10 4.8492E-05  2625 -1525 1201 -1202 imp:n=1  $ Position 25
1526 10 4.8492E-05       -1526 1201 -1202 imp:n=1  $ Position 26
1527 10 4.8492E-05  2627 -1527 1201 -1202 imp:n=1  $ Position 27
1528 10 4.8492E-05       -1528 1201 -1202 imp:n=1  $ Position 28
1529 10 4.8492E-05  2629 -1529 1201 -1202 imp:n=1  $ Position 29
1530 10 4.8492E-05  2630 -1530 1201 -1202 imp:n=1  $ Position 30
1531 10 4.8492E-05       -1531 1201 -1202 imp:n=1  $ Position 31
1532 10 4.8492E-05  2632 -1532 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 4 ---------
1601 10 4.8492E-05  2701 -1601 1201 -1202 imp:n=1  $ Position 1
1602 10 4.8492E-05  2702 -1602 1201 -1202 imp:n=1  $ Position 2
1603 10 4.8492E-05  2703 -1603 1201 -1202 imp:n=1  $ Position 3
1604 10 4.8492E-05  2704 -1604 1201 -1202 imp:n=1  $ Position 4
1605 10 4.8492E-05  2705 -1605 1201 -1202 imp:n=1  $ Position 5
1606 10 4.8492E-05  2706 -1606 1201 -1202 imp:n=1  $ Position 6
1607 10 4.8492E-05  2707 -1607 1201 -1202 imp:n=1  $ Position 7
1608 10 4.8492E-05  2708 -1608 1201 -1202 imp:n=1  $ Position 8
1609 10 4.8492E-05  2709 -1609 1201 -1202 imp:n=1  $ Position 9
1610 10 4.8492E-05  2710 -1610 1201 -1202 imp:n=1  $ Position 10
1611 10 4.8492E-05  2711 -1611 1201 -1202 imp:n=1  $ Position 11
1612 10 4.8492E-05  2712 -1612 1201 -1202 imp:n=1  $ Position 12
1613 10 4.8492E-05  2713 -1613 1201 -1202 imp:n=1  $ Position 13
1614 10 4.8492E-05  2714 -1614 1201 -1202 imp:n=1  $ Position 14
1615 10 4.8492E-05  2715 -1615 1201 -1202 imp:n=1  $ Position 15
1616 10 4.8492E-05  2716 -1616 1201 -1202 imp:n=1  $ Position 16
1617 10 4.8492E-05  2717 -1617 1201 -1202 imp:n=1  $ Position 17
1618 10 4.8492E-05  2718 -1618 1201 -1202 imp:n=1  $ Position 18
1619 10 4.8492E-05  2719 -1619 1201 -1202 imp:n=1  $ Position 19
1620 10 4.8492E-05  2720 -1620 1201 -1202 imp:n=1  $ Position 20
1621 10 4.8492E-05  2721 -1621 1201 -1202 imp:n=1  $ Position 21
1622 10 4.8492E-05  2722 -1622 1201 -1202 imp:n=1  $ Position 22
1623 10 4.8492E-05  2723 -1623 1201 -1202 imp:n=1  $ Position 23
1624 10 4.8492E-05  2724 -1624 1201 -1202 imp:n=1  $ Position 24
1625 10 4.8492E-05  2725 -1625 1201 -1202 imp:n=1  $ Position 25
1626 10 4.8492E-05  2726 -1626 1201 -1202 imp:n=1  $ Position 26
1627 10 4.8492E-05  2727 -1627 1201 -1202 imp:n=1  $ Position 27
1628 10 4.8492E-05  2728 -1628 1201 -1202 imp:n=1  $ Position 28
1629 10 4.8492E-05  2729 -1629 1201 -1202 imp:n=1  $ Position 29
1630 10 4.8492E-05  2730 -1630 1201 -1202 imp:n=1  $ Position 30
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1631 10 4.8492E-05  2731 -1631 1201 -1202 imp:n=1  $ Position 31
1632 10 4.8492E-05  2732 -1632 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 5 ---------
1701 10 4.8492E-05       -1701 1201 -1202 imp:n=1  $ Position 1
1702 10 4.8492E-05  2802 -1702 1201 -1202 imp:n=1  $ Position 2
1703 10 4.8492E-05  2803 -1703 1201 -1202 imp:n=1  $ Position 3
1704 10 4.8492E-05       -1704 1201 -1202 imp:n=1  $ Position 4
1705 10 4.8492E-05  2805 -1705 1201 -1202 imp:n=1  $ Position 5
1706 10 4.8492E-05  2806 -1706 1201 -1202 imp:n=1  $ Position 6
1707 10 4.8492E-05       -1707 1201 -1202 imp:n=1  $ Position 7
1708 10 4.8492E-05  2808 -1708 1201 -1202 imp:n=1  $ Position 8
1709 10 4.8492E-05  2809 -1709 1201 -1202 imp:n=1  $ Position 9
1710 10 4.8492E-05       -1710 1201 -1202 imp:n=1  $ Position 10
1711 10 4.8492E-05  2811 -1711 1201 -1202 imp:n=1  $ Position 11
1712 10 4.8492E-05  2812 -1712 1201 -1202 imp:n=1  $ Position 12
1713 10 4.8492E-05       -1713 1201 -1202 imp:n=1  $ Position 13
1714 10 4.8492E-05  2814 -1714 1201 -1202 imp:n=1  $ Position 14
1715 10 4.8492E-05  2815 -1715 1201 -1202 imp:n=1  $ Position 15
1716 10 4.8492E-05       -1716 1201 -1202 imp:n=1  $ Position 16
1717 10 4.8492E-05  2817 -1717 1201 -1202 imp:n=1  $ Position 17
1718 10 4.8492E-05  2818 -1718 1201 -1202 imp:n=1  $ Position 18
1719 10 4.8492E-05       -1719 1201 -1202 imp:n=1  $ Position 19
1720 10 4.8492E-05  2820 -1720 1201 -1202 imp:n=1  $ Position 20
1721 10 4.8492E-05  2821 -1721 1201 -1202 imp:n=1  $ Position 21
1722 10 4.8492E-05       -1722 1201 -1202 imp:n=1  $ Position 22
1723 10 4.8492E-05  2823 -1723 1201 -1202 imp:n=1  $ Position 23
1724 10 4.8492E-05  2824 -1724 1201 -1202 imp:n=1  $ Position 24
1725 10 4.8492E-05       -1725 1201 -1202 imp:n=1  $ Position 25
1726 10 4.8492E-05  2826 -1726 1201 -1202 imp:n=1  $ Position 26
1727 10 4.8492E-05       -1727 1201 -1202 imp:n=1  $ Position 27
1728 10 4.8492E-05  2828 -1728 1201 -1202 imp:n=1  $ Position 28
1729 10 4.8492E-05  2829 -1729 1201 -1202 imp:n=1  $ Position 29
1730 10 4.8492E-05       -1730 1201 -1202 imp:n=1  $ Position 30
1731 10 4.8492E-05  2831 -1731 1201 -1202 imp:n=1  $ Position 31
1732 10 4.8492E-05  2832 -1732 1201 -1202 imp:n=1  $ Position 32
c
c ------ Graphite Plugs ------
c --------- Ring 1 ---------
12401 29 8.8245E-02  -2401 1201 -1202 imp:n=1  $ Position 1
12402 29 8.8245E-02  -2402 1201 -1202 imp:n=1  $ Position 2
c    *Coolant Channel (No Plug)   $ Position 3
12404 29 8.8245E-02  -2404 1201 -1202 imp:n=1  $ Position 4
12405 29 8.8245E-02  -2405 1201 -1202 imp:n=1  $ Position 5
c    *Coolant Channel (No Plug)   $ Position 6
12407 29 8.8245E-02  -2407 1201 -1202 imp:n=1  $ Position 7
12408 29 8.8245E-02  -2408 1201 -1202 imp:n=1  $ Position 8
c    *Coolant Channel (No Plug)   $ Position 9
12410 29 8.8245E-02  -2410 1201 -1202 imp:n=1  $ Position 10
12411 29 8.8245E-02  -2411 1201 -1202 imp:n=1  $ Position 11
c    *Coolant Channel (No Plug)   $ Position 12
12413 29 8.8245E-02  -2413 1201 -1202 imp:n=1  $ Position 13
12414 29 8.8245E-02  -2414 1201 -1202 imp:n=1  $ Position 14
c    *Coolant Channel (No Plug)   $ Position 15
12416 29 8.8245E-02  -2416 1201 -1202 imp:n=1  $ Position 16
12417 29 8.8245E-02  -2417 1201 -1202 imp:n=1  $ Position 17
c    *Coolant Channel (No Plug)   $ Position 18
12419 29 8.8245E-02  -2419 1201 -1202 imp:n=1  $ Position 19
12420 29 8.8245E-02  -2420 1201 -1202 imp:n=1  $ Position 20
c    *Coolant Channel (No Plug)   $ Position 21
12422 29 8.8245E-02  -2422 1201 -1202 imp:n=1  $ Position 22
12423 29 8.8245E-02  -2423 1201 -1202 imp:n=1  $ Position 23
c    *Coolant Channel (No Plug)   $ Position 24
12425 29 8.8245E-02  -2425 1201 -1202 imp:n=1  $ Position 25
12426 29 8.8245E-02  -2426 1201 -1202 imp:n=1  $ Position 26
c    *Coolant Channel (No Plug)   $ Position 27
12428 29 8.8245E-02  -2428 1201 -1202 imp:n=1  $ Position 28
c    *Coolant Channel (No Plug)   $ Position 29
12430 29 8.8245E-02  -2430 1201 -1202 imp:n=1  $ Position 30
12431 29 8.8245E-02  -2431 1201 -1202 imp:n=1  $ Position 31
c    *Coolant Channel (No Plug)   $ Position 32
c
c --------- Ring 2 ---------
12501 29 8.8245E-02  -2501 1201 -1202 imp:n=1  $ Position 1
12502 29 8.8245E-02  -2502 1201 -1202 imp:n=1  $ Position 2
12503 29 8.8245E-02  -2503 1201 -1202 imp:n=1  $ Position 3
```

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12504 29 8.8245E-02  -2504 1201 -1202 imp:n=1  $ Position 4
12505 29 8.8245E-02  -2505 1201 -1202 imp:n=1  $ Position 5
12506 29 8.8245E-02  -2506 1201 -1202 imp:n=1  $ Position 6
12507 29 8.8245E-02  -2507 1201 -1202 imp:n=1  $ Position 7
12508 29 8.8245E-02  -2508 1201 -1202 imp:n=1  $ Position 8
12509 29 8.8245E-02  -2509 1201 -1202 imp:n=1  $ Position 9
12510 29 8.8245E-02  -2510 1201 -1202 imp:n=1  $ Position 10
12511 29 8.8245E-02  -2511 1201 -1202 imp:n=1  $ Position 11
12512 29 8.8245E-02  -2512 1201 -1202 imp:n=1  $ Position 12
12513 29 8.8245E-02  -2513 1201 -1202 imp:n=1  $ Position 13
12514 29 8.8245E-02  -2514 1201 -1202 imp:n=1  $ Position 14
12515 29 8.8245E-02  -2515 1201 -1202 imp:n=1  $ Position 15
12516 29 8.8245E-02  -2516 1201 -1202 imp:n=1  $ Position 16
12517 29 8.8245E-02  -2517 1201 -1202 imp:n=1  $ Position 17
12518 29 8.8245E-02  -2518 1201 -1202 imp:n=1  $ Position 18
12519 29 8.8245E-02  -2519 1201 -1202 imp:n=1  $ Position 19
12520 29 8.8245E-02  -2520 1201 -1202 imp:n=1  $ Position 20
12521 29 8.8245E-02  -2521 1201 -1202 imp:n=1  $ Position 21
12522 29 8.8245E-02  -2522 1201 -1202 imp:n=1  $ Position 22
12523 29 8.8245E-02  -2523 1201 -1202 imp:n=1  $ Position 23
12524 29 8.8245E-02  -2524 1201 -1202 imp:n=1  $ Position 24
12525 29 8.8245E-02  -2525 1201 -1202 imp:n=1  $ Position 25
12526 29 8.8245E-02  -2526 1201 -1202 imp:n=1  $ Position 26
12527 29 8.8245E-02  -2527 1201 -1202 imp:n=1  $ Position 27
12528 29 8.8245E-02  -2528 1201 -1202 imp:n=1  $ Position 28
12529 29 8.8245E-02  -2529 1201 -1202 imp:n=1  $ Position 29
12530 29 8.8245E-02  -2530 1201 -1202 imp:n=1  $ Position 30
12531 29 8.8245E-02  -2531 1201 -1202 imp:n=1  $ Position 31
12532 29 8.8245E-02  -2532 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 3 ---------
12601 29 8.8245E-02  -2601 1201 -1202 imp:n=1  $ Position 1
c    *Coolant Channel (No Plug)   $ Position 2
12603 29 8.8245E-02  -2603 1201 -1202 imp:n=1  $ Position 3
12604 29 8.8245E-02  -2604 1201 -1202 imp:n=1  $ Position 4
c    *Coolant Channel (No Plug)   $ Position 5
12606 29 8.8245E-02  -2606 1201 -1202 imp:n=1  $ Position 6
12607 29 8.8245E-02  -2607 1201 -1202 imp:n=1  $ Position 7
c    *Coolant Channel (No Plug)   $ Position 8
12609 29 8.8245E-02  -2609 1201 -1202 imp:n=1  $ Position 9
12610 29 8.8245E-02  -2610 1201 -1202 imp:n=1  $ Position 10
c    *Coolant Channel (No Plug)   $ Position 11
12612 29 8.8245E-02  -2612 1201 -1202 imp:n=1  $ Position 12
12613 29 8.8245E-02  -2613 1201 -1202 imp:n=1  $ Position 13
c    *Coolant Channel (No Plug)   $ Position 14
12615 29 8.8245E-02  -2615 1201 -1202 imp:n=1  $ Position 15
12616 29 8.8245E-02  -2616 1201 -1202 imp:n=1  $ Position 16
c    *Coolant Channel (No Plug)   $ Position 17
12618 29 8.8245E-02  -2618 1201 -1202 imp:n=1  $ Position 18
12619 29 8.8245E-02  -2619 1201 -1202 imp:n=1  $ Position 19
c    *Coolant Channel (No Plug)   $ Position 20
12621 29 8.8245E-02  -2621 1201 -1202 imp:n=1  $ Position 21
12622 29 8.8245E-02  -2622 1201 -1202 imp:n=1  $ Position 22
c    *Coolant Channel (No Plug)   $ Position 23
12624 29 8.8245E-02  -2624 1201 -1202 imp:n=1  $ Position 24
12625 29 8.8245E-02  -2625 1201 -1202 imp:n=1  $ Position 25
c    *Coolant Channel (No Plug)   $ Position 26
12627 29 8.8245E-02  -2627 1201 -1202 imp:n=1  $ Position 27
c    *Coolant Channel (No Plug)   $ Position 28
12629 29 8.8245E-02  -2629 1201 -1202 imp:n=1  $ Position 29
12630 29 8.8245E-02  -2630 1201 -1202 imp:n=1  $ Position 30
c    *Coolant Channel (No Plug)   $ Position 31
12632 29 8.8245E-02  -2632 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 4 ---------
12701 29 8.8245E-02  -2701 1201 -1202 imp:n=1  $ Position 1
12702 29 8.8245E-02  -2702 1201 -1202 imp:n=1  $ Position 2
12703 29 8.8245E-02  -2703 1201 -1202 imp:n=1  $ Position 3
12704 29 8.8245E-02  -2704 1201 -1202 imp:n=1  $ Position 4
12705 29 8.8245E-02  -2705 1201 -1202 imp:n=1  $ Position 5
12706 29 8.8245E-02  -2706 1201 -1202 imp:n=1  $ Position 6
12707 29 8.8245E-02  -2707 1201 -1202 imp:n=1  $ Position 7
12708 29 8.8245E-02  -2708 1201 -1202 imp:n=1  $ Position 8
12709 29 8.8245E-02  -2709 1201 -1202 imp:n=1  $ Position 9
12710 29 8.8245E-02  -2710 1201 -1202 imp:n=1  $ Position 10
12711 29 8.8245E-02  -2711 1201 -1202 imp:n=1  $ Position 11
```

```
12712 29 8.8245E-02  -2712 1201 -1202 imp:n=1  $ Position 12
12713 29 8.8245E-02  -2713 1201 -1202 imp:n=1  $ Position 13
12714 29 8.8245E-02  -2714 1201 -1202 imp:n=1  $ Position 14
12715 29 8.8245E-02  -2715 1201 -1202 imp:n=1  $ Position 15
12716 29 8.8245E-02  -2716 1201 -1202 imp:n=1  $ Position 16
12717 29 8.8245E-02  -2717 1201 -1202 imp:n=1  $ Position 17
12718 29 8.8245E-02  -2718 1201 -1202 imp:n=1  $ Position 18
12719 29 8.8245E-02  -2719 1201 -1202 imp:n=1  $ Position 19
12720 29 8.8245E-02  -2720 1201 -1202 imp:n=1  $ Position 20
12721 29 8.8245E-02  -2721 1201 -1202 imp:n=1  $ Position 21
12722 29 8.8245E-02  -2722 1201 -1202 imp:n=1  $ Position 22
12723 29 8.8245E-02  -2723 1201 -1202 imp:n=1  $ Position 23
12724 29 8.8245E-02  -2724 1201 -1202 imp:n=1  $ Position 24
12725 29 8.8245E-02  -2725 1201 -1202 imp:n=1  $ Position 25
12726 29 8.8245E-02  -2726 1201 -1202 imp:n=1  $ Position 26
12727 29 8.8245E-02  -2727 1201 -1202 imp:n=1  $ Position 27
12728 29 8.8245E-02  -2728 1201 -1202 imp:n=1  $ Position 28
12729 29 8.8245E-02  -2729 1201 -1202 imp:n=1  $ Position 29
12730 29 8.8245E-02  -2730 1201 -1202 imp:n=1  $ Position 30
12731 29 8.8245E-02  -2731 1201 -1202 imp:n=1  $ Position 31
12732 29 8.8245E-02  -2732 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 5 ---------
c    *Coolant Channel (No Plug)   $ Position 1
12802 29 8.8245E-02  -2802 1201 -1202 imp:n=1  $ Position 2
12803 29 8.8245E-02  -2803 1201 -1202 imp:n=1  $ Position 3
c    *Coolant Channel (No Plug)   $ Position 4
12805 29 8.8245E-02  -2805 1201 -1202 imp:n=1  $ Position 5
12806 29 8.8245E-02  -2806 1201 -1202 imp:n=1  $ Position 6
c    *Coolant Channel (No Plug)   $ Position 7
12808 29 8.8245E-02  -2808 1201 -1202 imp:n=1  $ Position 8
12809 29 8.8245E-02  -2809 1201 -1202 imp:n=1  $ Position 9
c    *Coolant Channel (No Plug)   $ Position 10
12811 29 8.8245E-02  -2811 1201 -1202 imp:n=1  $ Position 11
12812 29 8.8245E-02  -2812 1201 -1202 imp:n=1  $ Position 12
c    *Coolant Channel (No Plug)   $ Position 13
12814 29 8.8245E-02  -2814 1201 -1202 imp:n=1  $ Position 14
12815 29 8.8245E-02  -2815 1201 -1202 imp:n=1  $ Position 15
c    *Coolant Channel (No Plug)   $ Position 16
12817 29 8.8245E-02  -2817 1201 -1202 imp:n=1  $ Position 17
12818 29 8.8245E-02  -2818 1201 -1202 imp:n=1  $ Position 18
c    *Coolant Channel (No Plug)   $ Position 19
12820 29 8.8245E-02  -2820 1201 -1202 imp:n=1  $ Position 20
12821 29 8.8245E-02  -2821 1201 -1202 imp:n=1  $ Position 21
c    *Coolant Channel (No Plug)   $ Position 22
12823 29 8.8245E-02  -2823 1201 -1202 imp:n=1  $ Position 23
12824 29 8.8245E-02  -2824 1201 -1202 imp:n=1  $ Position 24
c    *Coolant Channel (No Plug)   $ Position 25
12826 29 8.8245E-02  -2826 1201 -1202 imp:n=1  $ Position 26
c    *Coolant Channel (No Plug)   $ Position 27
12828 29 8.8245E-02  -2828 1201 -1202 imp:n=1  $ Position 28
12829 29 8.8245E-02  -2829 1201 -1202 imp:n=1  $ Position 29
c    *Coolant Channel (No Plug)   $ Position 30
12831 29 8.8245E-02  -2831 1201 -1202 imp:n=1  $ Position 31
12832 29 8.8245E-02  -2832 1201 -1202 imp:n=1  $ Position 32
c
c ------ Aluminum Tank ------
1800   9 5.9018E-02  1801 -1201 -1221       imp:n=1  $ Bottom Center
1803   9 5.9018E-02  1801 -1201  1222 -1223 imp:n=1  $ Bottom Annulus
1804  10 4.8492E-05  1201 -1202  1204 -1221 imp:n=1  $ Air Gap
1805   9 5.9018E-02  1801 -1202  1221 -1222 imp:n=1  $ Inner Vertical Liner
1806  10 4.8492E-05  1201 -1202  1222 -1211 imp:n=1  $ Air Gap
1807  10 4.8492E-05  1201 -1202  1212 -1223 imp:n=1  $ Air Gap
1808   9 5.9018E-02  1801 -1202  1223 -1802 imp:n=1  $ Outer Vertical Liner
1819  10 4.8492E-05  1801 -1202  1802 -33 imp:n=1  $ Air Gap
c
c --- Lower Axial Reflector ----------------------------------------------------
1820  4 8.7744E-02  31 -1811 -1812 (1821:1823) imp:n=1  $ Inner Cylinder
1821  30 8.8245E-02  31 -1821 -1823 imp:n=1  $ Graphite Plug
c
c ------ Graphite Annulus ------
1831  10 4.8492E-05  31 -1811 1812 -1831 imp:n=1  $ Air Gap
1832  5 8.8245E-02  31 -1811 -1333 1831
          (1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913
           1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926
           1927 1928 1929 1930 1931 1932)
```

```
           imp:n=1  $ Ring 1 Region
1833  5 8.8245E-02  31 -1811 1333 -1433
          (2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
           2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026
           2027 2028 2029 2030 2031 2032)
           imp:n=1  $ Ring 2 Region
1834  5 8.8245E-02  31 -1811 1433 -1533
          (2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113
           2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126
           2127 2128 2129 2130 2131 2132)
           imp:n=1  $ Ring 3 Region
1835  5 8.8245E-02  31 -1811 1533 -1633
          (2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213
           2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226
           2227 2228 2229 2230 2231 2232)
           imp:n=1  $ Ring 4 Region
1836  5 8.8245E-02  31 -1811 1633 -1832
           (2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313
           2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326
           2327 2328 2329 2330 2331 2332)
           imp:n=1  $ Ring 5 Region
1837  10 4.8492E-05  31 -1811 1832 -33 imp:n=1  $ Air Gap
c
c ------ Coolant Channels ------
c --------- Ring 1 ---------
1901 10 4.8492E-05  2401 -1901 31 -1811 imp:n=1  $ Position 1
1902 10 4.8492E-05  2402 -1902 31 -1811 imp:n=1  $ Position 2
1903 10 4.8492E-05  2403 -1903 31 -1811 imp:n=1  $ Position 3
1904 10 4.8492E-05  2404 -1904 31 -1811 imp:n=1  $ Position 4
1905 10 4.8492E-05  2405 -1905 31 -1811 imp:n=1  $ Position 5
1906 10 4.8492E-05  2406 -1906 31 -1811 imp:n=1  $ Position 6
1907 10 4.8492E-05  2407 -1907 31 -1811 imp:n=1  $ Position 7
1908 10 4.8492E-05  2408 -1908 31 -1811 imp:n=1  $ Position 8
1909 10 4.8492E-05  2409 -1909 31 -1811 imp:n=1  $ Position 9
1910 10 4.8492E-05  2410 -1910 31 -1811 imp:n=1  $ Position 10
1911 10 4.8492E-05  2411 -1911 31 -1811 imp:n=1  $ Position 11
1912 10 4.8492E-05  2412 -1912 31 -1811 imp:n=1  $ Position 12
1913 10 4.8492E-05  2413 -1913 31 -1811 imp:n=1  $ Position 13
1914 10 4.8492E-05  2414 -1914 31 -1811 imp:n=1  $ Position 14
1915 10 4.8492E-05  2415 -1915 31 -1811 imp:n=1  $ Position 15
1916 10 4.8492E-05  2416 -1916 31 -1811 imp:n=1  $ Position 16
1917 10 4.8492E-05  2417 -1917 31 -1811 imp:n=1  $ Position 17
1918 10 4.8492E-05  2418 -1918 31 -1811 imp:n=1  $ Position 18
1919 10 4.8492E-05  2419 -1919 31 -1811 imp:n=1  $ Position 19
1920 10 4.8492E-05  2420 -1920 31 -1811 imp:n=1  $ Position 20
1921 10 4.8492E-05  2421 -1921 31 -1811 imp:n=1  $ Position 21
1922 10 4.8492E-05  2422 -1922 31 -1811 imp:n=1  $ Position 22
1923 10 4.8492E-05  2423 -1923 31 -1811 imp:n=1  $ Position 23
1924 10 4.8492E-05  2424 -1924 31 -1811 imp:n=1  $ Position 24
1925 10 4.8492E-05  2425 -1925 31 -1811 imp:n=1  $ Position 25
1926 10 4.8492E-05  2426 -1926 31 -1811 imp:n=1  $ Position 26
1927 10 4.8492E-05  2427 -1927 31 -1811 imp:n=1  $ Position 27
1928 10 4.8492E-05  2428 -1928 31 -1811 imp:n=1  $ Position 28
1929 10 4.8492E-05  2429 -1929 31 -1811 imp:n=1  $ Position 29
1930 10 4.8492E-05  2430 -1930 31 -1811 imp:n=1  $ Position 30
1931 10 4.8492E-05  2431 -1931 31 -1811 imp:n=1  $ Position 31
1932 10 4.8492E-05  2432 -1932 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 2 ---------
2001 10 4.8492E-05  2501 -2001 31 -1811 imp:n=1  $ Position 1
2002 10 4.8492E-05  2502 -2002 31 -1811 imp:n=1  $ Position 2
2003 10 4.8492E-05  2503 -2003 31 -1811 imp:n=1  $ Position 3
2004 10 4.8492E-05  2504 -2004 31 -1811 imp:n=1  $ Position 4
2005 10 4.8492E-05  2505 -2005 31 -1811 imp:n=1  $ Position 5
2006 10 4.8492E-05  2506 -2006 31 -1811 imp:n=1  $ Position 6
2007 10 4.8492E-05  2507 -2007 31 -1811 imp:n=1  $ Position 7
2008 10 4.8492E-05  2508 -2008 31 -1811 imp:n=1  $ Position 8
2009 10 4.8492E-05  2509 -2009 31 -1811 imp:n=1  $ Position 9
2010 10 4.8492E-05  2510 -2010 31 -1811 imp:n=1  $ Position 10
2011 10 4.8492E-05  2511 -2011 31 -1811 imp:n=1  $ Position 11
2012 10 4.8492E-05  2512 -2012 31 -1811 imp:n=1  $ Position 12
2013 10 4.8492E-05  2513 -2013 31 -1811 imp:n=1  $ Position 13
2014 10 4.8492E-05  2514 -2014 31 -1811 imp:n=1  $ Position 14
2015 10 4.8492E-05  2515 -2015 31 -1811 imp:n=1  $ Position 15
2016 10 4.8492E-05  2516 -2016 31 -1811 imp:n=1  $ Position 16
2017 10 4.8492E-05  2517 -2017 31 -1811 imp:n=1  $ Position 17
```

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2018 10 4.8492E-05  2518 -2018 31 -1811 imp:n=1  $ Position 18
2019 10 4.8492E-05  2519 -2019 31 -1811 imp:n=1  $ Position 19
2020 10 4.8492E-05  2520 -2020 31 -1811 imp:n=1  $ Position 20
2021 10 4.8492E-05  2521 -2021 31 -1811 imp:n=1  $ Position 21
2022 10 4.8492E-05  2522 -2022 31 -1811 imp:n=1  $ Position 22
2023 10 4.8492E-05  2523 -2023 31 -1811 imp:n=1  $ Position 23
2024 10 4.8492E-05  2524 -2024 31 -1811 imp:n=1  $ Position 24
2025 10 4.8492E-05  2525 -2025 31 -1811 imp:n=1  $ Position 25
2026 10 4.8492E-05  2526 -2026 31 -1811 imp:n=1  $ Position 26
2027 10 4.8492E-05  2527 -2027 31 -1811 imp:n=1  $ Position 27
2028 10 4.8492E-05  2528 -2028 31 -1811 imp:n=1  $ Position 28
2029 10 4.8492E-05  2529 -2029 31 -1811 imp:n=1  $ Position 29
2030 10 4.8492E-05  2530 -2030 31 -1811 imp:n=1  $ Position 30
2031 10 4.8492E-05  2531 -2031 31 -1811 imp:n=1  $ Position 31
2032 10 4.8492E-05  2532 -2032 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 3 ---------
2101 10 4.8492E-05  2601 -2101 31 -1811 imp:n=1  $ Position 1
2102 10 4.8492E-05  2602 -2102 31 -1811 imp:n=1  $ Position 2
2103 10 4.8492E-05  2603 -2103 31 -1811 imp:n=1  $ Position 3
2104 10 4.8492E-05  2604 -2104 31 -1811 imp:n=1  $ Position 4
2105 10 4.8492E-05  2605 -2105 31 -1811 imp:n=1  $ Position 5
2106 10 4.8492E-05  2606 -2106 31 -1811 imp:n=1  $ Position 6
2107 10 4.8492E-05  2607 -2107 31 -1811 imp:n=1  $ Position 7
2108 10 4.8492E-05  2608 -2108 31 -1811 imp:n=1  $ Position 8
2109 10 4.8492E-05  2609 -2109 31 -1811 imp:n=1  $ Position 9
2110 10 4.8492E-05  2610 -2110 31 -1811 imp:n=1  $ Position 10
2111 10 4.8492E-05  2611 -2111 31 -1811 imp:n=1  $ Position 11
2112 10 4.8492E-05  2612 -2112 31 -1811 imp:n=1  $ Position 12
2113 10 4.8492E-05  2613 -2113 31 -1811 imp:n=1  $ Position 13
2114 10 4.8492E-05  2614 -2114 31 -1811 imp:n=1  $ Position 14
2115 10 4.8492E-05  2615 -2115 31 -1811 imp:n=1  $ Position 15
2116 10 4.8492E-05  2616 -2116 31 -1811 imp:n=1  $ Position 16
2117 10 4.8492E-05  2617 -2117 31 -1811 imp:n=1  $ Position 17
2118 10 4.8492E-05  2618 -2118 31 -1811 imp:n=1  $ Position 18
2119 10 4.8492E-05  2619 -2119 31 -1811 imp:n=1  $ Position 19
2120 10 4.8492E-05  2620 -2120 31 -1811 imp:n=1  $ Position 20
2121 10 4.8492E-05  2621 -2121 31 -1811 imp:n=1  $ Position 21
2122 10 4.8492E-05  2622 -2122 31 -1811 imp:n=1  $ Position 22
2123 10 4.8492E-05  2623 -2123 31 -1811 imp:n=1  $ Position 23
2124 10 4.8492E-05  2624 -2124 31 -1811 imp:n=1  $ Position 24
2125 10 4.8492E-05  2625 -2125 31 -1811 imp:n=1  $ Position 25
2126 10 4.8492E-05  2626 -2126 31 -1811 imp:n=1  $ Position 26
2127 10 4.8492E-05  2627 -2127 31 -1811 imp:n=1  $ Position 27
2128 10 4.8492E-05  2628 -2128 31 -1811 imp:n=1  $ Position 28
2129 10 4.8492E-05  2629 -2129 31 -1811 imp:n=1  $ Position 29
2130 10 4.8492E-05  2630 -2130 31 -1811 imp:n=1  $ Position 30
2131 10 4.8492E-05  2631 -2131 31 -1811 imp:n=1  $ Position 31
2132 10 4.8492E-05  2632 -2132 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 4 ---------
2201 10 4.8492E-05  2701 -2201 31 -1811 imp:n=1  $ Position 1
2202 10 4.8492E-05  2702 -2202 31 -1811 imp:n=1  $ Position 2
2203 10 4.8492E-05  2703 -2203 31 -1811 imp:n=1  $ Position 3
2204 10 4.8492E-05  2704 -2204 31 -1811 imp:n=1  $ Position 4
2205 10 4.8492E-05  2705 -2205 31 -1811 imp:n=1  $ Position 5
2206 10 4.8492E-05  2706 -2206 31 -1811 imp:n=1  $ Position 6
2207 10 4.8492E-05  2707 -2207 31 -1811 imp:n=1  $ Position 7
2208 10 4.8492E-05  2708 -2208 31 -1811 imp:n=1  $ Position 8
2209 10 4.8492E-05  2709 -2209 31 -1811 imp:n=1  $ Position 9
2210 10 4.8492E-05  2710 -2210 31 -1811 imp:n=1  $ Position 10
2211 10 4.8492E-05  2711 -2211 31 -1811 imp:n=1  $ Position 11
2212 10 4.8492E-05  2712 -2212 31 -1811 imp:n=1  $ Position 12
2213 10 4.8492E-05  2713 -2213 31 -1811 imp:n=1  $ Position 13
2214 10 4.8492E-05  2714 -2214 31 -1811 imp:n=1  $ Position 14
2215 10 4.8492E-05  2715 -2215 31 -1811 imp:n=1  $ Position 15
2216 10 4.8492E-05  2716 -2216 31 -1811 imp:n=1  $ Position 16
2217 10 4.8492E-05  2717 -2217 31 -1811 imp:n=1  $ Position 17
2218 10 4.8492E-05  2718 -2218 31 -1811 imp:n=1  $ Position 18
2219 10 4.8492E-05  2719 -2219 31 -1811 imp:n=1  $ Position 19
2220 10 4.8492E-05  2720 -2220 31 -1811 imp:n=1  $ Position 20
2221 10 4.8492E-05  2721 -2221 31 -1811 imp:n=1  $ Position 21
2222 10 4.8492E-05  2722 -2222 31 -1811 imp:n=1  $ Position 22
2223 10 4.8492E-05  2723 -2223 31 -1811 imp:n=1  $ Position 23
2224 10 4.8492E-05  2724 -2224 31 -1811 imp:n=1  $ Position 24
2225 10 4.8492E-05  2725 -2225 31 -1811 imp:n=1  $ Position 25
```

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2226 10 4.8492E-05  2726 -2226 31 -1811 imp:n=1  $ Position 26
2227 10 4.8492E-05  2727 -2227 31 -1811 imp:n=1  $ Position 27
2228 10 4.8492E-05  2728 -2228 31 -1811 imp:n=1  $ Position 28
2229 10 4.8492E-05  2729 -2229 31 -1811 imp:n=1  $ Position 29
2230 10 4.8492E-05  2730 -2230 31 -1811 imp:n=1  $ Position 30
2231 10 4.8492E-05  2731 -2231 31 -1811 imp:n=1  $ Position 31
2232 10 4.8492E-05  2732 -2232 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 5 ---------
2301 10 4.8492E-05  2801 -2301 31 -1811 imp:n=1  $ Position 1
2302 10 4.8492E-05  2802 -2302 31 -1811 imp:n=1  $ Position 2
2303 10 4.8492E-05  2803 -2303 31 -1811 imp:n=1  $ Position 3
2304 10 4.8492E-05  2804 -2304 31 -1811 imp:n=1  $ Position 4
2305 10 4.8492E-05  2805 -2305 31 -1811 imp:n=1  $ Position 5
2306 10 4.8492E-05  2806 -2306 31 -1811 imp:n=1  $ Position 6
2307 10 4.8492E-05  2807 -2307 31 -1811 imp:n=1  $ Position 7
2308 10 4.8492E-05  2808 -2308 31 -1811 imp:n=1  $ Position 8
2309 10 4.8492E-05  2809 -2309 31 -1811 imp:n=1  $ Position 9
2310 10 4.8492E-05  2810 -2310 31 -1811 imp:n=1  $ Position 10
2311 10 4.8492E-05  2811 -2311 31 -1811 imp:n=1  $ Position 11
2312 10 4.8492E-05  2812 -2312 31 -1811 imp:n=1  $ Position 12
2313 10 4.8492E-05  2813 -2313 31 -1811 imp:n=1  $ Position 13
2314 10 4.8492E-05  2814 -2314 31 -1811 imp:n=1  $ Position 14
2315 10 4.8492E-05  2815 -2315 31 -1811 imp:n=1  $ Position 15
2316 10 4.8492E-05  2816 -2316 31 -1811 imp:n=1  $ Position 16
2317 10 4.8492E-05  2817 -2317 31 -1811 imp:n=1  $ Position 17
2318 10 4.8492E-05  2818 -2318 31 -1811 imp:n=1  $ Position 18
2319 10 4.8492E-05  2819 -2319 31 -1811 imp:n=1  $ Position 19
2320 10 4.8492E-05  2820 -2320 31 -1811 imp:n=1  $ Position 20
2321 10 4.8492E-05  2821 -2321 31 -1811 imp:n=1  $ Position 21
2322 10 4.8492E-05  2822 -2322 31 -1811 imp:n=1  $ Position 22
2323 10 4.8492E-05  2823 -2323 31 -1811 imp:n=1  $ Position 23
2324 10 4.8492E-05  2824 -2324 31 -1811 imp:n=1  $ Position 24
2325 10 4.8492E-05  2825 -2325 31 -1811 imp:n=1  $ Position 25
2326 10 4.8492E-05  2826 -2326 31 -1811 imp:n=1  $ Position 26
2327 10 4.8492E-05  2827 -2327 31 -1811 imp:n=1  $ Position 27
2328 10 4.8492E-05  2828 -2328 31 -1811 imp:n=1  $ Position 28
2329 10 4.8492E-05  2829 -2329 31 -1811 imp:n=1  $ Position 29
2330 10 4.8492E-05  2830 -2330 31 -1811 imp:n=1  $ Position 30
2331 10 4.8492E-05  2831 -2331 31 -1811 imp:n=1  $ Position 31
2332 10 4.8492E-05  2832 -2332 31 -1811 imp:n=1  $ Position 32
c
c ------ Graphite Plugs ------
c --------- Ring 1 ---------
2401 29 8.8245E-02  -2401 31 -1811 imp:n=1  $ Position 1
2402 29 8.8245E-02  -2402 31 -1811 imp:n=1  $ Position 2
2403 29 8.8245E-02  -2403 31 -1811 imp:n=1  $ Position 3
2404 29 8.8245E-02  -2404 31 -1811 imp:n=1  $ Position 4
2405 29 8.8245E-02  -2405 31 -1811 imp:n=1  $ Position 5
2406 29 8.8245E-02  -2406 31 -1811 imp:n=1  $ Position 6
2407 29 8.8245E-02  -2407 31 -1811 imp:n=1  $ Position 7
2408 29 8.8245E-02  -2408 31 -1811 imp:n=1  $ Position 8
2409 29 8.8245E-02  -2409 31 -1811 imp:n=1  $ Position 9
2410 29 8.8245E-02  -2410 31 -1811 imp:n=1  $ Position 10
2411 29 8.8245E-02  -2411 31 -1811 imp:n=1  $ Position 11
2412 29 8.8245E-02  -2412 31 -1811 imp:n=1  $ Position 12
2413 29 8.8245E-02  -2413 31 -1811 imp:n=1  $ Position 13
2414 29 8.8245E-02  -2414 31 -1811 imp:n=1  $ Position 14
2415 29 8.8245E-02  -2415 31 -1811 imp:n=1  $ Position 15
2416 29 8.8245E-02  -2416 31 -1811 imp:n=1  $ Position 16
2417 29 8.8245E-02  -2417 31 -1811 imp:n=1  $ Position 17
2418 29 8.8245E-02  -2418 31 -1811 imp:n=1  $ Position 18
2419 29 8.8245E-02  -2419 31 -1811 imp:n=1  $ Position 19
2420 29 8.8245E-02  -2420 31 -1811 imp:n=1  $ Position 20
2421 29 8.8245E-02  -2421 31 -1811 imp:n=1  $ Position 21
2422 29 8.8245E-02  -2422 31 -1811 imp:n=1  $ Position 22
2423 29 8.8245E-02  -2423 31 -1811 imp:n=1  $ Position 23
2424 29 8.8245E-02  -2424 31 -1811 imp:n=1  $ Position 24
2425 29 8.8245E-02  -2425 31 -1811 imp:n=1  $ Position 25
2426 29 8.8245E-02  -2426 31 -1811 imp:n=1  $ Position 26
2427 29 8.8245E-02  -2427 31 -1811 imp:n=1  $ Position 27
2428 29 8.8245E-02  -2428 31 -1811 imp:n=1  $ Position 28
2429 29 8.8245E-02  -2429 31 -1811 imp:n=1  $ Position 29
2430 29 8.8245E-02  -2430 31 -1811 imp:n=1  $ Position 30
2431 29 8.8245E-02  -2431 31 -1811 imp:n=1  $ Position 31
2432 29 8.8245E-02  -2432 31 -1811 imp:n=1  $ Position 32
```

```
c
c --------- Ring 2 ---------
2501 29 8.8245E-02  -2501 31 -1811 imp:n=1  $ Position 1
2502 29 8.8245E-02  -2502 31 -1811 imp:n=1  $ Position 2
2503 29 8.8245E-02  -2503 31 -1811 imp:n=1  $ Position 3
2504 29 8.8245E-02  -2504 31 -1811 imp:n=1  $ Position 4
2505 29 8.8245E-02  -2505 31 -1811 imp:n=1  $ Position 5
2506 29 8.8245E-02  -2506 31 -1811 imp:n=1  $ Position 6
2507 29 8.8245E-02  -2507 31 -1811 imp:n=1  $ Position 7
2508 29 8.8245E-02  -2508 31 -1811 imp:n=1  $ Position 8
2509 29 8.8245E-02  -2509 31 -1811 imp:n=1  $ Position 9
2510 29 8.8245E-02  -2510 31 -1811 imp:n=1  $ Position 10
2511 29 8.8245E-02  -2511 31 -1811 imp:n=1  $ Position 11
2512 29 8.8245E-02  -2512 31 -1811 imp:n=1  $ Position 12
2513 29 8.8245E-02  -2513 31 -1811 imp:n=1  $ Position 13
2514 29 8.8245E-02  -2514 31 -1811 imp:n=1  $ Position 14
2515 29 8.8245E-02  -2515 31 -1811 imp:n=1  $ Position 15
2516 29 8.8245E-02  -2516 31 -1811 imp:n=1  $ Position 16
2517 29 8.8245E-02  -2517 31 -1811 imp:n=1  $ Position 17
2518 29 8.8245E-02  -2518 31 -1811 imp:n=1  $ Position 18
2519 29 8.8245E-02  -2519 31 -1811 imp:n=1  $ Position 19
2520 29 8.8245E-02  -2520 31 -1811 imp:n=1  $ Position 20
2521 29 8.8245E-02  -2521 31 -1811 imp:n=1  $ Position 21
2522 29 8.8245E-02  -2522 31 -1811 imp:n=1  $ Position 22
2523 29 8.8245E-02  -2523 31 -1811 imp:n=1  $ Position 23
2524 29 8.8245E-02  -2524 31 -1811 imp:n=1  $ Position 24
2525 29 8.8245E-02  -2525 31 -1811 imp:n=1  $ Position 25
2526 29 8.8245E-02  -2526 31 -1811 imp:n=1  $ Position 26
2527 29 8.8245E-02  -2527 31 -1811 imp:n=1  $ Position 27
2528 29 8.8245E-02  -2528 31 -1811 imp:n=1  $ Position 28
2529 29 8.8245E-02  -2529 31 -1811 imp:n=1  $ Position 29
2530 29 8.8245E-02  -2530 31 -1811 imp:n=1  $ Position 30
2531 29 8.8245E-02  -2531 31 -1811 imp:n=1  $ Position 31
2532 29 8.8245E-02  -2532 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 3 ---------
2601 29 8.8245E-02  -2601 31 -1811 imp:n=1  $ Position 1
2602 29 8.8245E-02  -2602 31 -1811 imp:n=1  $ Position 2
2603 29 8.8245E-02  -2603 31 -1811 imp:n=1  $ Position 3
2604 29 8.8245E-02  -2604 31 -1811 imp:n=1  $ Position 4
2605 29 8.8245E-02  -2605 31 -1811 imp:n=1  $ Position 5
2606 29 8.8245E-02  -2606 31 -1811 imp:n=1  $ Position 6
2607 29 8.8245E-02  -2607 31 -1811 imp:n=1  $ Position 7
2608 29 8.8245E-02  -2608 31 -1811 imp:n=1  $ Position 8
2609 29 8.8245E-02  -2609 31 -1811 imp:n=1  $ Position 9
2610 29 8.8245E-02  -2610 31 -1811 imp:n=1  $ Position 10
2611 29 8.8245E-02  -2611 31 -1811 imp:n=1  $ Position 11
2612 29 8.8245E-02  -2612 31 -1811 imp:n=1  $ Position 12
2613 29 8.8245E-02  -2613 31 -1811 imp:n=1  $ Position 13
2614 29 8.8245E-02  -2614 31 -1811 imp:n=1  $ Position 14
2615 29 8.8245E-02  -2615 31 -1811 imp:n=1  $ Position 15
2616 29 8.8245E-02  -2616 31 -1811 imp:n=1  $ Position 16
2617 29 8.8245E-02  -2617 31 -1811 imp:n=1  $ Position 17
2618 29 8.8245E-02  -2618 31 -1811 imp:n=1  $ Position 18
2619 29 8.8245E-02  -2619 31 -1811 imp:n=1  $ Position 19
2620 29 8.8245E-02  -2620 31 -1811 imp:n=1  $ Position 20
2621 29 8.8245E-02  -2621 31 -1811 imp:n=1  $ Position 21
2622 29 8.8245E-02  -2622 31 -1811 imp:n=1  $ Position 22
2623 29 8.8245E-02  -2623 31 -1811 imp:n=1  $ Position 23
2624 29 8.8245E-02  -2624 31 -1811 imp:n=1  $ Position 24
2625 29 8.8245E-02  -2625 31 -1811 imp:n=1  $ Position 25
2626 29 8.8245E-02  -2626 31 -1811 imp:n=1  $ Position 26
2627 29 8.8245E-02  -2627 31 -1811 imp:n=1  $ Position 27
2628 29 8.8245E-02  -2628 31 -1811 imp:n=1  $ Position 28
2629 29 8.8245E-02  -2629 31 -1811 imp:n=1  $ Position 29
2630 29 8.8245E-02  -2630 31 -1811 imp:n=1  $ Position 30
2631 29 8.8245E-02  -2631 31 -1811 imp:n=1  $ Position 31
2632 29 8.8245E-02  -2632 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 4 ---------
2701 29 8.8245E-02  -2701 31 -1811 imp:n=1  $ Position 1
2702 29 8.8245E-02  -2702 31 -1811 imp:n=1  $ Position 2
2703 29 8.8245E-02  -2703 31 -1811 imp:n=1  $ Position 3
2704 29 8.8245E-02  -2704 31 -1811 imp:n=1  $ Position 4
2705 29 8.8245E-02  -2705 31 -1811 imp:n=1  $ Position 5
2706 29 8.8245E-02  -2706 31 -1811 imp:n=1  $ Position 6
```

```
2707 29 8.8245E-02  -2707 31 -1811 imp:n=1  $ Position 7
2708 29 8.8245E-02  -2708 31 -1811 imp:n=1  $ Position 8
2709 29 8.8245E-02  -2709 31 -1811 imp:n=1  $ Position 9
2710 29 8.8245E-02  -2710 31 -1811 imp:n=1  $ Position 10
2711 29 8.8245E-02  -2711 31 -1811 imp:n=1  $ Position 11
2712 29 8.8245E-02  -2712 31 -1811 imp:n=1  $ Position 12
2713 29 8.8245E-02  -2713 31 -1811 imp:n=1  $ Position 13
2714 29 8.8245E-02  -2714 31 -1811 imp:n=1  $ Position 14
2715 29 8.8245E-02  -2715 31 -1811 imp:n=1  $ Position 15
2716 29 8.8245E-02  -2716 31 -1811 imp:n=1  $ Position 16
2717 29 8.8245E-02  -2717 31 -1811 imp:n=1  $ Position 17
2718 29 8.8245E-02  -2718 31 -1811 imp:n=1  $ Position 18
2719 29 8.8245E-02  -2719 31 -1811 imp:n=1  $ Position 19
2720 29 8.8245E-02  -2720 31 -1811 imp:n=1  $ Position 20
2721 29 8.8245E-02  -2721 31 -1811 imp:n=1  $ Position 21
2722 29 8.8245E-02  -2722 31 -1811 imp:n=1  $ Position 22
2723 29 8.8245E-02  -2723 31 -1811 imp:n=1  $ Position 23
2724 29 8.8245E-02  -2724 31 -1811 imp:n=1  $ Position 24
2725 29 8.8245E-02  -2725 31 -1811 imp:n=1  $ Position 25
2726 29 8.8245E-02  -2726 31 -1811 imp:n=1  $ Position 26
2727 29 8.8245E-02  -2727 31 -1811 imp:n=1  $ Position 27
2728 29 8.8245E-02  -2728 31 -1811 imp:n=1  $ Position 28
2729 29 8.8245E-02  -2729 31 -1811 imp:n=1  $ Position 29
2730 29 8.8245E-02  -2730 31 -1811 imp:n=1  $ Position 30
2731 29 8.8245E-02  -2731 31 -1811 imp:n=1  $ Position 31
2732 29 8.8245E-02  -2732 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 5 ---------
2801 29 8.8245E-02  -2801 31 -1811 imp:n=1  $ Position 1
2802 29 8.8245E-02  -2802 31 -1811 imp:n=1  $ Position 2
2803 29 8.8245E-02  -2803 31 -1811 imp:n=1  $ Position 3
2804 29 8.8245E-02  -2804 31 -1811 imp:n=1  $ Position 4
2805 29 8.8245E-02  -2805 31 -1811 imp:n=1  $ Position 5
2806 29 8.8245E-02  -2806 31 -1811 imp:n=1  $ Position 6
2807 29 8.8245E-02  -2807 31 -1811 imp:n=1  $ Position 7
2808 29 8.8245E-02  -2808 31 -1811 imp:n=1  $ Position 8
2809 29 8.8245E-02  -2809 31 -1811 imp:n=1  $ Position 9
2810 29 8.8245E-02  -2810 31 -1811 imp:n=1  $ Position 10
2811 29 8.8245E-02  -2811 31 -1811 imp:n=1  $ Position 11
2812 29 8.8245E-02  -2812 31 -1811 imp:n=1  $ Position 12
2813 29 8.8245E-02  -2813 31 -1811 imp:n=1  $ Position 13
2814 29 8.8245E-02  -2814 31 -1811 imp:n=1  $ Position 14
2815 29 8.8245E-02  -2815 31 -1811 imp:n=1  $ Position 15
2816 29 8.8245E-02  -2816 31 -1811 imp:n=1  $ Position 16
2817 29 8.8245E-02  -2817 31 -1811 imp:n=1  $ Position 17
2818 29 8.8245E-02  -2818 31 -1811 imp:n=1  $ Position 18
2819 29 8.8245E-02  -2819 31 -1811 imp:n=1  $ Position 19
2820 29 8.8245E-02  -2820 31 -1811 imp:n=1  $ Position 20
2821 29 8.8245E-02  -2821 31 -1811 imp:n=1  $ Position 21
2822 29 8.8245E-02  -2822 31 -1811 imp:n=1  $ Position 22
2823 29 8.8245E-02  -2823 31 -1811 imp:n=1  $ Position 23
2824 29 8.8245E-02  -2824 31 -1811 imp:n=1  $ Position 24
2825 29 8.8245E-02  -2825 31 -1811 imp:n=1  $ Position 25
2826 29 8.8245E-02  -2826 31 -1811 imp:n=1  $ Position 26
2827 29 8.8245E-02  -2827 31 -1811 imp:n=1  $ Position 27
2828 29 8.8245E-02  -2828 31 -1811 imp:n=1  $ Position 28
2829 29 8.8245E-02  -2829 31 -1811 imp:n=1  $ Position 29
2830 29 8.8245E-02  -2830 31 -1811 imp:n=1  $ Position 30
2831 29 8.8245E-02  -2831 31 -1811 imp:n=1  $ Position 31
2832 29 8.8245E-02  -2832 31 -1811 imp:n=1  $ Position 32
c
c --- Control Rods -------------------------------------------------------------
c ------ Safety/Shutdown Rods ------
3001 11 9.1511E-02  3002 -3003 -3005 imp:n=1 u=1  $ Borated Steel Rod
3002 10 4.8129E-05  3002 -3003 3005 -3006 imp:n=1 u=1  $ Air
3003 12 8.6882E-02  3001 -3004 -3007 (-3002:3003:3006) imp:n=1 u=1  $ Steel Tube
3004 10 4.8129E-05  -3001:3004:3007 imp:n=1 u=1  $ Air
c
c ****** Safety/Shutdown Rods Fully Inserted @ z=0 and Withdrawn @ z=290   ***********
c ****** Safety/Shutdown Rods were Fully Withdrawn for Cores 1, 1A, 2, & 3 ***********
c
c --------- Rod 1 ---------
3005 10 4.8129E-05  3011 -3012 -3014 imp:n=1 u=2  $ Air
3006 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=2  $ Aluminum Shock Damper
3007 0    (-31:3013:3015) imp:n=1 u=2 fill=1 (0 0 290)
c
```

```
c --------- Rod 2 ---------
3008 10 4.8129E-05  3011 -3012 -3014 imp:n=1 u=3  $ Air
3009 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=3  $ Aluminum Shock Damper
3010 0    (-31:3013:3015) imp:n=1 u=3 fill=1 (0 0 290)
c
c --------- Rod 3 ---------
3011 10 4.8129E-05  3011 -3012 -3014 imp:n=1 u=4  $ Air
3012 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=4  $ Aluminum Shock Damper
3013 0    (-31:3013:3015) imp:n=1 u=4 fill=1 (0 0 290)
c
c --------- Rod 4 ---------
3014 10 4.8129E-05  3011 -3012 -3014 imp:n=1 u=5  $ Air
3015 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=5  $ Aluminum Shock Damper
3016 0    (-31:3013:3015) imp:n=1 u=5 fill=1 (0 0 290)
c
c --------- Rod 5 ---------
3017 10 4.8129E-05  3011 -3012 -3014 imp:n=1 u=6  $ Air
3018 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=6  $ Aluminum Shock Damper
3019 0    (-31:3013:3015) imp:n=1 u=6 fill=1 (0 0 290)
c
c --------- Rod 6 ---------
3020 10 4.8129E-05  3011 -3012 -3014 imp:n=1 u=7  $ Air
3021 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=7  $ Aluminum Shock Damper
3022 0    (-31:3013:3015) imp:n=1 u=7 fill=1 (0 0 290)
c
c --------- Rod 7 ---------
3023 10 4.8129E-05  3011 -3012 -3014 imp:n=1 u=8  $ Air
3024 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=8  $ Aluminum Shock Damper
3025 0    (-31:3013:3015) imp:n=1 u=8 fill=1 (0 0 290)
c
c --------- Rod 8 ---------
3026 10 4.8129E-05  3011 -3012 -3014 imp:n=1 u=9  $ Air
3027 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=9  $ Aluminum Shock Damper
3028 0    (-31:3013:3015) imp:n=1 u=9 fill=1 (0 0 290)
c
c ------ Autorod ------
3031 13 8.4303E-02  3031 -3032 -3033 -3034 -3035 imp:n=1 u=10  $ Copper Plate
3032 10 4.8492E-05  -3031:3032:3033:3034:3035 imp:n=1 u=10  $ Air
c
c ****** Autorod Fully Inserted @ z=0 and Withdrawn @ z=100 **************************
c ****** Autorod Withdrawn to z=25.8 for Core 9 &           **************************
c ******                      z= 1.5 for Core 10,           **************************
c
3033 0    -3036 imp:n=1 u=11 fill=10 (0 0 25.8)
3034 113 5.9746E-02  3036 -3037 31 -32 imp:n=1 u=11  $ Aluminum Tube
3035 10 4.8492E-05  3037:(3036 -31):(3036 32) imp:n=1 u=11  $ Air
c
c ------ Withdrawable Control Rods ------
3091 10 4.8492E-05  3083 -3084 -3087 imp:n=1 u=17  $ Air
3092 17 8.6477E-02  3082 -3085 3087 -3088 imp:n=1 u=17 $ Inner Tube
3093 10 4.8492E-05  3082 -3085 3088 -3089 imp:n=1 u=17 $ Air Gap
3094 18 8.6499E-02  3082 -3085 3089 -3090 imp:n=1 u=17 $ Outer Tube
3095 18 8.6499E-02  (3081 -3082 -3090):(3082 -3083 -3087) imp:n=1 u=17  $ Bottom End Plug
3096 18 8.6499E-02  (3084 -3085 -3087):(3085 -3086 -3090) imp:n=1 u=17  $ Top End Plug
3097 10 4.8492E-05  -3081:3086:3090 imp:n=1 u=17  $ Air
c
c ****** Control Rods Fully Inserted @ z=0 and Withdrawn @ z=249.4          **********
c ****** Opposite of Reported Values Inserted @ z=250 and Withdrawn @ z=0.6 **********
c ****** Control Rods Withdrawn to z=249.4 for Core 9                       **********
c ****** Control Rods Withdrawn to z=96.0  for Core 10                       **********
c
3098 0  -3095 imp:n=1 u=18 fill=17 (0 0 249.4)  $ Rod 1
3099 0  -3095 imp:n=1 u=19 fill=17 (0 0 249.4)  $ Rod 2
3100 0  -3095 imp:n=1 u=20 fill=17 (0 0 249.4)  $ Rod 3
3101 0  -3095 imp:n=1 u=21 fill=17 (0 0 249.4)  $ Rod 4
c
c --- Pebbles -----------------------------------------------------------------
c ------ TRISO ------
3111 19 7.2917E-02  -3111 imp:n=1 u=22  $ UO2 Kernel
3112 20 5.2640E-02  3111 -3112 imp:n=1 u=22  $ Buffer Coating
3113 21 9.5254E-02  3112 -3113 imp:n=1 u=22  $ IPyC Coating
3114 22 9.6110E-02  3113 -3114 imp:n=1 u=22  $ SiC Coating
3115 23 9.4772E-02  3114 -3115 imp:n=1 u=22  $ OPyC Coating
3116 24 8.6859E-02  3115 imp:n=1 u=22  $ Fueled Zone Graphite
c
3117 24 8.6859E-02  -9999 imp:n=1 u=23  $ Fueled Zone Graphite
```

```
c
c ------ TRISO Lattice ------
3121 24 8.6859E-02  -3121 imp:n=1 u=98 lat=1 fill=-14:14 -14:14 -14:14
c
     23 840r
c
     23 405r
     23 12r 22 2r 23 12r
     23 405r
c
     23 260r
     23 12r 22 2r 23 12r
     23 10r 22 6r 23 10r
     23 9r 22 8r 23 9r
     23 9r 22 8r 23 9r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 9r 22 8r 23 9r
     23 9r 22 8r 23 9r
     23 10r 22 6r 23 10r
     23 12r 22 2r 23 12r
     23 260r
c
     23 202r
     23 12r 22 2r 23 12r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 12r 22 2r 23 12r
     23 202r
c
     23 173r
     23 11r 22 4r 23 11r
     23 9r 22 8r 23 9r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 9r 22 8r 23 9r
     23 11r 22 4r 23 11r
     23 173r
c
     23 144r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
```

```
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 144r
c
     23 115r
     23 11r 22 4r 23 11r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 11r 22 4r 23 11r
     23 115r
c
     23 86r
     23 12r 22 2r 23 12r
     23 9r 22 8r 23 9r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 9r 22 8r 23 9r
     23 12r 22 2r 23 12r
     23 86r
c
     23 86r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
```

```
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 86r
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     23 12r 22 2r 23 12r
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     23 7r 22 12r 23 7r
     23 5r 22 16r 23 5r
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     23 10r 22 6r 23 10r
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     23 57r
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     23 28r
     23 12r 22 23 22 23 12r
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     23 5r 22 16r 23 5r
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     23 6r 22 14r 23 6r
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     23 28r
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     23 1r 22 24r 23 1r
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     23 7r 22 12r 23 7r
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     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 9r 22 8r 23 9r
     23 12r 22 2r 23 12r
     23 86r
c
     23 115r
     23 11r 22 4r 23 11r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
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     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 11r 22 4r 23 11r
     23 115r
c
     23 144r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
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     23 4r 22 18r 23 4r
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     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 144r
c
     23 173r
     23 11r 22 4r 23 11r
     23 9r 22 8r 23 9r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 9r 22 8r 23 9r
     23 11r 22 4r 23 11r
     23 173r
c
     23 202r
     23 12r 22 2r 23 12r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 12r 22 2r 23 12r
     23 202r
c
     23 260r
     23 12r 22 2r 23 12r
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     23 10r 22 6r 23 10r
     23 9r 22 8r 23 9r
     23 9r 22 8r 23 9r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 9r 22 8r 23 9r
     23 9r 22 8r 23 9r
     23 10r 22 6r 23 10r
     23 12r 22 2r 23 12r
     23 260r
c
     23 405r
     23 12r 22 2r 23 12r
     23 405r
c
     23 840r
c
c ------ Fuel Pebbles ------
3131 24 8.6859E-02  -3131       imp:n=1 u=24 fill=98 $ Fuel Zone
3132 24 8.6859E-02   3131 -3132 imp:n=1 u=24         $ Pebble Shell (Unfueled Zone)
3133 10 4.8413E-05   3132       imp:n=1 u=24         $ Air
c
c ------ Moderator Pebbles ------
4131 26 8.4461E-02  -3132       imp:n=1 u=25  $ Moderator Pebble
4132 10 4.8413E-05   3132       imp:n=1 u=25  $ Air
c
c ------ Air ------
5001 10 4.8413E-05  -9999 imp:n=1 u=26  $ Air
c
c ------ Pebble Stacks ---------------------------------------------------------
c --------- Standard Stacks ---------
c ------------ Stack 1 (Core 9) ------------
6001 10 4.8413E-05  -6001 imp:n=1 u=27 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
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     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
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     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 2 (Core 9) ------------
6002 10 4.8413E-05  -6001 imp:n=1 u=28 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
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     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 3 (Core 9) ------------
6003 10 4.8413E-05  -6001 imp:n=1 u=29 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
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     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 4 (Core 9) ------------
6004 10 4.8413E-05  -6001 imp:n=1 u=30 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
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     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 1 (Core 10) ------------
6005 10 4.8413E-05  -6001 imp:n=1 u=31 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 2 (Core 10) ------------
6006 10 4.8413E-05  -6001 imp:n=1 u=32 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
```

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c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 3 (Core 10) ------------
6007 10 4.8413E-05  -6001 imp:n=1 u=33 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
```

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     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 4 (Core 10) ------------
6008 10 4.8413E-05  -6001 imp:n=1 u=34 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
```

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     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------ Stacks with Polyethylene Rods (Full Set) ------
c    *Polyethylene Rods are Only in Core 10
c
c ------------ Stack 1 - NW, N, NE, SE, S, SW ------------
5101 34 1.2365E-01  -7021 -6003 -7027 imp:n=1 u=35  $ NW Rod
5102 34 1.2365E-01  -7022 -6003 -7027 imp:n=1 u=35  $ N Rod
5103 34 1.2365E-01  -7023 -6003 -7027 imp:n=1 u=35  $ NE Rod
5104 34 1.2365E-01  -7024 -6003 -7027 imp:n=1 u=35  $ SE Rod
5105 34 1.2365E-01  -7025 -6003 -7027 imp:n=1 u=35  $ S Rod
5106 34 1.2365E-01  -7026 -6003 -7027 imp:n=1 u=35  $ SW Rod
5107 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=35 fill=31
c
c ------------ Stack 2 - NW, N, NE, SE, S, SW ------------
5111 34 1.2365E-01  -7021 -6003 -7027 imp:n=1 u=36  $ NW Rod
5112 34 1.2365E-01  -7022 -6003 -7027 imp:n=1 u=36  $ N Rod
5113 34 1.2365E-01  -7023 -6003 -7027 imp:n=1 u=36  $ NE Rod
5114 34 1.2365E-01  -7024 -6003 -7027 imp:n=1 u=36  $ SE Rod
5115 34 1.2365E-01  -7025 -6003 -7027 imp:n=1 u=36  $ S Rod
5116 34 1.2365E-01  -7026 -6003 -7027 imp:n=1 u=36  $ SW Rod
5117 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=36 fill=32
c
c ------------ Stack 3 - NW, N, NE, SE, S, SW ------------
5121 34 1.2365E-01  -7021 -6003 -7027 imp:n=1 u=37  $ NW Rod
5122 34 1.2365E-01  -7022 -6003 -7027 imp:n=1 u=37  $ N Rod
5123 34 1.2365E-01  -7023 -6003 -7027 imp:n=1 u=37  $ NE Rod
5124 34 1.2365E-01  -7024 -6003 -7027 imp:n=1 u=37  $ SE Rod
5125 34 1.2365E-01  -7025 -6003 -7027 imp:n=1 u=37  $ S Rod
5126 34 1.2365E-01  -7026 -6003 -7027 imp:n=1 u=37  $ SW Rod
5127 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=37 fill=33
c
c ------------ Stack 4 - NW, N, NE, SE, S, SW ------------
5131 34 1.2365E-01  -7021 -6003 -7027 imp:n=1 u=38  $ NW Rod
5132 34 1.2365E-01  -7022 -6003 -7027 imp:n=1 u=38  $ N Rod
5133 34 1.2365E-01  -7023 -6003 -7027 imp:n=1 u=38  $ NE Rod
5134 34 1.2365E-01  -7024 -6003 -7027 imp:n=1 u=38  $ SE Rod
5135 34 1.2365E-01  -7025 -6003 -7027 imp:n=1 u=38  $ S Rod
5136 34 1.2365E-01  -7026 -6003 -7027 imp:n=1 u=38  $ SW Rod
5137 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=38 fill=34
c
c ------ Stacks with Polyethylene Rods (Partial Sets) ------
c ------------ Stack 1 - N, NE, SE, S ------------
5202 like 5102 but u=40  $ N Rod
5203 like 5103 but u=40  $ NE Rod
5204 like 5104 but u=40  $ SE Rod
5205 like 5105 but u=40  $ S Rod
5207 10 4.8413E-05  -6003 (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) imp:n=1 u=40 fill=31
c
c ------------ Stack 1 - NE, SE, S ------------
5213 like 5103 but u=41  $ NE Rod
5214 like 5104 but u=41  $ SE Rod
5215 like 5105 but u=41  $ S Rod
5217 10 4.8413E-05  -6003 (7023:7027) (7024:7027)
                          (7025:7027) imp:n=1 u=41 fill=31
c
c ------------ Stack 1 - SE, S ------------
5224 like 5104 but u=42  $ SE Rod
5225 like 5105 but u=42  $ S Rod
5227 10 4.8413E-05  -6003 (7024:7027) (7025:7027) imp:n=1 u=42 fill=31
c
c ------------ Stack 1 - S, SW ------------
5235 like 5105 but u=43  $ S Rod
5236 like 5106 but u=43  $ SW Rod
5237 10 4.8413E-05  -6003 (7025:7027) (7026:7027) imp:n=1 u=43 fill=31
c
c ------------ Stack 1 - NW, S, SW ------------
5241 like 5101 but u=44  $ NW Rod
5245 like 5105 but u=44  $ S Rod
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5246 like 5106 but u=44  $ SW Rod
5247 10 4.8413E-05  -6003 (7021:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=44 fill=31
c
c ------------ Stack 1 - NW, N, S, SW ------------
5251 like 5101 but u=45  $ NW Rod
5252 like 5102 but u=45  $ N Rod
5255 like 5105 but u=45  $ S Rod
5256 like 5106 but u=45  $ SW Rod
5257 10 4.8413E-05  -6003 (7021:7027) (7022:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=45 fill=31
c
c ------------ Stack 1 - NW, N, SW ------------
5261 like 5101 but u=46  $ NW Rod
5262 like 5102 but u=46  $ N Rod
5266 like 5106 but u=46  $ SW Rod
5267 10 4.8413E-05  -6003 (7021:7027) (7022:7027)
                          (7026:7027) imp:n=1 u=46 fill=31
c
c ------------ Stack 1 - NW, N ------------
5271 like 5101 but u=47  $ NW Rod
5272 like 5102 but u=47  $ N Rod
5277 10 4.8413E-05  -6003 (7021:7027) (7022:7027) imp:n=1 u=47 fill=31
c
c ------------ Stack 1 - N, NE ------------
5282 like 5102 but u=48  $ N Rod
5283 like 5103 but u=48  $ NE Rod
5287 10 4.8413E-05  -6003 (7022:7027) (7023:7027) imp:n=1 u=48 fill=31
c
c ------------ Stack 1 - N, NE, SE ------------
5292 like 5102 but u=49  $ N Rod
5293 like 5103 but u=49  $ NE Rod
5294 like 5104 but u=49  $ SE Rod
5297 10 4.8413E-05  -6003 (7022:7027) (7023:7027) (7024:7027)
                          imp:n=1 u=49 fill=31
c
c ------------ Stack 2 - N, NE, SE, S ------------
5302 like 5112 but u=50  $ N Rod
5303 like 5113 but u=50  $ NE Rod
5304 like 5114 but u=50  $ SE Rod
5305 like 5115 but u=50  $ S Rod
5307 10 4.8413E-05  -6003 (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) imp:n=1 u=50 fill=32
c
c ------------ Stack 2 - NE, SE, S, SW ------------
5313 like 5113 but u=51  $ NE Rod
5314 like 5114 but u=51  $ SE Rod
5315 like 5115 but u=51  $ S Rod
5316 like 5116 but u=51  $ SW Rod
5317 10 4.8413E-05  -6003 (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=51 fill=32
c
c ------------ Stack 2 - NW, SE, S, SW ------------
5321 like 5111 but u=52  $ NW Rod
5324 like 5114 but u=52  $ SE Rod
5325 like 5115 but u=52  $ S Rod
5326 like 5116 but u=52  $ SW Rod
5327 10 4.8413E-05  -6003 (7021:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=52 fill=32
c
c ------------ Stack 2 - NW, N, S, SW ------------
5331 like 5111 but u=53  $ NW Rod
5332 like 5112 but u=53  $ N Rod
5335 like 5115 but u=53  $ S Rod
5336 like 5116 but u=53  $ SW Rod
5337 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7025:7027) (7026:7027)
                          imp:n=1 u=53 fill=32
c
c ------------ Stack 2 - NW, N, NE, SW ------------
5341 like 5111 but u=54  $ NW Rod
5342 like 5112 but u=54  $ N Rod
5343 like 5113 but u=54  $ NE Rod
5346 like 5116 but u=54  $ SW Rod
5347 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027)
                          (7026:7027) imp:n=1 u=54 fill=32
c
```

```
c ------------ Stack 2 - NW, N, NE, SE ------------
5351 like 5111 but u=55  $ NW Rod
5352 like 5112 but u=55  $ N Rod
5353 like 5113 but u=55  $ NE Rod
5354 like 5114 but u=55  $ SE Rod
5357 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          imp:n=1 u=55 fill=32
c
c ------------ Stack 3 - NE, SE ------------
5403 like 5123 but u=60  $ NE Rod
5404 like 5124 but u=60  $ SE Rod
5407 10 4.8413E-05  -6003 (7023:7027) (7024:7027) imp:n=1 u=60 fill=33
c
c ------------ Stack 3 - NE, SE, S ------------
5413 like 5123 but u=61  $ NE Rod
5414 like 5124 but u=61  $ SE Rod
5415 like 5125 but u=61  $ S Rod
5417 10 4.8413E-05  -6003 (7023:7027) (7024:7027)
                          (7025:7027) imp:n=1 u=61 fill=33
c
c ------------ Stack 3 - NE, SE, S, SW ------------
5423 like 5123 but u=62  $ NE Rod
5424 like 5124 but u=62  $ SE Rod
5425 like 5125 but u=62  $ S Rod
5426 like 5126 but u=62  $ SW Rod
5427 10 4.8413E-05  -6003 (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=62 fill=33
c
c ------------ Stack 3 - SE, S, SW ------------
5434 like 5124 but u=63  $ SE Rod
5435 like 5125 but u=63  $ S Rod
5436 like 5126 but u=63  $ SW Rod
5437 10 4.8413E-05  -6003 (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=63 fill=33
c
c ------------ Stack 3 - S, SW ------------
5445 like 5125 but u=64  $ S Rod
5446 like 5126 but u=64  $ SW Rod
5447 10 4.8413E-05  -6003 (7025:7027) (7026:7027) imp:n=1 u=64 fill=33
c
c ------------ Stack 3 - NW, SW ------------
5451 like 5121 but u=65  $ NW Rod
5456 like 5126 but u=65  $ SW Rod
5457 10 4.8413E-05  -6003 (7021:7027) (7026:7027) imp:n=1 u=65 fill=33
c
c ------------ Stack 3 - NW, N, SW ------------
5461 like 5121 but u=66  $ NW Rod
5462 like 5122 but u=66  $ N Rod
5466 like 5126 but u=66  $ SW Rod
5467 10 4.8413E-05  -6003 (7021:7027) (7022:7027)
                          (7026:7027) imp:n=1 u=66 fill=33
c
c ------------ Stack 3 - NW, N, NE, SW ------------
5471 like 5121 but u=67  $ NW Rod
5472 like 5122 but u=67  $ N Rod
5473 like 5123 but u=67  $ NE Rod
5476 like 5126 but u=67  $ SW Rod
5477 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027)
                          (7026:7027) imp:n=1 u=67 fill=33
c
c ------------ Stack 3 - NW, N, NE ------------
5481 like 5121 but u=68  $ NW Rod
5482 like 5122 but u=68  $ N Rod
5483 like 5123 but u=68  $ NE Rod
5487 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027)
                          imp:n=1 u=68 fill=33
c
c ------------ Stack 3 - N, NE ------------
5492 like 5122 but u=69  $ N Rod
5493 like 5123 but u=69  $ NE Rod
5497 10 4.8413E-05  -6003 (7022:7027) (7023:7027) imp:n=1 u=69 fill=33
c
c ------------ Stack 4 - NE, SE ------------
5503 like 5133 but u=70  $ NE Rod
5504 like 5134 but u=70  $ SE Rod
5507 10 4.8413E-05  -6003 (7023:7027) (7024:7027) imp:n=1 u=70 fill=34
```

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c
c ------------ Stack 4 - SE, S ------------
5514 like 5134 but u=71  $ SE Rod
5515 like 5135 but u=71  $ S Rod
5517 10 4.8413E-05  -6003 (7024:7027) (7025:7027) imp:n=1 u=71 fill=34
c
c ------------ Stack 4 - SE, S, SW ------------
5524 like 5134 but u=72  $ SE Rod
5525 like 5135 but u=72  $ S Rod
5526 like 5136 but u=72  $ SW Rod
5527 10 4.8413E-05  -6003 (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=72 fill=34
c
c ------------ Stack 4 - NW, SE, S, SW ------------
5531 like 5131 but u=73  $ NW Rod
5534 like 5134 but u=73  $ SE Rod
5535 like 5135 but u=73  $ S Rod
5536 like 5136 but u=73  $ SW Rod
5537 10 4.8413E-05  -6003 (7021:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=73 fill=34
c
c ------------ Stack 4 - NW, S, SW ------------
5541 like 5131 but u=74  $ NW Rod
5545 like 5135 but u=74  $ S Rod
5546 like 5136 but u=74  $ SW Rod
5547 10 4.8413E-05  -6003 (7021:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=74 fill=34
c
c ------------ Stack 4 - NW, SW ------------
5551 like 5131 but u=75  $ NW Rod
5556 like 5136 but u=75  $ SW Rod
5557 10 4.8413E-05  -6003 (7021:7027) (7026:7027) imp:n=1 u=75 fill=34
c
c ------------ Stack 4 - NW, N ------------
5561 like 5131 but u=76  $ NW Rod
5562 like 5132 but u=76  $ N Rod
5567 10 4.8413E-05  -6003 (7021:7027) (7022:7027) imp:n=1 u=76 fill=34
c
c ------------ Stack 4 - NW, N, NE ------------
5571 like 5131 but u=77  $ NW Rod
5572 like 5132 but u=77  $ N Rod
5573 like 5133 but u=77  $ NE Rod
5577 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027)
                          imp:n=1 u=77 fill=34
c
c ------------ Stack 4 - NW, N, NE, SE ------------
5581 like 5131 but u=78  $ NW Rod
5582 like 5132 but u=78  $ N Rod
5583 like 5133 but u=78  $ NE Rod
5584 like 5134 but u=78  $ SE Rod
5587 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          imp:n=1 u=78 fill=34
c
c ------------ Stack 4 - N, NE, SE ------------
5592 like 5132 but u=79  $ N Rod
5593 like 5133 but u=79  $ NE Rod
5594 like 5134 but u=79  $ SE Rod
5597 10 4.8413E-05  -6003 (7022:7027) (7023:7027) (7024:7027)
                          imp:n=1 u=79 fill=34
c
c ------ Core Arrangement -----------------------------------------------------
c --------- Core 9 Lattice Description ---------
7001 10 4.8413E-05  -6002 imp:n=1 u=100 lat=2 fill=-12:12 -12:12 0:0
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 29 30 29 30 29 30 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 27 28 27 28 27 28 27 28 27 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 29 30 29 30 29 30 29 30 29 30 29 30 26 26
      26 26 26 26 26 26 26 26 26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26
      26 26 26 26 26 26 26 26 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 26
      26 26 26 26 26 26 26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26
      26 26 26 26 26 26 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 26
      26 26 26 26 26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26
      26 26 26 26 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 26
      26 26 26 26 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 26 26
      26 26 26 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 26 26
c
```

```
      26 26 26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26 26 26
c
      26 26 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 26 26 26
      26 26 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 26 26 26 26
      26 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 26 26 26 26
      26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26 26 26 26 26
      26 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 26 26 26 26 26 26
      26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26 26 26 26 26 26 26
      26 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 26 26 26 26 26 26 26 26
      26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26 26 26 26 26 26 26 26 26
      26 26 30 29 30 29 30 29 30 29 30 29 30 29 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 27 28 27 28 27 28 27 28 27 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 30 29 30 29 30 29 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
c
c --------- Core 10 Lattice Description ---------
7002 10 4.8413E-05  -6002 imp:n=1 u=101 lat=2 fill=-12:12 -12:12 0:0
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 69 77 68 77 68 76 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 48 55 35 36 35 36 35 54 47 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 69 78 37 38 37 38 37 38 37 38 67 76 26 26
      26 26 26 26 26 26 26 26 26 48 55 35 36 35 36 35 36 35 36 35 36 35 54 47 26
      26 26 26 26 26 26 26 26 79 37 38 37 38 37 38 37 38 37 38 37 38 37 38 66 26
      26 26 26 26 26 26 26 49 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 46 26
      26 26 26 26 26 26 79 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 66 26
      26 26 26 26 26 49 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 46 26
      26 26 26 26 70 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 65 26
      26 26 26 26 50 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 53 26 26
      26 26 26 60 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 75 26 26
c
      26 26 26 40 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 45 26 26 26
c
      26 26 70 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 65 26 26 26
      26 26 50 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 53 26 26 26 26
      26 60 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 75 26 26 26 26
      26 41 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 44 26 26 26 26 26
      26 61 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 74 26 26 26 26 26 26
      26 41 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 44 26 26 26 26 26 26 26
      26 61 38 37 38 37 38 37 38 37 38 37 38 37 38 37 74 26 26 26 26 26 26 26 26
      26 42 51 35 36 35 36 35 36 35 36 35 36 35 52 43 26 26 26 26 26 26 26 26 26
      26 26 71 62 38 37 38 37 38 37 38 37 73 64 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 42 51 35 36 35 36 35 52 43 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 71 63 72 63 72 64 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
c
c --------- Pebble-Filled Core Cavity ---------
7101 10 4.8413E-05  -7001 -7002 -7003 imp:n=1 fill=100 (0 0 75) $ Core 9
c 7101 10 4.8413E-05  -7001 -7002 -7003 imp:n=1 fill=101 (0 0 75) $ Core 10
c
c --- Model Boundary -----------------------------------------------------------
9999  0  -31:1202:34 imp:n=0  $ The Great Void
c

c Surface Cards ****************************************************************
c --- Radial Reflector ---------------------------------------------------------
c ------ Graphite Annulus ------
31    pz      0.0   $ Bottom of Reflector
32    pz   330.4   $ Top of Reflector
33    cz    62.83398  $ Inside Radial Equivalent-Area Cavity Surface
34    cz   163.76986  $ Outside Radial Equivalent-Area Surface
c
c ------ Safety/Shutdown Rod Holes ------
1101  c/z  -38.45  56.57  2.25  $ Rod 1
1102  c/z   32.74 -60.05  2.25  $ Rod 2
1103  c/z   57.17  37.55  2.25  $ Rod 3
1104  c/z  -53.23 -42.95  2.25  $ Rod 4
1105  c/z   67.19 -12.82  2.25  $ Rod 5
1106  c/z  -66.98  13.87  2.25  $ Rod 6
1107  c/z   19.31  65.62  2.25  $ Rod 7
1108  c/z  -13.87 -66.98  2.25  $ Rod 8
c
c ------ Withdrawable Control Rod Holes ------
503   c/z  -83.70  34.67  1.3715  $ Position 3 Hole
519   c/z   34.67  83.70  1.3715  $ Position 19 Hole
535   c/z   83.70 -34.67  1.3715  $ Position 35 Hole
551   c/z  -34.67 -83.70  1.3715  $ Position 51 Hole
```

```
1003  c/z  -83.70  34.67  1.325  $ Position 3 Plug
1019  c/z   34.67  83.70  1.325  $ Position 19 Plug
1035  c/z   83.70 -34.67  1.325  $ Position 35 Plug
1051  c/z  -34.67 -83.70  1.325  $ Position 51 Plug
c
c ------ Autorod Hole ------
1113  c/z   17.36 -87.29  2.75
c
c --- Upper Axial Reflector ---------------------------------------------------
c ------ Central Cylinder ------
1201  pz   267.3     $ Bottom of Graphite
1202  pz   345.3     $ Top of Graphite
1203  cz     1.3715  $ Central Coolant Channel
1204  cz    19.7     $ Outer Radius
c
c ------ Graphite Annulus ------
1211  cz    20.93    $ Inner Radius
1212  cz    61.7     $ Outer Radius
c
c ------ Air Gaps ------
1221  cz    19.8     $ Outside of Central Cylinder
1222  cz    20.5     $ Inside of Annulus
1223  cz    61.8     $ Outside of Annulus
c
c ------ Coolant Channels ------
c --------- Ring 1 ---------
1301  c/z  -29.86   2.94  1.3715  $ Position 1
1302  c/z  -28.71   8.71  1.3715  $ Position 2
1303  c/z  -26.46  14.14  1.3715  $ Position 3
1304  c/z  -23.19  19.03  1.3715  $ Position 4
1305  c/z  -19.03  23.19  1.3715  $ Position 5
1306  c/z  -14.14  26.46  1.3715  $ Position 6
1307  c/z   -8.71  28.71  1.3715  $ Position 7
1308  c/z   -2.94  29.86  1.3715  $ Position 8
1309  c/z    2.94  29.86  1.3715  $ Position 9
1310  c/z    8.71  28.71  1.3715  $ Position 10
1311  c/z   14.14  26.46  1.3715  $ Position 11
1312  c/z   19.03  23.19  1.3715  $ Position 12
1313  c/z   23.19  19.03  1.3715  $ Position 13
1314  c/z   26.46  14.14  1.3715  $ Position 14
1315  c/z   28.71   8.71  1.3715  $ Position 15
1316  c/z   29.86   2.94  1.3715  $ Position 16
1317  c/z   29.86  -2.94  1.3715  $ Position 17
1318  c/z   28.71  -8.71  1.3715  $ Position 18
1319  c/z   26.46 -14.14  1.3715  $ Position 19
1320  c/z   23.19 -19.03  1.3715  $ Position 20
1321  c/z   19.03 -23.19  1.3715  $ Position 21
1322  c/z   14.14 -26.46  1.3715  $ Position 22
1323  c/z    8.71 -28.71  1.3715  $ Position 23
1324  c/z    2.94 -29.86  1.3715  $ Position 24
1325  c/z   -2.94 -29.86  1.3715  $ Position 25
1326  c/z   -8.71 -28.71  1.3715  $ Position 26
1327  c/z  -14.14 -26.46  1.3715  $ Position 27
1328  c/z  -19.03 -23.19  1.3715  $ Position 28
1329  c/z  -23.19 -19.03  1.3715  $ Position 29
1330  c/z  -26.46 -14.14  1.3715  $ Position 30
1331  c/z  -28.71  -8.71  1.3715  $ Position 31
1332  c/z  -29.86  -2.94  1.3715  $ Position 32
c
1333  cz    32.75  $ Ring Divider for Modeling Simplification
c
c --------- Ring 2 ---------
1401  c/z  -34.82   6.93  1.3715  $ Position 1
1402  c/z  -32.80  13.59  1.3715  $ Position 2
1403  c/z  -29.52  19.72  1.3715  $ Position 3
1404  c/z  -25.10  25.10  1.3715  $ Position 4
1405  c/z  -19.72  29.52  1.3715  $ Position 5
1406  c/z  -13.59  32.80  1.3715  $ Position 6
1407  c/z   -6.93  34.82  1.3715  $ Position 7
1408  c/z    0.00  35.50  1.3715  $ Position 8
1409  c/z    6.93  34.82  1.3715  $ Position 9
1410  c/z   13.59  32.80  1.3715  $ Position 10
1411  c/z   19.72  29.52  1.3715  $ Position 11
1412  c/z   25.10  25.10  1.3715  $ Position 12
1413  c/z   29.52  19.72  1.3715  $ Position 13
1414  c/z   32.80  13.59  1.3715  $ Position 14
```

```
1415  c/z   34.82   6.93  1.3715  $ Position 15
1416  c/z   35.50   0.00  1.3715  $ Position 16
1417  c/z   34.82  -6.93  1.3715  $ Position 17
1418  c/z   32.80 -13.59  1.3715  $ Position 18
1419  c/z   29.52 -19.72  1.3715  $ Position 19
1420  c/z   25.10 -25.10  1.3715  $ Position 20
1421  c/z   19.72 -29.52  1.3715  $ Position 21
1422  c/z   13.59 -32.80  1.3715  $ Position 22
1423  c/z    6.93 -34.82  1.3715  $ Position 23
1424  c/z    0.00 -35.50  1.3715  $ Position 24
1425  c/z   -6.93 -34.82  1.3715  $ Position 25
1426  c/z  -13.59 -32.80  1.3715  $ Position 26
1427  c/z  -19.72 -29.52  1.3715  $ Position 27
1428  c/z  -25.10 -25.10  1.3715  $ Position 28
1429  c/z  -29.52 -19.72  1.3715  $ Position 29
1430  c/z  -32.80 -13.59  1.3715  $ Position 30
1431  c/z  -34.82  -6.93  1.3715  $ Position 31
1432  c/z  -35.50   0.00  1.3715  $ Position 32
c
1433  cz    38.25  $ Ring Divider for Modeling Simplification
c
c --------- Ring 3 ---------
1501  c/z  -39.23  11.90  1.3715  $ Position 1
1502  c/z  -36.16  19.33  1.3715  $ Position 2
1503  c/z  -31.69  26.01  1.3715  $ Position 3
1504  c/z  -26.01  31.69  1.3715  $ Position 4
1505  c/z  -19.33  36.16  1.3715  $ Position 5
1506  c/z  -11.90  39.23  1.3715  $ Position 6
1507  c/z   -4.02  40.80  1.3715  $ Position 7
1508  c/z    4.02  40.80  1.3715  $ Position 8
1509  c/z   11.90  39.23  1.3715  $ Position 9
1510  c/z   19.33  36.16  1.3715  $ Position 10
1511  c/z   26.01  31.69  1.3715  $ Position 11
1512  c/z   31.69  26.01  1.3715  $ Position 12
1513  c/z   36.16  19.33  1.3715  $ Position 13
1514  c/z   39.23  11.90  1.3715  $ Position 14
1515  c/z   40.80   4.02  1.3715  $ Position 15
1516  c/z   40.80  -4.02  1.3715  $ Position 16
1517  c/z   39.23 -11.90  1.3715  $ Position 17
1518  c/z   36.16 -19.33  1.3715  $ Position 18
1519  c/z   31.69 -26.01  1.3715  $ Position 19
1520  c/z   26.01 -31.69  1.3715  $ Position 20
1521  c/z   19.33 -36.16  1.3715  $ Position 21
1522  c/z   11.90 -39.23  1.3715  $ Position 22
1523  c/z    4.02 -40.80  1.3715  $ Position 23
1524  c/z   -4.02 -40.80  1.3715  $ Position 24
1525  c/z  -11.90 -39.23  1.3715  $ Position 25
1526  c/z  -19.33 -36.16  1.3715  $ Position 26
1527  c/z  -26.01 -31.69  1.3715  $ Position 27
1528  c/z  -31.69 -26.01  1.3715  $ Position 28
1529  c/z  -36.16 -19.33  1.3715  $ Position 29
1530  c/z  -39.23 -11.90  1.3715  $ Position 30
1531  c/z  -40.80  -4.02  1.3715  $ Position 31
1532  c/z  -40.80   4.02  1.3715  $ Position 32
c
1533  cz    43.625  $ Ring Divider for Modeling Simplification
c
c --------- Ring 4 ---------
1601  c/z  -42.73  17.70  1.3715  $ Position 1
1602  c/z  -38.46  25.70  1.3715  $ Position 2
1603  c/z  -32.70  32.70  1.3715  $ Position 3
1604  c/z  -25.70  38.46  1.3715  $ Position 4
1605  c/z  -17.70  42.73  1.3715  $ Position 5
1606  c/z   -9.02  45.36  1.3715  $ Position 6
1607  c/z    0.00  46.25  1.3715  $ Position 7
1608  c/z    9.02  45.36  1.3715  $ Position 8
1609  c/z   17.70  42.73  1.3715  $ Position 9
1610  c/z   25.70  38.46  1.3715  $ Position 10
1611  c/z   32.70  32.70  1.3715  $ Position 11
1612  c/z   38.46  25.70  1.3715  $ Position 12
1613  c/z   42.73  17.70  1.3715  $ Position 13
1614  c/z   45.36   9.02  1.3715  $ Position 14
1615  c/z   46.25   0.00  1.3715  $ Position 15
1616  c/z   45.36  -9.02  1.3715  $ Position 16
1617  c/z   42.73 -17.70  1.3715  $ Position 17
1618  c/z   38.46 -25.70  1.3715  $ Position 18
```

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1619  c/z   32.70 -32.70  1.3715  $ Position 19
1620  c/z   25.70 -38.46  1.3715  $ Position 20
1621  c/z   17.70 -42.73  1.3715  $ Position 21
1622  c/z    9.02 -45.36  1.3715  $ Position 22
1623  c/z    0.00 -46.25  1.3715  $ Position 23
1624  c/z   -9.02 -45.36  1.3715  $ Position 24
1625  c/z  -17.70 -42.73  1.3715  $ Position 25
1626  c/z  -25.70 -38.46  1.3715  $ Position 26
1627  c/z  -32.70 -32.70  1.3715  $ Position 27
1628  c/z  -38.46 -25.70  1.3715  $ Position 28
1629  c/z  -42.73 -17.70  1.3715  $ Position 29
1630  c/z  -45.36  -9.02  1.3715  $ Position 30
1631  c/z  -46.25   0.00  1.3715  $ Position 31
1632  c/z  -45.36   9.02  1.3715  $ Position 32
c
1633  cz    48.875  $ Ring Divider for Modeling Simplification
c
c --------- Ring 5 ---------
1701  c/z  -45.42  24.28  1.3715  $ Position 1
1702  c/z  -39.81  32.67  1.3715  $ Position 2
1703  c/z  -32.67  39.81  1.3715  $ Position 3
1704  c/z  -24.28  45.42  1.3715  $ Position 4
1705  c/z  -14.95  49.28  1.3715  $ Position 5
1706  c/z   -5.05  51.25  1.3715  $ Position 6
1707  c/z    5.05  51.25  1.3715  $ Position 7
1708  c/z   14.95  49.28  1.3715  $ Position 8
1709  c/z   24.28  45.42  1.3715  $ Position 9
1710  c/z   32.67  39.81  1.3715  $ Position 10
1711  c/z   39.81  32.67  1.3715  $ Position 11
1712  c/z   45.42  24.28  1.3715  $ Position 12
1713  c/z   49.28  14.95  1.3715  $ Position 13
1714  c/z   51.25   5.05  1.3715  $ Position 14
1715  c/z   51.25  -5.05  1.3715  $ Position 15
1716  c/z   49.28 -14.95  1.3715  $ Position 16
1717  c/z   45.42 -24.28  1.3715  $ Position 17
1718  c/z   39.81 -32.67  1.3715  $ Position 18
1719  c/z   32.67 -39.81  1.3715  $ Position 19
1720  c/z   24.28 -45.42  1.3715  $ Position 20
1721  c/z   14.95 -49.28  1.3715  $ Position 21
1722  c/z    5.05 -51.25  1.3715  $ Position 22
1723  c/z   -5.05 -51.25  1.3715  $ Position 23
1724  c/z  -14.95 -49.28  1.3715  $ Position 24
1725  c/z  -24.28 -45.42  1.3715  $ Position 25
1726  c/z  -32.67 -39.81  1.3715  $ Position 26
1727  c/z  -39.81 -32.67  1.3715  $ Position 27
1728  c/z  -45.42 -24.28  1.3715  $ Position 28
1729  c/z  -49.28 -14.95  1.3715  $ Position 29
1730  c/z  -51.25  -5.05  1.3715  $ Position 30
1731  c/z  -51.25   5.05  1.3715  $ Position 31
1732  c/z  -49.28  14.95  1.3715  $ Position 32
c
c ------ Aluminum Tank ------
1801  pz   266.3             $ Bottom of Aluminum
1802  cz    62.1             $ Outer Radius
c
c --- Lower Axial Reflector ---------------------------------------------------
c ------ Inner Cylinder ------
1811  pz    78.0   $ Inside Bottom of Cavity
1812  cz    24.75  $ Outer Radius
c
c ------ Graphite Plug ------
1821  pz    25.0
1823  cz     6.0
c
c ------ Graphite Annulus ------
1831  cz    25.05171  $ Inner Radial Equivalent-Area Surface
1832  cz    62.71754  $ Outer Radial Equivalent-Area Surface
c
c ------ Coolant Channels ------
c --------- Ring 1 ---------
1901  c/z  -29.86   2.94  1.371  $ Position 1
1902  c/z  -28.71   8.71  1.371  $ Position 2
1903  c/z  -26.46  14.14  1.371  $ Position 3
1904  c/z  -23.19  19.03  1.371  $ Position 4
1905  c/z  -19.03  23.19  1.371  $ Position 5
1906  c/z  -14.14  26.46  1.371  $ Position 6
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1907  c/z   -8.71  28.71  1.371  $ Position 7
1908  c/z   -2.94  29.86  1.371  $ Position 8
1909  c/z    2.94  29.86  1.371  $ Position 9
1910  c/z    8.71  28.71  1.371  $ Position 10
1911  c/z   14.14  26.46  1.371  $ Position 11
1912  c/z   19.03  23.19  1.371  $ Position 12
1913  c/z   23.19  19.03  1.371  $ Position 13
1914  c/z   26.46  14.14  1.371  $ Position 14
1915  c/z   28.71   8.71  1.371  $ Position 15
1916  c/z   29.86   2.94  1.371  $ Position 16
1917  c/z   29.86  -2.94  1.371  $ Position 17
1918  c/z   28.71  -8.71  1.371  $ Position 18
1919  c/z   26.46 -14.14  1.371  $ Position 19
1920  c/z   23.19 -19.03  1.371  $ Position 20
1921  c/z   19.03 -23.19  1.371  $ Position 21
1922  c/z   14.14 -26.46  1.371  $ Position 22
1923  c/z    8.71 -28.71  1.371  $ Position 23
1924  c/z    2.94 -29.86  1.371  $ Position 24
1925  c/z   -2.94 -29.86  1.371  $ Position 25
1926  c/z   -8.71 -28.71  1.371  $ Position 26
1927  c/z  -14.14 -26.46  1.371  $ Position 27
1928  c/z  -19.03 -23.19  1.371  $ Position 28
1929  c/z  -23.19 -19.03  1.371  $ Position 29
1930  c/z  -26.46 -14.14  1.371  $ Position 30
1931  c/z  -28.71 -8.71   1.371  $ Position 31
1932  c/z  -29.86 -2.94   1.371  $ Position 32
c
c --------- Ring 2 ---------
2001  c/z  -34.82   6.93  1.371  $ Position 1
2002  c/z  -32.80  13.59  1.371  $ Position 2
2003  c/z  -29.52  19.72  1.371  $ Position 3
2004  c/z  -25.10  25.10  1.371  $ Position 4
2005  c/z  -19.72  29.52  1.371  $ Position 5
2006  c/z  -13.59  32.80  1.371  $ Position 6
2007  c/z   -6.93  34.82  1.371  $ Position 7
2008  c/z    0.00  35.50  1.371  $ Position 8
2009  c/z    6.93  34.82  1.371  $ Position 9
2010  c/z   13.59  32.80  1.371  $ Position 10
2011  c/z   19.72  29.52  1.371  $ Position 11
2012  c/z   25.10  25.10  1.371  $ Position 12
2013  c/z   29.52  19.72  1.371  $ Position 13
2014  c/z   32.80  13.59  1.371  $ Position 14
2015  c/z   34.82   6.93  1.371  $ Position 15
2016  c/z   35.50   0.00  1.371  $ Position 16
2017  c/z   34.82  -6.93  1.371  $ Position 17
2018  c/z   32.80 -13.59  1.371  $ Position 18
2019  c/z   29.52 -19.72  1.371  $ Position 19
2020  c/z   25.10 -25.10  1.371  $ Position 20
2021  c/z   19.72 -29.52  1.371  $ Position 21
2022  c/z   13.59 -32.80  1.371  $ Position 22
2023  c/z    6.93 -34.82  1.371  $ Position 23
2024  c/z    0.00 -35.50  1.371  $ Position 24
2025  c/z   -6.93 -34.82  1.371  $ Position 25
2026  c/z  -13.59 -32.80  1.371  $ Position 26
2027  c/z  -19.72 -29.52  1.371  $ Position 27
2028  c/z  -25.10 -25.10  1.371  $ Position 28
2029  c/z  -29.52 -19.72  1.371  $ Position 29
2030  c/z  -32.80 -13.59  1.371  $ Position 30
2031  c/z  -34.82  -6.93  1.371  $ Position 31
2032  c/z  -35.50   0.00  1.371  $ Position 32
c
c --------- Ring 3 ---------
2101  c/z  -39.23  11.90  1.371  $ Position 1
2102  c/z  -36.16  19.33  1.371  $ Position 2
2103  c/z  -31.69  26.01  1.371  $ Position 3
2104  c/z  -26.01  31.69  1.371  $ Position 4
2105  c/z  -19.33  36.16  1.371  $ Position 5
2106  c/z  -11.90  39.23  1.371  $ Position 6
2107  c/z   -4.02  40.80  1.371  $ Position 7
2108  c/z    4.02  40.80  1.371  $ Position 8
2109  c/z   11.90  39.23  1.371  $ Position 9
2110  c/z   19.33  36.16  1.371  $ Position 10
2111  c/z   26.01  31.69  1.371  $ Position 11
2112  c/z   31.69  26.01  1.371  $ Position 12
2113  c/z   36.16  19.33  1.371  $ Position 13
2114  c/z   39.23  11.90  1.371  $ Position 14
```

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2115  c/z   40.80   4.02  1.371  $ Position 15
2116  c/z   40.80  -4.02  1.371  $ Position 16
2117  c/z   39.23 -11.90  1.371  $ Position 17
2118  c/z   36.16 -19.33  1.371  $ Position 18
2119  c/z   31.69 -26.01  1.371  $ Position 19
2120  c/z   26.01 -31.69  1.371  $ Position 20
2121  c/z   19.33 -36.16  1.371  $ Position 21
2122  c/z   11.90 -39.23  1.371  $ Position 22
2123  c/z    4.02 -40.80  1.371  $ Position 23
2124  c/z   -4.02 -40.80  1.371  $ Position 24
2125  c/z  -11.90 -39.23  1.371  $ Position 25
2126  c/z  -19.33 -36.16  1.371  $ Position 26
2127  c/z  -26.01 -31.69  1.371  $ Position 27
2128  c/z  -31.69 -26.01  1.371  $ Position 28
2129  c/z  -36.16 -19.33  1.371  $ Position 29
2130  c/z  -39.23 -11.90  1.371  $ Position 30
2131  c/z  -40.80  -4.02  1.371  $ Position 31
2132  c/z  -40.80   4.02  1.371  $ Position 32
c
c --------- Ring 4 ---------
2201  c/z  -42.73  17.70  1.371  $ Position 1
2202  c/z  -38.46  25.70  1.371  $ Position 2
2203  c/z  -32.70  32.70  1.371  $ Position 3
2204  c/z  -25.70  38.46  1.371  $ Position 4
2205  c/z  -17.70  42.73  1.371  $ Position 5
2206  c/z   -9.02  45.36  1.371  $ Position 6
2207  c/z    0.00  46.25  1.371  $ Position 7
2208  c/z    9.02  45.36  1.371  $ Position 8
2209  c/z   17.70  42.73  1.371  $ Position 9
2210  c/z   25.70  38.46  1.371  $ Position 10
2211  c/z   32.70  32.70  1.371  $ Position 11
2212  c/z   38.46  25.70  1.371  $ Position 12
2213  c/z   42.73  17.70  1.371  $ Position 13
2214  c/z   45.36   9.02  1.371  $ Position 14
2215  c/z   46.25   0.00  1.371  $ Position 15
2216  c/z   45.36  -9.02  1.371  $ Position 16
2217  c/z   42.73 -17.70  1.371  $ Position 17
2218  c/z   38.46 -25.70  1.371  $ Position 18
2219  c/z   32.70 -32.70  1.371  $ Position 19
2220  c/z   25.70 -38.46  1.371  $ Position 20
2221  c/z   17.70 -42.73  1.371  $ Position 21
2222  c/z    9.02 -45.36  1.371  $ Position 22
2223  c/z    0.00 -46.25  1.371  $ Position 23
2224  c/z   -9.02 -45.36  1.371  $ Position 24
2225  c/z  -17.70 -42.73  1.371  $ Position 25
2226  c/z  -25.70 -38.46  1.371  $ Position 26
2227  c/z  -32.70 -32.70  1.371  $ Position 27
2228  c/z  -38.46 -25.70  1.371  $ Position 28
2229  c/z  -42.73 -17.70  1.371  $ Position 29
2230  c/z  -45.36  -9.02  1.371  $ Position 30
2231  c/z  -46.25   0.00  1.371  $ Position 31
2232  c/z  -45.36   9.02  1.371  $ Position 32
c
c --------- Ring 5 ---------
2301  c/z  -45.42  24.28  1.371  $ Position 1
2302  c/z  -39.81  32.67  1.371  $ Position 2
2303  c/z  -32.67  39.81  1.371  $ Position 3
2304  c/z  -24.28  45.42  1.371  $ Position 4
2305  c/z  -14.95  49.28  1.371  $ Position 5
2306  c/z   -5.05  51.25  1.371  $ Position 6
2307  c/z    5.05  51.25  1.371  $ Position 7
2308  c/z   14.95  49.28  1.371  $ Position 8
2309  c/z   24.28  45.42  1.371  $ Position 9
2310  c/z   32.67  39.81  1.371  $ Position 10
2311  c/z   39.81  32.67  1.371  $ Position 11
2312  c/z   45.42  24.28  1.371  $ Position 12
2313  c/z   49.28  14.95  1.371  $ Position 13
2314  c/z   51.25   5.05  1.371  $ Position 14
2315  c/z   51.25  -5.05  1.371  $ Position 15
2316  c/z   49.28 -14.95  1.371  $ Position 16
2317  c/z   45.42 -24.28  1.371  $ Position 17
2318  c/z   39.81 -32.67  1.371  $ Position 18
2319  c/z   32.67 -39.81  1.371  $ Position 19
2320  c/z   24.28 -45.42  1.371  $ Position 20
2321  c/z   14.95 -49.28  1.371  $ Position 21
2322  c/z    5.05 -51.25  1.371  $ Position 22
```

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2323  c/z   -5.05 -51.25  1.371  $ Position 23
2324  c/z  -14.95 -49.28  1.371  $ Position 24
2325  c/z  -24.28 -45.42  1.371  $ Position 25
2326  c/z  -32.67 -39.81  1.371  $ Position 26
2327  c/z  -39.81 -32.67  1.371  $ Position 27
2328  c/z  -45.42 -24.28  1.371  $ Position 28
2329  c/z  -49.28 -14.95  1.371  $ Position 29
2330  c/z  -51.25  -5.05  1.371  $ Position 30
2331  c/z  -51.25   5.05  1.371  $ Position 31
2332  c/z  -49.28  14.95  1.371  $ Position 32
c
c ------ Graphite Plugs ------
c --------- Ring 1 ---------
2401  c/z  -29.86   2.94  1.325  $ Position 1
2402  c/z  -28.71   8.71  1.325  $ Position 2
2403  c/z  -26.46  14.14  1.325  $ Position 3
2404  c/z  -23.19  19.03  1.325  $ Position 4
2405  c/z  -19.03  23.19  1.325  $ Position 5
2406  c/z  -14.14  26.46  1.325  $ Position 6
2407  c/z   -8.71  28.71  1.325  $ Position 7
2408  c/z   -2.94  29.86  1.325  $ Position 8
2409  c/z    2.94  29.86  1.325  $ Position 9
2410  c/z    8.71  28.71  1.325  $ Position 10
2411  c/z   14.14  26.46  1.325  $ Position 11
2412  c/z   19.03  23.19  1.325  $ Position 12
2413  c/z   23.19  19.03  1.325  $ Position 13
2414  c/z   26.46  14.14  1.325  $ Position 14
2415  c/z   28.71   8.71  1.325  $ Position 15
2416  c/z   29.86   2.94  1.325  $ Position 16
2417  c/z   29.86  -2.94  1.325  $ Position 17
2418  c/z   28.71  -8.71  1.325  $ Position 18
2419  c/z   26.46 -14.14  1.325  $ Position 19
2420  c/z   23.19 -19.03  1.325  $ Position 20
2421  c/z   19.03 -23.19  1.325  $ Position 21
2422  c/z   14.14 -26.46  1.325  $ Position 22
2423  c/z    8.71 -28.71  1.325  $ Position 23
2424  c/z    2.94 -29.86  1.325  $ Position 24
2425  c/z   -2.94 -29.86  1.325  $ Position 25
2426  c/z   -8.71 -28.71  1.325  $ Position 26
2427  c/z  -14.14 -26.46  1.325  $ Position 27
2428  c/z  -19.03 -23.19  1.325  $ Position 28
2429  c/z  -23.19 -19.03  1.325  $ Position 29
2430  c/z  -26.46 -14.14  1.325  $ Position 30
2431  c/z  -28.71  -8.71  1.325  $ Position 31
2432  c/z  -29.86  -2.94  1.325  $ Position 32
c
c --------- Ring 2 ---------
2501  c/z  -34.82   6.93  1.325  $ Position 1
2502  c/z  -32.80  13.59  1.325  $ Position 2
2503  c/z  -29.52  19.72  1.325  $ Position 3
2504  c/z  -25.10  25.10  1.325  $ Position 4
2505  c/z  -19.72  29.52  1.325  $ Position 5
2506  c/z  -13.59  32.80  1.325  $ Position 6
2507  c/z   -6.93  34.82  1.325  $ Position 7
2508  c/z    0.00  35.50  1.325  $ Position 8
2509  c/z    6.93  34.82  1.325  $ Position 9
2510  c/z   13.59  32.80  1.325  $ Position 10
2511  c/z   19.72  29.52  1.325  $ Position 11
2512  c/z   25.10  25.10  1.325  $ Position 12
2513  c/z   29.52  19.72  1.325  $ Position 13
2514  c/z   32.80  13.59  1.325  $ Position 14
2515  c/z   34.82   6.93  1.325  $ Position 15
2516  c/z   35.50   0.00  1.325  $ Position 16
2517  c/z   34.82  -6.93  1.325  $ Position 17
2518  c/z   32.80 -13.59  1.325  $ Position 18
2519  c/z   29.52 -19.72  1.325  $ Position 19
2520  c/z   25.10 -25.10  1.325  $ Position 20
2521  c/z   19.72 -29.52  1.325  $ Position 21
2522  c/z   13.59 -32.80  1.325  $ Position 22
2523  c/z    6.93 -34.82  1.325  $ Position 23
2524  c/z    0.00 -35.50  1.325  $ Position 24
2525  c/z   -6.93 -34.82  1.325  $ Position 25
2526  c/z  -13.59 -32.80  1.325  $ Position 26
2527  c/z  -19.72 -29.52  1.325  $ Position 27
2528  c/z  -25.10 -25.10  1.325  $ Position 28
2529  c/z  -29.52 -19.72  1.325  $ Position 29
```

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2530  c/z  -32.80 -13.59  1.325  $ Position 30
2531  c/z  -34.82  -6.93  1.325  $ Position 31
2532  c/z  -35.50   0.00  1.325  $ Position 32
c
c --------- Ring 3 ---------
2601  c/z  -39.23  11.90  1.325  $ Position 1
2602  c/z  -36.16  19.33  1.325  $ Position 2
2603  c/z  -31.69  26.01  1.325  $ Position 3
2604  c/z  -26.01  31.69  1.325  $ Position 4
2605  c/z  -19.33  36.16  1.325  $ Position 5
2606  c/z  -11.90  39.23  1.325  $ Position 6
2607  c/z   -4.02  40.80  1.325  $ Position 7
2608  c/z    4.02  40.80  1.325  $ Position 8
2609  c/z   11.90  39.23  1.325  $ Position 9
2610  c/z   19.33  36.16  1.325  $ Position 10
2611  c/z   26.01  31.69  1.325  $ Position 11
2612  c/z   31.69  26.01  1.325  $ Position 12
2613  c/z   36.16  19.33  1.325  $ Position 13
2614  c/z   39.23  11.90  1.325  $ Position 14
2615  c/z   40.80   4.02  1.325  $ Position 15
2616  c/z   40.80  -4.02  1.325  $ Position 16
2617  c/z   39.23 -11.90  1.325  $ Position 17
2618  c/z   36.16 -19.33  1.325  $ Position 18
2619  c/z   31.69 -26.01  1.325  $ Position 19
2620  c/z   26.01 -31.69  1.325  $ Position 20
2621  c/z   19.33 -36.16  1.325  $ Position 21
2622  c/z   11.90 -39.23  1.325  $ Position 22
2623  c/z    4.02 -40.80  1.325  $ Position 23
2624  c/z   -4.02 -40.80  1.325  $ Position 24
2625  c/z  -11.90 -39.23  1.325  $ Position 25
2626  c/z  -19.33 -36.16  1.325  $ Position 26
2627  c/z  -26.01 -31.69  1.325  $ Position 27
2628  c/z  -31.69 -26.01  1.325  $ Position 28
2629  c/z  -36.16 -19.33  1.325  $ Position 29
2630  c/z  -39.23 -11.90  1.325  $ Position 30
2631  c/z  -40.80  -4.02  1.325  $ Position 31
2632  c/z  -40.80   4.02  1.325  $ Position 32
c
c --------- Ring 4 ---------
2701  c/z  -42.73  17.70  1.325  $ Position 1
2702  c/z  -38.46  25.70  1.325  $ Position 2
2703  c/z  -32.70  32.70  1.325  $ Position 3
2704  c/z  -25.70  38.46  1.325  $ Position 4
2705  c/z  -17.70  42.73  1.325  $ Position 5
2706  c/z   -9.02  45.36  1.325  $ Position 6
2707  c/z    0.00  46.25  1.325  $ Position 7
2708  c/z    9.02  45.36  1.325  $ Position 8
2709  c/z   17.70  42.73  1.325  $ Position 9
2710  c/z   25.70  38.46  1.325  $ Position 10
2711  c/z   32.70  32.70  1.325  $ Position 11
2712  c/z   38.46  25.70  1.325  $ Position 12
2713  c/z   42.73  17.70  1.325  $ Position 13
2714  c/z   45.36   9.02  1.325  $ Position 14
2715  c/z   46.25   0.00  1.325  $ Position 15
2716  c/z   45.36  -9.02  1.325  $ Position 16
2717  c/z   42.73 -17.70  1.325  $ Position 17
2718  c/z   38.46 -25.70  1.325  $ Position 18
2719  c/z   32.70 -32.70  1.325  $ Position 19
2720  c/z   25.70 -38.46  1.325  $ Position 20
2721  c/z   17.70 -42.73  1.325  $ Position 21
2722  c/z    9.02 -45.36  1.325  $ Position 22
2723  c/z    0.00 -46.25  1.325  $ Position 23
2724  c/z   -9.02 -45.36  1.325  $ Position 24
2725  c/z  -17.70 -42.73  1.325  $ Position 25
2726  c/z  -25.70 -38.46  1.325  $ Position 26
2727  c/z  -32.70 -32.70  1.325  $ Position 27
2728  c/z  -38.46 -25.70  1.325  $ Position 28
2729  c/z  -42.73 -17.70  1.325  $ Position 29
2730  c/z  -45.36  -9.02  1.325  $ Position 30
2731  c/z  -46.25   0.00  1.325  $ Position 31
2732  c/z  -45.36   9.02  1.325  $ Position 32
c
c --------- Ring 5 ---------
2801  c/z  -45.42  24.28  1.325  $ Position 1
2802  c/z  -39.81  32.67  1.325  $ Position 2
2803  c/z  -32.67  39.81  1.325  $ Position 3
```

```
2804  c/z  -24.28  45.42  1.325  $ Position 4
2805  c/z  -14.95  49.28  1.325  $ Position 5
2806  c/z   -5.05  51.25  1.325  $ Position 6
2807  c/z    5.05  51.25  1.325  $ Position 7
2808  c/z   14.95  49.28  1.325  $ Position 8
2809  c/z   24.28  45.42  1.325  $ Position 9
2810  c/z   32.67  39.81  1.325  $ Position 10
2811  c/z   39.81  32.67  1.325  $ Position 11
2812  c/z   45.42  24.28  1.325  $ Position 12
2813  c/z   49.28  14.95  1.325  $ Position 13
2814  c/z   51.25   5.05  1.325  $ Position 14
2815  c/z   51.25  -5.05  1.325  $ Position 15
2816  c/z   49.28 -14.95  1.325  $ Position 16
2817  c/z   45.42 -24.28  1.325  $ Position 17
2818  c/z   39.81 -32.67  1.325  $ Position 18
2819  c/z   32.67 -39.81  1.325  $ Position 19
2820  c/z   24.28 -45.42  1.325  $ Position 20
2821  c/z   14.95 -49.28  1.325  $ Position 21
2822  c/z    5.05 -51.25  1.325  $ Position 22
2823  c/z   -5.05 -51.25  1.325  $ Position 23
2824  c/z  -14.95 -49.28  1.325  $ Position 24
2825  c/z  -24.28 -45.42  1.325  $ Position 25
2826  c/z  -32.67 -39.81  1.325  $ Position 26
2827  c/z  -39.81 -32.67  1.325  $ Position 27
2828  c/z  -45.42 -24.28  1.325  $ Position 28
2829  c/z  -49.28 -14.95  1.325  $ Position 29
2830  c/z  -51.25  -5.05  1.325  $ Position 30
2831  c/z  -51.25   5.05  1.325  $ Position 31
2832  c/z  -49.28  14.95  1.325  $ Position 32
c
c --- Control Rods -------------------------------------------------------------
c ------ Safety/Shutdown Rods ------
3001  pz   33.1   $ Bottom of Steel Tube
3002  pz   43.0   $ Bottom of Borated Steel Rods
3003  pz  253.0   $ Top of Borated Steel Rods
3004  pz  254.2   $ Top of Steel Tube
3005  cz    1.75  $ Borated Steel Rod Radius
3006  cz    1.8   $ Steel Tube Inner Radius
3007  cz    2.0   $ Steel Tube Outer Radius
c
3011  pz    0.2   $ Bottom Aluminum End Plug
3012  pz   28.25  $ Bottom of Aluminum Shock Damper
3013  pz   28.45  $ Top Aluminum End Plug
3014  cz    1.45  $ Aluminum Tube Inner Radius
3015  cz    2.001 $ Aluminum Tube Outer Radius
c    *Steel Shock Damper Below Reflector Not Modeled
c
c ------ Autorod ------
3031  px   -0.15  $ Coreside Copper Plate Face
3032  px    0.15  $ Farside Copper Plate Face
3033  pz  222.5   $ Top Surface of Plate
3034  p    -0.15 0 -7.5  0.15 0 -7.5  -0.15 -1.95 222.5 $ Angled Plate Surface
3035  p    -0.15 0 -7.5  0.15 0 -7.5  -0.15 1.95 222.5  $ Angled Plate Surface
3036  cz    2     $ Aluminum Tube Inner Radius
3037  cz    2.2   $ Aluminum Tube Outer Radius
c
c ------ Withdrawable Control Rods ------
3081  pz   75.5    $ Bottom of Bottom End Plug
3082  pz   77.0    $ Bottom of Tubes
3083  pz   78.0    $ Top of Bottom End Plug
3084  pz  287.0    $ Bottom of Top End Plug
3085  pz  292.0    $ Top of Tubes
3086  pz  294.5    $ Top of Top End Plug
3087  cz    0.475  $ Inner Tube Inner Radius
3088  cz    0.675  $ Inner Tube Outer Radius
3089  cz    0.7    $ Outer Tube Inner Radius
3090  cz    1.1    $ Outer Tube Outer Radius
c
3091  pz   73.0    $ Top of Graphite Plug
3092  cz    1.325  $ Radius of Graphite Plug
c
3095  so 1000      $ A Very Large Sphere
c
c --- Pebbles ------------------------------------------------------------------
c ------ TRISO ------
3111  so  0.0251   $ UO2 Kernel
```

```
3112  so  0.03425  $ Buffer Coating
3113  so  0.03824  $ IPyC Coating
3114  so  0.04177  $ SiC Coating
3115  so  0.04577  $ OPyC Coating
c
c ------ TRISO Lattice ------
3121  rpp -0.0879 0.0879 -0.0879 0.0879 -0.0879 0.0879
c
c ------ Fuel Pebble ------
3131  s   0 0 0  2.35  $ Fuel Zone
3132  s   0 0 0  3.00  $ Pebble Shell (Unfueled Zone)
c
c ------ Moderator Pebble ------
c    *Same dimension as Fuel Pebble Shell
c
c ------ CHPOP Pebble Lattice ------
6001  hex  0 0 -3.00  0 0 6.00  3.00 0 0
c
c ------ CHPOP Pebble Stack Lattice ------
6002  hex  0 0 -9.00  0 0 264.  3.00 0 0  $ Core Lattice
6003  hex  0 0 -9.00  0 0 264.  3.4  0 0  $ Adding Poly Rods
c
c --- Graphite Fillers ----------------------------------------------------
c ------ Axial Modifiers ------
7001  hex  0 0 78  0 0 172.9  60.15 0 0
7002  hex  0 0 78  0 0 172.9  0 60.3 0
7003  pz  250.9  $ Top Surface
c
c --- Water Ingress Simulation --------------------------------------------
c ------ Polyethylene Rods ------
c    *Polyethylene Rods Not Used in Configuration 9
c
7021  c/z  -3.0  1.732050808 0.325  $ NW Rod
7022  c/z   0.0  3.464101615 0.325  $ N Rod
7023  c/z   3.0  1.732050808 0.325  $ NE Rod
7024  c/z   3.0 -1.732050808 0.325  $ SE Rod
7025  c/z   0.0 -3.464101615 0.325  $ S Rod
7026  c/z  -3.0 -1.732050808 0.325  $ SW Rod
7027  pz    148                     $ Top of Rods
c
c ------ Very Large Sphere ------
9999  so  1000  $ For Modeling Purposes Only
c

c Data Cards *****************************************************************
c
c *** Material Cards *********************************************************
c ------ Graphite (Radial Reflector) ------
m3     5010.70c 2.3253E-08   5011.70c 9.3597E-08   6000.70c 8.7858E-02
c         Total 8.7858E-02
mt3   grph.10t
c
c ------ Graphite (Lower Axial Reflector Cylinder) ------
m4     5010.70c 2.3223E-08   5011.70c 9.3476E-08   6000.70c 8.7744E-02
c         Total 8.7744E-02
mt4   grph.10t
c
c ------ Graphite (Lower Axial Reflector Annulus) ------
m5     5010.70c 2.3356E-08   5011.70c 9.4011E-08   6000.70c 8.8245E-02
c         Total 8.8245E-02
mt5   grph.10t
c
c ------ Graphite (Upper Axial Reflector Cylinder) ------
m6     5010.70c 2.3235E-08   5011.70c 9.3524E-08   6000.70c 8.7789E-02
c         Total 8.7789E-02
mt6   grph.10t
c
c ------ Graphite (Upper Axial Reflector Annulus) ------
m7     5010.70c 2.3368E-08   5011.70c 9.4059E-08   6000.70c 8.8291E-02
c         Total 8.8291E-02
mt7   grph.10t
c
c ------ Peraluman-300 (Upper Axial Reflector) ------
m9     5010.70c 1.4688E-07   5011.70c 5.9119E-07  12024.70c 8.0390E-04
      12025.70c 1.0177E-04  12026.70c 1.1205E-04  13027.70c 5.7575E-02
      14028.70c 2.0962E-04  14029.70c 1.0644E-05  14030.70c 7.0168E-06
```

```
      25055.70c 7.2621E-05  26054.70c 5.0109E-06  26056.70c 7.8660E-05
      26057.70c 1.8166E-06  26058.70c 2.4176E-07  29063.70c 8.6855E-06
      29065.70c 3.8712E-06  30000.70c 2.4398E-05  31069.70c 6.8789E-07
      31071.70c 4.5653E-07  48106.70c 8.8729E-10  48108.70c 6.3175E-10
      48110.70c 8.8658E-09  48111.70c 9.0858E-09  48112.70c 1.7128E-08
      48113.70c 8.6741E-09  48114.70c 2.0393E-08  48116.70c 5.3166E-09
c         Total 5.9018E-02
mt9   al27.12t fe56.12t
c
c ------ Air ------
m10    1001.70c 5.7091E-07   1002.70c 6.5663E-11   7014.70c 3.7225E-05
       7015.70c 1.3749E-07   8016.70c 1.0322E-05   8017.70c 3.9239E-09
      18036.70c 7.5192E-10  18038.70c 1.4122E-10  18040.70c 2.2256E-07
       6000.70c 9.1319E-09
c         Total 4.8492E-05
mt10  lwtr.10t hwtr.10t
c
c --- Control Rods -------------------------------------------------------------
c ------ 5 wt.% Borated Steel ------
m11    5010.70c 3.9257E-03   5011.70c 1.4282E-02  14028.70c 1.4007E-03
      14029.70c 7.1124E-05  14030.70c 4.6885E-05  24050.70c 1.4117E-03
      24052.70c 2.7224E-02  24053.70c 3.0870E-03  24054.70c 7.6842E-04
      25055.70c 9.8952E-04  26054.70c 1.8295E-03  26056.70c 2.8719E-02
      26057.70c 6.6325E-04  26058.70c 8.8267E-05  28058.70c 4.7678E-03
      28060.70c 1.8366E-03  28061.70c 7.9834E-05  28062.70c 2.5455E-04
      28064.70c 6.4825E-05
c         Total 9.1511E-02
mt11  fe56.12t
c
c ------ 18/8 Stainless Steel (i.e. SS 301/302/304) ------
m12   24050.70c 7.1741E-04  24052.70c 1.3834E-02  24053.70c 1.5687E-03
      24054.70c 3.9049E-04  26054.70c 3.6154E-03  26056.70c 5.6755E-02
      26057.70c 1.3107E-03  26058.70c 1.7443E-04  28058.70c 4.4256E-03
      28060.70c 1.7047E-03  28061.70c 7.4104E-05  28062.70c 2.3628E-04
      28064.70c 6.0172E-05   6000.70c 2.9783E-04  14028.70c 7.8313E-04
      14029.70c 3.9765E-05  14030.70c 2.6214E-05  25055.70c 8.6816E-04
c         Total 8.6882E-02
mt12  fe56.12t
c
c ------ Copper Autorod (i.e. C110) ------
m13   29063.70c 5.8245E-02  29065.70c 2.5961E-02   8016.70c 6.6898E-05
       8017.70c 2.5431E-08  47107.70c 1.9296E-06  47109.70c 1.7927E-06
      16032.70c 1.1887E-05  16033.70c 9.5169E-08  16034.70c 5.3720E-07
      16036.70c 2.5044E-09  28058.70c 4.6572E-06  28060.70c 1.7939E-06
      28061.70c 7.7981E-08  28062.70c 2.4864E-07  28064.70c 6.3321E-08
      26054.70c 4.2025E-07  26056.70c 6.5971E-06  26057.70c 1.5236E-07
      26058.70c 2.0276E-08
c         Total 8.4303E-02
mt13  fe56.12t
c
c ------ Pure Aluminum Autorod Guide Tube (i.e. AL 1100) ------
m113  14028.70c 2.6697E-04  14029.70c 1.3556E-05  14030.70c 8.9364E-06
      26054.70c 8.5091E-06  26056.70c 1.3357E-04  26057.70c 3.0848E-06
      26058.70c 4.1053E-07  29063.70c 2.2123E-05  29065.70c 9.8607E-06
      25055.70c 7.3991E-06  30000.70c 1.2429E-05  27059.70c 6.8975E-05
      28058.70c 4.7148E-05  28060.70c 1.8161E-05  28061.70c 7.8946E-07
      28062.70c 2.5171E-06  28064.70c 6.4104E-07  50112.70c 3.3215E-07
      50114.70c 2.2600E-07  50115.70c 1.1642E-07  50116.70c 4.9788E-06
      50117.70c 2.6298E-06  50118.70c 8.2935E-06  50119.70c 2.9414E-06
      50120.70c 1.1156E-05  50122.70c 1.5854E-06  50124.70c 1.9826E-06
      13027.70c 5.9087E-02
c         Total 5.9746E-02
mt113  al27.12t fe56.12t
c
c ------ Pure Aluminum Shock Dampers (i.e. AL 1100) ------
m14   14028.70c 3.6377E-04  14029.70c 1.8471E-05  14030.70c 1.2177E-05
      26054.70c 1.1594E-05  26056.70c 1.8200E-04  26057.70c 4.2033E-06
      26058.70c 5.5938E-07  29063.70c 3.0145E-05  29065.70c 1.3436E-05
      25055.70c 1.0082E-05  30000.70c 1.6936E-05  27059.70c 9.3983E-05
      28058.70c 6.4242E-05  28060.70c 2.4746E-05  28061.70c 1.0757E-06
      28062.70c 3.4298E-06  28064.70c 8.7346E-07  50112.70c 4.5258E-07
      50114.70c 3.0794E-07  50115.70c 1.5864E-07  50116.70c 6.7840E-06
      50117.70c 3.5833E-06  50118.70c 1.1300E-05  50119.70c 4.0079E-06
      50120.70c 1.5201E-05  50122.70c 2.1602E-06  50124.70c 2.7015E-06
      13027.70c 8.0510E-02
c         Total 8.1409E-02
```

```
mt14  al27.12t fe56.12t
c
c ------ St1.4301 Stainless Steel (Inner Tube) ------
m17    6000.70c 1.3864E-04  14028.70c 7.8115E-04  14029.70c 3.9665E-05
      14030.70c 2.6147E-05  25055.70c 8.6597E-04  24050.70c 7.3547E-04
      24052.70c 1.4183E-02  24053.70c 1.6082E-03  24054.70c 4.0032E-04
      28058.70c 5.6560E-03  28060.70c 2.1787E-03  28061.70c 9.4706E-05
      28062.70c 3.0196E-04  28064.70c 7.6901E-05  26054.70c 3.4714E-03
      26056.70c 5.4493E-02  26057.70c 1.2585E-03  26058.70c 1.6748E-04
c         Total 8.6477E-02
mt17  fe56.12t
c
c ------ St1.4541 Stainless Steel (Outer Tube) ------
m18     6000.70c 1.9805E-04  14028.70c 7.8115E-04  14029.70c 3.9665E-05
       14030.70c 2.6147E-05  25055.70c 8.6597E-04  24050.70c 7.1559E-04
       24052.70c 1.3800E-02  24053.70c 1.5648E-03  24054.70c 3.8950E-04
       28058.70c 5.6560E-03  28060.70c 2.1787E-03  28061.70c 9.4706E-05
       28062.70c 3.0196E-04  28064.70c 7.6901E-05  22046.70c 4.0998E-06
       22047.70c 3.6973E-06  22048.70c 3.6635E-05  22049.70c 2.6885E-06
       22050.70c 2.5742E-06  26054.70c 3.4930E-03  26056.70c 5.4833E-02
       26057.70c 1.2663E-03  26058.70c 1.6853E-04
c         Total 8.6499E-02
mt18  fe56.12t
c
c --- Pebbles ----------------------------------------------------------------
c ------ UO2 ------
m19    8016.70c 4.8593E-02   8017.70c 1.8472E-05  92234.70c 3.3079E-05
      92235.70c 4.1172E-03  92236.70c 2.0499E-05  92238.70c 2.0135E-02
c         Total 7.2917E-02
mt19  o2/u.10t u/o2.10t
c
c ------ Buffer ------
m20    6000.70c 5.2640E-02
c         Total 5.2640E-02
mt20  grph.10t
c
c ------ IPyC ------
m21    6000.70c 9.5254E-02
c         Total 9.5254E-02
mt21  grph.10t
c
c ------ SiC ------
m22   14028.70c 4.4321E-02  14029.70c 2.2505E-03  14030.70c 1.4836E-03
       6000.70c 4.8055E-02
c         Total 9.6110E-02
mt22  grph.10t
c
c ------ OPyC ------
m23    6000.70c 9.4752E-02
c         Total 9.4772E-02
mt23  grph.10t
c
c ------ Fuel Pebbles ------
m24    6000.70c 8.6842E-02  47107.70c 5.0131E-10  47109.70c 4.6575E-10
       5010.70c 1.9393E-09   5011.70c 7.8061E-09  20040.70c 2.3415E-07
      20042.70c 1.5628E-09  20043.70c 3.2608E-10  20044.70c 5.0385E-09
      20046.70c 9.6616E-12  20048.70c 4.5168E-10  48106.70c 5.9739E-12
      48108.70c 4.2534E-12  48110.70c 5.9691E-11  48111.70c 6.1172E-11
      48112.70c 1.1532E-10  48113.70c 5.8401E-11  48114.70c 1.3730E-10
      48116.70c 3.5795E-11  17035.70c 3.3446E-08  17037.70c 1.0690E-08
      27059.70c 1.1505E-09  24050.70c 1.5778E-09  24052.70c 3.0426E-08
      24053.70c 3.4500E-09  24054.70c 8.5879E-10  66156.70c 1.9258E-14
      66158.70c 3.2097E-14  66160.70c 7.5107E-13  66161.70c 6.0695E-12
      66162.70c 8.1879E-12  66163.70c 7.9921E-12  66164.70c 9.0449E-12
      63151.70c 1.6409E-11  63153.70c 1.7913E-11  26054.70c 3.2208E-09
      26056.70c 5.0560E-08  26057.70c 1.1677E-09  26058.70c 1.5539E-10
      64152.70c 6.6337E-14  64154.70c 7.2307E-13  64155.70c 4.9089E-12
      64156.70c 6.7896E-12  64157.70c 5.1909E-12  64158.70c 8.2391E-12
      64160.70c 7.2506E-12   3006.70c 5.7034E-09   3007.70c 6.9441E-08
      25055.70c 8.1647E-09  28058.70c 6.0496E-09  28060.70c 2.3303E-09
      28061.70c 1.0130E-10  28062.70c 3.2298E-10  28064.70c 8.2253E-11
      16032.70c 1.6986E-10  16033.70c 1.3599E-12  16034.70c 7.6760E-12
      16036.70c 3.5786E-14  22046.70c 8.9355E-10  22047.70c 8.0582E-10
      22048.70c 7.9846E-09  22049.70c 5.8596E-10  22050.70c 5.6104E-10
      23000.70c 4.4334E-09   1001.70c 1.1579E-05   1002.70c 1.3318E-09
       8016.70c 5.7882E-06   8017.70c 2.2003E-09
```

```
c         Total 8.6859E-02
mt24  grph.10t lwtr.10t hwtr.10t
c
c ------ Moderator Pebbles ------
m26     6000.70c 8.4434E-02   5010.70c 1.4193E-08   5011.70c 5.7130E-08
      20040.70c 3.1657E-06  20042.70c 2.1129E-08  20043.70c 4.4086E-09
      20044.70c 6.8121E-08  20046.70c 1.3062E-10  20048.70c 6.1067E-09
      48106.70c 3.3846E-11  48108.70c 2.4098E-11  48110.70c 3.3819E-10
      48111.70c 3.4658E-10  48112.70c 6.5336E-10  48113.70c 3.3088E-10
      48114.70c 7.7791E-10  48116.70c 2.0280E-10  17035.70c 4.0423E-07
      17037.70c 1.2920E-07  66156.70c 2.4350E-13  66158.70c 4.0583E-13
      66160.70c 9.4964E-12  66161.70c 7.6742E-11  66162.70c 1.0353E-10
      66163.70c 1.0105E-10  66164.70c 1.1436E-10  63151.70c 4.1496E-10
      63153.70c 4.5297E-10  26054.70c 6.2652E-09  26056.70c 9.8350E-08
      26057.70c 2.2713E-09  26058.70c 3.0227E-10  64152.70c 5.1616E-13
      64154.70c 5.6261E-12  64155.70c 3.8196E-11  64156.70c 5.2829E-11
      64157.70c 4.0389E-11  64158.70c 6.4107E-11  64160.70c 5.6416E-11
       3006.70c 9.7630E-09   3007.70c 1.1887E-07  28058.70c 9.1788E-09
      28060.70c 3.5357E-09  28061.70c 1.5369E-10  28062.70c 4.9004E-10
      28064.70c 1.2480E-10  16032.70c 4.2052E-06  16033.70c 3.3666E-08
      16034.70c 1.9004E-07  16036.70c 8.8595E-10  14028.70c 1.1661E-06
      14029.70c 5.9212E-08  14030.70c 3.9033E-08  62144.70c 1.7815E-11
      62147.70c 8.6986E-11  62148.70c 6.5225E-11  62149.70c 8.0197E-11
      62150.70c 4.2826E-11  62152.70c 1.5523E-10  62154.70c 1.3202E-10
      22046.70c 1.7486E-08  22047.70c 1.5770E-08  22048.70c 1.5625E-07
      22049.70c 1.1467E-08  22050.70c 1.0979E-08  23000.70c 2.5891E-07
       1001.70c 1.1262E-05   1002.70c 1.2953E-09   8016.70c 5.6296E-06
       8017.70c 2.1401E-09
c         Total 8.4461E-02
mt26  grph.10t lwtr.10t hwtr.10t
c
c --- Graphite Fillers --------------------------------------------------------
c ------ Short Plugs/Rods (Axial Reflectors) ------
m29    5010.70c 2.3356E-08   5011.70c 9.4011E-08   6000.70c 8.8245E-02
c         Total 8.8245E-02
mt29  grph.10t
c
c ------ Source Plug (Lower Axial Reflector) ------
m30    5010.70c 2.3356E-08   5011.70c 9.4011E-08   6000.70c 8.8245E-02
c         Total 8.8245E-02
mt30  grph.10t
c
c ------ Lattice Spacers ------
m32    5010.70c 2.3130E-08   5011.70c 9.3099E-08   6000.70c 8.7390E-02
c         Total 8.7390E-02
mt32  grph.10t
c
c --- Water Ingress Simulation ------------------------------------------------
c ------ Polyethylene Rods ------
m34    5010.70c 5.2797E-09   5011.70c 2.1252E-08   1001.70c 8.2835E-02
       1002.70c 9.5271E-06   6000.70c 4.0810E-02
c         Total 1.2365E-01
mt34  poly.10t
c
c *** Control Cards ***********************************************************
mode  n
kcode 100000 1 150 1650
ksrc  0 0  80  40 40  80  40 -40  80  -40 -40  80  -40 40  80
      0 0  90  40 40  90  40 -40  90  -40 -40  90  -40 40  90
      0 0 100  40 40 100  40 -40 100  -40 -40 100  -40 40 100
      0 0 110  40 40 110  40 -40 110  -40 -40 110  -40 40 110
      0 0 120  40 40 120  40 -40 120  -40 -40 120  -40 40 120
      0 0 130  40 40 130  40 -40 130  -40 -40 130  -40 40 130
      0 0 140  40 40 140  40 -40 140  -40 -40 140  -40 40 140
      0 0 150  40 40 150  40 -40 150  -40 -40 150  -40 40 150
      0 20  80  20 0  80  -20 0  80  0 -20  80
      0 20  90  20 0  90  -20 0  90  0 -20  90
      0 20 100  20 0 100  -20 0 100  0 -20 100
      0 20 110  20 0 110  -20 0 110  0 -20 110
      0 20 120  20 0 120  -20 0 120  0 -20 120
      0 20 130  20 0 130  -20 0 130  0 -20 130
      0 20 140  20 0 140  -20 0 140  0 -20 140
      0 20 150  20 0 150  -20 0 150  0 -20 150
      0 50  80  50 0  80  -50 0  80  0 -50  80
      0 50  90  50 0  90  -50 0  90  0 -50  90
      0 50 100  50 0 100  -50 0 100  0 -50 100
```

```
      0 50 110  50 0 110  -50 0 110  0 -50 110
      0 50 120  50 0 120  -50 0 120  0 -50 120
      0 50 130  50 0 130  -50 0 130  0 -50 130
      0 50 140  50 0 140  -50 0 140  0 -50 140
      0 50 150  50 0 150  -50 0 150  0 -50 150
c
kopts  blocksize=10 kinetics=yes precursor=yes
c print
c
```

A.5 Reactivity Coefficient Configurations

Reactivity coefficient measurements were performed but have not yet been evaluated.

A.6 Kinetics Parameter Configurations

Kinetics measurements were performed but have not yet been evaluated.

A.7 Reaction-Rate Configurations

Reaction-rate distribution measurements were performed but have not yet been evaluated.

A.8 Power Distribution Configurations

Power distribution measurements were not performed.

A.9 Isotopic Configurations

Isotopic measurements were not performed.

A.10 Configurations of Other Miscellaneous Types of Measurements

Other miscellaneous types of measurements were not performed.

APPENDIX B: CALCULATED SPECTRAL DATA

The neutron spectral calculations provided below were obtained from the output files for the input decks used to obtain the results in Section 4.1. Spectral data using the ENDF/B-VII.0 neutron cross section library is provided here for the MCNP5 analysis.

B.1 MCNP-Calculated Spectral Data

A summary of the computed neutron spectral data using MCNP5 for the benchmark model is provided in Tables B.1-1 and B.1-2 for Cases 1 and 2 (Cores 9 and 10), respectively.

Table B.1-1. Neutron Spectral Data for Benchmark Model for Case 1 (Core 9).

Neutron Cross Section Library		ENDF/B-VII.0
k_{eff}		1.00667
$\pm\sigma_k$		0.00007
Neutron Leakage (%)[a]		16.18
Fission Fraction, by Energy (%)	**Thermal (<0.625 eV)**	95.02
	Intermediate	4.65
	Fast (>100 keV)	0.33
Average Number of Neutrons Produced per Fission		2.437
Energy of Average Neutron Lethargy Causing Fission (eV)		0.054995
Neutron Generation Time, Λ (msec)		2.09855
Rossi-α ($msec^{-1}$)		-3.30178E-03
β_{eff}		0.00693

(a) The neutron leakage is calculated using the neutron balance tables provided in the MCNP output file. The weight fraction of neutrons lost due to escaping the boundaries of the benchmark model are divided by the total weight fraction of neutron loss.

Table B.1-2. Neutron Spectral Data for Benchmark Model for Case 2 (Core 10).

Neutron Cross Section Library		ENDF/B-VII.0
k_{eff} **$\pm\sigma_k$**		1.00743 0.00006
Neutron Leakage (%)[(a)]		13.66
Fission Fraction, by Energy (%)	**Thermal (<0.625 eV)**	96.52
	Intermediate	3.18
	Fast (>100 keV)	0.30
Average Number of Neutrons Produced per Fission		2.437
Energy of Average Neutron Lethargy Causing Fission (eV)		0.044361
Neutron Generation Time, Λ (msec)		1.69449
Rossi-α ($msec^{-1}$)		-4.04482E-03
β_{eff}		0.00685

(a) The neutron leakage is calculated using the neutron balance tables provided in the MCNP output file. The weight fraction of neutrons lost due to escaping the boundaries of the benchmark model are divided by the total weight fraction of neutron loss.

APPENDIX C: DETAILED MODELS OF HTR-PROTEUS

C.1 Detailed MCNP Models of the HTR-PROTEUS (NOT BENCHMARKED)

Detailed models of HTR-PROTEUS core configurations 9 and 10 were prepared to evaluate biases in the benchmark model. Because the effects of many of the model simplifications produced small or otherwise negligible biases (in regards to criticality) in the benchmark model, development of a detailed benchmark model was unnecessary. An example MCNP5 input deck, using ENDF/B-VII.0 neutron cross section data, is preserved in this appendix for future use. Calculations were performed with 1,650 generations with 100,000 neutrons per generation. The k_{eff} estimates (with the first 150 generations skipped) are the result of 150,000,000 neutron histories. Calculated results obtained with this input deck are provided in Tables C.1-1 and C.1-2 for each core, respectively.

The input deck provided below is for core configuration 9. The following portions of the code need reconfigured for core configuration 10:

- Autorod position,
- Withdrawable control rod positions,
- Core cavity filled with correct pebble configuration (including polyethylene rods), and
- Change air composition and atom density.

Table C.1-1. Neutron Spectral Data for Detailed Model (Core 9).

Neutron Cross Section Library		ENDF/B-VII.0
k_{eff}		1.00520
$\pm\sigma_k$		0.00007
Neutron Leakage (%)[(a)]		1.84
Fission Fraction, by Energy (%)	**Thermal (<0.625 eV)**	95.00
	Intermediate	4.66
	Fast (>100 keV)	0.33
Average Number of Neutrons Produced per Fission		2.437
Energy of Average Neutron Lethargy Causing Fission (eV)		0.055035
Neutron Generation Time, Λ (msec)		2.11558
Rossi-α ($msec^{-1}$)		-3.29941E-03
β_{eff}		0.00698

(a) The neutron leakage is calculated using the neutron balance tables provided in the MCNP output file. The weight fraction of neutrons lost due to escaping the boundaries of the benchmark model are divided by the total weight fraction of neutron loss.

Table C.1-2. Neutron Spectral Data for Detailed Model (Core 10).

Neutron Cross Section Library		ENDF/B-VII.0
k_{eff}		1.00647
$\pm\sigma_k$		0.00006
Neutron Leakage (%)[(a)]		1.43
Fission Fraction, by Energy (%)	**Thermal (<0.625 eV)**	96.52
	Intermediate	3.18
	Fast (>100 keV)	0.30
Average Number of Neutrons Produced per Fission		2.437
Energy of Average Neutron Lethargy Causing Fission (eV)		0.044377
Neutron Generation Time, Λ (msec)		1.70417
Rossi-α ($msec^{-1}$)		-4.05453E-03
β_{eff}		0.00691

(a) The neutron leakage is calculated using the neutron balance tables provided in the MCNP output file. The weight fraction of neutrons lost due to escaping the boundaries of the benchmark model are divided by the total weight fraction of neutron loss.

C.2 Input Listing for Detailed Models

MCNP5 Input Deck for Core 9 (can be modified for Core 10):

```
HTR-PROTEUS :: Cores 9 & 10
c Pebble Bed Experimental Program
c Columnar Hexagonal Point-On-Point Packing with a 1:1 Moderator to Fuel Pebble Ratio
c
c John Darrell Bess - Idaho National Laboratory
c Last Updated: July 23, 2012
c
c Cell Cards ******************************************************************
c --- Structural Surroundings --------------------------------------------------
c ------ Concrete ------
1    1 6.1726E-02  (-1:3:-5:7) 2 -4 6 -8 15 -9 imp:n=1
c
c ------ Steel Plate Pedestal ------
2    2 8.6882E-02  1 -3 5 -7 15 -31
          (1101 1102 1103 1104 1105 1106 1107 1108 1109 1110 1111 1112 1113)
          imp:n=1
c
c ------ Thermal Column ------
3    3 8.8245E-02  21 -22 23 -24 1 (7545:7546:7547:7548) imp:n=1
c
c ------ Air ------
4    10 4.8413E-05  (1 -3 5 -7 31 -9 #3)
          (7531:7532:7533:7534:7535:7536:7537:7538:7539:7540:7541:
          7542:7543:7544:7545:7546:7547:7548:7549:7550:7551:7552) imp:n=1
5    10 4.8413E-05  32 -9
          (7501:7502:7503:7504:7505:7506:7507:7508:7509:7510:7511:
          7512:7513:7514:7515:7516:7517:7518:7519:7520:7521:7522)
          -7531 -7532 -7533 -7534 -7535 -7536 -7537 -7538 -7539 -7540 -7541
          -7542 -7543 -7544 -7545 -7546 -7547 -7548 -7549 -7550 -7551 -7552
          (1101 1102 1103 1104 1105 1106 1107 1108)
          (1109 1110 1111 1112 1113) (503 519 535 551) imp:n=1
6    10 4.8413E-05  1202 -9
          -7501 -7502 -7503 -7504 -7505 -7506 -7507 -7508 -7509 -7510 -7511
          -7512 -7513 -7514 -7515 -7516 -7517 -7518 -7519 -7520 -7521 -7522
          imp:n=1
c
c --- Radial Reflector --------------------------------------------------------
11   3 8.8245E-02  (7501:7502:7503:7504:7505:7506:7507:7508:7509:7510:7511:
          7512:7513:7514:7515:7516:7517:7518:7519:7520:7521:7522)
          -165 31 -32 #21
          (1101 1102 1103 1104 1105 1106 1107 1108)
          (101 102     104 105 106 107 108 109 110     112 113 114 115 116
           117 118 119     121 122 123 124 125 126     128 129 130 131 132
           133 134     136 137 138 139 140 141 142 143     145 146 147 148
           149 150     152 153 154 155 156 157     159 160 161 162 163 164)
           imp:n=1  $ Ring 1 Region
12   3 8.8245E-02  165 -265 31 -32
          (1101 1102 1103 1104 1105 1106 1107 1108)
          (201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216
           217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232
           233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248
           249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264)
           imp:n=1  $ Ring 2 Region
13   3 8.8245E-02  265 -365 31 -32
          (301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316
           317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332
           333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348
           349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364)
           imp:n=1  $ Ring 3 Region
14   3 8.8245E-02  365 -465 31 -32
          (1109 1110 1111 1112 1113)
          (401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416
           417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432
           433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448
           449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464)
           imp:n=1  $ Ring 4 Region
15   3 8.8245E-02  465  31 -32
          -7531 -7532 -7533 -7534 -7535 -7536 -7537 -7538 -7539 -7540 -7541
          -7542 -7543 -7544 -7545 -7546 -7547 -7548 -7549 -7550 -7551 -7552
          (1109 1110 1111 1112 1113)
          (501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516
```

```
           517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532
           533 534 535 536 537 538 539 540 541 542 543 544     546 547 548
           549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564)
           imp:n=1  $ Ring 5 Region
c
c ------ Safety Ring ------
21   8 5.9018E-02  41 -42 43 -44
          (101 102     104 105 106 107 108 109 110     112 113 114 115 116
           117 118 119     121 122 123 124 125 126     128 129 130 131 132
           133 134     136 137 138 139 140 141 142 143     145 146 147 148
           149 150     152 153 154 155 156 157     159 160 161 162 163 164)
          (1101 1102 1103 1104 1105 1106 1107 1108)
           imp:n=1
c
c ------ Air Gap ------
22   10 4.8492E-05  7003 -1801 (-1804:1805:1802) #21
          -7501 -7502 -7503 -7504 -7505 -7506 -7507 -7508 -7509 -7510 -7511
          -7512 -7513 -7514 -7515 -7516 -7517 -7518 -7519 -7520 -7521 -7522
          imp:n=1
c
c ------ C-Driver Channels ------
c --------- Ring 1 ---------
101  10 4.8413E-05  -101 601 31 -32 imp:n=1  $ Position 1
102  10 4.8413E-05  -102 602 31 -32 imp:n=1  $ Position 2
c    *Replaced by Safety/Shutdown Rod  $ Position 3
104  10 4.8413E-05  -104 604 31 -32 imp:n=1  $ Position 4
105  10 4.8413E-05  -105 605 31 -32 imp:n=1  $ Position 5
106  10 4.8413E-05  -106 606 31 -32 imp:n=1  $ Position 6
107  10 4.8413E-05  -107 607 31 -32 imp:n=1  $ Position 7
108  10 4.8413E-05  -108 608 31 -32 imp:n=1  $ Position 8
109  10 4.8413E-05  -109 609 31 -32 imp:n=1  $ Position 9
110  10 4.8413E-05  -110 610 31 -32 imp:n=1  $ Position 10
c    *Replaced by Safety/Shutdown Rod  $ Position 11
112  10 4.8413E-05  -112 612 31 -32 imp:n=1  $ Position 12
113  10 4.8413E-05  -113 613 31 -32 imp:n=1  $ Position 13
114  10 4.8413E-05  -114 614 31 -32 imp:n=1  $ Position 14
115  10 4.8413E-05  -115 615 31 -32 imp:n=1  $ Position 15
116  10 4.8413E-05  -116 616 31 -32 imp:n=1  $ Position 16
117  10 4.8413E-05  -117 617 31 -32 imp:n=1  $ Position 17
118  10 4.8413E-05  -118 618 31 -32 imp:n=1  $ Position 18
119  10 4.8413E-05  -119 619 31 -32 imp:n=1  $ Position 19
c    *Replaced by Safety/Shutdown Rod  $ Position 20
121  10 4.8413E-05  -121 621 31 -32 imp:n=1  $ Position 21
122  10 4.8413E-05  -122 622 31 -32 imp:n=1  $ Position 22
123  10 4.8413E-05  -123 623 31 -32 imp:n=1  $ Position 23
124  10 4.8413E-05  -124 624 31 -32 imp:n=1  $ Position 24
125  10 4.8413E-05  -125 625 31 -32 imp:n=1  $ Position 25
126  10 4.8413E-05  -126 626 31 -32 imp:n=1  $ Position 26
c    *Replaced by Safety/Shutdown Rod  $ Position 27
128  10 4.8413E-05  -128 628 31 -32 imp:n=1  $ Position 28
129  10 4.8413E-05  -129 629 31 -32 imp:n=1  $ Position 29
130  10 4.8413E-05  -130 630 31 -32 imp:n=1  $ Position 30
131  10 4.8413E-05  -131 631 31 -32 imp:n=1  $ Position 31
132  10 4.8413E-05  -132 632 31 -32 imp:n=1  $ Position 32
133  10 4.8413E-05  -133 633 31 -32 imp:n=1  $ Position 33
134  10 4.8413E-05  -134 634 31 -32 imp:n=1  $ Position 34
c    *Replaced by Safety/Shutdown Rod  $ Position 35
136  10 4.8413E-05   -136 636 31 -32 imp:n=1  $ Position 36
137  10 4.8413E-05   -137 637 31 -32 imp:n=1  $ Position 37
138  10 4.8413E-05   -138 638 31 -32 imp:n=1  $ Position 38
139  10 4.8413E-05   -139 639 31 -32 imp:n=1  $ Position 39
140  10 4.8413E-05   -140 640 31 -32 imp:n=1  $ Position 40
141  10 4.8413E-05   -141 641 31 -32 imp:n=1  $ Position 41
142  10 4.8413E-05   -142 642 31 -32 imp:n=1  $ Position 42
143  10 4.8413E-05   -143 643 31 -32 imp:n=1  $ Position 43
c    *Replaced by Safety/Shutdown Rod  $ Position 44
145  10 4.8413E-05   -145 645 31 -32 imp:n=1  $ Position 45
146  10 4.8413E-05   -146 646 31 -32 imp:n=1  $ Position 46
147  10 4.8413E-05   -147 647 31 -32 imp:n=1  $ Position 47
148  10 4.8413E-05   -148 648 31 -32 imp:n=1  $ Position 48
149  10 4.8413E-05   -149 649 31 -32 imp:n=1  $ Position 49
150  10 4.8413E-05   -150 650 31 -32 imp:n=1  $ Position 50
c    *Replaced by Safety/Shutdown Rod  $ Position 51
152  10 4.8413E-05   -152 652 31 -32 imp:n=1  $ Position 52
153  10 4.8413E-05   -153 653 31 -32 imp:n=1  $ Position 53
154  10 4.8413E-05   -154 654 31 -32 imp:n=1  $ Position 54
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155  10 4.8413E-05   -155 655 31 -32 imp:n=1  $ Position 55
156  10 4.8413E-05   -156 656 31 -32 imp:n=1  $ Position 56
157  10 4.8413E-05   -157 657 31 -32 imp:n=1  $ Position 57
c    *Replaced by Safety/Shutdown Rod  $ Position 58
159  10 4.8413E-05   -159 659 31 -32 imp:n=1  $ Position 59
160  10 4.8413E-05   -160 660 31 -32 imp:n=1  $ Position 60
161  10 4.8413E-05   -161 661 31 -32 imp:n=1  $ Position 61
162  10 4.8413E-05   -162 662 31 -32 imp:n=1  $ Position 62
163  10 4.8413E-05   -163 663 31 -32 imp:n=1  $ Position 63
164  10 4.8413E-05   -164 664 31 -32 imp:n=1  $ Position 64
c
c --------- Ring 2 ---------
201  10 4.8413E-05   -201 701 31 -32 imp:n=1  $ Position 1
202  10 4.8413E-05   -202 702 31 -32 imp:n=1  $ Position 2
203  10 4.8413E-05   -203 703 31 -32 imp:n=1  $ Position 3
204  10 4.8413E-05   -204 704 31 -32 imp:n=1  $ Position 4
205  10 4.8413E-05   -205 705 31 -32 imp:n=1  $ Position 5
206  10 4.8413E-05   -206 706 31 -32 imp:n=1  $ Position 6
207  10 4.8413E-05   -207 707 31 -32 imp:n=1  $ Position 7
208  10 4.8413E-05   -208 708 31 -32 imp:n=1  $ Position 8
209  10 4.8413E-05   -209 709 31 -32 imp:n=1  $ Position 9
210  10 4.8413E-05   -210 710 31 -32 imp:n=1  $ Position 10
211  10 4.8413E-05   -211 711 31 -32 imp:n=1  $ Position 11
212  10 4.8413E-05   -212 712 31 -32 imp:n=1  $ Position 12
213  10 4.8413E-05   -213 713 31 -32 imp:n=1  $ Position 13
214  10 4.8413E-05   -214 714 31 -32 imp:n=1  $ Position 14
215  10 4.8413E-05   -215 715 31 -32 imp:n=1  $ Position 15
216  10 4.8413E-05   -216 716 31 -32 imp:n=1  $ Position 16
217  10 4.8413E-05   -217 717 31 -32 imp:n=1  $ Position 17
218  10 4.8413E-05   -218 718 31 -32 imp:n=1  $ Position 18
219  10 4.8413E-05   -219 719 31 -32 imp:n=1  $ Position 19
220  10 4.8413E-05   -220 720 31 -32 imp:n=1  $ Position 20
221  10 4.8413E-05   -221 721 31 -32 imp:n=1  $ Position 21
222  10 4.8413E-05   -222 722 31 -32 imp:n=1  $ Position 22
223  10 4.8413E-05   -223 723 31 -32 imp:n=1  $ Position 23
224  10 4.8413E-05   -224 724 31 -32 imp:n=1  $ Position 24
225  10 4.8413E-05   -225 725 31 -32 imp:n=1  $ Position 25
226  10 4.8413E-05   -226 726 31 -32 imp:n=1  $ Position 26
227  10 4.8413E-05   -227 727 31 -32 imp:n=1  $ Position 27
228  10 4.8413E-05   -228 728 31 -32 imp:n=1  $ Position 28
229  10 4.8413E-05   -229 729 31 -32 imp:n=1  $ Position 29
230  10 4.8413E-05   -230 730 31 -32 imp:n=1  $ Position 30
231  10 4.8413E-05   -231 731 31 -32 imp:n=1  $ Position 31
232  10 4.8413E-05   -232 732 31 -32 imp:n=1  $ Position 32
233  10 4.8413E-05   -233 733 31 -32 imp:n=1  $ Position 33
234  10 4.8413E-05   -234 734 31 -32 imp:n=1  $ Position 34
235  10 4.8413E-05   -235 735 31 -32 imp:n=1  $ Position 35
236  10 4.8413E-05   -236 736 31 -32 imp:n=1  $ Position 36
237  10 4.8413E-05   -237 737 31 -32 imp:n=1  $ Position 37
238  10 4.8413E-05   -238 738 31 -32 imp:n=1  $ Position 38
239  10 4.8413E-05   -239 739 31 -32 imp:n=1  $ Position 39
240  10 4.8413E-05   -240 740 31 -32 imp:n=1  $ Position 40
241  10 4.8413E-05   -241 741 31 -32 imp:n=1  $ Position 41
242  10 4.8413E-05   -242 742 31 -32 imp:n=1  $ Position 42
243  10 4.8413E-05   -243 743 31 -32 imp:n=1  $ Position 43
244  10 4.8413E-05   -244 744 31 -32 imp:n=1  $ Position 44
245  10 4.8413E-05   -245 745 31 -32 imp:n=1  $ Position 45
246  10 4.8413E-05   -246 746 31 -32 imp:n=1  $ Position 46
247  10 4.8413E-05   -247 747 31 -32 imp:n=1  $ Position 47
248  10 4.8413E-05   -248 748 31 -32 imp:n=1  $ Position 48
249  10 4.8413E-05   -249 749 31 -32 imp:n=1  $ Position 49
250  10 4.8413E-05   -250 750 31 -32 imp:n=1  $ Position 50
251  10 4.8413E-05   -251 751 31 -32 imp:n=1  $ Position 51
252  10 4.8413E-05   -252 752 31 -32 imp:n=1  $ Position 52
253  10 4.8413E-05   -253 753 31 -32 imp:n=1  $ Position 53
254  10 4.8413E-05   -254 754 31 -32 imp:n=1  $ Position 54
255  10 4.8413E-05   -255 755 31 -32 imp:n=1  $ Position 55
256  10 4.8413E-05   -256 756 31 -32 imp:n=1  $ Position 56
257  10 4.8413E-05   -257 757 31 -32 imp:n=1  $ Position 57
258  10 4.8413E-05   -258 758 31 -32 imp:n=1  $ Position 58
259  10 4.8413E-05   -259 759 31 -32 imp:n=1  $ Position 59
260  10 4.8413E-05   -260 760 31 -32 imp:n=1  $ Position 60
261  10 4.8413E-05   -261 761 31 -32 imp:n=1  $ Position 61
262  10 4.8413E-05   -262 762 31 -32 imp:n=1  $ Position 62
263  10 4.8413E-05   -263 763 31 -32 imp:n=1  $ Position 63
264  10 4.8413E-05   -264 764 31 -32 imp:n=1  $ Position 64
```

```
c
c --------- Ring 3 ---------
301  10 4.8413E-05   -301 801 31 -32 imp:n=1  $ Position 1
302  10 4.8413E-05   -302 802 31 -32 imp:n=1  $ Position 2
303  10 4.8413E-05   -303 803 31 -32 imp:n=1  $ Position 3
304  10 4.8413E-05   -304 804 31 -32 imp:n=1  $ Position 4
305  10 4.8413E-05   -305 805 31 -32 imp:n=1  $ Position 5
306  10 4.8413E-05   -306 806 31 -32 imp:n=1  $ Position 6
307  10 4.8413E-05   -307 807 31 -32 imp:n=1  $ Position 7
308  10 4.8413E-05   -308 808 31 -32 imp:n=1  $ Position 8
309  10 4.8413E-05   -309 809 31 -32 imp:n=1  $ Position 9
310  10 4.8413E-05   -310 810 31 -32 imp:n=1  $ Position 10
311  10 4.8413E-05   -311 811 31 -32 imp:n=1  $ Position 11
312  10 4.8413E-05   -312 812 31 -32 imp:n=1  $ Position 12
313  10 4.8413E-05   -313 813 31 -32 imp:n=1  $ Position 13
314  10 4.8413E-05   -314 814 31 -32 imp:n=1  $ Position 14
315  10 4.8413E-05   -315 815 31 -32 imp:n=1  $ Position 15
316  10 4.8413E-05   -316 816 31 -32 imp:n=1  $ Position 16
317  10 4.8413E-05   -317 817 31 -32 imp:n=1  $ Position 17
318  10 4.8413E-05   -318 818 31 -32 imp:n=1  $ Position 18
319  10 4.8413E-05   -319 819 31 -32 imp:n=1  $ Position 19
320  10 4.8413E-05   -320 820 31 -32 imp:n=1  $ Position 20
321  10 4.8413E-05   -321 821 31 -32 imp:n=1  $ Position 21
322  10 4.8413E-05   -322 822 31 -32 imp:n=1  $ Position 22
323  10 4.8413E-05   -323 823 31 -32 imp:n=1  $ Position 23
324  10 4.8413E-05   -324 824 31 -32 imp:n=1  $ Position 24
325  10 4.8413E-05   -325 825 31 -32 imp:n=1  $ Position 25
326  10 4.8413E-05   -326 826 31 -32 imp:n=1  $ Position 26
327  10 4.8413E-05   -327 827 31 -32 imp:n=1  $ Position 27
328  10 4.8413E-05   -328 828 31 -32 imp:n=1  $ Position 28
329  10 4.8413E-05   -329 829 31 -32 imp:n=1  $ Position 29
330  10 4.8413E-05   -330 830 31 -32 imp:n=1  $ Position 30
331  10 4.8413E-05   -331 831 31 -32 imp:n=1  $ Position 31
332  10 4.8413E-05   -332 832 31 -32 imp:n=1  $ Position 32
333  10 4.8413E-05   -333 833 31 -32 imp:n=1  $ Position 33
334  10 4.8413E-05   -334 834 31 -32 imp:n=1  $ Position 34
335  10 4.8413E-05   -335 835 31 -32 imp:n=1  $ Position 35
336  10 4.8413E-05   -336 836 31 -32 imp:n=1  $ Position 36
337  10 4.8413E-05   -337 837 31 -32 imp:n=1  $ Position 37
338  10 4.8413E-05   -338 838 31 -32 imp:n=1  $ Position 38
339  10 4.8413E-05   -339 839 31 -32 imp:n=1  $ Position 39
340  10 4.8413E-05   -340 840 31 -32 imp:n=1  $ Position 40
341  10 4.8413E-05   -341 841 31 -32 imp:n=1  $ Position 41
342  10 4.8413E-05   -342 842 31 -32 imp:n=1  $ Position 42
343  10 4.8413E-05   -343 843 31 -32 imp:n=1  $ Position 43
344  10 4.8413E-05   -344 844 31 -32 imp:n=1  $ Position 44
345  10 4.8413E-05   -345 845 31 -32 imp:n=1  $ Position 45
346  10 4.8413E-05   -346 846 31 -32 imp:n=1  $ Position 46
347  10 4.8413E-05   -347 847 31 -32 imp:n=1  $ Position 47
348  10 4.8413E-05   -348 848 31 -32 imp:n=1  $ Position 48
349  10 4.8413E-05   -349 849 31 -32 imp:n=1  $ Position 49
350  10 4.8413E-05   -350 850 31 -32 imp:n=1  $ Position 50
351  10 4.8413E-05   -351 851 31 -32 imp:n=1  $ Position 51
352  10 4.8413E-05   -352 852 31 -32 imp:n=1  $ Position 52
353  10 4.8413E-05   -353 853 31 -32 imp:n=1  $ Position 53
354  10 4.8413E-05   -354 854 31 -32 imp:n=1  $ Position 54
355  10 4.8413E-05   -355 855 31 -32 imp:n=1  $ Position 55
356  10 4.8413E-05   -356 856 31 -32 imp:n=1  $ Position 56
357  10 4.8413E-05   -357 857 31 -32 imp:n=1  $ Position 57
358  10 4.8413E-05   -358 858 31 -32 imp:n=1  $ Position 58
359  10 4.8413E-05   -359 859 31 -32 imp:n=1  $ Position 59
360  10 4.8413E-05   -360 860 31 -32 imp:n=1  $ Position 60
361  10 4.8413E-05   -361 861 31 -32 imp:n=1  $ Position 61
362  10 4.8413E-05   -362 862 31 -32 imp:n=1  $ Position 62
363  10 4.8413E-05   -363 863 31 -32 imp:n=1  $ Position 63
364  10 4.8413E-05   -364 864 31 -32 imp:n=1  $ Position 64
c
c --------- Ring 4 ---------
401  10 4.8413E-05   -401 901 31 -32 imp:n=1  $ Position 1
402  10 4.8413E-05   -402 902 31 -32 imp:n=1  $ Position 2
403  10 4.8413E-05   -403 903 31 -32 imp:n=1  $ Position 3
404  10 4.8413E-05   -404 904 31 -32 imp:n=1  $ Position 4
405  10 4.8413E-05   -405 905 31 -32 imp:n=1  $ Position 5
406  10 4.8413E-05   -406 906 31 -32 imp:n=1  $ Position 6
407  10 4.8413E-05   -407 907 31 -32 imp:n=1  $ Position 7
408  10 4.8413E-05   -408 908 31 -32 imp:n=1  $ Position 8
```

```
409  10 4.8413E-05   -409 909 31 -32 imp:n=1  $ Position 9
410  10 4.8413E-05   -410 910 31 -32 imp:n=1  $ Position 10
411  10 4.8413E-05   -411 911 31 -32 imp:n=1  $ Position 11
412  10 4.8413E-05   -412 912 31 -32 imp:n=1  $ Position 12
413  10 4.8413E-05   -413 913 31 -32 imp:n=1  $ Position 13
414  10 4.8413E-05   -414 914 31 -32 imp:n=1  $ Position 14
415  10 4.8413E-05   -415 915 31 -32 imp:n=1  $ Position 15
416  10 4.8413E-05   -416 916 31 -32 imp:n=1  $ Position 16
417  10 4.8413E-05   -417 917 31 -32 imp:n=1  $ Position 17
418  10 4.8413E-05   -418 918 31 -32 imp:n=1  $ Position 18
419  10 4.8413E-05   -419 919 31 -32 imp:n=1  $ Position 19
420  10 4.8413E-05   -420 920 31 -32 imp:n=1  $ Position 20
421  10 4.8413E-05   -421 921 31 -32 imp:n=1  $ Position 21
422  10 4.8413E-05   -422 922 31 -32 imp:n=1  $ Position 22
423  10 4.8413E-05   -423 923 31 -32 imp:n=1  $ Position 23
424  10 4.8413E-05   -424 924 31 -32 imp:n=1  $ Position 24
425  10 4.8413E-05   -425 925 31 -32 imp:n=1  $ Position 25
426  10 4.8413E-05   -426 926 31 -32 imp:n=1  $ Position 26
427  10 4.8413E-05   -427 927 31 -32 imp:n=1  $ Position 27
428  10 4.8413E-05   -428 928 31 -32 imp:n=1  $ Position 28
429  10 4.8413E-05   -429 929 31 -32 imp:n=1  $ Position 29
430  10 4.8413E-05   -430 930 31 -32 imp:n=1  $ Position 30
431  10 4.8413E-05   -431 931 31 -32 imp:n=1  $ Position 31
432  10 4.8413E-05   -432 932 31 -32 imp:n=1  $ Position 32
433  10 4.8413E-05   -433 933 31 -32 imp:n=1  $ Position 33
434  10 4.8413E-05   -434 934 31 -32 imp:n=1  $ Position 34
435  10 4.8413E-05   -435 935 31 -32 imp:n=1  $ Position 35
436  10 4.8413E-05   -436 936 31 -32 imp:n=1  $ Position 36
437  10 4.8413E-05   -437 937 31 -32 imp:n=1  $ Position 37
438  10 4.8413E-05   -438 938 31 -32 imp:n=1  $ Position 38
439  10 4.8413E-05   -439 939 31 -32 imp:n=1  $ Position 39
440  10 4.8413E-05   -440 940 31 -32 imp:n=1  $ Position 40
441  10 4.8413E-05   -441 941 31 -32 imp:n=1  $ Position 41
442  10 4.8413E-05   -442 942 31 -32 imp:n=1  $ Position 42
443  10 4.8413E-05   -443 943 31 -32 imp:n=1  $ Position 43
444  10 4.8413E-05   -444 944 31 -32 imp:n=1  $ Position 44
445  10 4.8413E-05   -445 945 31 -32 imp:n=1  $ Position 45
446  10 4.8413E-05   -446 946 31 -32 imp:n=1  $ Position 46
447  10 4.8413E-05   -447 947 31 -32 imp:n=1  $ Position 47
448  10 4.8413E-05   -448 948 31 -32 imp:n=1  $ Position 48
449  10 4.8413E-05   -449 949 31 -32 imp:n=1  $ Position 49
450  10 4.8413E-05   -450 950 31 -32 imp:n=1  $ Position 50
451  10 4.8413E-05   -451 951 31 -32 imp:n=1  $ Position 51
452  10 4.8413E-05   -452 952 31 -32 imp:n=1  $ Position 52
453  10 4.8413E-05   -453 953 31 -32 imp:n=1  $ Position 53
454  10 4.8413E-05   -454 954 31 -32 imp:n=1  $ Position 54
455  10 4.8413E-05   -455 955 31 -32 imp:n=1  $ Position 55
456  10 4.8413E-05   -456 956 31 -32 imp:n=1  $ Position 56
457  10 4.8413E-05   -457 957 31 -32 imp:n=1  $ Position 57
458  10 4.8413E-05   -458 958 31 -32 imp:n=1  $ Position 58
459  10 4.8413E-05   -459 959 31 -32 imp:n=1  $ Position 59
460  10 4.8413E-05   -460 960 31 -32 imp:n=1  $ Position 60
461  10 4.8413E-05   -461 961 31 -32 imp:n=1  $ Position 61
462  10 4.8413E-05   -462 962 31 -32 imp:n=1  $ Position 62
463  10 4.8413E-05   -463 963 31 -32 imp:n=1  $ Position 63
464  10 4.8413E-05   -464 964 31 -32 imp:n=1  $ Position 64
c
c --------- Ring 5 ---------
501  10 4.8413E-05   -501 1001 31 -32 imp:n=1  $ Position 1
502  10 4.8413E-05   -502 1002 31 -32 imp:n=1  $ Position 2
503  10 4.8413E-05   -503 1003 31 -3091 imp:n=1  $ Position 3
3105 0    -503 3091 -9 imp:n=1 fill=21 (-83.70  34.67 0)  $ Control Rod 4
504  10 4.8413E-05   -504 1004 31 -32 imp:n=1  $ Position 4
505  10 4.8413E-05   -505 1005 31 -32 imp:n=1  $ Position 5
506  10 4.8413E-05   -506 1006 31 -32 imp:n=1  $ Position 6
507  10 4.8413E-05   -507 1007 31 -32 imp:n=1  $ Position 7
508  10 4.8413E-05   -508 1008 31 -32 imp:n=1  $ Position 8
509  10 4.8413E-05   -509 1009 31 -32 imp:n=1  $ Position 9
510  10 4.8413E-05   -510 1010 31 -32 imp:n=1  $ Position 10
511  10 4.8413E-05   -511 1011 31 -32 imp:n=1  $ Position 11
512  10 4.8413E-05   -512 1012 31 -32 imp:n=1  $ Position 12
513  10 4.8413E-05   -513 1013 31 -32 imp:n=1  $ Position 13
514  10 4.8413E-05   -514 1014 31 -32 imp:n=1  $ Position 14
515  10 4.8413E-05   -515 1015 31 -32 imp:n=1  $ Position 15
516  10 4.8413E-05   -516 1016 31 -32 imp:n=1  $ Position 16
517  10 4.8413E-05   -517 1017 31 -32 imp:n=1  $ Position 17
```

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518  10 4.8413E-05   -518 1018 31 -32 imp:n=1  $ Position 18
519  10 4.8413E-05   -519 1019 31 -3091 imp:n=1  $ Position 19
3102 0    -519 3091 -9 imp:n=1 fill=18 ( 34.67  83.70 0)  $ Control Rod 1
520  10 4.8413E-05   -520 1020 31 -32 imp:n=1  $ Position 20
521  10 4.8413E-05   -521 1021 31 -32 imp:n=1  $ Position 21
522  10 4.8413E-05   -522 1022 31 -32 imp:n=1  $ Position 22
523  10 4.8413E-05   -523 1023 31 -32 imp:n=1  $ Position 23
524  10 4.8413E-05   -524 1024 31 -32 imp:n=1  $ Position 24
525  10 4.8413E-05   -525 1025 31 -32 imp:n=1  $ Position 25
526  10 4.8413E-05   -526 1026 31 -32 imp:n=1  $ Position 26
527  10 4.8413E-05   -527 1027 31 -32 imp:n=1  $ Position 27
528  10 4.8413E-05   -528 1028 31 -32 imp:n=1  $ Position 28
529  10 4.8413E-05   -529 1029 31 -32 imp:n=1  $ Position 29
530  10 4.8413E-05   -530 1030 31 -32 imp:n=1  $ Position 30
531  10 4.8413E-05   -531 1031 31 -32 imp:n=1  $ Position 31
532  10 4.8413E-05   -532 1032 31 -32 imp:n=1  $ Position 32
533  10 4.8413E-05   -533 1033 31 -32 imp:n=1  $ Position 33
534  10 4.8413E-05   -534 1034 31 -32 imp:n=1  $ Position 34
535  10 4.8413E-05   -535 1035 31 -3091 imp:n=1  $ Position 35
3103 0    -535 3091 -9 imp:n=1 fill=19 ( 83.70 -34.67 0)  $ Control Rod 2
536  10 4.8413E-05   -536 1036 31 -32 imp:n=1  $ Position 36
537  10 4.8413E-05   -537 1037 31 -32 imp:n=1  $ Position 37
538  10 4.8413E-05   -538 1038 31 -32 imp:n=1  $ Position 38
539  10 4.8413E-05   -539 1039 31 -32 imp:n=1  $ Position 39
540  10 4.8413E-05   -540 1040 31 -32 imp:n=1  $ Position 40
541  10 4.8413E-05   -541 1041 31 -32 imp:n=1  $ Position 41
542  10 4.8413E-05   -542 1042 31 -32 imp:n=1  $ Position 42
543  10 4.8413E-05   -543 1043 31 -32 imp:n=1  $ Position 43
544  10 4.8413E-05   -544 1044 31 -32 imp:n=1  $ Position 44
c    *Replaced by Autorod  $ Position 45
546  10 4.8413E-05   -546 1046 31 -32 imp:n=1  $ Position 46
547  10 4.8413E-05   -547 1047 31 -32 imp:n=1  $ Position 47
548  10 4.8413E-05   -548 1048 31 -32 imp:n=1  $ Position 48
549  10 4.8413E-05   -549 1049 31 -32 imp:n=1  $ Position 49
550  10 4.8413E-05   -550 1050 31 -32 imp:n=1  $ Position 50
551  10 4.8413E-05   -551 1051 31 -3091 imp:n=1  $ Position 51
3104 0    -551 3091 -9 imp:n=1 fill=20 (-34.67 -83.70 0)  $ Control Rod 3
552  10 4.8413E-05   -552 1052 31 -32 imp:n=1  $ Position 52
553  10 4.8413E-05   -553 1053 31 -32 imp:n=1  $ Position 53
554  10 4.8413E-05   -554 1054 31 -32 imp:n=1  $ Position 54
555  10 4.8413E-05   -555 1055 31 -32 imp:n=1  $ Position 55
556  10 4.8413E-05   -556 1056 31 -32 imp:n=1  $ Position 56
557  10 4.8413E-05   -557 1057 31 -32 imp:n=1  $ Position 57
558  10 4.8413E-05   -558 1058 31 -32 imp:n=1  $ Position 58
559  10 4.8413E-05   -559 1059 31 -32 imp:n=1  $ Position 59
560  10 4.8413E-05   -560 1060 31 -32 imp:n=1  $ Position 60
561  10 4.8413E-05   -561 1061 31 -32 imp:n=1  $ Position 61
562  10 4.8413E-05   -562 1062 31 -32 imp:n=1  $ Position 62
563  10 4.8413E-05   -563 1063 31 -32 imp:n=1  $ Position 63
564  10 4.8413E-05   -564 1064 31 -32 imp:n=1  $ Position 64
c
c ------ Graphite Plugs ------
c --------- Ring 1 ---------
601  27 8.8496E-02  -601 31 -32 imp:n=1  $ Position 1
602  27 8.8496E-02  -602 31 -32 imp:n=1  $ Position 2
c    *Replaced by Safety/Shutdown Rod  $ Position 3
604  27 8.8496E-02  -604 31 -32 imp:n=1  $ Position 4
605  27 8.8496E-02  -605 31 -32 imp:n=1  $ Position 5
606  27 8.8496E-02  -606 31 -32 imp:n=1  $ Position 6
607  27 8.8496E-02  -607 31 -32 imp:n=1  $ Position 7
608  27 8.8496E-02  -608 31 -32 imp:n=1  $ Position 8
609  27 8.8496E-02  -609 31 -32 imp:n=1  $ Position 9
610  27 8.8496E-02  -610 31 -32 imp:n=1  $ Position 10
c    *Replaced by Safety/Shutdown Rod  $ Position 11
612  27 8.8496E-02  -612 31 -32 imp:n=1  $ Position 12
613  27 8.8496E-02  -613 31 -32 imp:n=1  $ Position 13
614  27 8.8496E-02  -614 31 -32 imp:n=1  $ Position 14
615  27 8.8496E-02  -615 31 -32 imp:n=1  $ Position 15
616  27 8.8496E-02  -616 31 -32 imp:n=1  $ Position 16
617  27 8.8496E-02  -617 31 -32 imp:n=1  $ Position 17
618  27 8.8496E-02  -618 31 -32 imp:n=1  $ Position 18
619  27 8.8496E-02  -619 31 -32 imp:n=1  $ Position 19
c    *Replaced by Safety/Shutdown Rod  $ Position 20
621  27 8.8496E-02  -621 31 -32 imp:n=1  $ Position 21
622  27 8.8496E-02  -622 31 -32 imp:n=1  $ Position 22
623  27 8.8496E-02  -623 31 -32 imp:n=1  $ Position 23
```

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624  27 8.8496E-02  -624 31 -32 imp:n=1  $ Position 24
625  27 8.8496E-02  -625 31 -32 imp:n=1  $ Position 25
626  27 8.8496E-02  -626 31 -32 imp:n=1  $ Position 26
c    *Replaced by Safety/Shutdown Rod  $ Position 27
628  27 8.8496E-02  -628 31 -32 imp:n=1  $ Position 28
629  27 8.8496E-02  -629 31 -32 imp:n=1  $ Position 29
630  27 8.8496E-02  -630 31 -32 imp:n=1  $ Position 30
631  27 8.8496E-02  -631 31 -32 imp:n=1  $ Position 31
632  27 8.8496E-02  -632 31 -32 imp:n=1  $ Position 32
633  27 8.8496E-02  -633 31 -32 imp:n=1  $ Position 33
634  27 8.8496E-02  -634 31 -32 imp:n=1  $ Position 34
c    *Replaced by Safety/Shutdown Rod  $ Position 35
636  27 8.8496E-02  -636 31 -32 imp:n=1  $ Position 36
637  27 8.8496E-02  -637 31 -32 imp:n=1  $ Position 37
638  27 8.8496E-02  -638 31 -32 imp:n=1  $ Position 38
639  27 8.8496E-02  -639 31 -32 imp:n=1  $ Position 39
640  27 8.8496E-02  -640 31 -32 imp:n=1  $ Position 40
641  27 8.8496E-02  -641 31 -32 imp:n=1  $ Position 41
642  27 8.8496E-02  -642 31 -32 imp:n=1  $ Position 42
643  27 8.8496E-02  -643 31 -32 imp:n=1  $ Position 43
c    *Replaced by Safety/Shutdown Rod  $ Position 44
645  27 8.8496E-02  -645 31 -32 imp:n=1  $ Position 45
646  27 8.8496E-02  -646 31 -32 imp:n=1  $ Position 46
647  27 8.8496E-02  -647 31 -32 imp:n=1  $ Position 47
648  27 8.8496E-02  -648 31 -32 imp:n=1  $ Position 48
649  27 8.8496E-02  -649 31 -32 imp:n=1  $ Position 49
650  27 8.8496E-02  -650 31 -32 imp:n=1  $ Position 50
c    *Replaced by Safety/Shutdown Rod  $ Position 51
652  27 8.8496E-02  -652 31 -32 imp:n=1  $ Position 52
653  27 8.8496E-02  -653 31 -32 imp:n=1  $ Position 53
654  27 8.8496E-02  -654 31 -32 imp:n=1  $ Position 54
655  27 8.8496E-02  -655 31 -32 imp:n=1  $ Position 55
656  27 8.8496E-02  -656 31 -32 imp:n=1  $ Position 56
657  27 8.8496E-02  -657 31 -32 imp:n=1  $ Position 57
c    *Replaced by Safety/Shutdown Rod  $ Position 58
659  27 8.8496E-02  -659 31 -32 imp:n=1  $ Position 59
660  27 8.8496E-02  -660 31 -32 imp:n=1  $ Position 60
661  27 8.8496E-02  -661 31 -32 imp:n=1  $ Position 61
662  27 8.8496E-02  -662 31 -32 imp:n=1  $ Position 62
663  27 8.8496E-02  -663 31 -32 imp:n=1  $ Position 63
664  27 8.8496E-02  -664 31 -32 imp:n=1  $ Position 64
c
c --------- Ring 2 ---------
701  27 8.8496E-02  -701 31 -32 imp:n=1  $ Position 1
702  27 8.8496E-02  -702 31 -32 imp:n=1  $ Position 2
703  27 8.8496E-02  -703 31 -32 imp:n=1  $ Position 3
704  27 8.8496E-02  -704 31 -32 imp:n=1  $ Position 4
705  27 8.8496E-02  -705 31 -32 imp:n=1  $ Position 5
706  27 8.8496E-02  -706 31 -32 imp:n=1  $ Position 6
707  27 8.8496E-02  -707 31 -32 imp:n=1  $ Position 7
708  27 8.8496E-02  -708 31 -32 imp:n=1  $ Position 8
709  27 8.8496E-02  -709 31 -32 imp:n=1  $ Position 9
710  27 8.8496E-02  -710 31 -32 imp:n=1  $ Position 10
711  27 8.8496E-02  -711 31 -32 imp:n=1  $ Position 11
712  27 8.8496E-02  -712 31 -32 imp:n=1  $ Position 12
713  27 8.8496E-02  -713 31 -32 imp:n=1  $ Position 13
714  27 8.8496E-02  -714 31 -32 imp:n=1  $ Position 14
715  27 8.8496E-02  -715 31 -32 imp:n=1  $ Position 15
716  27 8.8496E-02  -716 31 -32 imp:n=1  $ Position 16
717  27 8.8496E-02  -717 31 -32 imp:n=1  $ Position 17
718  27 8.8496E-02  -718 31 -32 imp:n=1  $ Position 18
719  27 8.8496E-02  -719 31 -32 imp:n=1  $ Position 19
720  27 8.8496E-02  -720 31 -32 imp:n=1  $ Position 20
721  27 8.8496E-02  -721 31 -32 imp:n=1  $ Position 21
722  27 8.8496E-02  -722 31 -32 imp:n=1  $ Position 22
723  27 8.8496E-02  -723 31 -32 imp:n=1  $ Position 23
724  27 8.8496E-02  -724 31 -32 imp:n=1  $ Position 24
725  27 8.8496E-02  -725 31 -32 imp:n=1  $ Position 25
726  27 8.8496E-02  -726 31 -32 imp:n=1  $ Position 26
727  27 8.8496E-02  -727 31 -32 imp:n=1  $ Position 27
728  27 8.8496E-02  -728 31 -32 imp:n=1  $ Position 28
729  27 8.8496E-02  -729 31 -32 imp:n=1  $ Position 29
730  27 8.8496E-02  -730 31 -32 imp:n=1  $ Position 30
731  27 8.8496E-02  -731 31 -32 imp:n=1  $ Position 31
732  27 8.8496E-02  -732 31 -32 imp:n=1  $ Position 32
733  27 8.8496E-02  -733 31 -32 imp:n=1  $ Position 33
```

```
734  27 8.8496E-02  -734 31 -32 imp:n=1  $ Position 34
735  27 8.8496E-02  -735 31 -32 imp:n=1  $ Position 35
736  27 8.8496E-02  -736 31 -32 imp:n=1  $ Position 36
737  27 8.8496E-02  -737 31 -32 imp:n=1  $ Position 37
738  27 8.8496E-02  -738 31 -32 imp:n=1  $ Position 38
739  27 8.8496E-02  -739 31 -32 imp:n=1  $ Position 39
740  27 8.8496E-02  -740 31 -32 imp:n=1  $ Position 40
741  27 8.8496E-02  -741 31 -32 imp:n=1  $ Position 41
742  27 8.8496E-02  -742 31 -32 imp:n=1  $ Position 42
743  27 8.8496E-02  -743 31 -32 imp:n=1  $ Position 43
744  27 8.8496E-02  -744 31 -32 imp:n=1  $ Position 44
745  27 8.8496E-02  -745 31 -32 imp:n=1  $ Position 45
746  27 8.8496E-02  -746 31 -32 imp:n=1  $ Position 46
747  27 8.8496E-02  -747 31 -32 imp:n=1  $ Position 47
748  27 8.8496E-02  -748 31 -32 imp:n=1  $ Position 48
749  27 8.8496E-02  -749 31 -32 imp:n=1  $ Position 49
750  27 8.8496E-02  -750 31 -32 imp:n=1  $ Position 50
751  27 8.8496E-02  -751 31 -32 imp:n=1  $ Position 51
752  27 8.8496E-02  -752 31 -32 imp:n=1  $ Position 52
753  27 8.8496E-02  -753 31 -32 imp:n=1  $ Position 53
754  27 8.8496E-02  -754 31 -32 imp:n=1  $ Position 54
755  27 8.8496E-02  -755 31 -32 imp:n=1  $ Position 55
756  27 8.8496E-02  -756 31 -32 imp:n=1  $ Position 56
757  27 8.8496E-02  -757 31 -32 imp:n=1  $ Position 57
758  27 8.8496E-02  -758 31 -32 imp:n=1  $ Position 58
759  27 8.8496E-02  -759 31 -32 imp:n=1  $ Position 59
760  27 8.8496E-02  -760 31 -32 imp:n=1  $ Position 60
761  27 8.8496E-02  -761 31 -32 imp:n=1  $ Position 61
762  27 8.8496E-02  -762 31 -32 imp:n=1  $ Position 62
763  27 8.8496E-02  -763 31 -32 imp:n=1  $ Position 63
764  27 8.8496E-02  -764 31 -32 imp:n=1  $ Position 64
c
c --------- Ring 3 ---------
801  27 8.8496E-02  -801 31 -32 imp:n=1  $ Position 1
802  27 8.8496E-02  -802 31 -32 imp:n=1  $ Position 2
803  27 8.8496E-02  -803 31 -32 imp:n=1  $ Position 3
804  27 8.8496E-02  -804 31 -32 imp:n=1  $ Position 4
805  27 8.8496E-02  -805 31 -32 imp:n=1  $ Position 5
806  27 8.8496E-02  -806 31 -32 imp:n=1  $ Position 6
807  27 8.8496E-02  -807 31 -32 imp:n=1  $ Position 7
808  27 8.8496E-02  -808 31 -32 imp:n=1  $ Position 8
809  27 8.8496E-02  -809 31 -32 imp:n=1  $ Position 9
810  27 8.8496E-02  -810 31 -32 imp:n=1  $ Position 10
811  27 8.8496E-02  -811 31 -32 imp:n=1  $ Position 11
812  27 8.8496E-02  -812 31 -32 imp:n=1  $ Position 12
813  27 8.8496E-02  -813 31 -32 imp:n=1  $ Position 13
814  27 8.8496E-02  -814 31 -32 imp:n=1  $ Position 14
815  27 8.8496E-02  -815 31 -32 imp:n=1  $ Position 15
816  27 8.8496E-02  -816 31 -32 imp:n=1  $ Position 16
817  27 8.8496E-02  -817 31 -32 imp:n=1  $ Position 17
818  27 8.8496E-02  -818 31 -32 imp:n=1  $ Position 18
819  27 8.8496E-02  -819 31 -32 imp:n=1  $ Position 19
820  27 8.8496E-02  -820 31 -32 imp:n=1  $ Position 20
821  27 8.8496E-02  -821 31 -32 imp:n=1  $ Position 21
822  27 8.8496E-02  -822 31 -32 imp:n=1  $ Position 22
823  27 8.8496E-02  -823 31 -32 imp:n=1  $ Position 23
824  27 8.8496E-02  -824 31 -32 imp:n=1  $ Position 24
825  27 8.8496E-02  -825 31 -32 imp:n=1  $ Position 25
826  27 8.8496E-02  -826 31 -32 imp:n=1  $ Position 26
827  27 8.8496E-02  -827 31 -32 imp:n=1  $ Position 27
828  27 8.8496E-02  -828 31 -32 imp:n=1  $ Position 28
829  27 8.8496E-02  -829 31 -32 imp:n=1  $ Position 29
830  27 8.8496E-02  -830 31 -32 imp:n=1  $ Position 30
831  27 8.8496E-02  -831 31 -32 imp:n=1  $ Position 31
832  27 8.8496E-02  -832 31 -32 imp:n=1  $ Position 32
833  27 8.8496E-02  -833 31 -32 imp:n=1  $ Position 33
834  27 8.8496E-02  -834 31 -32 imp:n=1  $ Position 34
835  27 8.8496E-02  -835 31 -32 imp:n=1  $ Position 35
836  27 8.8496E-02  -836 31 -32 imp:n=1  $ Position 36
837  27 8.8496E-02  -837 31 -32 imp:n=1  $ Position 37
838  27 8.8496E-02  -838 31 -32 imp:n=1  $ Position 38
839  27 8.8496E-02  -839 31 -32 imp:n=1  $ Position 39
840  27 8.8496E-02  -840 31 -32 imp:n=1  $ Position 40
841  27 8.8496E-02  -841 31 -32 imp:n=1  $ Position 41
842  27 8.8496E-02  -842 31 -32 imp:n=1  $ Position 42
843  27 8.8496E-02  -843 31 -32 imp:n=1  $ Position 43
```

```
844  27 8.8496E-02  -844 31 -32 imp:n=1  $ Position 44
845  27 8.8496E-02  -845 31 -32 imp:n=1  $ Position 45
846  27 8.8496E-02  -846 31 -32 imp:n=1  $ Position 46
847  27 8.8496E-02  -847 31 -32 imp:n=1  $ Position 47
848  27 8.8496E-02  -848 31 -32 imp:n=1  $ Position 48
849  27 8.8496E-02  -849 31 -32 imp:n=1  $ Position 49
850  27 8.8496E-02  -850 31 -32 imp:n=1  $ Position 50
851  27 8.8496E-02  -851 31 -32 imp:n=1  $ Position 51
852  27 8.8496E-02  -852 31 -32 imp:n=1  $ Position 52
853  27 8.8496E-02  -853 31 -32 imp:n=1  $ Position 53
854  27 8.8496E-02  -854 31 -32 imp:n=1  $ Position 54
855  27 8.8496E-02  -855 31 -32 imp:n=1  $ Position 55
856  27 8.8496E-02  -856 31 -32 imp:n=1  $ Position 56
857  27 8.8496E-02  -857 31 -32 imp:n=1  $ Position 57
858  27 8.8496E-02  -858 31 -32 imp:n=1  $ Position 58
859  27 8.8496E-02  -859 31 -32 imp:n=1  $ Position 59
860  27 8.8496E-02  -860 31 -32 imp:n=1  $ Position 60
861  27 8.8496E-02  -861 31 -32 imp:n=1  $ Position 61
862  27 8.8496E-02  -862 31 -32 imp:n=1  $ Position 62
863  27 8.8496E-02  -863 31 -32 imp:n=1  $ Position 63
864  27 8.8496E-02  -864 31 -32 imp:n=1  $ Position 64
c
c --------- Ring 4 ---------
901  27 8.8496E-02  -901 31 -32 imp:n=1  $ Position 1
902  27 8.8496E-02  -902 31 -32 imp:n=1  $ Position 2
903  27 8.8496E-02  -903 31 -32 imp:n=1  $ Position 3
904  27 8.8496E-02  -904 31 -32 imp:n=1  $ Position 4
905  27 8.8496E-02  -905 31 -32 imp:n=1  $ Position 5
906  27 8.8496E-02  -906 31 -32 imp:n=1  $ Position 6
907  27 8.8496E-02  -907 31 -32 imp:n=1  $ Position 7
908  27 8.8496E-02  -908 31 -32 imp:n=1  $ Position 8
909  27 8.8496E-02  -909 31 -32 imp:n=1  $ Position 9
910  27 8.8496E-02  -910 31 -32 imp:n=1  $ Position 10
911  27 8.8496E-02  -911 31 -32 imp:n=1  $ Position 11
912  27 8.8496E-02  -912 31 -32 imp:n=1  $ Position 12
913  27 8.8496E-02  -913 31 -32 imp:n=1  $ Position 13
914  27 8.8496E-02  -914 31 -32 imp:n=1  $ Position 14
915  27 8.8496E-02  -915 31 -32 imp:n=1  $ Position 15
916  27 8.8496E-02  -916 31 -32 imp:n=1  $ Position 16
917  27 8.8496E-02  -917 31 -32 imp:n=1  $ Position 17
918  27 8.8496E-02  -918 31 -32 imp:n=1  $ Position 18
919  27 8.8496E-02  -919 31 -32 imp:n=1  $ Position 19
920  27 8.8496E-02  -920 31 -32 imp:n=1  $ Position 20
921  27 8.8496E-02  -921 31 -32 imp:n=1  $ Position 21
922  27 8.8496E-02  -922 31 -32 imp:n=1  $ Position 22
923  27 8.8496E-02  -923 31 -32 imp:n=1  $ Position 23
924  27 8.8496E-02  -924 31 -32 imp:n=1  $ Position 24
925  27 8.8496E-02  -925 31 -32 imp:n=1  $ Position 25
926  27 8.8496E-02  -926 31 -32 imp:n=1  $ Position 26
927  27 8.8496E-02  -927 31 -32 imp:n=1  $ Position 27
928  27 8.8496E-02  -928 31 -32 imp:n=1  $ Position 28
929  27 8.8496E-02  -929 31 -32 imp:n=1  $ Position 29
930  27 8.8496E-02  -930 31 -32 imp:n=1  $ Position 30
931  27 8.8496E-02  -931 31 -32 imp:n=1  $ Position 31
932  27 8.8496E-02  -932 31 -32 imp:n=1  $ Position 32
933  27 8.8496E-02  -933 31 -32 imp:n=1  $ Position 33
934  27 8.8496E-02  -934 31 -32 imp:n=1  $ Position 34
935  27 8.8496E-02  -935 31 -32 imp:n=1  $ Position 35
936  27 8.8496E-02  -936 31 -32 imp:n=1  $ Position 36
937  27 8.8496E-02  -937 31 -32 imp:n=1  $ Position 37
938  27 8.8496E-02  -938 31 -32 imp:n=1  $ Position 38
939  27 8.8496E-02  -939 31 -32 imp:n=1  $ Position 39
940  27 8.8496E-02  -940 31 -32 imp:n=1  $ Position 40
941  27 8.8496E-02  -941 31 -32 imp:n=1  $ Position 41
942  27 8.8496E-02  -942 31 -32 imp:n=1  $ Position 42
943  27 8.8496E-02  -943 31 -32 imp:n=1  $ Position 43
944  27 8.8496E-02  -944 31 -32 imp:n=1  $ Position 44
945  27 8.8496E-02  -945 31 -32 imp:n=1  $ Position 45
946  27 8.8496E-02  -946 31 -32 imp:n=1  $ Position 46
947  27 8.8496E-02  -947 31 -32 imp:n=1  $ Position 47
948  27 8.8496E-02  -948 31 -32 imp:n=1  $ Position 48
949  27 8.8496E-02  -949 31 -32 imp:n=1  $ Position 49
950  27 8.8496E-02  -950 31 -32 imp:n=1  $ Position 50
951  27 8.8496E-02  -951 31 -32 imp:n=1  $ Position 51
952  27 8.8496E-02  -952 31 -32 imp:n=1  $ Position 52
953  27 8.8496E-02  -953 31 -32 imp:n=1  $ Position 53
```

```
954  27 8.8496E-02  -954 31 -32 imp:n=1  $ Position 54
955  27 8.8496E-02  -955 31 -32 imp:n=1  $ Position 55
956  27 8.8496E-02  -956 31 -32 imp:n=1  $ Position 56
957  27 8.8496E-02  -957 31 -32 imp:n=1  $ Position 57
958  27 8.8496E-02  -958 31 -32 imp:n=1  $ Position 58
959  27 8.8496E-02  -959 31 -32 imp:n=1  $ Position 59
960  27 8.8496E-02  -960 31 -32 imp:n=1  $ Position 60
961  27 8.8496E-02  -961 31 -32 imp:n=1  $ Position 61
962  27 8.8496E-02  -962 31 -32 imp:n=1  $ Position 62
963  27 8.8496E-02  -963 31 -32 imp:n=1  $ Position 63
964  27 8.8496E-02  -964 31 -32 imp:n=1  $ Position 64
c
c --------- Ring 5 ---------
1001 27 8.8496E-02  -1001 31 -32 imp:n=1  $ Position 1
1002 27 8.8496E-02  -1002 31 -32 imp:n=1  $ Position 2
1003 27 8.8496E-02  -1003 31 -3091 imp:n=1  $ Position 3
1004 27 8.8496E-02  -1004 31 -32 imp:n=1  $ Position 4
1005 27 8.8496E-02  -1005 31 -32 imp:n=1  $ Position 5
1006 27 8.8496E-02  -1006 31 -32 imp:n=1  $ Position 6
1007 27 8.8496E-02  -1007 31 -32 imp:n=1  $ Position 7
1008 27 8.8496E-02  -1008 31 -32 imp:n=1  $ Position 8
1009 27 8.8496E-02  -1009 31 -32 imp:n=1  $ Position 9
1010 27 8.8496E-02  -1010 31 -32 imp:n=1  $ Position 10
1011 27 8.8496E-02  -1011 31 -32 imp:n=1  $ Position 11
1012 27 8.8496E-02  -1012 31 -32 imp:n=1  $ Position 12
1013 27 8.8496E-02  -1013 31 -32 imp:n=1  $ Position 13
1014 27 8.8496E-02  -1014 31 -32 imp:n=1  $ Position 14
1015 27 8.8496E-02  -1015 31 -32 imp:n=1  $ Position 15
1016 27 8.8496E-02  -1016 31 -32 imp:n=1  $ Position 16
1017 27 8.8496E-02  -1017 31 -32 imp:n=1  $ Position 17
1018 27 8.8496E-02  -1018 31 -32 imp:n=1  $ Position 18
1019 27 8.8496E-02  -1019 31 -3091 imp:n=1  $ Position 19
1020 27 8.8496E-02  -1020 31 -32 imp:n=1  $ Position 20
1021 27 8.8496E-02  -1021 31 -32 imp:n=1  $ Position 21
1022 27 8.8496E-02  -1022 31 -32 imp:n=1  $ Position 22
1023 27 8.8496E-02  -1023 31 -32 imp:n=1  $ Position 23
1024 27 8.8496E-02  -1024 31 -32 imp:n=1  $ Position 24
1025 27 8.8496E-02  -1025 31 -32 imp:n=1  $ Position 25
1026 27 8.8496E-02  -1026 31 -32 imp:n=1  $ Position 26
1027 27 8.8496E-02  -1027 31 -32 imp:n=1  $ Position 27
1028 27 8.8496E-02  -1028 31 -32 imp:n=1  $ Position 28
1029 27 8.8496E-02  -1029 31 -32 imp:n=1  $ Position 29
1030 27 8.8496E-02  -1030 31 -32 imp:n=1  $ Position 30
1031 27 8.8496E-02  -1031 31 -32 imp:n=1  $ Position 31
1032 27 8.8496E-02  -1032 31 -32 imp:n=1  $ Position 32
1033 27 8.8496E-02  -1033 31 -32 imp:n=1  $ Position 33
1034 27 8.8496E-02  -1034 31 -32 imp:n=1  $ Position 34
1035 27 8.8496E-02  -1035 31 -3091 imp:n=1  $ Position 35
1036 27 8.8496E-02  -1036 31 -32 imp:n=1  $ Position 36
1037 27 8.8496E-02  -1037 31 -32 imp:n=1  $ Position 37
1038 27 8.8496E-02  -1038 31 -32 imp:n=1  $ Position 38
1039 27 8.8496E-02  -1039 31 -32 imp:n=1  $ Position 39
1040 27 8.8496E-02  -1040 31 -32 imp:n=1  $ Position 40
1041 27 8.8496E-02  -1041 31 -32 imp:n=1  $ Position 41
1042 27 8.8496E-02  -1042 31 -32 imp:n=1  $ Position 42
1043 27 8.8496E-02  -1043 31 -32 imp:n=1  $ Position 43
1044 27 8.8496E-02  -1044 31 -32 imp:n=1  $ Position 44
c    *Replaced by Autorod  $ Position 45
1046 27 8.8496E-02  -1046 31 -32 imp:n=1  $ Position 46
1047 27 8.8496E-02  -1047 31 -32 imp:n=1  $ Position 47
1048 27 8.8496E-02  -1048 31 -32 imp:n=1  $ Position 48
1049 27 8.8496E-02  -1049 31 -32 imp:n=1  $ Position 49
1050 27 8.8496E-02  -1050 31 -32 imp:n=1  $ Position 50
1051 27 8.8496E-02  -1051 31 -3091 imp:n=1  $ Position 51
1052 27 8.8496E-02  -1052 31 -32 imp:n=1  $ Position 52
1053 27 8.8496E-02  -1053 31 -32 imp:n=1  $ Position 53
1054 27 8.8496E-02  -1054 31 -32 imp:n=1  $ Position 54
1055 27 8.8496E-02  -1055 31 -32 imp:n=1  $ Position 55
1056 27 8.8496E-02  -1056 31 -32 imp:n=1  $ Position 56
1057 27 8.8496E-02  -1057 31 -32 imp:n=1  $ Position 57
1058 27 8.8496E-02  -1058 31 -32 imp:n=1  $ Position 58
1059 27 8.8496E-02  -1059 31 -32 imp:n=1  $ Position 59
1060 27 8.8496E-02  -1060 31 -32 imp:n=1  $ Position 60
1061 27 8.8496E-02  -1061 31 -32 imp:n=1  $ Position 61
1062 27 8.8496E-02  -1062 31 -32 imp:n=1  $ Position 62
1063 27 8.8496E-02  -1063 31 -32 imp:n=1  $ Position 63
```

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1064 27 8.8496E-02  -1064 31 -32 imp:n=1  $ Position 64
c
c ------ Safety/Shutdown Rod Holes ------
1101 0  -1101 15 -9 imp:n=1 fill=2 (-38.45  56.57 0)  $ Rod 1
1102 0  -1102 15 -9 imp:n=1 fill=3 ( 32.74 -60.05 0)  $ Rod 2
1103 0  -1103 15 -9 imp:n=1 fill=4 ( 57.17  37.55 0)  $ Rod 3
1104 0  -1104 15 -9 imp:n=1 fill=5 (-53.23 -42.95 0)  $ Rod 4
1105 0  -1105 15 -9 imp:n=1 fill=6 ( 67.19 -12.82 0)  $ Rod 5
1106 0  -1106 15 -9 imp:n=1 fill=7 (-66.98  13.87 0)  $ Rod 6
1107 0  -1107 15 -9 imp:n=1 fill=8 ( 19.31  65.62 0)  $ Rod 7
1108 0  -1108 15 -9 imp:n=1 fill=9 (-13.87 -66.98 0)  $ Rod 8
c
c ------ ZEBRA Control Rod Holes ------
c    *There were no ZEBRA Control Rods in the Core
c
1109 10 4.8413E-05  (11109 -1109 15 -9):(-11109 32 -9) imp:n=1  $ Air
11109 28 8.9248E-02 -11109 15 -32 imp:n=1  $ Graphite Filler
1110 10 4.8413E-05  (11110 -1110 15 -9):(-11110 32 -9) imp:n=1  $ Air
11110 28 8.9248E-02 -11110 15 -32 imp:n=1  $ Graphite Filler
1111 10 4.8413E-05  (11111 -1111 15 -9):(-11111 32 -9) imp:n=1  $ Air
11111 28 8.9248E-02 -11111 15 -32 imp:n=1  $ Graphite Filler
1112 10 4.8413E-05  (11112 -1112 15 -9):(-11112 32 -9) imp:n=1  $ Air
11112 28 8.9248E-02 -11112 15 -32 imp:n=1  $ Graphite Filler
c
c ------ Withdrawable Control Rod Holes ------
c    *Same as Ring 5 Position 19 $ Rod 1
c    *Same as Ring 5 Position 35 $ Rod 2
c    *Same as Ring 5 Position 51 $ Rod 3
c    *Same as Ring 5 Position 3  $ Rod 4
c
c ------ Autorod Hole ------
1113 0  -1113 15 -9 imp:n=1 fill=11 (17.36 -87.29 0)
c
c --- Upper Axial Reflector ---------------------------------------------------
c ------ Central Cylinder ------
1201 10 4.8413E-05  1201 -1202 -1203 imp:n=1  $ Central Coolant Channel
1202 6 8.7789E-02  1201 -1202 1203 -1204 imp:n=1  $ Graphite
c
c ------ Graphite Annulus ------
1211 7 8.8291E-02  1201 -1202 1211 -1333
          (1301 1302 1303 1304 1305 1306 1307 1308 1309 1310 1311 1312 1313
           1314 1315 1316 1317 1318 1319 1320 1321 1322 1323 1324 1325 1326
           1327 1328 1329 1330 1331 1332)
           imp:n=1  $ Ring 1 Region
1212 7 8.8291E-02  1201 -1202 1333 -1433
          (1401 1402 1403 1404 1405 1406 1407 1408 1409 1410 1411 1412 1413
           1414 1415 1416 1417 1418 1419 1420 1421 1422 1423 1424 1425 1426
           1427 1428 1429 1430 1431 1432)
           imp:n=1  $ Ring 2 Region
1213 7 8.8291E-02  1201 -1202 1433 -1533
          (1501 1502 1503 1504 1505 1506 1507 1508 1509 1510 1511 1512 1513
           1514 1515 1516 1517 1518 1519 1520 1521 1522 1523 1524 1525 1526
           1527 1528 1529 1530 1531 1532)
           imp:n=1  $ Ring 3 Region
1214 7 8.8291E-02  1201 -1202 1533 -1633
          (1601 1602 1603 1604 1605 1606 1607 1608 1609 1610 1611 1612 1613
           1614 1615 1616 1617 1618 1619 1620 1621 1622 1623 1624 1625 1626
           1627 1628 1629 1630 1631 1632)
           imp:n=1  $ Ring 4 Region
1215 7 8.8291E-02  1201 -1202 1633 -1212
          (1701 1702 1703 1704 1705 1706 1707 1708 1709 1710 1711 1712 1713
           1714 1715 1716 1717 1718 1719 1720 1721 1722 1723 1724 1725 1726
           1727 1728 1729 1730 1731 1732)
           imp:n=1  $ Ring 5 Region
c
c ------ Coolant Channels ------
c --------- Ring 1 ---------
1301 10 4.8413E-05  2401 -1301 1201 -1202 imp:n=1  $ Position 1
1302 10 4.8413E-05  2402 -1302 1201 -1202 imp:n=1  $ Position 2
1303 10 4.8413E-05       -1303 1201 -1202 imp:n=1  $ Position 3
1304 10 4.8413E-05  2404 -1304 1201 -1202 imp:n=1  $ Position 4
1305 10 4.8413E-05  2405 -1305 1201 -1202 imp:n=1  $ Position 5
1306 10 4.8413E-05       -1306 1201 -1202 imp:n=1  $ Position 6
1307 10 4.8413E-05  2407 -1307 1201 -1202 imp:n=1  $ Position 7
1308 10 4.8413E-05  2408 -1308 1201 -1202 imp:n=1  $ Position 8
1309 10 4.8413E-05       -1309 1201 -1202 imp:n=1  $ Position 9
```

```
1310 10 4.8413E-05  2410 -1310 1201 -1202 imp:n=1  $ Position 10
1311 10 4.8413E-05  2411 -1311 1201 -1202 imp:n=1  $ Position 11
1312 10 4.8413E-05       -1312 1201 -1202 imp:n=1  $ Position 12
1313 10 4.8413E-05  2413 -1313 1201 -1202 imp:n=1  $ Position 13
1314 10 4.8413E-05  2414 -1314 1201 -1202 imp:n=1  $ Position 14
1315 10 4.8413E-05       -1315 1201 -1202 imp:n=1  $ Position 15
1316 10 4.8413E-05  2416 -1316 1201 -1202 imp:n=1  $ Position 16
1317 10 4.8413E-05  2417 -1317 1201 -1202 imp:n=1  $ Position 17
1318 10 4.8413E-05       -1318 1201 -1202 imp:n=1  $ Position 18
1319 10 4.8413E-05  2419 -1319 1201 -1202 imp:n=1  $ Position 19
1320 10 4.8413E-05  2420 -1320 1201 -1202 imp:n=1  $ Position 20
1321 10 4.8413E-05       -1321 1201 -1202 imp:n=1  $ Position 21
1322 10 4.8413E-05  2422 -1322 1201 -1202 imp:n=1  $ Position 22
1323 10 4.8413E-05  2423 -1323 1201 -1202 imp:n=1  $ Position 23
1324 10 4.8413E-05       -1324 1201 -1202 imp:n=1  $ Position 24
1325 10 4.8413E-05  2425 -1325 1201 -1202 imp:n=1  $ Position 25
1326 10 4.8413E-05  2426 -1326 1201 -1202 imp:n=1  $ Position 26
1327 10 4.8413E-05       -1327 1201 -1202 imp:n=1  $ Position 27
1328 10 4.8413E-05  2428 -1328 1201 -1202 imp:n=1  $ Position 28
1329 10 4.8413E-05       -1329 1201 -1202 imp:n=1  $ Position 29
1330 10 4.8413E-05  2430 -1330 1201 -1202 imp:n=1  $ Position 30
1331 10 4.8413E-05  2431 -1331 1201 -1202 imp:n=1  $ Position 31
1332 10 4.8413E-05       -1332 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 2 ---------
1401 10 4.8413E-05  2501 -1401 1201 -1202 imp:n=1  $ Position 1
1402 10 4.8413E-05  2502 -1402 1201 -1202 imp:n=1  $ Position 2
1403 10 4.8413E-05  2503 -1403 1201 -1202 imp:n=1  $ Position 3
1404 10 4.8413E-05  2504 -1404 1201 -1202 imp:n=1  $ Position 4
1405 10 4.8413E-05  2505 -1405 1201 -1202 imp:n=1  $ Position 5
1406 10 4.8413E-05  2506 -1406 1201 -1202 imp:n=1  $ Position 6
1407 10 4.8413E-05  2507 -1407 1201 -1202 imp:n=1  $ Position 7
1408 10 4.8413E-05  2508 -1408 1201 -1202 imp:n=1  $ Position 8
1409 10 4.8413E-05  2509 -1409 1201 -1202 imp:n=1  $ Position 9
1410 10 4.8413E-05  2510 -1410 1201 -1202 imp:n=1  $ Position 10
1411 10 4.8413E-05  2511 -1411 1201 -1202 imp:n=1  $ Position 11
1412 10 4.8413E-05  2512 -1412 1201 -1202 imp:n=1  $ Position 12
1413 10 4.8413E-05  2513 -1413 1201 -1202 imp:n=1  $ Position 13
1414 10 4.8413E-05  2514 -1414 1201 -1202 imp:n=1  $ Position 14
1415 10 4.8413E-05  2515 -1415 1201 -1202 imp:n=1  $ Position 15
1416 10 4.8413E-05  2516 -1416 1201 -1202 imp:n=1  $ Position 16
1417 10 4.8413E-05  2517 -1417 1201 -1202 imp:n=1  $ Position 17
1418 10 4.8413E-05  2518 -1418 1201 -1202 imp:n=1  $ Position 18
1419 10 4.8413E-05  2519 -1419 1201 -1202 imp:n=1  $ Position 19
1420 10 4.8413E-05  2520 -1420 1201 -1202 imp:n=1  $ Position 20
1421 10 4.8413E-05  2521 -1421 1201 -1202 imp:n=1  $ Position 21
1422 10 4.8413E-05  2522 -1422 1201 -1202 imp:n=1  $ Position 22
1423 10 4.8413E-05  2523 -1423 1201 -1202 imp:n=1  $ Position 23
1424 10 4.8413E-05  2524 -1424 1201 -1202 imp:n=1  $ Position 24
1425 10 4.8413E-05  2525 -1425 1201 -1202 imp:n=1  $ Position 25
1426 10 4.8413E-05  2526 -1426 1201 -1202 imp:n=1  $ Position 26
1427 10 4.8413E-05  2527 -1427 1201 -1202 imp:n=1  $ Position 27
1428 10 4.8413E-05  2528 -1428 1201 -1202 imp:n=1  $ Position 28
1429 10 4.8413E-05  2529 -1429 1201 -1202 imp:n=1  $ Position 29
1430 10 4.8413E-05  2530 -1430 1201 -1202 imp:n=1  $ Position 30
1431 10 4.8413E-05  2531 -1431 1201 -1202 imp:n=1  $ Position 31
1432 10 4.8413E-05  2532 -1432 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 3 ---------
1501 10 4.8413E-05  2601 -1501 1201 -1202 imp:n=1  $ Position 1
1502 10 4.8413E-05       -1502 1201 -1202 imp:n=1  $ Position 2
1503 10 4.8413E-05  2603 -1503 1201 -1202 imp:n=1  $ Position 3
1504 10 4.8413E-05  2604 -1504 1201 -1202 imp:n=1  $ Position 4
1505 10 4.8413E-05       -1505 1201 -1202 imp:n=1  $ Position 5
1506 10 4.8413E-05  2606 -1506 1201 -1202 imp:n=1  $ Position 6
1507 10 4.8413E-05  2607 -1507 1201 -1202 imp:n=1  $ Position 7
1508 10 4.8413E-05       -1508 1201 -1202 imp:n=1  $ Position 8
1509 10 4.8413E-05  2609 -1509 1201 -1202 imp:n=1  $ Position 9
1510 10 4.8413E-05  2610 -1510 1201 -1202 imp:n=1  $ Position 10
1511 10 4.8413E-05       -1511 1201 -1202 imp:n=1  $ Position 11
1512 10 4.8413E-05  2612 -1512 1201 -1202 imp:n=1  $ Position 12
1513 10 4.8413E-05  2613 -1513 1201 -1202 imp:n=1  $ Position 13
1514 10 4.8413E-05       -1514 1201 -1202 imp:n=1  $ Position 14
1515 10 4.8413E-05  2615 -1515 1201 -1202 imp:n=1  $ Position 15
1516 10 4.8413E-05  2616 -1516 1201 -1202 imp:n=1  $ Position 16
1517 10 4.8413E-05       -1517 1201 -1202 imp:n=1  $ Position 17
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1518 10 4.8413E-05  2618 -1518 1201 -1202 imp:n=1  $ Position 18
1519 10 4.8413E-05  2619 -1519 1201 -1202 imp:n=1  $ Position 19
1520 10 4.8413E-05       -1520 1201 -1202 imp:n=1  $ Position 20
1521 10 4.8413E-05  2621 -1521 1201 -1202 imp:n=1  $ Position 21
1522 10 4.8413E-05  2622 -1522 1201 -1202 imp:n=1  $ Position 22
1523 10 4.8413E-05       -1523 1201 -1202 imp:n=1  $ Position 23
1524 10 4.8413E-05  2624 -1524 1201 -1202 imp:n=1  $ Position 24
1525 10 4.8413E-05  2625 -1525 1201 -1202 imp:n=1  $ Position 25
1526 10 4.8413E-05       -1526 1201 -1202 imp:n=1  $ Position 26
1527 10 4.8413E-05  2627 -1527 1201 -1202 imp:n=1  $ Position 27
1528 10 4.8413E-05       -1528 1201 -1202 imp:n=1  $ Position 28
1529 10 4.8413E-05  2629 -1529 1201 -1202 imp:n=1  $ Position 29
1530 10 4.8413E-05  2630 -1530 1201 -1202 imp:n=1  $ Position 30
1531 10 4.8413E-05       -1531 1201 -1202 imp:n=1  $ Position 31
1532 10 4.8413E-05  2632 -1532 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 4 ---------
1601 10 4.8413E-05  2701 -1601 1201 -1202 imp:n=1  $ Position 1
1602 10 4.8413E-05  2702 -1602 1201 -1202 imp:n=1  $ Position 2
1603 10 4.8413E-05  2703 -1603 1201 -1202 imp:n=1  $ Position 3
1604 10 4.8413E-05  2704 -1604 1201 -1202 imp:n=1  $ Position 4
1605 10 4.8413E-05  2705 -1605 1201 -1202 imp:n=1  $ Position 5
1606 10 4.8413E-05  2706 -1606 1201 -1202 imp:n=1  $ Position 6
1607 10 4.8413E-05  2707 -1607 1201 -1202 imp:n=1  $ Position 7
1608 10 4.8413E-05  2708 -1608 1201 -1202 imp:n=1  $ Position 8
1609 10 4.8413E-05  2709 -1609 1201 -1202 imp:n=1  $ Position 9
1610 10 4.8413E-05  2710 -1610 1201 -1202 imp:n=1  $ Position 10
1611 10 4.8413E-05  2711 -1611 1201 -1202 imp:n=1  $ Position 11
1612 10 4.8413E-05  2712 -1612 1201 -1202 imp:n=1  $ Position 12
1613 10 4.8413E-05  2713 -1613 1201 -1202 imp:n=1  $ Position 13
1614 10 4.8413E-05  2714 -1614 1201 -1202 imp:n=1  $ Position 14
1615 10 4.8413E-05  2715 -1615 1201 -1202 imp:n=1  $ Position 15
1616 10 4.8413E-05  2716 -1616 1201 -1202 imp:n=1  $ Position 16
1617 10 4.8413E-05  2717 -1617 1201 -1202 imp:n=1  $ Position 17
1618 10 4.8413E-05  2718 -1618 1201 -1202 imp:n=1  $ Position 18
1619 10 4.8413E-05  2719 -1619 1201 -1202 imp:n=1  $ Position 19
1620 10 4.8413E-05  2720 -1620 1201 -1202 imp:n=1  $ Position 20
1621 10 4.8413E-05  2721 -1621 1201 -1202 imp:n=1  $ Position 21
1622 10 4.8413E-05  2722 -1622 1201 -1202 imp:n=1  $ Position 22
1623 10 4.8413E-05  2723 -1623 1201 -1202 imp:n=1  $ Position 23
1624 10 4.8413E-05  2724 -1624 1201 -1202 imp:n=1  $ Position 24
1625 10 4.8413E-05  2725 -1625 1201 -1202 imp:n=1  $ Position 25
1626 10 4.8413E-05  2726 -1626 1201 -1202 imp:n=1  $ Position 26
1627 10 4.8413E-05  2727 -1627 1201 -1202 imp:n=1  $ Position 27
1628 10 4.8413E-05  2728 -1628 1201 -1202 imp:n=1  $ Position 28
1629 10 4.8413E-05  2729 -1629 1201 -1202 imp:n=1  $ Position 29
1630 10 4.8413E-05  2730 -1630 1201 -1202 imp:n=1  $ Position 30
1631 10 4.8413E-05  2731 -1631 1201 -1202 imp:n=1  $ Position 31
1632 10 4.8413E-05  2732 -1632 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 5 ---------
1701 10 4.8413E-05       -1701 1201 -1202 imp:n=1  $ Position 1
1702 10 4.8413E-05  2802 -1702 1201 -1202 imp:n=1  $ Position 2
1703 10 4.8413E-05  2803 -1703 1201 -1202 imp:n=1  $ Position 3
1704 10 4.8413E-05       -1704 1201 -1202 imp:n=1  $ Position 4
1705 10 4.8413E-05  2805 -1705 1201 -1202 imp:n=1  $ Position 5
1706 10 4.8413E-05  2806 -1706 1201 -1202 imp:n=1  $ Position 6
1707 10 4.8413E-05       -1707 1201 -1202 imp:n=1  $ Position 7
1708 10 4.8413E-05  2808 -1708 1201 -1202 imp:n=1  $ Position 8
1709 10 4.8413E-05  2809 -1709 1201 -1202 imp:n=1  $ Position 9
1710 10 4.8413E-05       -1710 1201 -1202 imp:n=1  $ Position 10
1711 10 4.8413E-05  2811 -1711 1201 -1202 imp:n=1  $ Position 11
1712 10 4.8413E-05  2812 -1712 1201 -1202 imp:n=1  $ Position 12
1713 10 4.8413E-05       -1713 1201 -1202 imp:n=1  $ Position 13
1714 10 4.8413E-05  2814 -1714 1201 -1202 imp:n=1  $ Position 14
1715 10 4.8413E-05  2815 -1715 1201 -1202 imp:n=1  $ Position 15
1716 10 4.8413E-05       -1716 1201 -1202 imp:n=1  $ Position 16
1717 10 4.8413E-05  2817 -1717 1201 -1202 imp:n=1  $ Position 17
1718 10 4.8413E-05  2818 -1718 1201 -1202 imp:n=1  $ Position 18
1719 10 4.8413E-05       -1719 1201 -1202 imp:n=1  $ Position 19
1720 10 4.8413E-05  2820 -1720 1201 -1202 imp:n=1  $ Position 20
1721 10 4.8413E-05  2821 -1721 1201 -1202 imp:n=1  $ Position 21
1722 10 4.8413E-05       -1722 1201 -1202 imp:n=1  $ Position 22
1723 10 4.8413E-05  2823 -1723 1201 -1202 imp:n=1  $ Position 23
1724 10 4.8413E-05  2824 -1724 1201 -1202 imp:n=1  $ Position 24
1725 10 4.8413E-05       -1725 1201 -1202 imp:n=1  $ Position 25
```

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1726 10 4.8413E-05  2826 -1726 1201 -1202 imp:n=1  $ Position 26
1727 10 4.8413E-05       -1727 1201 -1202 imp:n=1  $ Position 27
1728 10 4.8413E-05  2828 -1728 1201 -1202 imp:n=1  $ Position 28
1729 10 4.8413E-05  2829 -1729 1201 -1202 imp:n=1  $ Position 29
1730 10 4.8413E-05       -1730 1201 -1202 imp:n=1  $ Position 30
1731 10 4.8413E-05  2831 -1731 1201 -1202 imp:n=1  $ Position 31
1732 10 4.8413E-05  2832 -1732 1201 -1202 imp:n=1  $ Position 32
c
c ------ Graphite Plugs ------
c --------- Ring 1 ---------
12401 29 8.8245E-02  -2401 1201 -1202 imp:n=1  $ Position 1
12402 29 8.8245E-02  -2402 1201 -1202 imp:n=1  $ Position 2
c    *Coolant Channel (No Plug)   $ Position 3
12404 29 8.8245E-02  -2404 1201 -1202 imp:n=1  $ Position 4
12405 29 8.8245E-02  -2405 1201 -1202 imp:n=1  $ Position 5
c    *Coolant Channel (No Plug)   $ Position 6
12407 29 8.8245E-02  -2407 1201 -1202 imp:n=1  $ Position 7
12408 29 8.8245E-02  -2408 1201 -1202 imp:n=1  $ Position 8
c    *Coolant Channel (No Plug)   $ Position 9
12410 29 8.8245E-02  -2410 1201 -1202 imp:n=1  $ Position 10
12411 29 8.8245E-02  -2411 1201 -1202 imp:n=1  $ Position 11
c    *Coolant Channel (No Plug)   $ Position 12
12413 29 8.8245E-02  -2413 1201 -1202 imp:n=1  $ Position 13
12414 29 8.8245E-02  -2414 1201 -1202 imp:n=1  $ Position 14
c    *Coolant Channel (No Plug)   $ Position 15
12416 29 8.8245E-02  -2416 1201 -1202 imp:n=1  $ Position 16
12417 29 8.8245E-02  -2417 1201 -1202 imp:n=1  $ Position 17
c    *Coolant Channel (No Plug)   $ Position 18
12419 29 8.8245E-02  -2419 1201 -1202 imp:n=1  $ Position 19
12420 29 8.8245E-02  -2420 1201 -1202 imp:n=1  $ Position 20
c    *Coolant Channel (No Plug)   $ Position 21
12422 29 8.8245E-02  -2422 1201 -1202 imp:n=1  $ Position 22
12423 29 8.8245E-02  -2423 1201 -1202 imp:n=1  $ Position 23
c    *Coolant Channel (No Plug)   $ Position 24
12425 29 8.8245E-02  -2425 1201 -1202 imp:n=1  $ Position 25
12426 29 8.8245E-02  -2426 1201 -1202 imp:n=1  $ Position 26
c    *Coolant Channel (No Plug)   $ Position 27
12428 29 8.8245E-02  -2428 1201 -1202 imp:n=1  $ Position 28
c    *Coolant Channel (No Plug)   $ Position 29
12430 29 8.8245E-02  -2430 1201 -1202 imp:n=1  $ Position 30
12431 29 8.8245E-02  -2431 1201 -1202 imp:n=1  $ Position 31
c    *Coolant Channel (No Plug)   $ Position 32
c
c --------- Ring 2 ---------
12501 29 8.8245E-02  -2501 1201 -1202 imp:n=1  $ Position 1
12502 29 8.8245E-02  -2502 1201 -1202 imp:n=1  $ Position 2
12503 29 8.8245E-02  -2503 1201 -1202 imp:n=1  $ Position 3
12504 29 8.8245E-02  -2504 1201 -1202 imp:n=1  $ Position 4
12505 29 8.8245E-02  -2505 1201 -1202 imp:n=1  $ Position 5
12506 29 8.8245E-02  -2506 1201 -1202 imp:n=1  $ Position 6
12507 29 8.8245E-02  -2507 1201 -1202 imp:n=1  $ Position 7
12508 29 8.8245E-02  -2508 1201 -1202 imp:n=1  $ Position 8
12509 29 8.8245E-02  -2509 1201 -1202 imp:n=1  $ Position 9
12510 29 8.8245E-02  -2510 1201 -1202 imp:n=1  $ Position 10
12511 29 8.8245E-02  -2511 1201 -1202 imp:n=1  $ Position 11
12512 29 8.8245E-02  -2512 1201 -1202 imp:n=1  $ Position 12
12513 29 8.8245E-02  -2513 1201 -1202 imp:n=1  $ Position 13
12514 29 8.8245E-02  -2514 1201 -1202 imp:n=1  $ Position 14
12515 29 8.8245E-02  -2515 1201 -1202 imp:n=1  $ Position 15
12516 29 8.8245E-02  -2516 1201 -1202 imp:n=1  $ Position 16
12517 29 8.8245E-02  -2517 1201 -1202 imp:n=1  $ Position 17
12518 29 8.8245E-02  -2518 1201 -1202 imp:n=1  $ Position 18
12519 29 8.8245E-02  -2519 1201 -1202 imp:n=1  $ Position 19
12520 29 8.8245E-02  -2520 1201 -1202 imp:n=1  $ Position 20
12521 29 8.8245E-02  -2521 1201 -1202 imp:n=1  $ Position 21
12522 29 8.8245E-02  -2522 1201 -1202 imp:n=1  $ Position 22
12523 29 8.8245E-02  -2523 1201 -1202 imp:n=1  $ Position 23
12524 29 8.8245E-02  -2524 1201 -1202 imp:n=1  $ Position 24
12525 29 8.8245E-02  -2525 1201 -1202 imp:n=1  $ Position 25
12526 29 8.8245E-02  -2526 1201 -1202 imp:n=1  $ Position 26
12527 29 8.8245E-02  -2527 1201 -1202 imp:n=1  $ Position 27
12528 29 8.8245E-02  -2528 1201 -1202 imp:n=1  $ Position 28
12529 29 8.8245E-02  -2529 1201 -1202 imp:n=1  $ Position 29
12530 29 8.8245E-02  -2530 1201 -1202 imp:n=1  $ Position 30
12531 29 8.8245E-02  -2531 1201 -1202 imp:n=1  $ Position 31
12532 29 8.8245E-02  -2532 1201 -1202 imp:n=1  $ Position 32
```

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c
c --------- Ring 3 ---------
12601 29 8.8245E-02  -2601 1201 -1202 imp:n=1  $ Position 1
c    *Coolant Channel (No Plug)   $ Position 2
12603 29 8.8245E-02  -2603 1201 -1202 imp:n=1  $ Position 3
12604 29 8.8245E-02  -2604 1201 -1202 imp:n=1  $ Position 4
c    *Coolant Channel (No Plug)   $ Position 5
12606 29 8.8245E-02  -2606 1201 -1202 imp:n=1  $ Position 6
12607 29 8.8245E-02  -2607 1201 -1202 imp:n=1  $ Position 7
c    *Coolant Channel (No Plug)   $ Position 8
12609 29 8.8245E-02  -2609 1201 -1202 imp:n=1  $ Position 9
12610 29 8.8245E-02  -2610 1201 -1202 imp:n=1  $ Position 10
c    *Coolant Channel (No Plug)   $ Position 11
12612 29 8.8245E-02  -2612 1201 -1202 imp:n=1  $ Position 12
12613 29 8.8245E-02  -2613 1201 -1202 imp:n=1  $ Position 13
c    *Coolant Channel (No Plug)   $ Position 14
12615 29 8.8245E-02  -2615 1201 -1202 imp:n=1  $ Position 15
12616 29 8.8245E-02  -2616 1201 -1202 imp:n=1  $ Position 16
c    *Coolant Channel (No Plug)   $ Position 17
12618 29 8.8245E-02  -2618 1201 -1202 imp:n=1  $ Position 18
12619 29 8.8245E-02  -2619 1201 -1202 imp:n=1  $ Position 19
c    *Coolant Channel (No Plug)   $ Position 20
12621 29 8.8245E-02  -2621 1201 -1202 imp:n=1  $ Position 21
12622 29 8.8245E-02  -2622 1201 -1202 imp:n=1  $ Position 22
c    *Coolant Channel (No Plug)   $ Position 23
12624 29 8.8245E-02  -2624 1201 -1202 imp:n=1  $ Position 24
12625 29 8.8245E-02  -2625 1201 -1202 imp:n=1  $ Position 25
c    *Coolant Channel (No Plug)   $ Position 26
12627 29 8.8245E-02  -2627 1201 -1202 imp:n=1  $ Position 27
c    *Coolant Channel (No Plug)   $ Position 28
12629 29 8.8245E-02  -2629 1201 -1202 imp:n=1  $ Position 29
12630 29 8.8245E-02  -2630 1201 -1202 imp:n=1  $ Position 30
c    *Coolant Channel (No Plug)   $ Position 31
12632 29 8.8245E-02  -2632 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 4 ---------
12701 29 8.8245E-02  -2701 1201 -1202 imp:n=1  $ Position 1
12702 29 8.8245E-02  -2702 1201 -1202 imp:n=1  $ Position 2
12703 29 8.8245E-02  -2703 1201 -1202 imp:n=1  $ Position 3
12704 29 8.8245E-02  -2704 1201 -1202 imp:n=1  $ Position 4
12705 29 8.8245E-02  -2705 1201 -1202 imp:n=1  $ Position 5
12706 29 8.8245E-02  -2706 1201 -1202 imp:n=1  $ Position 6
12707 29 8.8245E-02  -2707 1201 -1202 imp:n=1  $ Position 7
12708 29 8.8245E-02  -2708 1201 -1202 imp:n=1  $ Position 8
12709 29 8.8245E-02  -2709 1201 -1202 imp:n=1  $ Position 9
12710 29 8.8245E-02  -2710 1201 -1202 imp:n=1  $ Position 10
12711 29 8.8245E-02  -2711 1201 -1202 imp:n=1  $ Position 11
12712 29 8.8245E-02  -2712 1201 -1202 imp:n=1  $ Position 12
12713 29 8.8245E-02  -2713 1201 -1202 imp:n=1  $ Position 13
12714 29 8.8245E-02  -2714 1201 -1202 imp:n=1  $ Position 14
12715 29 8.8245E-02  -2715 1201 -1202 imp:n=1  $ Position 15
12716 29 8.8245E-02  -2716 1201 -1202 imp:n=1  $ Position 16
12717 29 8.8245E-02  -2717 1201 -1202 imp:n=1  $ Position 17
12718 29 8.8245E-02  -2718 1201 -1202 imp:n=1  $ Position 18
12719 29 8.8245E-02  -2719 1201 -1202 imp:n=1  $ Position 19
12720 29 8.8245E-02  -2720 1201 -1202 imp:n=1  $ Position 20
12721 29 8.8245E-02  -2721 1201 -1202 imp:n=1  $ Position 21
12722 29 8.8245E-02  -2722 1201 -1202 imp:n=1  $ Position 22
12723 29 8.8245E-02  -2723 1201 -1202 imp:n=1  $ Position 23
12724 29 8.8245E-02  -2724 1201 -1202 imp:n=1  $ Position 24
12725 29 8.8245E-02  -2725 1201 -1202 imp:n=1  $ Position 25
12726 29 8.8245E-02  -2726 1201 -1202 imp:n=1  $ Position 26
12727 29 8.8245E-02  -2727 1201 -1202 imp:n=1  $ Position 27
12728 29 8.8245E-02  -2728 1201 -1202 imp:n=1  $ Position 28
12729 29 8.8245E-02  -2729 1201 -1202 imp:n=1  $ Position 29
12730 29 8.8245E-02  -2730 1201 -1202 imp:n=1  $ Position 30
12731 29 8.8245E-02  -2731 1201 -1202 imp:n=1  $ Position 31
12732 29 8.8245E-02  -2732 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 5 ---------
c    *Coolant Channel (No Plug)   $ Position 1
12802 29 8.8245E-02  -2802 1201 -1202 imp:n=1  $ Position 2
12803 29 8.8245E-02  -2803 1201 -1202 imp:n=1  $ Position 3
c    *Coolant Channel (No Plug)   $ Position 4
12805 29 8.8245E-02  -2805 1201 -1202 imp:n=1  $ Position 5
12806 29 8.8245E-02  -2806 1201 -1202 imp:n=1  $ Position 6
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c    *Coolant Channel (No Plug)   $ Position 7
12808 29 8.8245E-02  -2808 1201 -1202 imp:n=1  $ Position 8
12809 29 8.8245E-02  -2809 1201 -1202 imp:n=1  $ Position 9
c    *Coolant Channel (No Plug)   $ Position 10
12811 29 8.8245E-02  -2811 1201 -1202 imp:n=1  $ Position 11
12812 29 8.8245E-02  -2812 1201 -1202 imp:n=1  $ Position 12
c    *Coolant Channel (No Plug)   $ Position 13
12814 29 8.8245E-02  -2814 1201 -1202 imp:n=1  $ Position 14
12815 29 8.8245E-02  -2815 1201 -1202 imp:n=1  $ Position 15
c    *Coolant Channel (No Plug)   $ Position 16
12817 29 8.8245E-02  -2817 1201 -1202 imp:n=1  $ Position 17
12818 29 8.8245E-02  -2818 1201 -1202 imp:n=1  $ Position 18
c    *Coolant Channel (No Plug)   $ Position 19
12820 29 8.8245E-02  -2820 1201 -1202 imp:n=1  $ Position 20
12821 29 8.8245E-02  -2821 1201 -1202 imp:n=1  $ Position 21
c    *Coolant Channel (No Plug)   $ Position 22
12823 29 8.8245E-02  -2823 1201 -1202 imp:n=1  $ Position 23
12824 29 8.8245E-02  -2824 1201 -1202 imp:n=1  $ Position 24
c    *Coolant Channel (No Plug)   $ Position 25
12826 29 8.8245E-02  -2826 1201 -1202 imp:n=1  $ Position 26
c    *Coolant Channel (No Plug)   $ Position 27
12828 29 8.8245E-02  -2828 1201 -1202 imp:n=1  $ Position 28
12829 29 8.8245E-02  -2829 1201 -1202 imp:n=1  $ Position 29
c    *Coolant Channel (No Plug)   $ Position 30
12831 29 8.8245E-02  -2831 1201 -1202 imp:n=1  $ Position 31
12832 29 8.8245E-02  -2832 1201 -1202 imp:n=1  $ Position 32
c
c ------ Aluminum Tank ------
1800   9 5.9018E-02  1801 -1201 -1221       imp:n=1  $ Bottom Center
1801  10 4.8413E-05  1803 -1801 -1221       imp:n=1  $ Air Gap
1802   9 5.9018E-02  1804 -1803 -1222       imp:n=1  $ Very Bottom Center
1803   9 5.9018E-02  1801 -1201  1222 -1223 imp:n=1  $ Bottom Annulus
1804  10 4.8413E-05  1201 -1202  1204 -1221 imp:n=1  $ Air Gap
1805   9 5.9018E-02  1803 -1202  1221 -1222 imp:n=1  $ Inner Vertical Liner
1806  10 4.8413E-05  1201 -1202  1222 -1211 imp:n=1  $ Air Gap
1807  10 4.8413E-05  1201 -1202  1212 -1223 imp:n=1  $ Air Gap
1808   9 5.9018E-02  1803 -1202  1223 -1802 -1806 imp:n=1  $ Outer Vertical Liner
1809  10 4.8413E-05  1803 -1801 -1806  1222 -1807 imp:n=1  $ Air Gap
1810   9 5.9018E-02  1803 -1801 -1806  1807 -1808 imp:n=1  $ Support
1811  10 4.8413E-05  1803 -1801 -1806  1808 -1223 imp:n=1  $ Air Gap
1812   9 5.9018E-02  (1806:-1803) -1805 -1801  1222 -1802 1804 imp:n=1  $ Curved Liner
1819  10 4.8413E-05  1801 -1202  1802
           -7501 -7502 -7503 -7504 -7505 -7506 -7507 -7508 -7509 -7510 -7511
           -7512 -7513 -7514 -7515 -7516 -7517 -7518 -7519 -7520 -7521 -7522
           imp:n=1  $ Air Gap
c
c --- Lower Axial Reflector ---------------------------------------------------
c ------ Inner Cylinder ------
1820  4 8.7744E-02  31 -1811 -1812 (1821:1822) imp:n=1
c
c ------ Neutron Source Position ------
1821  30 8.8245E-02  31 -1821 -1823 imp:n=1  $ Graphite Plug
1822  10 4.8413E-05  31 -1821 1823 -1822 imp:n=1  $ Neutron Source Channel
c
c ------ Graphite Annulus ------
1831  10 4.8413E-05  31 -1811 1812
           -7561 -7562 -7563 -7564 -7565 -7566 -7567 -7568 -7569 -7570 -7571
           -7572 -7573 -7574 -7575 -7576 -7577 -7578 -7579 -7580 -7581 imp:n=1  $ Air Gap
1832  5 8.8245E-02  31 -1811 -1333
           (7561:7562:7563:7564:7565:7566:7567:7568:7569:7570:7571:
           7572:7573:7574:7575:7576:7577:7578:7579:7580:7581)
          (1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913
           1914 1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926
           1927 1928 1929 1930 1931 1932)
           imp:n=1  $ Ring 1 Region
1833  5 8.8245E-02  31 -1811 1333 -1433
          (2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
           2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026
           2027 2028 2029 2030 2031 2032)
           imp:n=1  $ Ring 2 Region
1834  5 8.8245E-02  31 -1811 1433 -1533
          (2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113
           2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126
           2127 2128 2129 2130 2131 2132)
           imp:n=1  $ Ring 3 Region
1835  5 8.8245E-02  31 -1811 1533 -1633
```

```
           (2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213
            2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226
            2227 2228 2229 2230 2231 2232)
            imp:n=1  $ Ring 4 Region
1836  5 8.8245E-02  31 -1811 1633
            -7601 -7602 -7603 -7604 -7605 -7606 -7607 -7608 -7609 -7610 -7611
            -7612 -7613 -7614 -7615 -7616 -7617 -7618 -7619 -7620 -7621
            (2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313
            2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326
            2327 2328 2329 2330 2331 2332)
            imp:n=1  $ Ring 5 Region
1837  10 4.8413E-05  31 -1811
            (7601:7602:7603:7604:7605:7606:7607:7608:7609:7610:7611:
            7612:7613:7614:7615:7616:7617:7618:7619:7620:7621)
            -7501 -7502 -7503 -7504 -7505 -7506 -7507 -7508 -7509 -7510 -7511
            -7512 -7513 -7514 -7515 -7516 -7517 -7518 -7519 -7520 -7521 -7522
            imp:n=1  $ Air Gap
c
c ------ Coolant Channels ------
c --------- Ring 1 ---------
1901 10 4.8413E-05  2401 -1901 31 -1811 imp:n=1  $ Position 1
1902 10 4.8413E-05  2402 -1902 31 -1811 imp:n=1  $ Position 2
1903 10 4.8413E-05  2403 -1903 31 -1811 imp:n=1  $ Position 3
1904 10 4.8413E-05  2404 -1904 31 -1811 imp:n=1  $ Position 4
1905 10 4.8413E-05  2405 -1905 31 -1811 imp:n=1  $ Position 5
1906 10 4.8413E-05  2406 -1906 31 -1811 imp:n=1  $ Position 6
1907 10 4.8413E-05  2407 -1907 31 -1811 imp:n=1  $ Position 7
1908 10 4.8413E-05  2408 -1908 31 -1811 imp:n=1  $ Position 8
1909 10 4.8413E-05  2409 -1909 31 -1811 imp:n=1  $ Position 9
1910 10 4.8413E-05  2410 -1910 31 -1811 imp:n=1  $ Position 10
1911 10 4.8413E-05  2411 -1911 31 -1811 imp:n=1  $ Position 11
1912 10 4.8413E-05  2412 -1912 31 -1811 imp:n=1  $ Position 12
1913 10 4.8413E-05  2413 -1913 31 -1811 imp:n=1  $ Position 13
1914 10 4.8413E-05  2414 -1914 31 -1811 imp:n=1  $ Position 14
1915 10 4.8413E-05  2415 -1915 31 -1811 imp:n=1  $ Position 15
1916 10 4.8413E-05  2416 -1916 31 -1811 imp:n=1  $ Position 16
1917 10 4.8413E-05  2417 -1917 31 -1811 imp:n=1  $ Position 17
1918 10 4.8413E-05  2418 -1918 31 -1811 imp:n=1  $ Position 18
1919 10 4.8413E-05  2419 -1919 31 -1811 imp:n=1  $ Position 19
1920 10 4.8413E-05  2420 -1920 31 -1811 imp:n=1  $ Position 20
1921 10 4.8413E-05  2421 -1921 31 -1811 imp:n=1  $ Position 21
1922 10 4.8413E-05  2422 -1922 31 -1811 imp:n=1  $ Position 22
1923 10 4.8413E-05  2423 -1923 31 -1811 imp:n=1  $ Position 23
1924 10 4.8413E-05  2424 -1924 31 -1811 imp:n=1  $ Position 24
1925 10 4.8413E-05  2425 -1925 31 -1811 imp:n=1  $ Position 25
1926 10 4.8413E-05  2426 -1926 31 -1811 imp:n=1  $ Position 26
1927 10 4.8413E-05  2427 -1927 31 -1811 imp:n=1  $ Position 27
1928 10 4.8413E-05  2428 -1928 31 -1811 imp:n=1  $ Position 28
1929 10 4.8413E-05  2429 -1929 31 -1811 imp:n=1  $ Position 29
1930 10 4.8413E-05  2430 -1930 31 -1811 imp:n=1  $ Position 30
1931 10 4.8413E-05  2431 -1931 31 -1811 imp:n=1  $ Position 31
1932 10 4.8413E-05  2432 -1932 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 2 ---------
2001 10 4.8413E-05  2501 -2001 31 -1811 imp:n=1  $ Position 1
2002 10 4.8413E-05  2502 -2002 31 -1811 imp:n=1  $ Position 2
2003 10 4.8413E-05  2503 -2003 31 -1811 imp:n=1  $ Position 3
2004 10 4.8413E-05  2504 -2004 31 -1811 imp:n=1  $ Position 4
2005 10 4.8413E-05  2505 -2005 31 -1811 imp:n=1  $ Position 5
2006 10 4.8413E-05  2506 -2006 31 -1811 imp:n=1  $ Position 6
2007 10 4.8413E-05  2507 -2007 31 -1811 imp:n=1  $ Position 7
2008 10 4.8413E-05  2508 -2008 31 -1811 imp:n=1  $ Position 8
2009 10 4.8413E-05  2509 -2009 31 -1811 imp:n=1  $ Position 9
2010 10 4.8413E-05  2510 -2010 31 -1811 imp:n=1  $ Position 10
2011 10 4.8413E-05  2511 -2011 31 -1811 imp:n=1  $ Position 11
2012 10 4.8413E-05  2512 -2012 31 -1811 imp:n=1  $ Position 12
2013 10 4.8413E-05  2513 -2013 31 -1811 imp:n=1  $ Position 13
2014 10 4.8413E-05  2514 -2014 31 -1811 imp:n=1  $ Position 14
2015 10 4.8413E-05  2515 -2015 31 -1811 imp:n=1  $ Position 15
2016 10 4.8413E-05  2516 -2016 31 -1811 imp:n=1  $ Position 16
2017 10 4.8413E-05  2517 -2017 31 -1811 imp:n=1  $ Position 17
2018 10 4.8413E-05  2518 -2018 31 -1811 imp:n=1  $ Position 18
2019 10 4.8413E-05  2519 -2019 31 -1811 imp:n=1  $ Position 19
2020 10 4.8413E-05  2520 -2020 31 -1811 imp:n=1  $ Position 20
2021 10 4.8413E-05  2521 -2021 31 -1811 imp:n=1  $ Position 21
2022 10 4.8413E-05  2522 -2022 31 -1811 imp:n=1  $ Position 22
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2023 10 4.8413E-05  2523 -2023 31 -1811 imp:n=1  $ Position 23
2024 10 4.8413E-05  2524 -2024 31 -1811 imp:n=1  $ Position 24
2025 10 4.8413E-05  2525 -2025 31 -1811 imp:n=1  $ Position 25
2026 10 4.8413E-05  2526 -2026 31 -1811 imp:n=1  $ Position 26
2027 10 4.8413E-05  2527 -2027 31 -1811 imp:n=1  $ Position 27
2028 10 4.8413E-05  2528 -2028 31 -1811 imp:n=1  $ Position 28
2029 10 4.8413E-05  2529 -2029 31 -1811 imp:n=1  $ Position 29
2030 10 4.8413E-05  2530 -2030 31 -1811 imp:n=1  $ Position 30
2031 10 4.8413E-05  2531 -2031 31 -1811 imp:n=1  $ Position 31
2032 10 4.8413E-05  2532 -2032 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 3 ---------
2101 10 4.8413E-05  2601 -2101 31 -1811 imp:n=1  $ Position 1
2102 10 4.8413E-05  2602 -2102 31 -1811 imp:n=1  $ Position 2
2103 10 4.8413E-05  2603 -2103 31 -1811 imp:n=1  $ Position 3
2104 10 4.8413E-05  2604 -2104 31 -1811 imp:n=1  $ Position 4
2105 10 4.8413E-05  2605 -2105 31 -1811 imp:n=1  $ Position 5
2106 10 4.8413E-05  2606 -2106 31 -1811 imp:n=1  $ Position 6
2107 10 4.8413E-05  2607 -2107 31 -1811 imp:n=1  $ Position 7
2108 10 4.8413E-05  2608 -2108 31 -1811 imp:n=1  $ Position 8
2109 10 4.8413E-05  2609 -2109 31 -1811 imp:n=1  $ Position 9
2110 10 4.8413E-05  2610 -2110 31 -1811 imp:n=1  $ Position 10
2111 10 4.8413E-05  2611 -2111 31 -1811 imp:n=1  $ Position 11
2112 10 4.8413E-05  2612 -2112 31 -1811 imp:n=1  $ Position 12
2113 10 4.8413E-05  2613 -2113 31 -1811 imp:n=1  $ Position 13
2114 10 4.8413E-05  2614 -2114 31 -1811 imp:n=1  $ Position 14
2115 10 4.8413E-05  2615 -2115 31 -1811 imp:n=1  $ Position 15
2116 10 4.8413E-05  2616 -2116 31 -1811 imp:n=1  $ Position 16
2117 10 4.8413E-05  2617 -2117 31 -1811 imp:n=1  $ Position 17
2118 10 4.8413E-05  2618 -2118 31 -1811 imp:n=1  $ Position 18
2119 10 4.8413E-05  2619 -2119 31 -1811 imp:n=1  $ Position 19
2120 10 4.8413E-05  2620 -2120 31 -1811 imp:n=1  $ Position 20
2121 10 4.8413E-05  2621 -2121 31 -1811 imp:n=1  $ Position 21
2122 10 4.8413E-05  2622 -2122 31 -1811 imp:n=1  $ Position 22
2123 10 4.8413E-05  2623 -2123 31 -1811 imp:n=1  $ Position 23
2124 10 4.8413E-05  2624 -2124 31 -1811 imp:n=1  $ Position 24
2125 10 4.8413E-05  2625 -2125 31 -1811 imp:n=1  $ Position 25
2126 10 4.8413E-05  2626 -2126 31 -1811 imp:n=1  $ Position 26
2127 10 4.8413E-05  2627 -2127 31 -1811 imp:n=1  $ Position 27
2128 10 4.8413E-05  2628 -2128 31 -1811 imp:n=1  $ Position 28
2129 10 4.8413E-05  2629 -2129 31 -1811 imp:n=1  $ Position 29
2130 10 4.8413E-05  2630 -2130 31 -1811 imp:n=1  $ Position 30
2131 10 4.8413E-05  2631 -2131 31 -1811 imp:n=1  $ Position 31
2132 10 4.8413E-05  2632 -2132 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 4 ---------
2201 10 4.8413E-05  2701 -2201 31 -1811 imp:n=1  $ Position 1
2202 10 4.8413E-05  2702 -2202 31 -1811 imp:n=1  $ Position 2
2203 10 4.8413E-05  2703 -2203 31 -1811 imp:n=1  $ Position 3
2204 10 4.8413E-05  2704 -2204 31 -1811 imp:n=1  $ Position 4
2205 10 4.8413E-05  2705 -2205 31 -1811 imp:n=1  $ Position 5
2206 10 4.8413E-05  2706 -2206 31 -1811 imp:n=1  $ Position 6
2207 10 4.8413E-05  2707 -2207 31 -1811 imp:n=1  $ Position 7
2208 10 4.8413E-05  2708 -2208 31 -1811 imp:n=1  $ Position 8
2209 10 4.8413E-05  2709 -2209 31 -1811 imp:n=1  $ Position 9
2210 10 4.8413E-05  2710 -2210 31 -1811 imp:n=1  $ Position 10
2211 10 4.8413E-05  2711 -2211 31 -1811 imp:n=1  $ Position 11
2212 10 4.8413E-05  2712 -2212 31 -1811 imp:n=1  $ Position 12
2213 10 4.8413E-05  2713 -2213 31 -1811 imp:n=1  $ Position 13
2214 10 4.8413E-05  2714 -2214 31 -1811 imp:n=1  $ Position 14
2215 10 4.8413E-05  2715 -2215 31 -1811 imp:n=1  $ Position 15
2216 10 4.8413E-05  2716 -2216 31 -1811 imp:n=1  $ Position 16
2217 10 4.8413E-05  2717 -2217 31 -1811 imp:n=1  $ Position 17
2218 10 4.8413E-05  2718 -2218 31 -1811 imp:n=1  $ Position 18
2219 10 4.8413E-05  2719 -2219 31 -1811 imp:n=1  $ Position 19
2220 10 4.8413E-05  2720 -2220 31 -1811 imp:n=1  $ Position 20
2221 10 4.8413E-05  2721 -2221 31 -1811 imp:n=1  $ Position 21
2222 10 4.8413E-05  2722 -2222 31 -1811 imp:n=1  $ Position 22
2223 10 4.8413E-05  2723 -2223 31 -1811 imp:n=1  $ Position 23
2224 10 4.8413E-05  2724 -2224 31 -1811 imp:n=1  $ Position 24
2225 10 4.8413E-05  2725 -2225 31 -1811 imp:n=1  $ Position 25
2226 10 4.8413E-05  2726 -2226 31 -1811 imp:n=1  $ Position 26
2227 10 4.8413E-05  2727 -2227 31 -1811 imp:n=1  $ Position 27
2228 10 4.8413E-05  2728 -2228 31 -1811 imp:n=1  $ Position 28
2229 10 4.8413E-05  2729 -2229 31 -1811 imp:n=1  $ Position 29
2230 10 4.8413E-05  2730 -2230 31 -1811 imp:n=1  $ Position 30
```

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2231 10 4.8413E-05  2731 -2231 31 -1811 imp:n=1  $ Position 31
2232 10 4.8413E-05  2732 -2232 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 5 ---------
2301 10 4.8413E-05  2801 -2301 31 -1811 imp:n=1  $ Position 1
2302 10 4.8413E-05  2802 -2302 31 -1811 imp:n=1  $ Position 2
2303 10 4.8413E-05  2803 -2303 31 -1811 imp:n=1  $ Position 3
2304 10 4.8413E-05  2804 -2304 31 -1811 imp:n=1  $ Position 4
2305 10 4.8413E-05  2805 -2305 31 -1811 imp:n=1  $ Position 5
2306 10 4.8413E-05  2806 -2306 31 -1811 imp:n=1  $ Position 6
2307 10 4.8413E-05  2807 -2307 31 -1811 imp:n=1  $ Position 7
2308 10 4.8413E-05  2808 -2308 31 -1811 imp:n=1  $ Position 8
2309 10 4.8413E-05  2809 -2309 31 -1811 imp:n=1  $ Position 9
2310 10 4.8413E-05  2810 -2310 31 -1811 imp:n=1  $ Position 10
2311 10 4.8413E-05  2811 -2311 31 -1811 imp:n=1  $ Position 11
2312 10 4.8413E-05  2812 -2312 31 -1811 imp:n=1  $ Position 12
2313 10 4.8413E-05  2813 -2313 31 -1811 imp:n=1  $ Position 13
2314 10 4.8413E-05  2814 -2314 31 -1811 imp:n=1  $ Position 14
2315 10 4.8413E-05  2815 -2315 31 -1811 imp:n=1  $ Position 15
2316 10 4.8413E-05  2816 -2316 31 -1811 imp:n=1  $ Position 16
2317 10 4.8413E-05  2817 -2317 31 -1811 imp:n=1  $ Position 17
2318 10 4.8413E-05  2818 -2318 31 -1811 imp:n=1  $ Position 18
2319 10 4.8413E-05  2819 -2319 31 -1811 imp:n=1  $ Position 19
2320 10 4.8413E-05  2820 -2320 31 -1811 imp:n=1  $ Position 20
2321 10 4.8413E-05  2821 -2321 31 -1811 imp:n=1  $ Position 21
2322 10 4.8413E-05  2822 -2322 31 -1811 imp:n=1  $ Position 22
2323 10 4.8413E-05  2823 -2323 31 -1811 imp:n=1  $ Position 23
2324 10 4.8413E-05  2824 -2324 31 -1811 imp:n=1  $ Position 24
2325 10 4.8413E-05  2825 -2325 31 -1811 imp:n=1  $ Position 25
2326 10 4.8413E-05  2826 -2326 31 -1811 imp:n=1  $ Position 26
2327 10 4.8413E-05  2827 -2327 31 -1811 imp:n=1  $ Position 27
2328 10 4.8413E-05  2828 -2328 31 -1811 imp:n=1  $ Position 28
2329 10 4.8413E-05  2829 -2329 31 -1811 imp:n=1  $ Position 29
2330 10 4.8413E-05  2830 -2330 31 -1811 imp:n=1  $ Position 30
2331 10 4.8413E-05  2831 -2331 31 -1811 imp:n=1  $ Position 31
2332 10 4.8413E-05  2832 -2332 31 -1811 imp:n=1  $ Position 32
c
c ------ Graphite Plugs ------
c --------- Ring 1 ---------
2401 29 8.8245E-02  -2401 31 -1811 imp:n=1  $ Position 1
2402 29 8.8245E-02  -2402 31 -1811 imp:n=1  $ Position 2
2403 29 8.8245E-02  -2403 31 -1811 imp:n=1  $ Position 3
2404 29 8.8245E-02  -2404 31 -1811 imp:n=1  $ Position 4
2405 29 8.8245E-02  -2405 31 -1811 imp:n=1  $ Position 5
2406 29 8.8245E-02  -2406 31 -1811 imp:n=1  $ Position 6
2407 29 8.8245E-02  -2407 31 -1811 imp:n=1  $ Position 7
2408 29 8.8245E-02  -2408 31 -1811 imp:n=1  $ Position 8
2409 29 8.8245E-02  -2409 31 -1811 imp:n=1  $ Position 9
2410 29 8.8245E-02  -2410 31 -1811 imp:n=1  $ Position 10
2411 29 8.8245E-02  -2411 31 -1811 imp:n=1  $ Position 11
2412 29 8.8245E-02  -2412 31 -1811 imp:n=1  $ Position 12
2413 29 8.8245E-02  -2413 31 -1811 imp:n=1  $ Position 13
2414 29 8.8245E-02  -2414 31 -1811 imp:n=1  $ Position 14
2415 29 8.8245E-02  -2415 31 -1811 imp:n=1  $ Position 15
2416 29 8.8245E-02  -2416 31 -1811 imp:n=1  $ Position 16
2417 29 8.8245E-02  -2417 31 -1811 imp:n=1  $ Position 17
2418 29 8.8245E-02  -2418 31 -1811 imp:n=1  $ Position 18
2419 29 8.8245E-02  -2419 31 -1811 imp:n=1  $ Position 19
2420 29 8.8245E-02  -2420 31 -1811 imp:n=1  $ Position 20
2421 29 8.8245E-02  -2421 31 -1811 imp:n=1  $ Position 21
2422 29 8.8245E-02  -2422 31 -1811 imp:n=1  $ Position 22
2423 29 8.8245E-02  -2423 31 -1811 imp:n=1  $ Position 23
2424 29 8.8245E-02  -2424 31 -1811 imp:n=1  $ Position 24
2425 29 8.8245E-02  -2425 31 -1811 imp:n=1  $ Position 25
2426 29 8.8245E-02  -2426 31 -1811 imp:n=1  $ Position 26
2427 29 8.8245E-02  -2427 31 -1811 imp:n=1  $ Position 27
2428 29 8.8245E-02  -2428 31 -1811 imp:n=1  $ Position 28
2429 29 8.8245E-02  -2429 31 -1811 imp:n=1  $ Position 29
2430 29 8.8245E-02  -2430 31 -1811 imp:n=1  $ Position 30
2431 29 8.8245E-02  -2431 31 -1811 imp:n=1  $ Position 31
2432 29 8.8245E-02  -2432 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 2 ---------
2501 29 8.8245E-02  -2501 31 -1811 imp:n=1  $ Position 1
2502 29 8.8245E-02  -2502 31 -1811 imp:n=1  $ Position 2
2503 29 8.8245E-02  -2503 31 -1811 imp:n=1  $ Position 3
```

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2504 29 8.8245E-02  -2504 31 -1811 imp:n=1  $ Position 4
2505 29 8.8245E-02  -2505 31 -1811 imp:n=1  $ Position 5
2506 29 8.8245E-02  -2506 31 -1811 imp:n=1  $ Position 6
2507 29 8.8245E-02  -2507 31 -1811 imp:n=1  $ Position 7
2508 29 8.8245E-02  -2508 31 -1811 imp:n=1  $ Position 8
2509 29 8.8245E-02  -2509 31 -1811 imp:n=1  $ Position 9
2510 29 8.8245E-02  -2510 31 -1811 imp:n=1  $ Position 10
2511 29 8.8245E-02  -2511 31 -1811 imp:n=1  $ Position 11
2512 29 8.8245E-02  -2512 31 -1811 imp:n=1  $ Position 12
2513 29 8.8245E-02  -2513 31 -1811 imp:n=1  $ Position 13
2514 29 8.8245E-02  -2514 31 -1811 imp:n=1  $ Position 14
2515 29 8.8245E-02  -2515 31 -1811 imp:n=1  $ Position 15
2516 29 8.8245E-02  -2516 31 -1811 imp:n=1  $ Position 16
2517 29 8.8245E-02  -2517 31 -1811 imp:n=1  $ Position 17
2518 29 8.8245E-02  -2518 31 -1811 imp:n=1  $ Position 18
2519 29 8.8245E-02  -2519 31 -1811 imp:n=1  $ Position 19
2520 29 8.8245E-02  -2520 31 -1811 imp:n=1  $ Position 20
2521 29 8.8245E-02  -2521 31 -1811 imp:n=1  $ Position 21
2522 29 8.8245E-02  -2522 31 -1811 imp:n=1  $ Position 22
2523 29 8.8245E-02  -2523 31 -1811 imp:n=1  $ Position 23
2524 29 8.8245E-02  -2524 31 -1811 imp:n=1  $ Position 24
2525 29 8.8245E-02  -2525 31 -1811 imp:n=1  $ Position 25
2526 29 8.8245E-02  -2526 31 -1811 imp:n=1  $ Position 26
2527 29 8.8245E-02  -2527 31 -1811 imp:n=1  $ Position 27
2528 29 8.8245E-02  -2528 31 -1811 imp:n=1  $ Position 28
2529 29 8.8245E-02  -2529 31 -1811 imp:n=1  $ Position 29
2530 29 8.8245E-02  -2530 31 -1811 imp:n=1  $ Position 30
2531 29 8.8245E-02  -2531 31 -1811 imp:n=1  $ Position 31
2532 29 8.8245E-02  -2532 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 3 ---------
2601 29 8.8245E-02  -2601 31 -1811 imp:n=1  $ Position 1
2602 29 8.8245E-02  -2602 31 -1811 imp:n=1  $ Position 2
2603 29 8.8245E-02  -2603 31 -1811 imp:n=1  $ Position 3
2604 29 8.8245E-02  -2604 31 -1811 imp:n=1  $ Position 4
2605 29 8.8245E-02  -2605 31 -1811 imp:n=1  $ Position 5
2606 29 8.8245E-02  -2606 31 -1811 imp:n=1  $ Position 6
2607 29 8.8245E-02  -2607 31 -1811 imp:n=1  $ Position 7
2608 29 8.8245E-02  -2608 31 -1811 imp:n=1  $ Position 8
2609 29 8.8245E-02  -2609 31 -1811 imp:n=1  $ Position 9
2610 29 8.8245E-02  -2610 31 -1811 imp:n=1  $ Position 10
2611 29 8.8245E-02  -2611 31 -1811 imp:n=1  $ Position 11
2612 29 8.8245E-02  -2612 31 -1811 imp:n=1  $ Position 12
2613 29 8.8245E-02  -2613 31 -1811 imp:n=1  $ Position 13
2614 29 8.8245E-02  -2614 31 -1811 imp:n=1  $ Position 14
2615 29 8.8245E-02  -2615 31 -1811 imp:n=1  $ Position 15
2616 29 8.8245E-02  -2616 31 -1811 imp:n=1  $ Position 16
2617 29 8.8245E-02  -2617 31 -1811 imp:n=1  $ Position 17
2618 29 8.8245E-02  -2618 31 -1811 imp:n=1  $ Position 18
2619 29 8.8245E-02  -2619 31 -1811 imp:n=1  $ Position 19
2620 29 8.8245E-02  -2620 31 -1811 imp:n=1  $ Position 20
2621 29 8.8245E-02  -2621 31 -1811 imp:n=1  $ Position 21
2622 29 8.8245E-02  -2622 31 -1811 imp:n=1  $ Position 22
2623 29 8.8245E-02  -2623 31 -1811 imp:n=1  $ Position 23
2624 29 8.8245E-02  -2624 31 -1811 imp:n=1  $ Position 24
2625 29 8.8245E-02  -2625 31 -1811 imp:n=1  $ Position 25
2626 29 8.8245E-02  -2626 31 -1811 imp:n=1  $ Position 26
2627 29 8.8245E-02  -2627 31 -1811 imp:n=1  $ Position 27
2628 29 8.8245E-02  -2628 31 -1811 imp:n=1  $ Position 28
2629 29 8.8245E-02  -2629 31 -1811 imp:n=1  $ Position 29
2630 29 8.8245E-02  -2630 31 -1811 imp:n=1  $ Position 30
2631 29 8.8245E-02  -2631 31 -1811 imp:n=1  $ Position 31
2632 29 8.8245E-02  -2632 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 4 ---------
2701 29 8.8245E-02  -2701 31 -1811 imp:n=1  $ Position 1
2702 29 8.8245E-02  -2702 31 -1811 imp:n=1  $ Position 2
2703 29 8.8245E-02  -2703 31 -1811 imp:n=1  $ Position 3
2704 29 8.8245E-02  -2704 31 -1811 imp:n=1  $ Position 4
2705 29 8.8245E-02  -2705 31 -1811 imp:n=1  $ Position 5
2706 29 8.8245E-02  -2706 31 -1811 imp:n=1  $ Position 6
2707 29 8.8245E-02  -2707 31 -1811 imp:n=1  $ Position 7
2708 29 8.8245E-02  -2708 31 -1811 imp:n=1  $ Position 8
2709 29 8.8245E-02  -2709 31 -1811 imp:n=1  $ Position 9
2710 29 8.8245E-02  -2710 31 -1811 imp:n=1  $ Position 10
2711 29 8.8245E-02  -2711 31 -1811 imp:n=1  $ Position 11
```

```
2712 29 8.8245E-02  -2712 31 -1811 imp:n=1  $ Position 12
2713 29 8.8245E-02  -2713 31 -1811 imp:n=1  $ Position 13
2714 29 8.8245E-02  -2714 31 -1811 imp:n=1  $ Position 14
2715 29 8.8245E-02  -2715 31 -1811 imp:n=1  $ Position 15
2716 29 8.8245E-02  -2716 31 -1811 imp:n=1  $ Position 16
2717 29 8.8245E-02  -2717 31 -1811 imp:n=1  $ Position 17
2718 29 8.8245E-02  -2718 31 -1811 imp:n=1  $ Position 18
2719 29 8.8245E-02  -2719 31 -1811 imp:n=1  $ Position 19
2720 29 8.8245E-02  -2720 31 -1811 imp:n=1  $ Position 20
2721 29 8.8245E-02  -2721 31 -1811 imp:n=1  $ Position 21
2722 29 8.8245E-02  -2722 31 -1811 imp:n=1  $ Position 22
2723 29 8.8245E-02  -2723 31 -1811 imp:n=1  $ Position 23
2724 29 8.8245E-02  -2724 31 -1811 imp:n=1  $ Position 24
2725 29 8.8245E-02  -2725 31 -1811 imp:n=1  $ Position 25
2726 29 8.8245E-02  -2726 31 -1811 imp:n=1  $ Position 26
2727 29 8.8245E-02  -2727 31 -1811 imp:n=1  $ Position 27
2728 29 8.8245E-02  -2728 31 -1811 imp:n=1  $ Position 28
2729 29 8.8245E-02  -2729 31 -1811 imp:n=1  $ Position 29
2730 29 8.8245E-02  -2730 31 -1811 imp:n=1  $ Position 30
2731 29 8.8245E-02  -2731 31 -1811 imp:n=1  $ Position 31
2732 29 8.8245E-02  -2732 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 5 ---------
2801 29 8.8245E-02  -2801 31 -1811 imp:n=1  $ Position 1
2802 29 8.8245E-02  -2802 31 -1811 imp:n=1  $ Position 2
2803 29 8.8245E-02  -2803 31 -1811 imp:n=1  $ Position 3
2804 29 8.8245E-02  -2804 31 -1811 imp:n=1  $ Position 4
2805 29 8.8245E-02  -2805 31 -1811 imp:n=1  $ Position 5
2806 29 8.8245E-02  -2806 31 -1811 imp:n=1  $ Position 6
2807 29 8.8245E-02  -2807 31 -1811 imp:n=1  $ Position 7
2808 29 8.8245E-02  -2808 31 -1811 imp:n=1  $ Position 8
2809 29 8.8245E-02  -2809 31 -1811 imp:n=1  $ Position 9
2810 29 8.8245E-02  -2810 31 -1811 imp:n=1  $ Position 10
2811 29 8.8245E-02  -2811 31 -1811 imp:n=1  $ Position 11
2812 29 8.8245E-02  -2812 31 -1811 imp:n=1  $ Position 12
2813 29 8.8245E-02  -2813 31 -1811 imp:n=1  $ Position 13
2814 29 8.8245E-02  -2814 31 -1811 imp:n=1  $ Position 14
2815 29 8.8245E-02  -2815 31 -1811 imp:n=1  $ Position 15
2816 29 8.8245E-02  -2816 31 -1811 imp:n=1  $ Position 16
2817 29 8.8245E-02  -2817 31 -1811 imp:n=1  $ Position 17
2818 29 8.8245E-02  -2818 31 -1811 imp:n=1  $ Position 18
2819 29 8.8245E-02  -2819 31 -1811 imp:n=1  $ Position 19
2820 29 8.8245E-02  -2820 31 -1811 imp:n=1  $ Position 20
2821 29 8.8245E-02  -2821 31 -1811 imp:n=1  $ Position 21
2822 29 8.8245E-02  -2822 31 -1811 imp:n=1  $ Position 22
2823 29 8.8245E-02  -2823 31 -1811 imp:n=1  $ Position 23
2824 29 8.8245E-02  -2824 31 -1811 imp:n=1  $ Position 24
2825 29 8.8245E-02  -2825 31 -1811 imp:n=1  $ Position 25
2826 29 8.8245E-02  -2826 31 -1811 imp:n=1  $ Position 26
2827 29 8.8245E-02  -2827 31 -1811 imp:n=1  $ Position 27
2828 29 8.8245E-02  -2828 31 -1811 imp:n=1  $ Position 28
2829 29 8.8245E-02  -2829 31 -1811 imp:n=1  $ Position 29
2830 29 8.8245E-02  -2830 31 -1811 imp:n=1  $ Position 30
2831 29 8.8245E-02  -2831 31 -1811 imp:n=1  $ Position 31
2832 29 8.8245E-02  -2832 31 -1811 imp:n=1  $ Position 32
c
c ------ Aluminum Plugs ------
c    *There were no aluminum plugs in the Core
c
c --- Control Rods ---------------------------------------------------------------
c ------ Safety/Shutdown Rods ------
3001 11 9.1511E-02  3002 -3003 -3005 imp:n=1 u=1  $ Borated Steel Rod
3002 10 4.8413E-05  3002 -3003 3005 -3006 imp:n=1 u=1  $ Air
3003 12 8.6882E-02  3001 -3004 -3007 (-3002:3003:3006) imp:n=1 u=1  $ Steel Tube
3004 10 4.8413E-05  -3001:3004:3007 imp:n=1 u=1  $ Air
c
c ****** Safety/Shutdown Rods Fully Inserted @ z=0 and Withdrawn @ z=290   ***********
c ****** Safety/Shutdown Rods were Fully Withdrawn for Cores 1, 1A, 2, & 3 ***********
c
c --------- Rod 1 ---------
3005 10 4.8413E-05  3011 -3012 -3014 imp:n=1 u=2  $ Air
3006 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=2  $ Aluminum Shock Damper
3007 0    (-31:3013:3015) imp:n=1 u=2 fill=1 (0 0 290)
c
c --------- Rod 2 ---------
3008 10 4.8413E-05  3011 -3012 -3014 imp:n=1 u=3  $ Air
```

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3009 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=3  $ Aluminum Shock Damper
3010 0    (-31:3013:3015) imp:n=1 u=3 fill=1 (0 0 290)
c
c --------- Rod 3 ---------
3011 10 4.8413E-05  3011 -3012 -3014 imp:n=1 u=4  $ Air
3012 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=4  $ Aluminum Shock Damper
3013 0    (-31:3013:3015) imp:n=1 u=4 fill=1 (0 0 290)
c
c --------- Rod 4 ---------
3014 10 4.8413E-05  3011 -3012 -3014 imp:n=1 u=5  $ Air
3015 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=5  $ Aluminum Shock Damper
3016 0    (-31:3013:3015) imp:n=1 u=5 fill=1 (0 0 290)
c
c --------- Rod 5 ---------
3017 10 4.8413E-05  3011 -3012 -3014 imp:n=1 u=6  $ Air
3018 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=6  $ Aluminum Shock Damper
3019 0    (-31:3013:3015) imp:n=1 u=6 fill=1 (0 0 290)
c
c --------- Rod 6 ---------
3020 10 4.8413E-05  3011 -3012 -3014 imp:n=1 u=7  $ Air
3021 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=7  $ Aluminum Shock Damper
3022 0    (-31:3013:3015) imp:n=1 u=7 fill=1 (0 0 290)
c
c --------- Rod 7 ---------
3023 10 4.8413E-05  3011 -3012 -3014 imp:n=1 u=8  $ Air
3024 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=8  $ Aluminum Shock Damper
3025 0    (-31:3013:3015) imp:n=1 u=8 fill=1 (0 0 290)
c
c --------- Rod 8 ---------
3026 10 4.8413E-05  3011 -3012 -3014 imp:n=1 u=9  $ Air
3027 14 8.1409E-02  31 -3013 -3015 (-3011:3012:3014) imp:n=1 u=9  $ Aluminum Shock Damper
3028 0    (-31:3013:3015) imp:n=1 u=9 fill=1 (0 0 290)
c
c ------ Autorod ------
3031 13 8.4303E-02  3031 -3032 -3033 -3034 -3035 imp:n=1 u=10  $ Copper Plate
3032 10 4.8413E-05  -3031:3032:3033:3034:3035 imp:n=1 u=10  $ Air
c
c ****** Autorod Fully Inserted @ z=0 and Withdrawn @ z=100 **************************
c ****** Autorod Withdrawn to z=25.8 for Core 9 &           **************************
c ******                      z= 1.5 for Core 10,          **************************
c
3033 0    -3036 imp:n=1 u=11 fill=10 (0 0 25.8)
3034 113 5.9746E-02  3036 -3037 15 -32 imp:n=1 u=11  $ Aluminum Tube
3035 10 4.8413E-05  3037:(3036 -15):(3036 32) imp:n=1 u=11  $ Air
c
c ------ Static Measurement Rods ------
c    *There were no Static Measurement Rods in the Core
c
c ------ ZEBRA Rods ------
c    *There were no ZEBRA Control Rods in the Core
c
c ------ Withdrawable Control Rods ------
3091 10 4.8413E-05  3083 -3084 -3087 imp:n=1 u=17  $ Air
3092 17 8.6477E-02  3082 -3085 3087 -3088 imp:n=1 u=17 $ Inner Tube
3093 10 4.8413E-05  3082 -3085 3088 -3089 imp:n=1 u=17 $ Air Gap
3094 18 8.6499E-02  3082 -3085 3089 -3090 imp:n=1 u=17 $ Outer Tube
3095 18 8.6499E-02  (3081 -3082 -3090):(3082 -3083 -3087) imp:n=1 u=17  $ Bottom End Plug
3096 18 8.6499E-02  (3084 -3085 -3087):(3085 -3086 -3090) imp:n=1 u=17  $ Top End Plug
3097 10 4.8413E-05  -3081:3086:3090 imp:n=1 u=17  $ Air
c
c ****** Control Rods Fully Inserted @ z=0 and Withdrawn @ z=249.4          **********
c ****** Opposite of Reported Values Inserted @ z=250 and Withdrawn @ z=0.6 **********
c ****** Control Rods Withdrawn to z=249.4 for Core 9                       **********
c ****** Control Rods Withdrawn to z=96.0  for Core 10                      **********
c
3098 0  -3095 imp:n=1 u=18 fill=17 (0 0 249.4)  $ Rod 1
3099 0  -3095 imp:n=1 u=19 fill=17 (0 0 249.4)  $ Rod 2
3100 0  -3095 imp:n=1 u=20 fill=17 (0 0 249.4)  $ Rod 3
3101 0  -3095 imp:n=1 u=21 fill=17 (0 0 249.4)  $ Rod 4
c
c --- Pebbles ------------------------------------------------------------------
c ------ TRISO ------
3111 19 7.2935E-02  -3111 imp:n=1 u=22  $ UO2 Kernel
3112 20 5.2651E-02  3111 -3112 imp:n=1 u=22  $ Buffer Coating
3113 21 9.5273E-02  3112 -3113 imp:n=1 u=22  $ IPyC Coating
3114 22 9.6142E-02  3113 -3114 imp:n=1 u=22  $ SiC Coating
```

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3115 23 9.4772E-02  3114 -3115 imp:n=1 u=22  $ OPyC Coating
3116 24 8.6859E-02  3115 imp:n=1 u=22  $ Fueled Zone Graphite
c
3117 24 8.6859E-02  -9999 imp:n=1 u=23  $ Fueled Zone Graphite
c
c ------ TRISO Lattice ------
3121 24 8.6859E-02  -3121 imp:n=1 u=98 lat=1 fill=-14:14 -14:14 -14:14
c
     23 840r
c
     23 405r
     23 12r 22 2r 23 12r
     23 405r
c
     23 260r
     23 12r 22 2r 23 12r
     23 10r 22 6r 23 10r
     23 9r 22 8r 23 9r
     23 9r 22 8r 23 9r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 9r 22 8r 23 9r
     23 9r 22 8r 23 9r
     23 10r 22 6r 23 10r
     23 12r 22 2r 23 12r
     23 260r
c
     23 202r
     23 12r 22 2r 23 12r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 12r 22 2r 23 12r
     23 202r
c
     23 173r
     23 11r 22 4r 23 11r
     23 9r 22 8r 23 9r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 9r 22 8r 23 9r
     23 11r 22 4r 23 11r
     23 173r
c
     23 144r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
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     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 144r
c
     23 115r
     23 11r 22 4r 23 11r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
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     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 11r 22 4r 23 11r
     23 115r
c
     23 86r
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     23 9r 22 8r 23 9r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
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     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 9r 22 8r 23 9r
     23 12r 22 2r 23 12r
     23 86r
c
     23 86r
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     23 8r 22 10r 23 8r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
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     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 86r
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     23 4r 22 18r 23 4r
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     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 12r 22 2r 23 12r
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     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
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     23 5r 22 16r 23 5r
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     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 57r
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     23 57r
     23 9r 22 8r 23 9r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 2r 22 22r 23 2r
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     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
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     23 4r 22 18r 23 4r
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     23 9r 22 8r 23 9r
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     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 7r 22 12r 23 7r
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c
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     23 4r 22 18r 23 4r
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     23 1r 22 24r 23 1r
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     23 2r 22 22r 23 2r
     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 8r 22 10r 23 8r
     23 57r
c
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     23 28r
     23 12r 22 23 22 23 12r
     23 8r 22 10r 23 8r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 2r 22 22r 23 2r
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     23 1r 22 24r 23 1r
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     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 8r 22 10r 23 8r
     23 57r
c
     23 57r
     23 9r 22 8r 23 9r
     23 7r 22 12r 23 7r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
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     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 7r 22 12r 23 7r
     23 9r 22 8r 23 9r
     23 57r
c
     23 57r
     23 9r 22 8r 23 9r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 9r 22 8r 23 9r
     23 57r
c
     23 57r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 57r
c
     23 57r
     23 12r 22 2r 23 12r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
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     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 1r 22 24r 23 1r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 12r 22 2r 23 12r
     23 57r
c
     23 86r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 86r
c
     23 86r
     23 12r 22 2r 23 12r
     23 9r 22 8r 23 9r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 2r 22 22r 23 2r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 9r 22 8r 23 9r
     23 12r 22 2r 23 12r
     23 86r
c
     23 115r
     23 11r 22 4r 23 11r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
```

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     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 3r 22 20r 23 3r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 11r 22 4r 23 11r
     23 115r
c
     23 144r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 144r
c
     23 173r
     23 11r 22 4r 23 11r
     23 9r 22 8r 23 9r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 9r 22 8r 23 9r
     23 11r 22 4r 23 11r
     23 173r
c
     23 202r
     23 12r 22 2r 23 12r
     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 7r 22 12r 23 7r
     23 7r 22 12r 23 7r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 6r 22 14r 23 6r
     23 7r 22 12r 23 7r
     23 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 12r 22 2r 23 12r
```

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     23 202r
c
     23 260r
     23 12r 22 2r 23 12r
     23 10r 22 6r 23 10r
     23 9r 22 8r 23 9r
     23 9r 22 8r 23 9r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
     23 9r 22 8r 23 9r
     23 9r 22 8r 23 9r
     23 10r 22 6r 23 10r
     23 12r 22 2r 23 12r
     23 260r
c
     23 405r
     23 12r 22 2r 23 12r
     23 405r
c
     23 840r
c
c
c
c ------ Fuel Pebbles ------
3131 24 8.6859E-02  -3131       imp:n=1 u=24 fill=98 $ Fuel Zone
3132 25 8.6859E-02   3131 -3132 imp:n=1 u=24         $ Pebble Shell (Unfueled Zone)
3133 10 4.8413E-05   3132       imp:n=1 u=24         $ Air
c
c ------ Moderator Pebbles ------
4131 26 8.4461E-02  -3132       imp:n=1 u=25  $ Moderator Pebble
4132 10 4.8413E-05   3132       imp:n=1 u=25  $ Air
c
c ------ Air ------
5001 10 4.8413E-05  -9999 imp:n=1 u=26  $ Air
c
c ------ Pebble Stacks --------------------------------------------------------
c --------- Standard Stacks ---------
c ------------ Stack 1 (Core 9) ------------
6001 10 4.8413E-05  -6001 imp:n=1 u=27 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
```

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     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 2 (Core 9) ------------
6002 10 4.8413E-05  -6001 imp:n=1 u=28 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 3 (Core 9) ------------
6003 10 4.8413E-05  -6001 imp:n=1 u=29 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
```

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     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 4 (Core 9) ------------
6004 10 4.8413E-05  -6001 imp:n=1 u=30 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
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     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 1 (Core 10) ------------
6005 10 4.8413E-05  -6001 imp:n=1 u=31 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
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     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 2 (Core 10) ------------
6006 10 4.8413E-05  -6001 imp:n=1 u=32 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 3 (Core 10) ------------
6007 10 4.8413E-05  -6001 imp:n=1 u=33 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
```

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     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------------ Stack 4 (Core 10) ------------
6008 10 4.8413E-05  -6001 imp:n=1 u=34 lat=2 fill=-1:1 -1:1 0:44
     26 26 26  26 26 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 24 26  26 26 26
     26 26 26  26 25 26  26 26 26
c
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
```

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     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
     26 26 26  26 26 26  26 26 26
c
c ------ Stacks with Polyethylene Rods (Full Set) ------
c    *Polyethylene Rods are Only in Core 10
c
c ------------ Stack 1 - NW, N, NE, SE, S, SW ------------
5101 34 1.2365E-01  -7021 -6003 -7027 imp:n=1 u=35  $ NW Rod
5102 34 1.2365E-01  -7022 -6003 -7027 imp:n=1 u=35  $ N Rod
5103 34 1.2365E-01  -7023 -6003 -7027 imp:n=1 u=35  $ NE Rod
5104 34 1.2365E-01  -7024 -6003 -7027 imp:n=1 u=35  $ SE Rod
5105 34 1.2365E-01  -7025 -6003 -7027 imp:n=1 u=35  $ S Rod
5106 34 1.2365E-01  -7026 -6003 -7027 imp:n=1 u=35  $ SW Rod
5107 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=35 fill=31
c
c ------------ Stack 2 - NW, N, NE, SE, S, SW ------------
5111 34 1.2365E-01  -7021 -6003 -7027 imp:n=1 u=36  $ NW Rod
5112 34 1.2365E-01  -7022 -6003 -7027 imp:n=1 u=36  $ N Rod
5113 34 1.2365E-01  -7023 -6003 -7027 imp:n=1 u=36  $ NE Rod
5114 34 1.2365E-01  -7024 -6003 -7027 imp:n=1 u=36  $ SE Rod
5115 34 1.2365E-01  -7025 -6003 -7027 imp:n=1 u=36  $ S Rod
5116 34 1.2365E-01  -7026 -6003 -7027 imp:n=1 u=36  $ SW Rod
5117 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=36 fill=32
c
c ------------ Stack 3 - NW, N, NE, SE, S, SW ------------
5121 34 1.2365E-01  -7021 -6003 -7027 imp:n=1 u=37  $ NW Rod
5122 34 1.2365E-01  -7022 -6003 -7027 imp:n=1 u=37  $ N Rod
5123 34 1.2365E-01  -7023 -6003 -7027 imp:n=1 u=37  $ NE Rod
5124 34 1.2365E-01  -7024 -6003 -7027 imp:n=1 u=37  $ SE Rod
5125 34 1.2365E-01  -7025 -6003 -7027 imp:n=1 u=37  $ S Rod
5126 34 1.2365E-01  -7026 -6003 -7027 imp:n=1 u=37  $ SW Rod
5127 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=37 fill=33
c
c ------------ Stack 4 - NW, N, NE, SE, S, SW ------------
5131 34 1.2365E-01  -7021 -6003 -7027 imp:n=1 u=38  $ NW Rod
5132 34 1.2365E-01  -7022 -6003 -7027 imp:n=1 u=38  $ N Rod
5133 34 1.2365E-01  -7023 -6003 -7027 imp:n=1 u=38  $ NE Rod
5134 34 1.2365E-01  -7024 -6003 -7027 imp:n=1 u=38  $ SE Rod
5135 34 1.2365E-01  -7025 -6003 -7027 imp:n=1 u=38  $ S Rod
5136 34 1.2365E-01  -7026 -6003 -7027 imp:n=1 u=38  $ SW Rod
5137 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=38 fill=34
c
c ------ Stacks with Polyethylene Rods (Partial Sets) ------
c ------------ Stack 1 - N, NE, SE, S ------------
5202 like 5102 but u=40  $ N Rod
5203 like 5103 but u=40  $ NE Rod
5204 like 5104 but u=40  $ SE Rod
5205 like 5105 but u=40  $ S Rod
5207 10 4.8413E-05  -6003 (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) imp:n=1 u=40 fill=31
c
c ------------ Stack 1 - NE, SE, S ------------
5213 like 5103 but u=41  $ NE Rod
5214 like 5104 but u=41  $ SE Rod
5215 like 5105 but u=41  $ S Rod
5217 10 4.8413E-05  -6003 (7023:7027) (7024:7027)
                          (7025:7027) imp:n=1 u=41 fill=31
c
c ------------ Stack 1 - SE, S ------------
5224 like 5104 but u=42  $ SE Rod
5225 like 5105 but u=42  $ S Rod
5227 10 4.8413E-05  -6003 (7024:7027) (7025:7027) imp:n=1 u=42 fill=31
c
c ------------ Stack 1 - S, SW ------------
5235 like 5105 but u=43  $ S Rod
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5236 like 5106 but u=43  $ SW Rod
5237 10 4.8413E-05  -6003 (7025:7027) (7026:7027) imp:n=1 u=43 fill=31
c
c ------------ Stack 1 - NW, S, SW ------------
5241 like 5101 but u=44  $ NW Rod
5245 like 5105 but u=44  $ S Rod
5246 like 5106 but u=44  $ SW Rod
5247 10 4.8413E-05  -6003 (7021:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=44 fill=31
c
c ------------ Stack 1 - NW, N, S, SW ------------
5251 like 5101 but u=45  $ NW Rod
5252 like 5102 but u=45  $ N Rod
5255 like 5105 but u=45  $ S Rod
5256 like 5106 but u=45  $ SW Rod
5257 10 4.8413E-05  -6003 (7021:7027) (7022:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=45 fill=31
c
c ------------ Stack 1 - NW, N, SW ------------
5261 like 5101 but u=46  $ NW Rod
5262 like 5102 but u=46  $ N Rod
5266 like 5106 but u=46  $ SW Rod
5267 10 4.8413E-05  -6003 (7021:7027) (7022:7027)
                          (7026:7027) imp:n=1 u=46 fill=31
c
c ------------ Stack 1 - NW, N ------------
5271 like 5101 but u=47  $ NW Rod
5272 like 5102 but u=47  $ N Rod
5277 10 4.8413E-05  -6003 (7021:7027) (7022:7027) imp:n=1 u=47 fill=31
c
c ------------ Stack 1 - N, NE ------------
5282 like 5102 but u=48  $ N Rod
5283 like 5103 but u=48  $ NE Rod
5287 10 4.8413E-05  -6003 (7022:7027) (7023:7027) imp:n=1 u=48 fill=31
c
c ------------ Stack 1 - N, NE, SE ------------
5292 like 5102 but u=49  $ N Rod
5293 like 5103 but u=49  $ NE Rod
5294 like 5104 but u=49  $ SE Rod
5297 10 4.8413E-05  -6003 (7022:7027) (7023:7027) (7024:7027)
                          imp:n=1 u=49 fill=31
c
c ------------ Stack 2 - N, NE, SE, S ------------
5302 like 5112 but u=50  $ N Rod
5303 like 5113 but u=50  $ NE Rod
5304 like 5114 but u=50  $ SE Rod
5305 like 5115 but u=50  $ S Rod
5307 10 4.8413E-05  -6003 (7022:7027) (7023:7027) (7024:7027)
                          (7025:7027) imp:n=1 u=50 fill=32
c
c ------------ Stack 2 - NE, SE, S, SW ------------
5313 like 5113 but u=51  $ NE Rod
5314 like 5114 but u=51  $ SE Rod
5315 like 5115 but u=51  $ S Rod
5316 like 5116 but u=51  $ SW Rod
5317 10 4.8413E-05  -6003 (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=51 fill=32
c
c ------------ Stack 2 - NW, SE, S, SW ------------
5321 like 5111 but u=52  $ NW Rod
5324 like 5114 but u=52  $ SE Rod
5325 like 5115 but u=52  $ S Rod
5326 like 5116 but u=52  $ SW Rod
5327 10 4.8413E-05  -6003 (7021:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=52 fill=32
c
c ------------ Stack 2 - NW, N, S, SW ------------
5331 like 5111 but u=53  $ NW Rod
5332 like 5112 but u=53  $ N Rod
5335 like 5115 but u=53  $ S Rod
5336 like 5116 but u=53  $ SW Rod
5337 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7025:7027) (7026:7027)
                          imp:n=1 u=53 fill=32
c
c ------------ Stack 2 - NW, N, NE, SW ------------
5341 like 5111 but u=54  $ NW Rod
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5342 like 5112 but u=54  $ N Rod
5343 like 5113 but u=54  $ NE Rod
5346 like 5116 but u=54  $ SW Rod
5347 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027)
                          (7026:7027) imp:n=1 u=54 fill=32
c
c ------------ Stack 2 - NW, N, NE, SE ------------
5351 like 5111 but u=55  $ NW Rod
5352 like 5112 but u=55  $ N Rod
5353 like 5113 but u=55  $ NE Rod
5354 like 5114 but u=55  $ SE Rod
5357 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          imp:n=1 u=55 fill=32
c
c ------------ Stack 3 - NE, SE ------------
5403 like 5123 but u=60  $ NE Rod
5404 like 5124 but u=60  $ SE Rod
5407 10 4.8413E-05  -6003 (7023:7027) (7024:7027) imp:n=1 u=60 fill=33
c
c ------------ Stack 3 - NE, SE, S ------------
5413 like 5123 but u=61  $ NE Rod
5414 like 5124 but u=61  $ SE Rod
5415 like 5125 but u=61  $ S Rod
5417 10 4.8413E-05  -6003 (7023:7027) (7024:7027)
                          (7025:7027) imp:n=1 u=61 fill=33
c
c ------------ Stack 3 - NE, SE, S, SW ------------
5423 like 5123 but u=62  $ NE Rod
5424 like 5124 but u=62  $ SE Rod
5425 like 5125 but u=62  $ S Rod
5426 like 5126 but u=62  $ SW Rod
5427 10 4.8413E-05  -6003 (7023:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=62 fill=33
c
c ------------ Stack 3 - SE, S, SW ------------
5434 like 5124 but u=63  $ SE Rod
5435 like 5125 but u=63  $ S Rod
5436 like 5126 but u=63  $ SW Rod
5437 10 4.8413E-05  -6003 (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=63 fill=33
c
c ------------ Stack 3 - S, SW ------------
5445 like 5125 but u=64  $ S Rod
5446 like 5126 but u=64  $ SW Rod
5447 10 4.8413E-05  -6003 (7025:7027) (7026:7027) imp:n=1 u=64 fill=33
c
c ------------ Stack 3 - NW, SW ------------
5451 like 5121 but u=65  $ NW Rod
5456 like 5126 but u=65  $ SW Rod
5457 10 4.8413E-05  -6003 (7021:7027) (7026:7027) imp:n=1 u=65 fill=33
c
c ------------ Stack 3 - NW, N, SW ------------
5461 like 5121 but u=66  $ NW Rod
5462 like 5122 but u=66  $ N Rod
5466 like 5126 but u=66  $ SW Rod
5467 10 4.8413E-05  -6003 (7021:7027) (7022:7027)
                          (7026:7027) imp:n=1 u=66 fill=33
c
c ------------ Stack 3 - NW, N, NE, SW ------------
5471 like 5121 but u=67  $ NW Rod
5472 like 5122 but u=67  $ N Rod
5473 like 5123 but u=67  $ NE Rod
5476 like 5126 but u=67  $ SW Rod
5477 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027)
                          (7026:7027) imp:n=1 u=67 fill=33
c
c ------------ Stack 3 - NW, N, NE ------------
5481 like 5121 but u=68  $ NW Rod
5482 like 5122 but u=68  $ N Rod
5483 like 5123 but u=68  $ NE Rod
5487 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027)
                          imp:n=1 u=68 fill=33
c
c ------------ Stack 3 - N, NE ------------
5492 like 5122 but u=69  $ N Rod
5493 like 5123 but u=69  $ NE Rod
```

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5497 10 4.8413E-05  -6003 (7022:7027) (7023:7027) imp:n=1 u=69 fill=33
c
c ------------ Stack 4 - NE, SE ------------
5503 like 5133 but u=70  $ NE Rod
5504 like 5134 but u=70  $ SE Rod
5507 10 4.8413E-05  -6003 (7023:7027) (7024:7027) imp:n=1 u=70 fill=34
c
c ------------ Stack 4 - SE, S ------------
5514 like 5134 but u=71  $ SE Rod
5515 like 5135 but u=71  $ S Rod
5517 10 4.8413E-05  -6003 (7024:7027) (7025:7027) imp:n=1 u=71 fill=34
c
c ------------ Stack 4 - SE, S, SW ------------
5524 like 5134 but u=72  $ SE Rod
5525 like 5135 but u=72  $ S Rod
5526 like 5136 but u=72  $ SW Rod
5527 10 4.8413E-05  -6003 (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=72 fill=34
c
c ------------ Stack 4 - NW, SE, S, SW ------------
5531 like 5131 but u=73  $ NW Rod
5534 like 5134 but u=73  $ SE Rod
5535 like 5135 but u=73  $ S Rod
5536 like 5136 but u=73  $ SW Rod
5537 10 4.8413E-05  -6003 (7021:7027) (7024:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=73 fill=34
c
c ------------ Stack 4 - NW, S, SW ------------
5541 like 5131 but u=74  $ NW Rod
5545 like 5135 but u=74  $ S Rod
5546 like 5136 but u=74  $ SW Rod
5547 10 4.8413E-05  -6003 (7021:7027)
                          (7025:7027) (7026:7027) imp:n=1 u=74 fill=34
c
c ------------ Stack 4 - NW, SW ------------
5551 like 5131 but u=75  $ NW Rod
5556 like 5136 but u=75  $ SW Rod
5557 10 4.8413E-05  -6003 (7021:7027) (7026:7027) imp:n=1 u=75 fill=34
c
c ------------ Stack 4 - NW, N ------------
5561 like 5131 but u=76  $ NW Rod
5562 like 5132 but u=76  $ N Rod
5567 10 4.8413E-05  -6003 (7021:7027) (7022:7027) imp:n=1 u=76 fill=34
c
c ------------ Stack 4 - NW, N, NE ------------
5571 like 5131 but u=77  $ NW Rod
5572 like 5132 but u=77  $ N Rod
5573 like 5133 but u=77  $ NE Rod
5577 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027)
                          imp:n=1 u=77 fill=34
c
c ------------ Stack 4 - NW, N, NE, SE ------------
5581 like 5131 but u=78  $ NW Rod
5582 like 5132 but u=78  $ N Rod
5583 like 5133 but u=78  $ NE Rod
5584 like 5134 but u=78  $ SE Rod
5587 10 4.8413E-05  -6003 (7021:7027) (7022:7027) (7023:7027) (7024:7027)
                          imp:n=1 u=78 fill=34
c
c ------------ Stack 4 - N, NE, SE ------------
5592 like 5132 but u=79  $ N Rod
5593 like 5133 but u=79  $ NE Rod
5594 like 5134 but u=79  $ SE Rod
5597 10 4.8413E-05  -6003 (7022:7027) (7023:7027) (7024:7027)
                          imp:n=1 u=79 fill=34
c
c ------ Core Arrangement ------------------------------------------------------
c --------- Core 9 Lattice Description ---------
7001 10 4.8413E-05  -6002 imp:n=1 u=100 lat=2 fill=-12:12 -12:12 0:0
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 29 30 29 30 29 30 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 27 28 27 28 27 28 27 28 27 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 29 30 29 30 29 30 29 30 29 30 29 30 26 26
      26 26 26 26 26 26 26 26 26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26
      26 26 26 26 26 26 26 26 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 26
      26 26 26 26 26 26 26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26
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      26 26 26 26 26 26 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 26
      26 26 26 26 26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26
      26 26 26 26 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 26
      26 26 26 26 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 26 26
      26 26 26 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 26 26
c
      26 26 26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26 26 26
c
      26 26 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 26 26 26
      26 26 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 26 26 26 26
      26 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 26 26 26 26
      26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26 26 26 26 26
      26 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 26 26 26 26 26 26
      26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26 26 26 26 26 26 26
      26 29 30 29 30 29 30 29 30 29 30 29 30 29 30 29 30 26 26 26 26 26 26 26 26
      26 27 28 27 28 27 28 27 28 27 28 27 28 27 28 27 26 26 26 26 26 26 26 26 26
      26 26 30 29 30 29 30 29 30 29 30 29 30 29 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 27 28 27 28 27 28 27 28 27 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 30 29 30 29 30 29 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
c
c --------- Core 10 Lattice Description ---------
7002 10 4.8413E-05  -6002 imp:n=1 u=101 lat=2 fill=-12:12 -12:12 0:0
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 69 77 68 77 68 76 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 48 55 35 36 35 36 35 54 47 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 69 78 37 38 37 38 37 38 37 38 67 76 26 26
      26 26 26 26 26 26 26 26 26 48 55 35 36 35 36 35 36 35 36 35 36 35 54 47 26
      26 26 26 26 26 26 26 26 79 37 38 37 38 37 38 37 38 37 38 37 38 37 38 66 26
      26 26 26 26 26 26 26 49 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 46 26
      26 26 26 26 26 26 79 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 66 26
      26 26 26 26 26 49 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 46 26
      26 26 26 26 70 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 65 26
      26 26 26 26 50 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 53 26 26
      26 26 26 60 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 75 26 26
c
      26 26 26 40 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 45 26 26 26
c
      26 26 70 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 65 26 26 26
      26 26 50 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 53 26 26 26 26
      26 60 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 75 26 26 26 26
      26 41 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 44 26 26 26 26 26
      26 61 38 37 38 37 38 37 38 37 38 37 38 37 38 37 38 37 74 26 26 26 26 26 26
      26 41 36 35 36 35 36 35 36 35 36 35 36 35 36 35 36 44 26 26 26 26 26 26 26
      26 61 38 37 38 37 38 37 38 37 38 37 38 37 38 37 74 26 26 26 26 26 26 26 26
      26 42 51 35 36 35 36 35 36 35 36 35 36 35 52 43 26 26 26 26 26 26 26 26 26
      26 26 71 62 38 37 38 37 38 37 38 37 73 64 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 42 51 35 36 35 36 35 52 43 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 71 63 72 63 72 64 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26 26
c
c --------- Pebble-Filled Core Cavity ---------
7101 10 4.8413E-05  -7001 -7002 -7003 imp:n=1 fill=100 (0 0 75) $ Core 9
c 7101 10 4.8413E-05  -7001 -7002 -7003 imp:n=1 fill=101 (0 0 75) $ Core 10
c
c --- Graphite Fillers --------------------------------------------------------
c ------ Axial Modifiers ------
9001 31 8.2629E-02  (7001:7002) 1811 -7003
          -7501 -7502 -7503 -7504 -7505 -7506 -7507 -7508 -7509 -7510 -7511
          -7512 -7513 -7514 -7515 -7516 -7517 -7518 -7519 -7520 -7521 -7522
          imp:n=1
c
c ------ Lattice Spacers ------
c    *Lattice Spacers Not Used
c
c ------ Cavity Floor ------
c    *Cavity Floor Fillers Not Used
c
c --- Water Ingress Simulation ------------------------------------------------
c ------ Polyethylene Rods ------
c    *Polyethylene Rods Not Used in Configurations 1, 1A, & 2
c    *Modeled above in the Pebble Lattices
c
c ------ Copper Wire ------
c    *Copper Wire Not Used
c
```

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c --- Auxiliary Components -----------------------------------------------------
c ------ Start-Up Source ------
c    *Start-Up Source Information Unknown
c
c ------ Detectors ------
c    *Detector Information Unknown
c
c ------ Temperature Sensors ------
c    *Temperature Sensor Information Unknown
c
c --- Model Boundary -----------------------------------------------------------
9999  0  -2:4:-6:8:-15:9 imp:n=0  $ The Great Void
c

c Surface Cards ****************************************************************
c --- Structural Surroundings --------------------------------------------------
c ------ Concrete ------
1     py  -205.0  $ Inside South Face
2     py  -285.0  $ Outside South Face
3     py   205.0  $ Inside North Face
4     py   285.0  $ Outside North Face
5     px  -205.0  $ Inside West Face
6     px  -285.0  $ Outside West Face
7     px   205.0  $ Inside East Face
8     px   285.0  $ Outside East Face
9     pz   620.4   $ Top of Concrete Shielding
c
c ------ Steel Plate Pedestal ------
15    pz    -7.5
c
c ------ Thermal Column ------
21    pz    98.4 $ Bottom of Column
22    pz   218.4 $ Top of Column
c    *Same as Inside South Face of Concrete $ South Face of Concrete
23    px   -60   $ West Face of Column
24    px    60   $ East Face of Column
c
c --- Radial Reflector ---------------------------------------------------------
c ------ Graphite Annulus ------
31    pz     0.0   $ Bottom of Reflector
32    pz   330.4   $ Top of Reflector
33    cz    62.79726  $ Inside Radial Equivalent-Area Cavity Surface
34    cz   163.76986  $ Outside Radial Equivalent-Area Surface
c
c --------- Inside Surfaces of 22-Sided Polygon ---------
7501  p  -63.28338   0.00000 0  -60.56463  18.34968 0  -60.56463  18.34968 1
7502  p  -60.56463  18.34968 0  -52.64200  35.12271 0  -52.64200  35.12271 1
7503  p  -52.64200  35.12271 0  -40.19623  48.87790 0  -40.19623  48.87790 1
7504  p  -40.19623  48.87790 0  -24.29668  58.43336 0  -24.29668  58.43336 1
7505  p  -24.29668  58.43336 0   -6.30949  62.96806 0   -6.30949  62.96806 1
7506  p   -6.30949  62.96806 0   12.21983  62.09236 0   12.21983  62.09236 1
7507  p   12.21983  62.09236 0   29.69919  55.88152 0   29.69919  55.88152 1
7508  p   29.69919  55.88152 0   44.62671  44.86917 0   44.62671  44.86917 1
7509  p   44.62671  44.86917 0   55.71977  30.00154 0   55.71977  30.00154 1
7510  p   55.71977  30.00154 0   62.02524  12.55610 0   62.02524  12.55610 1
7511  p   62.02524  12.55610 0   63.00132  -5.96821 0   63.00132  -5.96821 1
7512  p   63.00132  -5.96821 0   58.56415 -23.97970 0   58.56415 -23.97970 1
7513  p   58.56415 -23.97970 0   49.09498 -39.93080 0   49.09498 -39.93080 1
7514  p   49.09498 -39.93080 0   35.40743 -52.45092 0   35.40743 -52.45092 1
7515  p   35.40743 -52.45092 0   18.67758 -60.46432 0   18.67758 -60.46432 1
7516  p   18.67758 -60.46432 0    0.34290 -63.28245 0    0.34290 -63.28245 1
7517  p    0.34290 -63.28245 0  -18.02125 -60.66320 0  -18.02125 -60.66320 1
7518  p  -18.02125 -60.66320 0  -34.83696 -52.83154 0  -34.83696 -52.83154 1
7519  p  -34.83696 -52.83154 0  -40.19623 -48.87790 0  -40.19623 -48.87790 1
7520  p  -40.19623 -48.87790 0  -52.64200 -35.12271 0  -52.64200 -35.12271 1
7521  p  -52.64200 -35.12271 0  -60.56463 -18.34968 0  -60.56463 -18.34968 1
7522  p  -60.56463 -18.34968 0  -63.28338   0.00000 0  -63.28338   0.00000 1
c
c --------- Outside Surfaces of 22-Sided Polygon ---------
7531  p -164.94114    0.00000 0 -157.85504   47.82643 0 -157.85504   47.82643 1
7532  p -157.85504   47.82643 0 -137.20558   91.54348 0 -137.20558   91.54348 1
7533  p -137.20558   91.54348 0 -104.76704  127.39485 0 -104.76704  127.39485 1
7534  p -104.76704  127.39485 0  -63.32661  152.30010 0  -63.32661  152.30010 1
7535  p  -63.32661  152.30010 0  -16.44498  164.11930 0  -16.44498  164.11930 1
7536  p  -16.44498  164.11930 0   31.84963  161.83690 0   31.84963  161.83690 1
7537  p   31.84963  161.83690 0   77.40766  145.64901 0   77.40766  145.64901 1
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7538  p   77.40766  145.64901 0  116.31459  116.94655 0  116.31459  116.94655 1
7539  p  116.31459  116.94655 0  145.22745   78.19572 0  145.22745   78.19572 1
7540  p  145.22745   78.19572 0  161.66194   32.72608 0  161.66194   32.72608 1
7541  p  161.66194   32.72608 0  164.20599  -15.55547 0  164.20599  -15.55547 1
7542  p  164.20599  -15.55547 0  152.64100  -62.50045 0  152.64100  -62.50045 1
7543  p  152.64100  -62.50045 0  127.96066 -104.07522 0  127.96066 -104.07522 1
7544  p  127.96066 -104.07522 0   92.28558 -136.70755 0   92.28558 -136.70755 1
7545  p   92.28558 -136.70755 0   48.68106 -157.59358 0   48.68106 -157.59358 1
7546  p   48.68106 -157.59358 0    0.89372 -164.93872 0    0.89372 -164.93872 1
7547  p    0.89372 -164.93872 0  -46.97040 -158.11187 0  -46.97040 -158.11187 1
7548  p  -46.97040 -158.11187 0  -90.79870 -137.69959 0  -90.79870 -137.69959 1
7549  p  -90.79870 -137.69959 0 -104.76704 -127.39485 0 -104.76704 -127.39485 1
7550  p -104.76704 -127.39485 0 -137.20558  -91.54348 0 -137.20558  -91.54348 1
7551  p -137.20558  -91.54348 0 -157.85504  -47.82643 0 -157.85504  -47.82643 1
7552  p -157.85504  -47.82643 0 -164.94114    0.00000 0 -164.94114    0.00000 1
c
c ------ Safety Ring ------
41    pz   254.4  $ Bottom Surface
42    pz   255.4  $ Top Surface
43    cz    60.4  $ Inner Radius
44    cz    70.0  $ Outer Radius
c
c ------ C-Driver Channels ------
c --------- Ring 1 ---------
101   c/z  -67.20   0.00  1.3715  $ Position 1
102   c/z  -66.88   6.59  1.3715  $ Position 2
103   c/z  -65.91  13.11  1.3715  $ Position 3
104   c/z  -64.31  19.51  1.3715  $ Position 4
105   c/z  -62.08  25.72  1.3715  $ Position 5
106   c/z  -59.27  31.68  1.3715  $ Position 6
107   c/z  -55.87  37.33  1.3715  $ Position 7
108   c/z  -51.95  42.63  1.3715  $ Position 8
109   c/z  -47.52  47.52  1.3715  $ Position 9
110   c/z  -42.63  51.95  1.3715  $ Position 10
111   c/z  -37.33  55.87  1.3715  $ Position 11
112   c/z  -31.68  59.27  1.3715  $ Position 12
113   c/z  -25.72  62.08  1.3715  $ Position 13
114   c/z  -19.51  64.31  1.3715  $ Position 14
115   c/z  -13.11  65.91  1.3715  $ Position 15
116   c/z   -6.59  66.88  1.3715  $ Position 16
117   c/z    0.00  67.20  1.3715  $ Position 17
118   c/z    6.59  66.88  1.3715  $ Position 18
119   c/z   13.11  65.91  1.3715  $ Position 19
120   c/z   19.51  64.31  1.3715  $ Position 20
121   c/z   25.72  62.08  1.3715  $ Position 21
122   c/z   31.68  59.27  1.3715  $ Position 22
123   c/z   37.33  55.87  1.3715  $ Position 23
124   c/z   42.63  51.95  1.3715  $ Position 24
125   c/z   47.52  47.52  1.3715  $ Position 25
126   c/z   51.95  42.63  1.3715  $ Position 26
127   c/z   55.87  37.33  1.3715  $ Position 27
128   c/z   59.27  31.68  1.3715  $ Position 28
129   c/z   62.08  25.72  1.3715  $ Position 29
130   c/z   64.31  19.51  1.3715  $ Position 30
131   c/z   65.91  13.11  1.3715  $ Position 31
132   c/z   66.88   6.59  1.3715  $ Position 32
133   c/z   67.20   0.00  1.3715  $ Position 33
134   c/z   66.88  -6.59  1.3715  $ Position 34
135   c/z   65.91 -13.11  1.3715  $ Position 35
136   c/z   64.31 -19.51  1.3715  $ Position 36
137   c/z   62.08 -25.72  1.3715  $ Position 37
138   c/z   59.27 -31.68  1.3715  $ Position 38
139   c/z   55.87 -37.33  1.3715  $ Position 39
140   c/z   51.95 -42.63  1.3715  $ Position 40
141   c/z   47.52 -47.52  1.3715  $ Position 41
142   c/z   42.63 -51.95  1.3715  $ Position 42
143   c/z   37.33 -55.87  1.3715  $ Position 43
144   c/z   31.68 -59.27  1.3715  $ Position 44
145   c/z   25.72 -62.08  1.3715  $ Position 45
146   c/z   19.51 -64.31  1.3715  $ Position 46
147   c/z   13.11 -65.91  1.3715  $ Position 47
148   c/z    6.59 -66.88  1.3715  $ Position 48
149   c/z    0.00 -67.20  1.3715  $ Position 49
150   c/z   -6.59 -66.88  1.3715  $ Position 50
151   c/z  -13.11 -65.91  1.3715  $ Position 51
152   c/z  -19.51 -64.31  1.3715  $ Position 52
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153   c/z  -25.72 -62.08  1.3715  $ Position 53
154   c/z  -31.68 -59.27  1.3715  $ Position 54
155   c/z  -37.33 -55.87  1.3715  $ Position 55
156   c/z  -42.63 -51.95  1.3715  $ Position 56
157   c/z  -47.52 -47.52  1.3715  $ Position 57
158   c/z  -51.95 -42.63  1.3715  $ Position 58
159   c/z  -55.87 -37.33  1.3715  $ Position 59
160   c/z  -59.27 -31.68  1.3715  $ Position 60
161   c/z  -62.08 -25.72  1.3715  $ Position 61
162   c/z  -64.31 -19.51  1.3715  $ Position 62
163   c/z  -65.91 -13.11  1.3715  $ Position 63
164   c/z  -66.88  -6.59  1.3715  $ Position 64
c
165   cz    70.125  $ Ring Divider for Modeling Simplification
c
c --------- Ring 2 ---------
201   c/z  -72.96   3.58  1.3715  $ Position 1
202   c/z  -72.26  10.72  1.3715  $ Position 2
203   c/z  -70.86  17.75  1.3715  $ Position 3
204   c/z  -68.78  24.61  1.3715  $ Position 4
205   c/z  -66.04  31.23  1.3715  $ Position 5
206   c/z  -62.66  37.56  1.3715  $ Position 6
207   c/z  -58.67  43.52  1.3715  $ Position 7
208   c/z  -54.13  49.06  1.3715  $ Position 8
209   c/z  -49.06  54.13  1.3715  $ Position 9
210   c/z  -43.52  58.67  1.3715  $ Position 10
211   c/z  -37.56  62.66  1.3715  $ Position 11
212   c/z  -31.23  66.04  1.3715  $ Position 12
213   c/z  -24.61  68.78  1.3715  $ Position 13
214   c/z  -17.75  70.86  1.3715  $ Position 14
215   c/z  -10.72  72.26  1.3715  $ Position 15
216   c/z   -3.58  72.96  1.3715  $ Position 16
217   c/z    3.58  72.96  1.3715  $ Position 17
218   c/z   10.72  72.26  1.3715  $ Position 18
219   c/z   17.75  70.86  1.3715  $ Position 19
220   c/z   24.61  68.78  1.3715  $ Position 20
221   c/z   31.23  66.04  1.3715  $ Position 21
222   c/z   37.56  62.66  1.3715  $ Position 22
223   c/z   43.52  58.67  1.3715  $ Position 23
224   c/z   49.06  54.13  1.3715  $ Position 24
225   c/z   54.13  49.06  1.3715  $ Position 25
226   c/z   58.67  43.52  1.3715  $ Position 26
227   c/z   62.66  37.56  1.3715  $ Position 27
228   c/z   66.04  31.23  1.3715  $ Position 28
229   c/z   68.78  24.61  1.3715  $ Position 29
230   c/z   70.86  17.75  1.3715  $ Position 30
231   c/z   72.26  10.72  1.3715  $ Position 31
232   c/z   72.96   3.58  1.3715  $ Position 32
233   c/z   72.96  -3.58  1.3715  $ Position 33
234   c/z   72.26 -10.72  1.3715  $ Position 34
235   c/z   70.86 -17.75  1.3715  $ Position 35
236   c/z   68.78 -24.61  1.3715  $ Position 36
237   c/z   66.04 -31.23  1.3715  $ Position 37
238   c/z   62.66 -37.56  1.3715  $ Position 38
239   c/z   58.67 -43.52  1.3715  $ Position 39
240   c/z   54.13 -49.06  1.3715  $ Position 40
241   c/z   49.06 -54.13  1.3715  $ Position 41
242   c/z   43.52 -58.67  1.3715  $ Position 42
243   c/z   37.56 -62.66  1.3715  $ Position 43
244   c/z   31.23 -66.04  1.3715  $ Position 44
245   c/z   24.61 -68.78  1.3715  $ Position 45
246   c/z   17.75 -70.86  1.3715  $ Position 46
247   c/z   10.72 -72.26  1.3715  $ Position 47
248   c/z    3.58 -72.96  1.3715  $ Position 48
249   c/z   -3.58 -72.96  1.3715  $ Position 49
250   c/z  -10.72 -72.26  1.3715  $ Position 50
251   c/z  -17.75 -70.86  1.3715  $ Position 51
252   c/z  -24.61 -68.78  1.3715  $ Position 52
253   c/z  -31.23 -66.04  1.3715  $ Position 53
254   c/z  -37.56 -62.66  1.3715  $ Position 54
255   c/z  -43.52 -58.67  1.3715  $ Position 55
256   c/z  -49.06 -54.13  1.3715  $ Position 56
257   c/z  -54.13 -49.06  1.3715  $ Position 57
258   c/z  -58.67 -43.52  1.3715  $ Position 58
259   c/z  -62.66 -37.56  1.3715  $ Position 59
260   c/z  -66.04 -31.23  1.3715  $ Position 60
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261   c/z  -68.78 -24.61  1.3715  $ Position 61
262   c/z  -70.86 -17.75  1.3715  $ Position 62
263   c/z  -72.26 -10.72  1.3715  $ Position 63
264   c/z  -72.96  -3.58  1.3715  $ Position 64
c
265   cz    75.975  $ Ring Divider for Modeling Simplification
c
c --------- Ring 3 ---------
301   c/z  -78.52   7.73  1.3715  $ Position 1
302   c/z  -77.38  15.39  1.3715  $ Position 2
303   c/z  -75.50  22.90  1.3715  $ Position 3
304   c/z  -72.89  30.19  1.3715  $ Position 4
305   c/z  -69.58  37.19  1.3715  $ Position 5
306   c/z  -65.60  43.83  1.3715  $ Position 6
307   c/z  -60.99  50.05  1.3715  $ Position 7
308   c/z  -55.79  55.79  1.3715  $ Position 8
309   c/z  -50.05  60.99  1.3715  $ Position 9
310   c/z  -43.83  65.60  1.3715  $ Position 10
311   c/z  -37.19  69.58  1.3715  $ Position 11
312   c/z  -30.19  72.89  1.3715  $ Position 12
313   c/z  -22.90  75.50  1.3715  $ Position 13
314   c/z  -15.39  77.38  1.3715  $ Position 14
315   c/z   -7.73  78.52  1.3715  $ Position 15
316   c/z    0.00  78.90  1.3715  $ Position 16
317   c/z    7.73  78.52  1.3715  $ Position 17
318   c/z   15.39  77.38  1.3715  $ Position 18
319   c/z   22.90  75.50  1.3715  $ Position 19
320   c/z   30.19  72.89  1.3715  $ Position 20
321   c/z   37.19  69.58  1.3715  $ Position 21
322   c/z   43.83  65.60  1.3715  $ Position 22
323   c/z   50.05  60.99  1.3715  $ Position 23
324   c/z   55.79  55.79  1.3715  $ Position 24
325   c/z   60.99  50.05  1.3715  $ Position 25
326   c/z   65.60  43.83  1.3715  $ Position 26
327   c/z   69.58  37.19  1.3715  $ Position 27
328   c/z   72.89  30.19  1.3715  $ Position 28
329   c/z   75.50  22.90  1.3715  $ Position 29
330   c/z   77.38  15.39  1.3715  $ Position 30
331   c/z   78.52   7.73  1.3715  $ Position 31
332   c/z   78.90   0.00  1.3715  $ Position 32
333   c/z   78.52  -7.73  1.3715  $ Position 33
334   c/z   77.38 -15.39  1.3715  $ Position 34
335   c/z   75.50 -22.90  1.3715  $ Position 35
336   c/z   72.89 -30.19  1.3715  $ Position 36
337   c/z   69.58 -37.19  1.3715  $ Position 37
338   c/z   65.60 -43.83  1.3715  $ Position 38
339   c/z   60.99 -50.05  1.3715  $ Position 39
340   c/z   55.79 -55.79  1.3715  $ Position 40
341   c/z   50.05 -60.99  1.3715  $ Position 41
342   c/z   43.83 -65.60  1.3715  $ Position 42
343   c/z   37.19 -69.58  1.3715  $ Position 43
344   c/z   30.19 -72.89  1.3715  $ Position 44
345   c/z   22.90 -75.50  1.3715  $ Position 45
346   c/z   15.39 -77.38  1.3715  $ Position 46
347   c/z    7.73 -78.52  1.3715  $ Position 47
348   c/z    0.00 -78.90  1.3715  $ Position 48
349   c/z   -7.73 -78.52  1.3715  $ Position 49
350   c/z  -15.39 -77.38  1.3715  $ Position 50
351   c/z  -22.90 -75.50  1.3715  $ Position 51
352   c/z  -30.19 -72.89  1.3715  $ Position 52
353   c/z  -37.19 -69.58  1.3715  $ Position 53
354   c/z  -43.83 -65.60  1.3715  $ Position 54
355   c/z  -50.05 -60.99  1.3715  $ Position 55
356   c/z  -55.79 -55.79  1.3715  $ Position 56
357   c/z  -60.99 -50.05  1.3715  $ Position 57
358   c/z  -65.60 -43.83  1.3715  $ Position 58
359   c/z  -69.58 -37.19  1.3715  $ Position 59
360   c/z  -72.89 -30.19  1.3715  $ Position 60
361   c/z  -75.50 -22.90  1.3715  $ Position 61
362   c/z  -77.38 -15.39  1.3715  $ Position 62
363   c/z  -78.52  -7.73  1.3715  $ Position 63
364   c/z  -78.90   0.00  1.3715  $ Position 64
c
365   cz    81.825  $ Ring Divider for Modeling Simplification
c
c --------- Ring 4 ---------
```

```
401   c/z  -83.83  12.44  1.3715  $ Position 1
402   c/z  -82.21  20.59  1.3715  $ Position 2
403   c/z  -79.80  28.55  1.3715  $ Position 3
404   c/z  -76.61  36.24  1.3715  $ Position 4
405   c/z  -72.69  43.57  1.3715  $ Position 5
406   c/z  -68.07  50.49  1.3715  $ Position 6
407   c/z  -62.80  56.91  1.3715  $ Position 7
408   c/z  -56.91  62.80  1.3715  $ Position 8
409   c/z  -50.49  68.07  1.3715  $ Position 9
410   c/z  -43.57  72.69  1.3715  $ Position 10
411   c/z  -36.24  76.61  1.3715  $ Position 11
412   c/z  -28.55  79.80  1.3715  $ Position 12
413   c/z  -20.59  82.21  1.3715  $ Position 13
414   c/z  -12.44  83.83  1.3715  $ Position 14
415   c/z   -4.16  84.65  1.3715  $ Position 15
416   c/z    4.16  84.65  1.3715  $ Position 16
417   c/z   12.44  83.83  1.3715  $ Position 17
418   c/z   20.59  82.21  1.3715  $ Position 18
419   c/z   28.55  79.80  1.3715  $ Position 19
420   c/z   36.24  76.61  1.3715  $ Position 20
421   c/z   43.57  72.69  1.3715  $ Position 21
422   c/z   50.49  68.07  1.3715  $ Position 22
423   c/z   56.91  62.80  1.3715  $ Position 23
424   c/z   62.80  56.91  1.3715  $ Position 24
425   c/z   68.07  50.49  1.3715  $ Position 25
426   c/z   72.69  43.57  1.3715  $ Position 26
427   c/z   76.61  36.24  1.3715  $ Position 27
428   c/z   79.80  28.55  1.3715  $ Position 28
429   c/z   82.21  20.59  1.3715  $ Position 29
430   c/z   83.83  12.44  1.3715  $ Position 30
431   c/z   84.65   4.16  1.3715  $ Position 31
432   c/z   84.65  -4.16  1.3715  $ Position 32
433   c/z   83.83 -12.44  1.3715  $ Position 33
434   c/z   82.21 -20.59  1.3715  $ Position 34
435   c/z   79.80 -28.55  1.3715  $ Position 35
436   c/z   76.61 -36.24  1.3715  $ Position 36
437   c/z   72.69 -43.57  1.3715  $ Position 37
438   c/z   68.07 -50.49  1.3715  $ Position 38
439   c/z   62.80 -56.91  1.3715  $ Position 39
440   c/z   56.91 -62.80  1.3715  $ Position 40
441   c/z   50.49 -68.07  1.3715  $ Position 41
442   c/z   43.57 -72.69  1.3715  $ Position 42
443   c/z   36.24 -76.61  1.3715  $ Position 43
444   c/z   28.55 -79.80  1.3715  $ Position 44
445   c/z   20.59 -82.21  1.3715  $ Position 45
446   c/z   12.44 -83.83  1.3715  $ Position 46
447   c/z    4.16 -84.65  1.3715  $ Position 47
448   c/z   -4.16 -84.65  1.3715  $ Position 48
449   c/z  -12.44 -83.83  1.3715  $ Position 49
450   c/z  -20.59 -82.21  1.3715  $ Position 50
451   c/z  -28.55 -79.80  1.3715  $ Position 51
452   c/z  -36.24 -76.61  1.3715  $ Position 52
453   c/z  -43.57 -72.69  1.3715  $ Position 53
454   c/z  -50.49 -68.07  1.3715  $ Position 54
455   c/z  -56.91 -62.80  1.3715  $ Position 55
456   c/z  -62.80 -56.91  1.3715  $ Position 56
457   c/z  -68.07 -50.49  1.3715  $ Position 57
458   c/z  -72.69 -43.57  1.3715  $ Position 58
459   c/z  -76.61 -36.24  1.3715  $ Position 59
460   c/z  -79.80 -28.55  1.3715  $ Position 60
461   c/z  -82.21 -20.59  1.3715  $ Position 61
462   c/z  -83.83 -12.44  1.3715  $ Position 62
463   c/z  -84.65  -4.16  1.3715  $ Position 63
464   c/z  -84.65   4.16  1.3715  $ Position 64
c
465   cz    87.675  $ Ring Divider for Modeling Simplification
c
c --------- Ring 5 ---------
501   c/z  -88.86  17.68  1.3715  $ Position 1
502   c/z  -86.70  26.30  1.3715  $ Position 2
503   c/z  -83.70  34.67  1.3715  $ Position 3
504   c/z  -79.90  42.71  1.3715  $ Position 4
505   c/z  -75.33  50.33  1.3715  $ Position 5
506   c/z  -70.03  57.48  1.3715  $ Position 6
507   c/z  -64.06  64.06  1.3715  $ Position 7
508   c/z  -57.48  70.03  1.3715  $ Position 8
```

```
509   c/z  -50.33  75.33  1.3715  $ Position 9
510   c/z  -42.71  79.90  1.3715  $ Position 10
511   c/z  -34.67  83.70  1.3715  $ Position 11
512   c/z  -26.30  86.70  1.3715  $ Position 12
513   c/z  -17.68  88.86  1.3715  $ Position 13
514   c/z   -8.88  90.16  1.3715  $ Position 14
515   c/z    0.00  90.60  1.3715  $ Position 15
516   c/z    8.88  90.16  1.3715  $ Position 16
517   c/z   17.68  88.86  1.3715  $ Position 17
518   c/z   26.30  86.70  1.3715  $ Position 18
519   c/z   34.67  83.70  1.3715  $ Position 19
520   c/z   42.71  79.90  1.3715  $ Position 20
521   c/z   50.33  75.33  1.3715  $ Position 21
522   c/z   57.48  70.03  1.3715  $ Position 22
523   c/z   64.06  64.06  1.3715  $ Position 23
524   c/z   70.03  57.48  1.3715  $ Position 24
525   c/z   75.33  50.33  1.3715  $ Position 25
526   c/z   79.90  42.71  1.3715  $ Position 26
527   c/z   83.70  34.67  1.3715  $ Position 27
528   c/z   86.70  26.30  1.3715  $ Position 28
529   c/z   88.86  17.68  1.3715  $ Position 29
530   c/z   90.16   8.88  1.3715  $ Position 30
531   c/z   90.60   0.00  1.3715  $ Position 31
532   c/z   90.16  -8.88  1.3715  $ Position 32
533   c/z   88.86 -17.68  1.3715  $ Position 33
534   c/z   86.70 -26.30  1.3715  $ Position 34
535   c/z   83.70 -34.67  1.3715  $ Position 35
536   c/z   79.90 -42.71  1.3715  $ Position 36
537   c/z   75.33 -50.33  1.3715  $ Position 37
538   c/z   70.03 -57.48  1.3715  $ Position 38
539   c/z   64.06 -64.06  1.3715  $ Position 39
540   c/z   57.48 -70.03  1.3715  $ Position 40
541   c/z   50.33 -75.33  1.3715  $ Position 41
542   c/z   42.71 -79.90  1.3715  $ Position 42
543   c/z   34.67 -83.70  1.3715  $ Position 43
544   c/z   26.30 -86.70  1.3715  $ Position 44
545   c/z   17.68 -88.86  1.3715  $ Position 45
546   c/z    8.88 -90.16  1.3715  $ Position 46
547   c/z    0.00 -90.60  1.3715  $ Position 47
548   c/z   -8.88 -90.16  1.3715  $ Position 48
549   c/z  -17.68 -88.86  1.3715  $ Position 49
550   c/z  -26.30 -86.70  1.3715  $ Position 50
551   c/z  -34.67 -83.70  1.3715  $ Position 51
552   c/z  -42.71 -79.90  1.3715  $ Position 52
553   c/z  -50.33 -75.33  1.3715  $ Position 53
554   c/z  -57.48 -70.03  1.3715  $ Position 54
555   c/z  -64.06 -64.06  1.3715  $ Position 55
556   c/z  -70.03 -57.48  1.3715  $ Position 56
557   c/z  -75.33 -50.33  1.3715  $ Position 57
558   c/z  -79.90 -42.71  1.3715  $ Position 58
559   c/z  -83.70 -34.67  1.3715  $ Position 59
560   c/z  -86.70 -26.30  1.3715  $ Position 60
561   c/z  -88.86 -17.68  1.3715  $ Position 61
562   c/z  -90.16  -8.88  1.3715  $ Position 62
563   c/z  -90.60   0.00  1.3715  $ Position 63
564   c/z  -90.16   8.88  1.3715  $ Position 64
c
c ------ Graphite Plugs ------
c --------- Ring 1 ---------
601   c/z  -67.20   0.00  1.325  $ Position 1
602   c/z  -66.88   6.59  1.325  $ Position 2
603   c/z  -65.91  13.11  1.325  $ Position 3
604   c/z  -64.31  19.51  1.325  $ Position 4
605   c/z  -62.08  25.72  1.325  $ Position 5
606   c/z  -59.27  31.68  1.325  $ Position 6
607   c/z  -55.87  37.33  1.325  $ Position 7
608   c/z  -51.95  42.63  1.325  $ Position 8
609   c/z  -47.52  47.52  1.325  $ Position 9
610   c/z  -42.63  51.95  1.325  $ Position 10
611   c/z  -37.33  55.87  1.325  $ Position 11
612   c/z  -31.68  59.27  1.325  $ Position 12
613   c/z  -25.72  62.08  1.325  $ Position 13
614   c/z  -19.51  64.31  1.325  $ Position 14
615   c/z  -13.11  65.91  1.325  $ Position 15
616   c/z   -6.59  66.88  1.325  $ Position 16
617   c/z    0.00  67.20  1.325  $ Position 17
```

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618   c/z    6.59  66.88  1.325  $ Position 18
619   c/z   13.11  65.91  1.325  $ Position 19
620   c/z   19.51  64.31  1.325  $ Position 20
621   c/z   25.72  62.08  1.325  $ Position 21
622   c/z   31.68  59.27  1.325  $ Position 22
623   c/z   37.33  55.87  1.325  $ Position 23
624   c/z   42.63  51.95  1.325  $ Position 24
625   c/z   47.52  47.52  1.325  $ Position 25
626   c/z   51.95  42.63  1.325  $ Position 26
627   c/z   55.87  37.33  1.325  $ Position 27
628   c/z   59.27  31.68  1.325  $ Position 28
629   c/z   62.08  25.72  1.325  $ Position 29
630   c/z   64.31  19.51  1.325  $ Position 30
631   c/z   65.91  13.11  1.325  $ Position 31
632   c/z   66.88   6.59  1.325  $ Position 32
633   c/z   67.20   0.00  1.325  $ Position 33
634   c/z   66.88  -6.59  1.325  $ Position 34
635   c/z   65.91 -13.11  1.325  $ Position 35
636   c/z   64.31 -19.51  1.325  $ Position 36
637   c/z   62.08 -25.72  1.325  $ Position 37
638   c/z   59.27 -31.68  1.325  $ Position 38
639   c/z   55.87 -37.33  1.325  $ Position 39
640   c/z   51.95 -42.63  1.325  $ Position 40
641   c/z   47.52 -47.52  1.325  $ Position 41
642   c/z   42.63 -51.95  1.325  $ Position 42
643   c/z   37.33 -55.87  1.325  $ Position 43
644   c/z   31.68 -59.27  1.325  $ Position 44
645   c/z   25.72 -62.08  1.325  $ Position 45
646   c/z   19.51 -64.31  1.325  $ Position 46
647   c/z   13.11 -65.91  1.325  $ Position 47
648   c/z    6.59 -66.88  1.325  $ Position 48
649   c/z    0.00 -67.20  1.325  $ Position 49
650   c/z   -6.59 -66.88  1.325  $ Position 50
651   c/z  -13.11 -65.91  1.325  $ Position 51
652   c/z  -19.51 -64.31  1.325  $ Position 52
653   c/z  -25.72 -62.08  1.325  $ Position 53
654   c/z  -31.68 -59.27  1.325  $ Position 54
655   c/z  -37.33 -55.87  1.325  $ Position 55
656   c/z  -42.63 -51.95  1.325  $ Position 56
657   c/z  -47.52 -47.52  1.325  $ Position 57
658   c/z  -51.95 -42.63  1.325  $ Position 58
659   c/z  -55.87 -37.33  1.325  $ Position 59
660   c/z  -59.27 -31.68  1.325  $ Position 60
661   c/z  -62.08 -25.72  1.325  $ Position 61
662   c/z  -64.31 -19.51  1.325  $ Position 62
663   c/z  -65.91 -13.11  1.325  $ Position 63
664   c/z  -66.88  -6.59  1.325  $ Position 64
c
c --------- Ring 2 ---------
701   c/z  -72.96   3.58  1.325  $ Position 1
702   c/z  -72.26  10.72  1.325  $ Position 2
703   c/z  -70.86  17.75  1.325  $ Position 3
704   c/z  -68.78  24.61  1.325  $ Position 4
705   c/z  -66.04  31.23  1.325  $ Position 5
706   c/z  -62.66  37.56  1.325  $ Position 6
707   c/z  -58.67  43.52  1.325  $ Position 7
708   c/z  -54.13  49.06  1.325  $ Position 8
709   c/z  -49.06  54.13  1.325  $ Position 9
710   c/z  -43.52  58.67  1.325  $ Position 10
711   c/z  -37.56  62.66  1.325  $ Position 11
712   c/z  -31.23  66.04  1.325  $ Position 12
713   c/z  -24.61  68.78  1.325  $ Position 13
714   c/z  -17.75  70.86  1.325  $ Position 14
715   c/z  -10.72  72.26  1.325  $ Position 15
716   c/z   -3.58  72.96  1.325  $ Position 16
717   c/z    3.58  72.96  1.325  $ Position 17
718   c/z   10.72  72.26  1.325  $ Position 18
719   c/z   17.75  70.86  1.325  $ Position 19
720   c/z   24.61  68.78  1.325  $ Position 20
721   c/z   31.23  66.04  1.325  $ Position 21
722   c/z   37.56  62.66  1.325  $ Position 22
723   c/z   43.52  58.67  1.325  $ Position 23
724   c/z   49.06  54.13  1.325  $ Position 24
725   c/z   54.13  49.06  1.325  $ Position 25
726   c/z   58.67  43.52  1.325  $ Position 26
727   c/z   62.66  37.56  1.325  $ Position 27
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728   c/z   66.04  31.23  1.325  $ Position 28
729   c/z   68.78  24.61  1.325  $ Position 29
730   c/z   70.86  17.75  1.325  $ Position 30
731   c/z   72.26  10.72  1.325  $ Position 31
732   c/z   72.96   3.58  1.325  $ Position 32
733   c/z   72.96  -3.58  1.325  $ Position 33
734   c/z   72.26 -10.72  1.325  $ Position 34
735   c/z   70.86 -17.75  1.325  $ Position 35
736   c/z   68.78 -24.61  1.325  $ Position 36
737   c/z   66.04 -31.23  1.325  $ Position 37
738   c/z   62.66 -37.56  1.325  $ Position 38
739   c/z   58.67 -43.52  1.325  $ Position 39
740   c/z   54.13 -49.06  1.325  $ Position 40
741   c/z   49.06 -54.13  1.325  $ Position 41
742   c/z   43.52 -58.67  1.325  $ Position 42
743   c/z   37.56 -62.66  1.325  $ Position 43
744   c/z   31.23 -66.04  1.325  $ Position 44
745   c/z   24.61 -68.78  1.325  $ Position 45
746   c/z   17.75 -70.86  1.325  $ Position 46
747   c/z   10.72 -72.26  1.325  $ Position 47
748   c/z    3.58 -72.96  1.325  $ Position 48
749   c/z   -3.58 -72.96  1.325  $ Position 49
750   c/z  -10.72 -72.26  1.325  $ Position 50
751   c/z  -17.75 -70.86  1.325  $ Position 51
752   c/z  -24.61 -68.78  1.325  $ Position 52
753   c/z  -31.23 -66.04  1.325  $ Position 53
754   c/z  -37.56 -62.66  1.325  $ Position 54
755   c/z  -43.52 -58.67  1.325  $ Position 55
756   c/z  -49.06 -54.13  1.325  $ Position 56
757   c/z  -54.13 -49.06  1.325  $ Position 57
758   c/z  -58.67 -43.52  1.325  $ Position 58
759   c/z  -62.66 -37.56  1.325  $ Position 59
760   c/z  -66.04 -31.23  1.325  $ Position 60
761   c/z  -68.78 -24.61  1.325  $ Position 61
762   c/z  -70.86 -17.75  1.325  $ Position 62
763   c/z  -72.26 -10.72  1.325  $ Position 63
764   c/z  -72.96  -3.58  1.325  $ Position 64
c
c --------- Ring 3 ---------
801   c/z  -78.52   7.73  1.325  $ Position 1
802   c/z  -77.38  15.39  1.325  $ Position 2
803   c/z  -75.50  22.90  1.325  $ Position 3
804   c/z  -72.89  30.19  1.325  $ Position 4
805   c/z  -69.58  37.19  1.325  $ Position 5
806   c/z  -65.60  43.83  1.325  $ Position 6
807   c/z  -60.99  50.05  1.325  $ Position 7
808   c/z  -55.79  55.79  1.325  $ Position 8
809   c/z  -50.05  60.99  1.325  $ Position 9
810   c/z  -43.83  65.60  1.325  $ Position 10
811   c/z  -37.19  69.58  1.325  $ Position 11
812   c/z  -30.19  72.89  1.325  $ Position 12
813   c/z  -22.90  75.50  1.325  $ Position 13
814   c/z  -15.39  77.38  1.325  $ Position 14
815   c/z   -7.73  78.52  1.325  $ Position 15
816   c/z    0.00  78.90  1.325  $ Position 16
817   c/z    7.73  78.52  1.325  $ Position 17
818   c/z   15.39  77.38  1.325  $ Position 18
819   c/z   22.90  75.50  1.325  $ Position 19
820   c/z   30.19  72.89  1.325  $ Position 20
821   c/z   37.19  69.58  1.325  $ Position 21
822   c/z   43.83  65.60  1.325  $ Position 22
823   c/z   50.05  60.99  1.325  $ Position 23
824   c/z   55.79  55.79  1.325  $ Position 24
825   c/z   60.99  50.05  1.325  $ Position 25
826   c/z   65.60  43.83  1.325  $ Position 26
827   c/z   69.58  37.19  1.325  $ Position 27
828   c/z   72.89  30.19  1.325  $ Position 28
829   c/z   75.50  22.90  1.325  $ Position 29
830   c/z   77.38  15.39  1.325  $ Position 30
831   c/z   78.52   7.73  1.325  $ Position 31
832   c/z   78.90   0.00  1.325  $ Position 32
833   c/z   78.52  -7.73  1.325  $ Position 33
834   c/z   77.38 -15.39  1.325  $ Position 34
835   c/z   75.50 -22.90  1.325  $ Position 35
836   c/z   72.89 -30.19  1.325  $ Position 36
837   c/z   69.58 -37.19  1.325  $ Position 37
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838   c/z   65.60 -43.83  1.325  $ Position 38
839   c/z   60.99 -50.05  1.325  $ Position 39
840   c/z   55.79 -55.79  1.325  $ Position 40
841   c/z   50.05 -60.99  1.325  $ Position 41
842   c/z   43.83 -65.60  1.325  $ Position 42
843   c/z   37.19 -69.58  1.325  $ Position 43
844   c/z   30.19 -72.89  1.325  $ Position 44
845   c/z   22.90 -75.50  1.325  $ Position 45
846   c/z   15.39 -77.38  1.325  $ Position 46
847   c/z    7.73 -78.52  1.325  $ Position 47
848   c/z    0.00 -78.90  1.325  $ Position 48
849   c/z   -7.73 -78.52  1.325  $ Position 49
850   c/z  -15.39 -77.38  1.325  $ Position 50
851   c/z  -22.90 -75.50  1.325  $ Position 51
852   c/z  -30.19 -72.89  1.325  $ Position 52
853   c/z  -37.19 -69.58  1.325  $ Position 53
854   c/z  -43.83 -65.60  1.325  $ Position 54
855   c/z  -50.05 -60.99  1.325  $ Position 55
856   c/z  -55.79 -55.79  1.325  $ Position 56
857   c/z  -60.99 -50.05  1.325  $ Position 57
858   c/z  -65.60 -43.83  1.325  $ Position 58
859   c/z  -69.58 -37.19  1.325  $ Position 59
860   c/z  -72.89 -30.19  1.325  $ Position 60
861   c/z  -75.50 -22.90  1.325  $ Position 61
862   c/z  -77.38 -15.39  1.325  $ Position 62
863   c/z  -78.52  -7.73  1.325  $ Position 63
864   c/z  -78.90   0.00  1.325  $ Position 64
c
c --------- Ring 4 ---------
901   c/z  -83.83  12.44  1.325  $ Position 1
902   c/z  -82.21  20.59  1.325  $ Position 2
903   c/z  -79.80  28.55  1.325  $ Position 3
904   c/z  -76.61  36.24  1.325  $ Position 4
905   c/z  -72.69  43.57  1.325  $ Position 5
906   c/z  -68.07  50.49  1.325  $ Position 6
907   c/z  -62.80  56.91  1.325  $ Position 7
908   c/z  -56.91  62.80  1.325  $ Position 8
909   c/z  -50.49  68.07  1.325  $ Position 9
910   c/z  -43.57  72.69  1.325  $ Position 10
911   c/z  -36.24  76.61  1.325  $ Position 11
912   c/z  -28.55  79.80  1.325  $ Position 12
913   c/z  -20.59  82.21  1.325  $ Position 13
914   c/z  -12.44  83.83  1.325  $ Position 14
915   c/z   -4.16  84.65  1.325  $ Position 15
916   c/z    4.16  84.65  1.325  $ Position 16
917   c/z   12.44  83.83  1.325  $ Position 17
918   c/z   20.59  82.21  1.325  $ Position 18
919   c/z   28.55  79.80  1.325  $ Position 19
920   c/z   36.24  76.61  1.325  $ Position 20
921   c/z   43.57  72.69  1.325  $ Position 21
922   c/z   50.49  68.07  1.325  $ Position 22
923   c/z   56.91  62.80  1.325  $ Position 23
924   c/z   62.80  56.91  1.325  $ Position 24
925   c/z   68.07  50.49  1.325  $ Position 25
926   c/z   72.69  43.57  1.325  $ Position 26
927   c/z   76.61  36.24  1.325  $ Position 27
928   c/z   79.80  28.55  1.325  $ Position 28
929   c/z   82.21  20.59  1.325  $ Position 29
930   c/z   83.83  12.44  1.325  $ Position 30
931   c/z   84.65   4.16  1.325  $ Position 31
932   c/z   84.65  -4.16  1.325  $ Position 32
933   c/z   83.83 -12.44  1.325  $ Position 33
934   c/z   82.21 -20.59  1.325  $ Position 34
935   c/z   79.80 -28.55  1.325  $ Position 35
936   c/z   76.61 -36.24  1.325  $ Position 36
937   c/z   72.69 -43.57  1.325  $ Position 37
938   c/z   68.07 -50.49  1.325  $ Position 38
939   c/z   62.80 -56.91  1.325  $ Position 39
940   c/z   56.91 -62.80  1.325  $ Position 40
941   c/z   50.49 -68.07  1.325  $ Position 41
942   c/z   43.57 -72.69  1.325  $ Position 42
943   c/z   36.24 -76.61  1.325  $ Position 43
944   c/z   28.55 -79.80  1.325  $ Position 44
945   c/z   20.59 -82.21  1.325  $ Position 45
946   c/z   12.44 -83.83  1.325  $ Position 46
947   c/z    4.16 -84.65  1.325  $ Position 47
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948   c/z   -4.16 -84.65  1.325  $ Position 48
949   c/z  -12.44 -83.83  1.325  $ Position 49
950   c/z  -20.59 -82.21  1.325  $ Position 50
951   c/z  -28.55 -79.80  1.325  $ Position 51
952   c/z  -36.24 -76.61  1.325  $ Position 52
953   c/z  -43.57 -72.69  1.325  $ Position 53
954   c/z  -50.49 -68.07  1.325  $ Position 54
955   c/z  -56.91 -62.80  1.325  $ Position 55
956   c/z  -62.80 -56.91  1.325  $ Position 56
957   c/z  -68.07 -50.49  1.325  $ Position 57
958   c/z  -72.69 -43.57  1.325  $ Position 58
959   c/z  -76.61 -36.24  1.325  $ Position 59
960   c/z  -79.80 -28.55  1.325  $ Position 60
961   c/z  -82.21 -20.59  1.325  $ Position 61
962   c/z  -83.83 -12.44  1.325  $ Position 62
963   c/z  -84.65  -4.16  1.325  $ Position 63
964   c/z  -84.65   4.16  1.325  $ Position 64
c
c --------- Ring 5 ---------
1001  c/z  -88.86  17.68  1.325  $ Position 1
1002  c/z  -86.70  26.30  1.325  $ Position 2
1003  c/z  -83.70  34.67  1.325  $ Position 3
1004  c/z  -79.90  42.71  1.325  $ Position 4
1005  c/z  -75.33  50.33  1.325  $ Position 5
1006  c/z  -70.03  57.48  1.325  $ Position 6
1007  c/z  -64.06  64.06  1.325  $ Position 7
1008  c/z  -57.48  70.03  1.325  $ Position 8
1009  c/z  -50.33  75.33  1.325  $ Position 9
1010  c/z  -42.71  79.90  1.325  $ Position 10
1011  c/z  -34.67  83.70  1.325  $ Position 11
1012  c/z  -26.30  86.70  1.325  $ Position 12
1013  c/z  -17.68  88.86  1.325  $ Position 13
1014  c/z   -8.88  90.16  1.325  $ Position 14
1015  c/z    0.00  90.60  1.325  $ Position 15
1016  c/z    8.88  90.16  1.325  $ Position 16
1017  c/z   17.68  88.86  1.325  $ Position 17
1018  c/z   26.30  86.70  1.325  $ Position 18
1019  c/z   34.67  83.70  1.325  $ Position 19
1020  c/z   42.71  79.90  1.325  $ Position 20
1021  c/z   50.33  75.33  1.325  $ Position 21
1022  c/z   57.48  70.03  1.325  $ Position 22
1023  c/z   64.06  64.06  1.325  $ Position 23
1024  c/z   70.03  57.48  1.325  $ Position 24
1025  c/z   75.33  50.33  1.325  $ Position 25
1026  c/z   79.90  42.71  1.325  $ Position 26
1027  c/z   83.70  34.67  1.325  $ Position 27
1028  c/z   86.70  26.30  1.325  $ Position 28
1029  c/z   88.86  17.68  1.325  $ Position 29
1030  c/z   90.16   8.88  1.325  $ Position 30
1031  c/z   90.60   0.00  1.325  $ Position 31
1032  c/z   90.16  -8.88  1.325  $ Position 32
1033  c/z   88.86 -17.68  1.325  $ Position 33
1034  c/z   86.70 -26.30  1.325  $ Position 34
1035  c/z   83.70 -34.67  1.325  $ Position 35
1036  c/z   79.90 -42.71  1.325  $ Position 36
1037  c/z   75.33 -50.33  1.325  $ Position 37
1038  c/z   70.03 -57.48  1.325  $ Position 38
1039  c/z   64.06 -64.06  1.325  $ Position 39
1040  c/z   57.48 -70.03  1.325  $ Position 40
1041  c/z   50.33 -75.33  1.325  $ Position 41
1042  c/z   42.71 -79.90  1.325  $ Position 42
1043  c/z   34.67 -83.70  1.325  $ Position 43
1044  c/z   26.30 -86.70  1.325  $ Position 44
1045  c/z   17.68 -88.86  1.325  $ Position 45
1046  c/z    8.88 -90.16  1.325  $ Position 46
1047  c/z    0.00 -90.60  1.325  $ Position 47
1048  c/z   -8.88 -90.16  1.325  $ Position 48
1049  c/z  -17.68 -88.86  1.325  $ Position 49
1050  c/z  -26.30 -86.70  1.325  $ Position 50
1051  c/z  -34.67 -83.70  1.325  $ Position 51
1052  c/z  -42.71 -79.90  1.325  $ Position 52
1053  c/z  -50.33 -75.33  1.325  $ Position 53
1054  c/z  -57.48 -70.03  1.325  $ Position 54
1055  c/z  -64.06 -64.06  1.325  $ Position 55
1056  c/z  -70.03 -57.48  1.325  $ Position 56
1057  c/z  -75.33 -50.33  1.325  $ Position 57
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1058  c/z  -79.90 -42.71  1.325  $ Position 58
1059  c/z  -83.70 -34.67  1.325  $ Position 59
1060  c/z  -86.70 -26.30  1.325  $ Position 60
1061  c/z  -88.86 -17.68  1.325  $ Position 61
1062  c/z  -90.16  -8.88  1.325  $ Position 62
1063  c/z  -90.60   0.00  1.325  $ Position 63
1064  c/z  -90.16   8.88  1.325  $ Position 64
c
c ------ Safety/Shutdown Rod Holes ------
1101  c/z  -38.45  56.57  2.25  $ Rod 1
1102  c/z   32.74 -60.05  2.25  $ Rod 2
1103  c/z   57.17  37.55  2.25  $ Rod 3
1104  c/z  -53.23 -42.95  2.25  $ Rod 4
1105  c/z   67.19 -12.82  2.25  $ Rod 5
1106  c/z  -66.98  13.87  2.25  $ Rod 6
1107  c/z   19.31  65.62  2.25  $ Rod 7
1108  c/z  -13.87 -66.98  2.25  $ Rod 8
c
c ------ ZEBRA Control Rod Holes ------
1109  c/z   21.84  86.93  2.25  $ Rod 1
1110  c/z   86.93 -21.84  2.25  $ Rod 2
1111  c/z  -21.84 -86.93  2.25  $ Rod 3
1112  c/z  -86.93  21.84  2.25  $ Rod 4
c
c ------ ZEBRA Control Rod Hole Fillers ------
11109  c/z   21.84  86.93  2.2  $ Rod Position 1
11110  c/z   86.93 -21.84  2.2  $ Rod Position 2
11111  c/z  -21.84 -86.93  2.2  $ Rod Position 3
11112  c/z  -86.93  21.84  2.2  $ Rod Position 4
c
c ------ Withdrawable Control Rod Holes ------
c    *Same as Ring 5 Position 19 $ Rod 1
c    *Same as Ring 5 Position 35 $ Rod 2
c    *Same as Ring 5 Position 51 $ Rod 3
c    *Same as Ring 5 Position 3  $ Rod 4
c
c ------ Autorod Hole ------
1113  c/z   17.36 -87.29  2.75
c
c --- Upper Axial Reflector ----------------------------------------------------
c ------ Central Cylinder ------
1201  pz   267.3     $ Bottom of Graphite
1202  pz   345.3     $ Top of Graphite
1203  cz     1.3715  $ Central Coolant Channel
1204  cz    19.7     $ Outer Radius
c
c ------ Graphite Annulus ------
1211  cz    20.93    $ Inner Radius
1212  cz    61.7     $ Outer Radius
c
c ------ Air Gaps ------
1221  cz    19.8     $ Outside of Central Cylinder
1222  cz    20.5     $ Inside of Annulus
1223  cz    61.8     $ Outside of Annulus
c
c ------ Coolant Channels ------
c --------- Ring 1 ---------
1301  c/z  -29.86   2.94  1.3715  $ Position 1
1302  c/z  -28.71   8.71  1.3715  $ Position 2
1303  c/z  -26.46  14.14  1.3715  $ Position 3
1304  c/z  -23.19  19.03  1.3715  $ Position 4
1305  c/z  -19.03  23.19  1.3715  $ Position 5
1306  c/z  -14.14  26.46  1.3715  $ Position 6
1307  c/z   -8.71  28.71  1.3715  $ Position 7
1308  c/z   -2.94  29.86  1.3715  $ Position 8
1309  c/z    2.94  29.86  1.3715  $ Position 9
1310  c/z    8.71  28.71  1.3715  $ Position 10
1311  c/z   14.14  26.46  1.3715  $ Position 11
1312  c/z   19.03  23.19  1.3715  $ Position 12
1313  c/z   23.19  19.03  1.3715  $ Position 13
1314  c/z   26.46  14.14  1.3715  $ Position 14
1315  c/z   28.71   8.71  1.3715  $ Position 15
1316  c/z   29.86   2.94  1.3715  $ Position 16
1317  c/z   29.86  -2.94  1.3715  $ Position 17
1318  c/z   28.71  -8.71  1.3715  $ Position 18
1319  c/z   26.46 -14.14  1.3715  $ Position 19
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1320  c/z   23.19 -19.03  1.3715  $ Position 20
1321  c/z   19.03 -23.19  1.3715  $ Position 21
1322  c/z   14.14 -26.46  1.3715  $ Position 22
1323  c/z    8.71 -28.71  1.3715  $ Position 23
1324  c/z    2.94 -29.86  1.3715  $ Position 24
1325  c/z   -2.94 -29.86  1.3715  $ Position 25
1326  c/z   -8.71 -28.71  1.3715  $ Position 26
1327  c/z  -14.14 -26.46  1.3715  $ Position 27
1328  c/z  -19.03 -23.19  1.3715  $ Position 28
1329  c/z  -23.19 -19.03  1.3715  $ Position 29
1330  c/z  -26.46 -14.14  1.3715  $ Position 30
1331  c/z  -28.71  -8.71  1.3715  $ Position 31
1332  c/z  -29.86  -2.94  1.3715  $ Position 32
c
1333  cz    32.75  $ Ring Divider for Modeling Simplification
c
c --------- Ring 2 ---------
1401  c/z  -34.82   6.93  1.3715  $ Position 1
1402  c/z  -32.80  13.59  1.3715  $ Position 2
1403  c/z  -29.52  19.72  1.3715  $ Position 3
1404  c/z  -25.10  25.10  1.3715  $ Position 4
1405  c/z  -19.72  29.52  1.3715  $ Position 5
1406  c/z  -13.59  32.80  1.3715  $ Position 6
1407  c/z   -6.93  34.82  1.3715  $ Position 7
1408  c/z    0.00  35.50  1.3715  $ Position 8
1409  c/z    6.93  34.82  1.3715  $ Position 9
1410  c/z   13.59  32.80  1.3715  $ Position 10
1411  c/z   19.72  29.52  1.3715  $ Position 11
1412  c/z   25.10  25.10  1.3715  $ Position 12
1413  c/z   29.52  19.72  1.3715  $ Position 13
1414  c/z   32.80  13.59  1.3715  $ Position 14
1415  c/z   34.82   6.93  1.3715  $ Position 15
1416  c/z   35.50   0.00  1.3715  $ Position 16
1417  c/z   34.82  -6.93  1.3715  $ Position 17
1418  c/z   32.80 -13.59  1.3715  $ Position 18
1419  c/z   29.52 -19.72  1.3715  $ Position 19
1420  c/z   25.10 -25.10  1.3715  $ Position 20
1421  c/z   19.72 -29.52  1.3715  $ Position 21
1422  c/z   13.59 -32.80  1.3715  $ Position 22
1423  c/z    6.93 -34.82  1.3715  $ Position 23
1424  c/z    0.00 -35.50  1.3715  $ Position 24
1425  c/z   -6.93 -34.82  1.3715  $ Position 25
1426  c/z  -13.59 -32.80  1.3715  $ Position 26
1427  c/z  -19.72 -29.52  1.3715  $ Position 27
1428  c/z  -25.10 -25.10  1.3715  $ Position 28
1429  c/z  -29.52 -19.72  1.3715  $ Position 29
1430  c/z  -32.80 -13.59  1.3715  $ Position 30
1431  c/z  -34.82  -6.93  1.3715  $ Position 31
1432  c/z  -35.50   0.00  1.3715  $ Position 32
c
1433  cz    38.25  $ Ring Divider for Modeling Simplification
c
c --------- Ring 3 ---------
1501  c/z  -39.23  11.90  1.3715  $ Position 1
1502  c/z  -36.16  19.33  1.3715  $ Position 2
1503  c/z  -31.69  26.01  1.3715  $ Position 3
1504  c/z  -26.01  31.69  1.3715  $ Position 4
1505  c/z  -19.33  36.16  1.3715  $ Position 5
1506  c/z  -11.90  39.23  1.3715  $ Position 6
1507  c/z   -4.02  40.80  1.3715  $ Position 7
1508  c/z    4.02  40.80  1.3715  $ Position 8
1509  c/z   11.90  39.23  1.3715  $ Position 9
1510  c/z   19.33  36.16  1.3715  $ Position 10
1511  c/z   26.01  31.69  1.3715  $ Position 11
1512  c/z   31.69  26.01  1.3715  $ Position 12
1513  c/z   36.16  19.33  1.3715  $ Position 13
1514  c/z   39.23  11.90  1.3715  $ Position 14
1515  c/z   40.80   4.02  1.3715  $ Position 15
1516  c/z   40.80  -4.02  1.3715  $ Position 16
1517  c/z   39.23 -11.90  1.3715  $ Position 17
1518  c/z   36.16 -19.33  1.3715  $ Position 18
1519  c/z   31.69 -26.01  1.3715  $ Position 19
1520  c/z   26.01 -31.69  1.3715  $ Position 20
1521  c/z   19.33 -36.16  1.3715  $ Position 21
1522  c/z   11.90 -39.23  1.3715  $ Position 22
1523  c/z    4.02 -40.80  1.3715  $ Position 23
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1524  c/z   -4.02 -40.80  1.3715  $ Position 24
1525  c/z  -11.90 -39.23  1.3715  $ Position 25
1526  c/z  -19.33 -36.16  1.3715  $ Position 26
1527  c/z  -26.01 -31.69  1.3715  $ Position 27
1528  c/z  -31.69 -26.01  1.3715  $ Position 28
1529  c/z  -36.16 -19.33  1.3715  $ Position 29
1530  c/z  -39.23 -11.90  1.3715  $ Position 30
1531  c/z  -40.80  -4.02  1.3715  $ Position 31
1532  c/z  -40.80   4.02  1.3715  $ Position 32
c
1533  cz    43.625  $ Ring Divider for Modeling Simplification
c
c --------- Ring 4 ---------
1601  c/z  -42.73  17.70  1.3715  $ Position 1
1602  c/z  -38.46  25.70  1.3715  $ Position 2
1603  c/z  -32.70  32.70  1.3715  $ Position 3
1604  c/z  -25.70  38.46  1.3715  $ Position 4
1605  c/z  -17.70  42.73  1.3715  $ Position 5
1606  c/z   -9.02  45.36  1.3715  $ Position 6
1607  c/z    0.00  46.25  1.3715  $ Position 7
1608  c/z    9.02  45.36  1.3715  $ Position 8
1609  c/z   17.70  42.73  1.3715  $ Position 9
1610  c/z   25.70  38.46  1.3715  $ Position 10
1611  c/z   32.70  32.70  1.3715  $ Position 11
1612  c/z   38.46  25.70  1.3715  $ Position 12
1613  c/z   42.73  17.70  1.3715  $ Position 13
1614  c/z   45.36   9.02  1.3715  $ Position 14
1615  c/z   46.25   0.00  1.3715  $ Position 15
1616  c/z   45.36  -9.02  1.3715  $ Position 16
1617  c/z   42.73 -17.70  1.3715  $ Position 17
1618  c/z   38.46 -25.70  1.3715  $ Position 18
1619  c/z   32.70 -32.70  1.3715  $ Position 19
1620  c/z   25.70 -38.46  1.3715  $ Position 20
1621  c/z   17.70 -42.73  1.3715  $ Position 21
1622  c/z    9.02 -45.36  1.3715  $ Position 22
1623  c/z    0.00 -46.25  1.3715  $ Position 23
1624  c/z   -9.02 -45.36  1.3715  $ Position 24
1625  c/z  -17.70 -42.73  1.3715  $ Position 25
1626  c/z  -25.70 -38.46  1.3715  $ Position 26
1627  c/z  -32.70 -32.70  1.3715  $ Position 27
1628  c/z  -38.46 -25.70  1.3715  $ Position 28
1629  c/z  -42.73 -17.70  1.3715  $ Position 29
1630  c/z  -45.36  -9.02  1.3715  $ Position 30
1631  c/z  -46.25   0.00  1.3715  $ Position 31
1632  c/z  -45.36   9.02  1.3715  $ Position 32
c
1633  cz    48.875  $ Ring Divider for Modeling Simplification
c
c --------- Ring 5 ---------
1701  c/z  -45.42  24.28  1.3715  $ Position 1
1702  c/z  -39.81  32.67  1.3715  $ Position 2
1703  c/z  -32.67  39.81  1.3715  $ Position 3
1704  c/z  -24.28  45.42  1.3715  $ Position 4
1705  c/z  -14.95  49.28  1.3715  $ Position 5
1706  c/z   -5.05  51.25  1.3715  $ Position 6
1707  c/z    5.05  51.25  1.3715  $ Position 7
1708  c/z   14.95  49.28  1.3715  $ Position 8
1709  c/z   24.28  45.42  1.3715  $ Position 9
1710  c/z   32.67  39.81  1.3715  $ Position 10
1711  c/z   39.81  32.67  1.3715  $ Position 11
1712  c/z   45.42  24.28  1.3715  $ Position 12
1713  c/z   49.28  14.95  1.3715  $ Position 13
1714  c/z   51.25   5.05  1.3715  $ Position 14
1715  c/z   51.25  -5.05  1.3715  $ Position 15
1716  c/z   49.28 -14.95  1.3715  $ Position 16
1717  c/z   45.42 -24.28  1.3715  $ Position 17
1718  c/z   39.81 -32.67  1.3715  $ Position 18
1719  c/z   32.67 -39.81  1.3715  $ Position 19
1720  c/z   24.28 -45.42  1.3715  $ Position 20
1721  c/z   14.95 -49.28  1.3715  $ Position 21
1722  c/z    5.05 -51.25  1.3715  $ Position 22
1723  c/z   -5.05 -51.25  1.3715  $ Position 23
1724  c/z  -14.95 -49.28  1.3715  $ Position 24
1725  c/z  -24.28 -45.42  1.3715  $ Position 25
1726  c/z  -32.67 -39.81  1.3715  $ Position 26
1727  c/z  -39.81 -32.67  1.3715  $ Position 27
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1728  c/z  -45.42 -24.28  1.3715  $ Position 28
1729  c/z  -49.28 -14.95  1.3715  $ Position 29
1730  c/z  -51.25  -5.05  1.3715  $ Position 30
1731  c/z  -51.25   5.05  1.3715  $ Position 31
1732  c/z  -49.28  14.95  1.3715  $ Position 32
c
c ------ Aluminum Tank ------
1801  pz   266.9            $ Bottom of Aluminum
1802  cz    62.1            $ Outer Radius
1803  pz   251.7            $ Top of Bottom Center
1804  pz   251.3            $ Bottom of Bottom Center
1805  sz   376.7612 127.125  $ Outer Curved Liner
1806  sz   377.1612 127.125  $ Inner Curved Liner
1807  cz    43.4            $ Inner Support Radius
1808  cz    43.8            $ Outer Support Radius
c
c --- Lower Axial Reflector -----------------------------------------------------
c ------ Inner Cylinder ------
1811  pz    78.0   $ Inside Bottom of Cavity
1812  cz    24.75  $ Outer Radius
c
c ------ Neutron Source Position ------
1821  pz    25.0   $ Neutron Source Channel
1822  cz     6.05  $ Neutron Source Channel
1823  cz     6.0   $ Graphite Plug
c
c ------ Graphite Annulus ------
1831  cz    25.04581  $ Inner Radial Equivalent-Area Surface
1832  cz    62.49876  $ Outer Radial Equivalent-Area Surface
c
c --------- Inside Surfaces of 21-Sided Polygon ---------
7561  p -25.24309   0.00000 0  -24.15733   7.32375 0  -24.15733   7.32375 1
7562  p -24.15733   7.32375 0  -20.99343  14.01747 0  -20.99343  14.01747 1
7563  p -20.99343  14.01747 0  -16.02358  19.50535 0  -16.02358  19.50535 1
7564  p -16.02358  19.50535 0   -9.67530  23.31528 0   -9.67530  23.31528 1
7565  p  -9.67530  23.31528 0   -2.49471  25.11952 0   -2.49471  25.11952 1
7566  p  -2.49471  25.11952 0    4.90049  24.76285 0    4.90049  24.76285 1
7567  p   4.90049  24.76285 0   11.87412  22.27597 0   11.87412  22.27597 1
7568  p  11.87412  22.27597 0   17.82629  17.87280 0   17.82629  17.87280 1
7569  p  17.82629  17.87280 0   22.24495  11.93213 0   22.24495  11.93213 1
7570  p  22.24495  11.93213 0   24.75000   4.96500 0   24.75000   4.96500 1
7571  p  24.75000   4.96500 0   25.12593  -2.42924 0   25.12593  -2.42924 1
7572  p  25.12593  -2.42924 0   23.34041  -9.61451 0   23.34041  -9.61451 1
7573  p  23.34041  -9.61451 0   19.54704 -15.97270 0   19.54704 -15.97270 1
7574  p  19.54704 -15.97270 0   14.07213 -20.95683 0   14.07213 -20.95683 1
7575  p  14.07213 -20.95683 0    7.38668 -24.13816 0    7.38668 -24.13816 1
7576  p   7.38668 -24.13816 0    0.06578 -25.24301 0    0.06578 -25.24301 1
7577  p   0.06578 -25.24301 0   -7.26077 -24.17633 0   -7.26077 -24.17633 1
7578  p  -7.26077 -24.17633 0  -16.02358 -19.50535 0  -16.02358 -19.50535 1
7579  p -16.02358 -19.50535 0  -20.99343 -14.01747 0  -20.99343 -14.01747 1
7580  p -20.99343 -14.01747 0  -24.15733  -7.32375 0  -24.15733  -7.32375 1
7581  p -24.15733  -7.32375 0  -25.24309   0.00000 0  -25.24309   0.00000 1
c
c --------- Outside Surfaces of 21-Sided Polygon ---------
7601  p -63.19671   0.00000 0  -60.47846  18.33519 0  -60.47846  18.33519 1
7602  p -60.47846  18.33519 0  -52.55757  35.09309 0  -52.55757  35.09309 1
7603  p -52.55757  35.09309 0  -40.11543  48.83212 0  -40.11543  48.83212 1
7604  p -40.11543  48.83212 0  -24.22236  58.37037 0  -24.22236  58.37037 1
7605  p -24.22236  58.37037 0   -6.24557  62.88733 0   -6.24557  62.88733 1
7606  p  -6.24557  62.88733 0   12.26849  61.99442 0   12.26849  61.99442 1
7607  p  12.26849  61.99442 0   29.72716  55.76845 0   29.72716  55.76845 1
7608  p  29.72716  55.76845 0   44.62856  44.74501 0   44.62856  44.74501 1
7609  p  44.62856  44.74501 0   55.69079  29.87239 0   55.69079  29.87239 1
7610  p  55.69079  29.87239 0   61.96224  12.43000 0   61.96224  12.43000 1
7611  p  61.96224  12.43000 0   62.90339  -6.08167 0   62.90339  -6.08167 1
7612  p  62.90339  -6.08167 0   58.43330 -24.07017 0   58.43330 -24.07017 1
7613  p  58.43330 -24.07017 0   48.93649 -39.98804 0   48.93649 -39.98804 1
7614  p  48.93649 -39.98804 0   35.22993 -52.46595 0   35.22993 -52.46595 1
7615  p  35.22993 -52.46595 0   18.49273 -60.43048 0   18.49273 -60.43048 1
7616  p  18.49273 -60.43048 0    0.16469 -63.19649 0    0.16469 -63.19649 1
7617  p   0.16469 -63.19649 0  -18.17752 -60.52604 0  -18.17752 -60.52604 1
7618  p -18.17752 -60.52604 0  -40.11543 -48.83212 0  -40.11543 -48.83212 1
7619  p -40.11543 -48.83212 0  -52.55757 -35.09309 0  -52.55757 -35.09309 1
7620  p -52.55757 -35.09309 0  -60.47846 -18.33519 0  -60.47846 -18.33519 1
7621  p -60.47846 -18.33519 0  -63.19671   0.00000 0  -63.19671   0.00000 1
c
```

```
c ------ Coolant Channels ------
c --------- Ring 1 ---------
1901  c/z  -29.86   2.94  1.371  $ Position 1
1902  c/z  -28.71   8.71  1.371  $ Position 2
1903  c/z  -26.46  14.14  1.371  $ Position 3
1904  c/z  -23.19  19.03  1.371  $ Position 4
1905  c/z  -19.03  23.19  1.371  $ Position 5
1906  c/z  -14.14  26.46  1.371  $ Position 6
1907  c/z   -8.71  28.71  1.371  $ Position 7
1908  c/z   -2.94  29.86  1.371  $ Position 8
1909  c/z    2.94  29.86  1.371  $ Position 9
1910  c/z    8.71  28.71  1.371  $ Position 10
1911  c/z   14.14  26.46  1.371  $ Position 11
1912  c/z   19.03  23.19  1.371  $ Position 12
1913  c/z   23.19  19.03  1.371  $ Position 13
1914  c/z   26.46  14.14  1.371  $ Position 14
1915  c/z   28.71   8.71  1.371  $ Position 15
1916  c/z   29.86   2.94  1.371  $ Position 16
1917  c/z   29.86  -2.94  1.371  $ Position 17
1918  c/z   28.71  -8.71  1.371  $ Position 18
1919  c/z   26.46 -14.14  1.371  $ Position 19
1920  c/z   23.19 -19.03  1.371  $ Position 20
1921  c/z   19.03 -23.19  1.371  $ Position 21
1922  c/z   14.14 -26.46  1.371  $ Position 22
1923  c/z    8.71 -28.71  1.371  $ Position 23
1924  c/z    2.94 -29.86  1.371  $ Position 24
1925  c/z   -2.94 -29.86  1.371  $ Position 25
1926  c/z   -8.71 -28.71  1.371  $ Position 26
1927  c/z  -14.14 -26.46  1.371  $ Position 27
1928  c/z  -19.03 -23.19  1.371  $ Position 28
1929  c/z  -23.19 -19.03  1.371  $ Position 29
1930  c/z  -26.46 -14.14  1.371  $ Position 30
1931  c/z  -28.71 -8.71   1.371  $ Position 31
1932  c/z  -29.86 -2.94   1.371  $ Position 32
c
c --------- Ring 2 ---------
2001  c/z  -34.82   6.93  1.371  $ Position 1
2002  c/z  -32.80  13.59  1.371  $ Position 2
2003  c/z  -29.52  19.72  1.371  $ Position 3
2004  c/z  -25.10  25.10  1.371  $ Position 4
2005  c/z  -19.72  29.52  1.371  $ Position 5
2006  c/z  -13.59  32.80  1.371  $ Position 6
2007  c/z   -6.93  34.82  1.371  $ Position 7
2008  c/z    0.00  35.50  1.371  $ Position 8
2009  c/z    6.93  34.82  1.371  $ Position 9
2010  c/z   13.59  32.80  1.371  $ Position 10
2011  c/z   19.72  29.52  1.371  $ Position 11
2012  c/z   25.10  25.10  1.371  $ Position 12
2013  c/z   29.52  19.72  1.371  $ Position 13
2014  c/z   32.80  13.59  1.371  $ Position 14
2015  c/z   34.82   6.93  1.371  $ Position 15
2016  c/z   35.50   0.00  1.371  $ Position 16
2017  c/z   34.82  -6.93  1.371  $ Position 17
2018  c/z   32.80 -13.59  1.371  $ Position 18
2019  c/z   29.52 -19.72  1.371  $ Position 19
2020  c/z   25.10 -25.10  1.371  $ Position 20
2021  c/z   19.72 -29.52  1.371  $ Position 21
2022  c/z   13.59 -32.80  1.371  $ Position 22
2023  c/z    6.93 -34.82  1.371  $ Position 23
2024  c/z    0.00 -35.50  1.371  $ Position 24
2025  c/z   -6.93 -34.82  1.371  $ Position 25
2026  c/z  -13.59 -32.80  1.371  $ Position 26
2027  c/z  -19.72 -29.52  1.371  $ Position 27
2028  c/z  -25.10 -25.10  1.371  $ Position 28
2029  c/z  -29.52 -19.72  1.371  $ Position 29
2030  c/z  -32.80 -13.59  1.371  $ Position 30
2031  c/z  -34.82  -6.93  1.371  $ Position 31
2032  c/z  -35.50   0.00  1.371  $ Position 32
c
c --------- Ring 3 ---------
2101  c/z  -39.23  11.90  1.371  $ Position 1
2102  c/z  -36.16  19.33  1.371  $ Position 2
2103  c/z  -31.69  26.01  1.371  $ Position 3
2104  c/z  -26.01  31.69  1.371  $ Position 4
2105  c/z  -19.33  36.16  1.371  $ Position 5
2106  c/z  -11.90  39.23  1.371  $ Position 6
```

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2107  c/z   -4.02  40.80  1.371  $ Position 7
2108  c/z    4.02  40.80  1.371  $ Position 8
2109  c/z   11.90  39.23  1.371  $ Position 9
2110  c/z   19.33  36.16  1.371  $ Position 10
2111  c/z   26.01  31.69  1.371  $ Position 11
2112  c/z   31.69  26.01  1.371  $ Position 12
2113  c/z   36.16  19.33  1.371  $ Position 13
2114  c/z   39.23  11.90  1.371  $ Position 14
2115  c/z   40.80   4.02  1.371  $ Position 15
2116  c/z   40.80  -4.02  1.371  $ Position 16
2117  c/z   39.23 -11.90  1.371  $ Position 17
2118  c/z   36.16 -19.33  1.371  $ Position 18
2119  c/z   31.69 -26.01  1.371  $ Position 19
2120  c/z   26.01 -31.69  1.371  $ Position 20
2121  c/z   19.33 -36.16  1.371  $ Position 21
2122  c/z   11.90 -39.23  1.371  $ Position 22
2123  c/z    4.02 -40.80  1.371  $ Position 23
2124  c/z   -4.02 -40.80  1.371  $ Position 24
2125  c/z  -11.90 -39.23  1.371  $ Position 25
2126  c/z  -19.33 -36.16  1.371  $ Position 26
2127  c/z  -26.01 -31.69  1.371  $ Position 27
2128  c/z  -31.69 -26.01  1.371  $ Position 28
2129  c/z  -36.16 -19.33  1.371  $ Position 29
2130  c/z  -39.23 -11.90  1.371  $ Position 30
2131  c/z  -40.80  -4.02  1.371  $ Position 31
2132  c/z  -40.80   4.02  1.371  $ Position 32
c
c --------- Ring 4 ---------
2201  c/z  -42.73  17.70  1.371  $ Position 1
2202  c/z  -38.46  25.70  1.371  $ Position 2
2203  c/z  -32.70  32.70  1.371  $ Position 3
2204  c/z  -25.70  38.46  1.371  $ Position 4
2205  c/z  -17.70  42.73  1.371  $ Position 5
2206  c/z   -9.02  45.36  1.371  $ Position 6
2207  c/z    0.00  46.25  1.371  $ Position 7
2208  c/z    9.02  45.36  1.371  $ Position 8
2209  c/z   17.70  42.73  1.371  $ Position 9
2210  c/z   25.70  38.46  1.371  $ Position 10
2211  c/z   32.70  32.70  1.371  $ Position 11
2212  c/z   38.46  25.70  1.371  $ Position 12
2213  c/z   42.73  17.70  1.371  $ Position 13
2214  c/z   45.36   9.02  1.371  $ Position 14
2215  c/z   46.25   0.00  1.371  $ Position 15
2216  c/z   45.36  -9.02  1.371  $ Position 16
2217  c/z   42.73 -17.70  1.371  $ Position 17
2218  c/z   38.46 -25.70  1.371  $ Position 18
2219  c/z   32.70 -32.70  1.371  $ Position 19
2220  c/z   25.70 -38.46  1.371  $ Position 20
2221  c/z   17.70 -42.73  1.371  $ Position 21
2222  c/z    9.02 -45.36  1.371  $ Position 22
2223  c/z    0.00 -46.25  1.371  $ Position 23
2224  c/z   -9.02 -45.36  1.371  $ Position 24
2225  c/z  -17.70 -42.73  1.371  $ Position 25
2226  c/z  -25.70 -38.46  1.371  $ Position 26
2227  c/z  -32.70 -32.70  1.371  $ Position 27
2228  c/z  -38.46 -25.70  1.371  $ Position 28
2229  c/z  -42.73 -17.70  1.371  $ Position 29
2230  c/z  -45.36  -9.02  1.371  $ Position 30
2231  c/z  -46.25   0.00  1.371  $ Position 31
2232  c/z  -45.36   9.02  1.371  $ Position 32
c
c --------- Ring 5 ---------
2301  c/z  -45.42  24.28  1.371  $ Position 1
2302  c/z  -39.81  32.67  1.371  $ Position 2
2303  c/z  -32.67  39.81  1.371  $ Position 3
2304  c/z  -24.28  45.42  1.371  $ Position 4
2305  c/z  -14.95  49.28  1.371  $ Position 5
2306  c/z   -5.05  51.25  1.371  $ Position 6
2307  c/z    5.05  51.25  1.371  $ Position 7
2308  c/z   14.95  49.28  1.371  $ Position 8
2309  c/z   24.28  45.42  1.371  $ Position 9
2310  c/z   32.67  39.81  1.371  $ Position 10
2311  c/z   39.81  32.67  1.371  $ Position 11
2312  c/z   45.42  24.28  1.371  $ Position 12
2313  c/z   49.28  14.95  1.371  $ Position 13
2314  c/z   51.25   5.05  1.371  $ Position 14
```

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2315  c/z   51.25  -5.05  1.371  $ Position 15
2316  c/z   49.28 -14.95  1.371  $ Position 16
2317  c/z   45.42 -24.28  1.371  $ Position 17
2318  c/z   39.81 -32.67  1.371  $ Position 18
2319  c/z   32.67 -39.81  1.371  $ Position 19
2320  c/z   24.28 -45.42  1.371  $ Position 20
2321  c/z   14.95 -49.28  1.371  $ Position 21
2322  c/z    5.05 -51.25  1.371  $ Position 22
2323  c/z   -5.05 -51.25  1.371  $ Position 23
2324  c/z  -14.95 -49.28  1.371  $ Position 24
2325  c/z  -24.28 -45.42  1.371  $ Position 25
2326  c/z  -32.67 -39.81  1.371  $ Position 26
2327  c/z  -39.81 -32.67  1.371  $ Position 27
2328  c/z  -45.42 -24.28  1.371  $ Position 28
2329  c/z  -49.28 -14.95  1.371  $ Position 29
2330  c/z  -51.25  -5.05  1.371  $ Position 30
2331  c/z  -51.25   5.05  1.371  $ Position 31
2332  c/z  -49.28  14.95  1.371  $ Position 32
c
c ------ Graphite Plugs ------
c --------- Ring 1 ---------
2401  c/z  -29.86   2.94  1.325  $ Position 1
2402  c/z  -28.71   8.71  1.325  $ Position 2
2403  c/z  -26.46  14.14  1.325  $ Position 3
2404  c/z  -23.19  19.03  1.325  $ Position 4
2405  c/z  -19.03  23.19  1.325  $ Position 5
2406  c/z  -14.14  26.46  1.325  $ Position 6
2407  c/z   -8.71  28.71  1.325  $ Position 7
2408  c/z   -2.94  29.86  1.325  $ Position 8
2409  c/z    2.94  29.86  1.325  $ Position 9
2410  c/z    8.71  28.71  1.325  $ Position 10
2411  c/z   14.14  26.46  1.325  $ Position 11
2412  c/z   19.03  23.19  1.325  $ Position 12
2413  c/z   23.19  19.03  1.325  $ Position 13
2414  c/z   26.46  14.14  1.325  $ Position 14
2415  c/z   28.71   8.71  1.325  $ Position 15
2416  c/z   29.86   2.94  1.325  $ Position 16
2417  c/z   29.86  -2.94  1.325  $ Position 17
2418  c/z   28.71  -8.71  1.325  $ Position 18
2419  c/z   26.46 -14.14  1.325  $ Position 19
2420  c/z   23.19 -19.03  1.325  $ Position 20
2421  c/z   19.03 -23.19  1.325  $ Position 21
2422  c/z   14.14 -26.46  1.325  $ Position 22
2423  c/z    8.71 -28.71  1.325  $ Position 23
2424  c/z    2.94 -29.86  1.325  $ Position 24
2425  c/z   -2.94 -29.86  1.325  $ Position 25
2426  c/z   -8.71 -28.71  1.325  $ Position 26
2427  c/z  -14.14 -26.46  1.325  $ Position 27
2428  c/z  -19.03 -23.19  1.325  $ Position 28
2429  c/z  -23.19 -19.03  1.325  $ Position 29
2430  c/z  -26.46 -14.14  1.325  $ Position 30
2431  c/z  -28.71  -8.71  1.325  $ Position 31
2432  c/z  -29.86  -2.94  1.325  $ Position 32
c
c --------- Ring 2 ---------
2501  c/z  -34.82   6.93  1.325  $ Position 1
2502  c/z  -32.80  13.59  1.325  $ Position 2
2503  c/z  -29.52  19.72  1.325  $ Position 3
2504  c/z  -25.10  25.10  1.325  $ Position 4
2505  c/z  -19.72  29.52  1.325  $ Position 5
2506  c/z  -13.59  32.80  1.325  $ Position 6
2507  c/z   -6.93  34.82  1.325  $ Position 7
2508  c/z    0.00  35.50  1.325  $ Position 8
2509  c/z    6.93  34.82  1.325  $ Position 9
2510  c/z   13.59  32.80  1.325  $ Position 10
2511  c/z   19.72  29.52  1.325  $ Position 11
2512  c/z   25.10  25.10  1.325  $ Position 12
2513  c/z   29.52  19.72  1.325  $ Position 13
2514  c/z   32.80  13.59  1.325  $ Position 14
2515  c/z   34.82   6.93  1.325  $ Position 15
2516  c/z   35.50   0.00  1.325  $ Position 16
2517  c/z   34.82  -6.93  1.325  $ Position 17
2518  c/z   32.80 -13.59  1.325  $ Position 18
2519  c/z   29.52 -19.72  1.325  $ Position 19
2520  c/z   25.10 -25.10  1.325  $ Position 20
2521  c/z   19.72 -29.52  1.325  $ Position 21
```

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2522  c/z   13.59 -32.80  1.325  $ Position 22
2523  c/z    6.93 -34.82  1.325  $ Position 23
2524  c/z    0.00 -35.50  1.325  $ Position 24
2525  c/z   -6.93 -34.82  1.325  $ Position 25
2526  c/z  -13.59 -32.80  1.325  $ Position 26
2527  c/z  -19.72 -29.52  1.325  $ Position 27
2528  c/z  -25.10 -25.10  1.325  $ Position 28
2529  c/z  -29.52 -19.72  1.325  $ Position 29
2530  c/z  -32.80 -13.59  1.325  $ Position 30
2531  c/z  -34.82  -6.93  1.325  $ Position 31
2532  c/z  -35.50   0.00  1.325  $ Position 32
c
c --------- Ring 3 ---------
2601  c/z  -39.23  11.90  1.325  $ Position 1
2602  c/z  -36.16  19.33  1.325  $ Position 2
2603  c/z  -31.69  26.01  1.325  $ Position 3
2604  c/z  -26.01  31.69  1.325  $ Position 4
2605  c/z  -19.33  36.16  1.325  $ Position 5
2606  c/z  -11.90  39.23  1.325  $ Position 6
2607  c/z   -4.02  40.80  1.325  $ Position 7
2608  c/z    4.02  40.80  1.325  $ Position 8
2609  c/z   11.90  39.23  1.325  $ Position 9
2610  c/z   19.33  36.16  1.325  $ Position 10
2611  c/z   26.01  31.69  1.325  $ Position 11
2612  c/z   31.69  26.01  1.325  $ Position 12
2613  c/z   36.16  19.33  1.325  $ Position 13
2614  c/z   39.23  11.90  1.325  $ Position 14
2615  c/z   40.80   4.02  1.325  $ Position 15
2616  c/z   40.80  -4.02  1.325  $ Position 16
2617  c/z   39.23 -11.90  1.325  $ Position 17
2618  c/z   36.16 -19.33  1.325  $ Position 18
2619  c/z   31.69 -26.01  1.325  $ Position 19
2620  c/z   26.01 -31.69  1.325  $ Position 20
2621  c/z   19.33 -36.16  1.325  $ Position 21
2622  c/z   11.90 -39.23  1.325  $ Position 22
2623  c/z    4.02 -40.80  1.325  $ Position 23
2624  c/z   -4.02 -40.80  1.325  $ Position 24
2625  c/z  -11.90 -39.23  1.325  $ Position 25
2626  c/z  -19.33 -36.16  1.325  $ Position 26
2627  c/z  -26.01 -31.69  1.325  $ Position 27
2628  c/z  -31.69 -26.01  1.325  $ Position 28
2629  c/z  -36.16 -19.33  1.325  $ Position 29
2630  c/z  -39.23 -11.90  1.325  $ Position 30
2631  c/z  -40.80  -4.02  1.325  $ Position 31
2632  c/z  -40.80   4.02  1.325  $ Position 32
c
c --------- Ring 4 ---------
2701  c/z  -42.73  17.70  1.325  $ Position 1
2702  c/z  -38.46  25.70  1.325  $ Position 2
2703  c/z  -32.70  32.70  1.325  $ Position 3
2704  c/z  -25.70  38.46  1.325  $ Position 4
2705  c/z  -17.70  42.73  1.325  $ Position 5
2706  c/z   -9.02  45.36  1.325  $ Position 6
2707  c/z    0.00  46.25  1.325  $ Position 7
2708  c/z    9.02  45.36  1.325  $ Position 8
2709  c/z   17.70  42.73  1.325  $ Position 9
2710  c/z   25.70  38.46  1.325  $ Position 10
2711  c/z   32.70  32.70  1.325  $ Position 11
2712  c/z   38.46  25.70  1.325  $ Position 12
2713  c/z   42.73  17.70  1.325  $ Position 13
2714  c/z   45.36   9.02  1.325  $ Position 14
2715  c/z   46.25   0.00  1.325  $ Position 15
2716  c/z   45.36  -9.02  1.325  $ Position 16
2717  c/z   42.73 -17.70  1.325  $ Position 17
2718  c/z   38.46 -25.70  1.325  $ Position 18
2719  c/z   32.70 -32.70  1.325  $ Position 19
2720  c/z   25.70 -38.46  1.325  $ Position 20
2721  c/z   17.70 -42.73  1.325  $ Position 21
2722  c/z    9.02 -45.36  1.325  $ Position 22
2723  c/z    0.00 -46.25  1.325  $ Position 23
2724  c/z   -9.02 -45.36  1.325  $ Position 24
2725  c/z  -17.70 -42.73  1.325  $ Position 25
2726  c/z  -25.70 -38.46  1.325  $ Position 26
2727  c/z  -32.70 -32.70  1.325  $ Position 27
2728  c/z  -38.46 -25.70  1.325  $ Position 28
2729  c/z  -42.73 -17.70  1.325  $ Position 29
```

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2730  c/z  -45.36  -9.02  1.325  $ Position 30
2731  c/z  -46.25   0.00  1.325  $ Position 31
2732  c/z  -45.36   9.02  1.325  $ Position 32
c
c --------- Ring 5 ---------
2801  c/z  -45.42  24.28  1.325  $ Position 1
2802  c/z  -39.81  32.67  1.325  $ Position 2
2803  c/z  -32.67  39.81  1.325  $ Position 3
2804  c/z  -24.28  45.42  1.325  $ Position 4
2805  c/z  -14.95  49.28  1.325  $ Position 5
2806  c/z   -5.05  51.25  1.325  $ Position 6
2807  c/z    5.05  51.25  1.325  $ Position 7
2808  c/z   14.95  49.28  1.325  $ Position 8
2809  c/z   24.28  45.42  1.325  $ Position 9
2810  c/z   32.67  39.81  1.325  $ Position 10
2811  c/z   39.81  32.67  1.325  $ Position 11
2812  c/z   45.42  24.28  1.325  $ Position 12
2813  c/z   49.28  14.95  1.325  $ Position 13
2814  c/z   51.25   5.05  1.325  $ Position 14
2815  c/z   51.25  -5.05  1.325  $ Position 15
2816  c/z   49.28 -14.95  1.325  $ Position 16
2817  c/z   45.42 -24.28  1.325  $ Position 17
2818  c/z   39.81 -32.67  1.325  $ Position 18
2819  c/z   32.67 -39.81  1.325  $ Position 19
2820  c/z   24.28 -45.42  1.325  $ Position 20
2821  c/z   14.95 -49.28  1.325  $ Position 21
2822  c/z    5.05 -51.25  1.325  $ Position 22
2823  c/z   -5.05 -51.25  1.325  $ Position 23
2824  c/z  -14.95 -49.28  1.325  $ Position 24
2825  c/z  -24.28 -45.42  1.325  $ Position 25
2826  c/z  -32.67 -39.81  1.325  $ Position 26
2827  c/z  -39.81 -32.67  1.325  $ Position 27
2828  c/z  -45.42 -24.28  1.325  $ Position 28
2829  c/z  -49.28 -14.95  1.325  $ Position 29
2830  c/z  -51.25  -5.05  1.325  $ Position 30
2831  c/z  -51.25   5.05  1.325  $ Position 31
2832  c/z  -49.28  14.95  1.325  $ Position 32
c
c ------ Aluminum Plugs ------
c    *There were no aluminum plugs in the Core
c
c --- Control Rods ---------------------------------------------------------------
c ------ Safety/Shutdown Rods ------
3001  pz   32.2   $ Bottom of Steel Tube
3002  pz   41.0   $ Bottom of Borated Steel Rods
3003  pz  253.0   $ Top of Borated Steel Rods
3004  pz  254.2   $ Top of Steel Tube
3005  cz    1.75  $ Borated Steel Rod Radius
3006  cz    1.8   $ Steel Tube Inner Radius
3007  cz    2.0   $ Steel Tube Outer Radius
c
3011  pz    0.2   $ Bottom Aluminum End Plug
3012  pz   28.25  $ Bottom of Aluminum Shock Damper
3013  pz   28.45  $ Top Aluminum End Plug
3014  cz    1.45  $ Aluminum Tube Inner Radius
3015  cz    2.001 $ Aluminum Tube Outer Radius
c    *Steel Shock Damper Below Reflector Not Modeled
c
c ------ Autorod ------
3031  px   -0.15  $ Coreside Copper Plate Face
3032  px    0.15  $ Farside Copper Plate Face
3033  pz  222.5   $ Top Surface of Plate
3034  p    -0.15 0 -7.5  0.15 0 -7.5  -0.15 -1.95 222.5 $ Angled Plate Surface
3035  p    -0.15 0 -7.5  0.15 0 -7.5  -0.15 1.95 222.5  $ Angled Plate Surface
3036  cz    2     $ Aluminum Tube Inner Radius
3037  cz    2.2   $ Aluminum Tube Outer Radius
c
c ------ Static Measurement Rods ------
c    *There were no Static Measurement Rods in the Core
c
c ------ ZEBRA Rods ------
c    *There were no ZEBRA Control Rods in the Core
c
c ------ Withdrawable Control Rods ------
3081  pz   75.5    $ Bottom of Bottom End Plug
3082  pz   77.0    $ Bottom of Tubes
```

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3083  pz   78.0    $ Top of Bottom End Plug
3084  pz  287.0    $ Bottom of Top End Plug
3085  pz  292.0    $ Top of Tubes
3086  pz  294.5    $ Top of Top End Plug
3087  cz    0.475  $ Inner Tube Inner Radius
3088  cz    0.675  $ Inner Tube Outer Radius
3089  cz    0.7    $ Outer Tube Inner Radius
3090  cz    1.1    $ Outer Tube Outer Radius
c
3091  pz   73.0    $ Top of Graphite Plug
3092  cz    1.325  $ Radius of Graphite Plug
c
3095  so 1000      $ A Very Large Sphere
c
c --- Pebbles -----------------------------------------------------------------
c ------ TRISO ------
3111  so  0.0251   $ UO2 Kernel
3112  so  0.03425  $ Buffer Coating
3113  so  0.03824  $ IPyC Coating
3114  so  0.04177  $ SiC Coating
3115  so  0.04577  $ OPyC Coating
c
c ------ TRISO Lattice ------
3121  rpp -0.0879 0.0879 -0.0879 0.0879 -0.0879 0.0879
c
c ------ Fuel Pebble ------
3131  s   0 0 0  2.35  $ Fuel Zone
3132  s   0 0 0  3.00  $ Pebble Shell (Unfueled Zone)
c
c ------ Moderator Pebble ------
c    *Same dimension as Fuel Pebble Shell
c
c ------ CHPOP Pebble Lattice ------
6001  hex  0 0 -3.00  0 0 6.00  3.00 0 0
c
c ------ CHPOP Pebble Stack Lattice ------
6002  hex  0 0 -9.00  0 0 264.  3.00 0 0  $ Core Lattice
6003  hex  0 0 -9.00  0 0 264.  3.4  0 0  $ Adding Poly Rods
c
c --- Graphite Fillers --------------------------------------------------------
c ------ Axial Modifiers ------
7000  cz   60.92759  $ Radial Equivalent-Area Surface
7001  hex  0 0 78  0 0 172.9  60.15 0 0
7002  hex  0 0 78  0 0 172.9  0 60.3 0
7003  pz  250.9  $ Top Surface
c
c ------ Lattice Spacers ------
c    *Lattice Spacers Not Used
c
c ------ Cavity Floor ------
c    *Cavity Floor Fillers Not Used
c
c --- Water Ingress Simulation ------------------------------------------------
c ------ Polyethylene Rods ------
c    *Polyethylene Rods Not Used in Configuration 9
c
7021  c/z  -3.0  1.732050808 0.325  $ NW Rod
7022  c/z   0.0  3.464101615 0.325  $ N Rod
7023  c/z   3.0  1.732050808 0.325  $ NE Rod
7024  c/z   3.0 -1.732050808 0.325  $ SE Rod
7025  c/z   0.0 -3.464101615 0.325  $ S Rod
7026  c/z  -3.0 -1.732050808 0.325  $ SW Rod
7027  pz    148                     $ Top of Rods
c
c ------ Copper Wire ------
c    *Copper Wire Not Used
c
c --- Auxiliary Components ----------------------------------------------------
c ------ Start-Up Source ------
c    *Start-Up Source Information Unknown
c
c ------ Detectors ------
c    *Detector Information Unknown
c
c ------ Temperature Sensors ------
c    *Temperature Sensor Information Unknown
```

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c
c ------ Very Large Sphere ------
9999  so  1000  $ For Modeling Purposes Only
c

c Data Cards ***************************************************************
c
c *** Material Cards *******************************************************
c --- Structural Surroundings ----------------------------------------------
c ------ Concrete ------
m1    56130.70c 7.2096E-06  56132.70c 6.8695E-06  56134.70c 1.6439E-04
      56135.70c 4.4836E-04  56136.70c 5.3419E-04  56137.70c 7.6395E-04
      56138.70c 4.8766E-03   8016.70c 1.3583E-02   8017.70c 5.1633E-06
      16032.70c 2.0325E-02  16033.70c 1.6272E-04  16034.70c 9.1849E-04
      16036.70c 4.2820E-06  20040.70c 2.4517E-03  20042.70c 1.6363E-05
      20043.70c 3.4142E-06  20044.70c 5.2756E-05  20046.70c 1.0116E-07
      20048.70c 4.7293E-06  26054.70c 1.0031E-04  26056.70c 1.5747E-03
      26057.70c 3.6367E-05  26058.70c 4.8398E-06  14028.70c 6.9592E-04
      14029.70c 3.5337E-05  14030.70c 2.3295E-05   1001.70c 1.4518E-02
       1002.70c 1.6697E-06  13027.70c 3.1016E-04  12024.70c 7.7127E-05
      12025.70c 9.7642E-06  12026.70c 1.0750E-05
c         Total 6.1726E-02
mt1   lwtr.10t hwtr.10t
c
c ------ Steel Plate (i.e. SS 301/302/304) ------
m2    24050.70c 7.1741E-04  24052.70c 1.3834E-02  24053.70c 1.5687E-03
      24054.70c 3.9049E-04  26054.70c 3.6154E-03  26056.70c 5.6755E-02
      26057.70c 1.3107E-03  26058.70c 1.7443E-04  28058.70c 4.4256E-03
      28060.70c 1.7047E-03  28061.70c 7.4104E-05  28062.70c 2.3628E-04
      28064.70c 6.0172E-05   6000.70c 2.9783E-04  14028.70c 7.8313E-04
      14029.70c 3.9765E-05  14030.70c 2.6214E-05  25055.70c 8.6816E-04
c         Total 8.6882E-02
mt2   fe56.12t
c
c ------ Graphite (Radial Reflector Annulus & Thermal Column) ------
m3     5010.70c 2.3356E-08   5011.70c 9.4011E-08   6000.70c 8.8245E-02
c         Total 8.8245E-02
mt3   grph.10t
c
c ------ Graphite (Lower Axial Reflector Cylinder) ------
m4     5010.70c 2.3223E-08   5011.70c 9.3476E-08   6000.70c 8.7744E-02
c         Total 8.7744E-02
mt4   grph.10t
c
c ------ Graphite (Lower Axial Reflector Annulus) ------
m5     5010.70c 2.3356E-08   5011.70c 9.4011E-08   6000.70c 8.8245E-02
c         Total 8.8245E-02
mt5   grph.10t
c
c ------ Graphite (Upper Axial Reflector Cylinder) ------
m6     5010.70c 2.3235E-08   5011.70c 9.3524E-08   6000.70c 8.7789E-02
c         Total 8.7789E-02
mt6   grph.10t
c
c ------ Graphite (Upper Axial Reflector Annulus) ------
m7     5010.70c 2.3368E-08   5011.70c 9.4059E-08   6000.70c 8.8291E-02
c         Total 8.8291E-02
mt7   grph.10t
c
c ------ Peraluman-300 (Safety Ring) ------
m8     5010.70c 1.4688E-07   5011.70c 5.9119E-07  12024.70c 8.0390E-04
      12025.70c 1.0177E-04  12026.70c 1.1205E-04  13027.70c 5.7575E-02
      14028.70c 2.0962E-04  14029.70c 1.0644E-05  14030.70c 7.0168E-06
      25055.70c 7.2621E-05  26054.70c 5.0109E-06  26056.70c 7.8660E-05
      26057.70c 1.8166E-06  26058.70c 2.4176E-07  29063.70c 8.6855E-06
      29065.70c 3.8712E-06  30000.70c 2.4398E-05  31069.70c 6.8789E-07
      31071.70c 4.5653E-07  48106.70c 8.8729E-10  48108.70c 6.3175E-10
      48110.70c 8.8658E-09  48111.70c 9.0858E-09  48112.70c 1.7128E-08
      48113.70c 8.6741E-09  48114.70c 2.0393E-08  48116.70c 5.3166E-09
c         Total 5.9018E-02
mt8   al27.12t fe56.12t
c
c ------ Peraluman-300 (Upper Axial Reflector) ------
m9     5010.70c 1.4688E-07   5011.70c 5.9119E-07  12024.70c 8.0390E-04
      12025.70c 1.0177E-04  12026.70c 1.1205E-04  13027.70c 5.7575E-02
      14028.70c 2.0962E-04  14029.70c 1.0644E-05  14030.70c 7.0168E-06
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      25055.70c 7.2621E-05  26054.70c 5.0109E-06  26056.70c 7.8660E-05
      26057.70c 1.8166E-06  26058.70c 2.4176E-07  29063.70c 8.6855E-06
      29065.70c 3.8712E-06  30000.70c 2.4398E-05  31069.70c 6.8789E-07
      31071.70c 4.5653E-07  48106.70c 8.8729E-10  48108.70c 6.3175E-10
      48110.70c 8.8658E-09  48111.70c 9.0858E-09  48112.70c 1.7128E-08
      48113.70c 8.6741E-09  48114.70c 2.0393E-08  48116.70c 5.3166E-09
c         Total 5.9018E-02
mt9   al27.12t fe56.12t
c
c ------ Air (Core 9) ------
m10    1001.70c 2.8065E-07   1002.70c 3.2278E-11   7014.70c 3.7504E-05
        7015.70c 1.3852E-07   8016.70c 1.0252E-05   8017.70c 3.8973E-09
      18036.70c 7.5755E-10  18038.70c 1.4228E-10  18040.70c 2.2423E-07
        6000.70c 9.2003E-09   2003.70c 1.7303E-16   2004.70c 1.2630E-10
      36078.70c 9.6173E-14  36080.70c 6.2650E-13  36082.70c 3.1820E-12
      36083.70c 3.1572E-12  36084.70c 1.5663E-11  36086.70c 4.7537E-12
c         Total 4.8413E-05
c
c ------ Air (Core 10) ------
c m10    1001.70c 9.2536E-07   1002.70c 1.0643E-10   7014.70c 3.6572E-05
c         7015.70c 1.3508E-07   8016.70c 1.0323E-05   8017.70c 3.9243E-09
c       18036.70c 7.3873E-10  18038.70c 1.3875E-10  18040.70c 2.1866E-07
c         6000.70c 8.9717E-09   2003.70c 1.6874E-16   2004.70c 1.2316E-10
c       36078.70c 9.3784E-14  36080.70c 6.1093E-13  36082.70c 3.1029E-12
c       36083.70c 3.0788E-12  36084.70c 1.5273E-11  36086.70c 4.6356E-12
c         Total 4.8188E-05
c
mt10  lwtr.10t hwtr.10t
c
c ------ Aluminum Plugs ------
c    *There were no aluminum plugs in the Core
c
c --- Control Rods ------------------------------------------------------------
c ------ 5 wt.% Borated Steel ------
m11    5010.70c 3.9257E-03   5011.70c 1.4282E-02  14028.70c 1.4007E-03
      14029.70c 7.1124E-05  14030.70c 4.6885E-05  24050.70c 1.4117E-03
      24052.70c 2.7224E-02  24053.70c 3.0870E-03  24054.70c 7.6842E-04
      25055.70c 9.8952E-04  26054.70c 1.8295E-03  26056.70c 2.8719E-02
      26057.70c 6.6325E-04  26058.70c 8.8267E-05  28058.70c 4.7678E-03
      28060.70c 1.8366E-03  28061.70c 7.9834E-05  28062.70c 2.5455E-04
      28064.70c 6.4825E-05
c         Total 9.1511E-02
mt11  fe56.12t
c
c ------ 18/8 Stainless Steel (i.e. SS 301/302/304) ------
m12   24050.70c 7.1741E-04  24052.70c 1.3834E-02  24053.70c 1.5687E-03
      24054.70c 3.9049E-04  26054.70c 3.6154E-03  26056.70c 5.6755E-02
      26057.70c 1.3107E-03  26058.70c 1.7443E-04  28058.70c 4.4256E-03
      28060.70c 1.7047E-03  28061.70c 7.4104E-05  28062.70c 2.3628E-04
      28064.70c 6.0172E-05   6000.70c 2.9783E-04  14028.70c 7.8313E-04
      14029.70c 3.9765E-05  14030.70c 2.6214E-05  25055.70c 8.6816E-04
c         Total 8.6882E-02
mt12  fe56.12t
c
c ------ Copper Autorod (i.e. C110) ------
m13   29063.70c 5.8245E-02  29065.70c 2.5961E-02   8016.70c 6.6898E-05
        8017.70c 2.5431E-08  47107.70c 1.9296E-06  47109.70c 1.7927E-06
      16032.70c 1.1887E-05  16033.70c 9.5169E-08  16034.70c 5.3720E-07
      16036.70c 2.5044E-09  28058.70c 4.6572E-06  28060.70c 1.7939E-06
      28061.70c 7.7981E-08  28062.70c 2.4864E-07  28064.70c 6.3321E-08
      26054.70c 4.2025E-07  26056.70c 6.5971E-06  26057.70c 1.5236E-07
      26058.70c 2.0276E-08
c         Total 8.4303E-02
mt13  fe56.12t
c
c ------ Pure Aluminum Autorod Guide Tube (i.e. AL 1100) ------
m113  14028.70c 2.6697E-04  14029.70c 1.3556E-05  14030.70c 8.9364E-06
      26054.70c 8.5091E-06  26056.70c 1.3357E-04  26057.70c 3.0848E-06
      26058.70c 4.1053E-07  29063.70c 2.2123E-05  29065.70c 9.8607E-06
      25055.70c 7.3991E-06  30000.70c 1.2429E-05  27059.70c 6.8975E-05
      28058.70c 4.7148E-05  28060.70c 1.8161E-05  28061.70c 7.8946E-07
      28062.70c 2.5171E-06  28064.70c 6.4104E-07  50112.70c 3.3215E-07
      50114.70c 2.2600E-07  50115.70c 1.1642E-07  50116.70c 4.9788E-06
      50117.70c 2.6298E-06  50118.70c 8.2935E-06  50119.70c 2.9414E-06
      50120.70c 1.1156E-05  50122.70c 1.5854E-06  50124.70c 1.9826E-06
      13027.70c 5.9087E-02
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c         Total 5.9746E-02
mt113  al27.12t fe56.12t
c
c ------ Pure Aluminum Shock Dampers (i.e. AL 1100) ------
m14   14028.70c 3.6377E-04  14029.70c 1.8471E-05  14030.70c 1.2177E-05
      26054.70c 1.1594E-05  26056.70c 1.8200E-04  26057.70c 4.2033E-06
      26058.70c 5.5938E-07  29063.70c 3.0145E-05  29065.70c 1.3436E-05
      25055.70c 1.0082E-05  30000.70c 1.6936E-05  27059.70c 9.3983E-05
      28058.70c 6.4242E-05  28060.70c 2.4746E-05  28061.70c 1.0757E-06
      28062.70c 3.4298E-06  28064.70c 8.7346E-07  50112.70c 4.5258E-07
      50114.70c 3.0794E-07  50115.70c 1.5864E-07  50116.70c 6.7840E-06
      50117.70c 3.5833E-06  50118.70c 1.1300E-05  50119.70c 4.0079E-06
      50120.70c 1.5201E-05  50122.70c 2.1602E-06  50124.70c 2.7015E-06
      13027.70c 8.0510E-02
c         Total 8.1409E-02
mt14  al27.12t fe56.12t
c
c ------ St1.4301 Stainless Steel (Inner Tube) ------
m17    6000.70c 1.3864E-04  14028.70c 7.8115E-04  14029.70c 3.9665E-05
      14030.70c 2.6147E-05  25055.70c 8.6597E-04  24050.70c 7.3547E-04
      24052.70c 1.4183E-02  24053.70c 1.6082E-03  24054.70c 4.0032E-04
      28058.70c 5.6560E-03  28060.70c 2.1787E-03  28061.70c 9.4706E-05
      28062.70c 3.0196E-04  28064.70c 7.6901E-05  26054.70c 3.4714E-03
      26056.70c 5.4493E-02  26057.70c 1.2585E-03  26058.70c 1.6748E-04
c         Total 8.6477E-02
mt17  fe56.12t
c
c ------ St1.4541 Stainless Steel (Outer Tube) ------
m18     6000.70c 1.9805E-04  14028.70c 7.8115E-04  14029.70c 3.9665E-05
       14030.70c 2.6147E-05  25055.70c 8.6597E-04  24050.70c 7.1559E-04
       24052.70c 1.3800E-02  24053.70c 1.5648E-03  24054.70c 3.8950E-04
       28058.70c 5.6560E-03  28060.70c 2.1787E-03  28061.70c 9.4706E-05
       28062.70c 3.0196E-04  28064.70c 7.6901E-05  22046.70c 4.0998E-06
       22047.70c 3.6973E-06  22048.70c 3.6635E-05  22049.70c 2.6885E-06
       22050.70c 2.5742E-06  26054.70c 3.4930E-03  26056.70c 5.4833E-02
       26057.70c 1.2663E-03  26058.70c 1.6853E-04
c         Total 8.6499E-02
mt18  fe56.12t
c
c --- Pebbles -----------------------------------------------------------------
c ------ UO2 ------
m19    8016.70c 4.8593E-02   8017.70c 1.8472E-05  92234.70c 3.3079E-05
      92235.70c 4.1172E-03  92236.70c 2.0499E-05  92238.70c 2.0135E-02
      47107.70c 3.1488E-09  47109.70c 2.9254E-09   5010.70c 1.0251E-08
       5011.70c 4.1263E-08  20040.70c 8.0826E-06  20042.70c 5.3944E-08
      20043.70c 1.1256E-08  20044.70c 1.7392E-07  20046.70c 3.3350E-10
      20048.70c 1.5591E-08  48106.70c 7.2858E-11  48108.70c 5.1875E-11
      48110.70c 7.2800E-10  48111.70c 7.4607E-10  48112.70c 1.4065E-09
      48113.70c 7.1226E-10  48114.70c 1.6746E-09  48116.70c 4.3657E-10
      17035.70c 2.1007E-07  17037.70c 6.7141E-08  27059.70c 5.5589E-08
      24050.70c 1.2593E-07  24052.70c 2.4284E-06  24053.70c 2.7536E-07
      24054.70c 6.8543E-08  66156.70c 2.4192E-13  66158.70c 4.0320E-13
      66160.70c 9.4349E-12  66161.70c 7.6246E-11  66162.70c 1.0286E-10
      66163.70c 1.0040E-10  66164.70c 1.1362E-10  63151.70c 2.0614E-10
      63153.70c 2.2502E-10  26054.70c 1.9201E-07  26056.70c 3.0142E-06
      26057.70c 6.9612E-08  26058.70c 9.2640E-09  64152.70c 8.3333E-13
      64154.70c 9.0833E-12  64155.70c 6.1666E-11  64156.70c 8.5291E-11
      64157.70c 6.5208E-11  64158.70c 1.0350E-10  64160.70c 9.1083E-11
       3006.70c 3.5823E-08   3007.70c 4.3616E-07  25055.70c 8.9447E-07
      42092.70c 1.5202E-08  42094.70c 9.4757E-09  42095.70c 1.6308E-08
      42096.70c 1.7087E-08  42097.70c 9.7830E-09  42098.70c 2.4719E-08
      42100.70c 9.8649E-09  28058.70c 1.8999E-07  28060.70c 7.3183E-08
      28061.70c 3.1812E-09  28062.70c 1.0143E-08  28064.70c 2.5832E-09
      16032.70c 3.8795E-09  16033.70c 3.1059E-11  16034.70c 1.7532E-10
      16036.70c 8.1735E-13  22046.70c 5.6463E-08  22047.70c 5.0919E-08
      22048.70c 5.0454E-07  22049.70c 3.7026E-08  22050.70c 3.5452E-08
      23000.70c 6.4310E-07
c         Total 7.2935E-02
mt19  o2/u.10t u/o2.10t
c
c ------ Buffer ------
m20    6000.70c 5.2640E-02  47107.70c 3.0388E-10  47109.70c 2.8232E-10
       5010.70c 1.1756E-09   5011.70c 4.7318E-09  20040.70c 1.4193E-07
      20042.70c 9.4729E-10  20043.70c 1.9766E-10  20044.70c 3.0542E-09
      20046.70c 5.8565E-12  20048.70c 2.7379E-10  48106.70c 3.6211E-12
      48108.70c 2.5783E-12  48110.70c 3.6182E-11  48111.70c 3.7081E-11
```

```
      48112.70c 6.9903E-11  48113.70c 3.5400E-11  48114.70c 8.3228E-11
      48116.70c 2.1698E-11  17035.70c 2.0274E-08  17037.70c 6.4796E-09
      27059.70c 6.9741E-10  24050.70c 9.5639E-10  24052.70c 1.8443E-08
      24053.70c 2.0913E-09  24054.70c 5.2057E-10  66156.70c 1.1674E-14
      66158.70c 1.9456E-14  66160.70c 4.5527E-13  66161.70c 3.6791E-12
      66162.70c 4.9632E-12  66163.70c 4.8445E-12  66164.70c 5.4827E-12
      63151.70c 9.9468E-12  63153.70c 1.0858E-11  26054.70c 1.9524E-09
      26056.70c 3.0648E-08  26057.70c 7.0779E-10  26058.70c 9.4194E-11
      64152.70c 4.0211E-14  64154.70c 4.3830E-13  64155.70c 2.9756E-12
      64156.70c 4.1156E-12  64157.70c 3.1465E-12  64158.70c 4.9942E-12
      64160.70c 4.3951E-12   3006.70c 3.4572E-09   3007.70c 4.2092E-08
      25055.70c 4.9492E-09  28058.70c 3.6671E-09  28060.70c 1.4125E-09
      28061.70c 6.1402E-11  28062.70c 1.9578E-10  28064.70c 4.9859E-11
      16032.70c 1.0296E-10  16033.70c 8.2429E-13  16034.70c 4.6529E-12
      16036.70c 2.1692E-14  22046.70c 5.4164E-10  22047.70c 4.8846E-10
      22048.70c 4.8400E-09  22049.70c 3.5519E-10  22050.70c 3.4008E-10
      23000.70c 2.6873E-09   1001.70c 7.0190E-06   1002.70c 8.0728E-10
       8016.70c 3.5086E-06   8017.70c 1.3338E-09
c          Total 5.2651E-02
mt20  grph.10t lwtr.10t hwtr.10t
c
c ------ IPyC ------
m21    6000.70c 9.5254E-02  47107.70c 5.4988E-10  47109.70c 5.1086E-10
       5010.70c 2.1272E-09   5011.70c 8.5623E-09  20040.70c 2.5683E-07
      20042.70c 1.7141E-09  20043.70c 3.5767E-10  20044.70c 5.5266E-09
      20046.70c 1.0598E-11  20048.70c 4.9543E-10  48106.70c 6.5525E-12
      48108.70c 4.6654E-12  48110.70c 6.5473E-11  48111.70c 6.7098E-11
      48112.70c 1.2649E-10  48113.70c 6.4058E-11  48114.70c 1.5060E-10
      48116.70c 3.9263E-11  17035.70c 3.6685E-08  17037.70c 1.1725E-08
      27059.70c 1.2620E-09  24050.70c 1.7306E-09  24052.70c 3.3373E-08
      24053.70c 3.7842E-09  24054.70c 9.4198E-10  66156.70c 2.1124E-14
      66158.70c 3.5206E-14  66160.70c 8.2382E-13  66161.70c 6.6575E-12
      66162.70c 8.9811E-12  66163.70c 8.7663E-12  66164.70c 9.9211E-12
      63151.70c 1.7999E-11  63153.70c 1.9648E-11  26054.70c 3.5328E-09
      26056.70c 5.5458E-08  26057.70c 1.2808E-09  26058.70c 1.7045E-10
      64152.70c 7.2763E-14  64154.70c 7.9312E-13  64155.70c 5.3845E-12
      64156.70c 7.4473E-12  64157.70c 5.6937E-12  64158.70c 9.0372E-12
      64160.70c 7.9530E-12   3006.70c 6.2559E-09   3007.70c 7.6167E-08
      25055.70c 8.9556E-09  28058.70c 6.6356E-09  28060.70c 2.5560E-09
      28061.70c 1.1111E-10  28062.70c 3.5426E-10  28064.70c 9.0221E-11
      16032.70c 1.8631E-10  16033.70c 1.4916E-12  16034.70c 8.4196E-12
      16036.70c 3.9252E-14  22046.70c 9.8011E-10  22047.70c 8.8388E-10
      22048.70c 8.7580E-09  22049.70c 6.4272E-10  22050.70c 6.1539E-10
      23000.70c 4.8628E-09   1001.70c 1.2701E-05   1002.70c 1.4608E-09
       8016.70c 6.3489E-06   8017.70c 2.4135E-09
c          Total 9.5273E-02
mt21  grph.10t lwtr.10t hwtr.10t
c
c ------ SiC ------
m22   14028.70c 4.4323E-02  14029.70c 2.2506E-03  14030.70c 1.4836E-03
       6000.70c 4.8052E-02  47107.70c 9.2611E-10  47109.70c 8.6040E-10
       5010.70c 3.5827E-09   5011.70c 1.4421E-08  20040.70c 4.3256E-07
      20042.70c 2.8870E-09  20043.70c 6.0238E-10  20044.70c 9.3080E-09
      20046.70c 1.7848E-11  20048.70c 8.3441E-10  48106.70c 1.1036E-11
      48108.70c 7.8575E-12  48110.70c 1.1027E-10  48111.70c 1.1301E-10
      48112.70c 2.1304E-10  48113.70c 1.0789E-10  48114.70c 2.5365E-10
      48116.70c 6.6127E-11  17035.70c 6.1786E-08  17037.70c 1.9747E-08
      27059.70c 2.1255E-09  24050.70c 2.9147E-09  24052.70c 5.6207E-08
      24053.70c 6.3735E-09  24054.70c 1.5865E-09  66156.70c 3.5577E-14
      66158.70c 5.9295E-14  66160.70c 1.3875E-12  66161.70c 1.1213E-11
      66162.70c 1.5126E-11  66163.70c 1.4764E-11  66164.70c 1.6709E-11
      63151.70c 3.0314E-11  63153.70c 3.3091E-11  26054.70c 5.9500E-09
      26056.70c 9.3403E-08  26057.70c 2.1571E-09  26058.70c 2.8707E-10
      64152.70c 1.2255E-13  64154.70c 1.3358E-12  64155.70c 9.0686E-12
      64156.70c 1.2543E-11  64157.70c 9.5894E-12  64158.70c 1.5220E-11
      64160.70c 1.3395E-11   3006.70c 1.0536E-08   3007.70c 1.2828E-07
      25055.70c 1.5083E-08  28058.70c 1.1176E-08  28060.70c 4.3049E-09
      28061.70c 1.8713E-10  28062.70c 5.9666E-10  28064.70c 1.5195E-10
      16032.70c 3.1379E-10  16033.70c 2.5121E-12  16034.70c 1.4180E-11
      16036.70c 6.6109E-14  22046.70c 1.6507E-09  22047.70c 1.4886E-09
      22048.70c 1.4750E-08  22049.70c 1.0825E-09  22050.70c 1.0364E-09
      23000.70c 8.1900E-09   1001.70c 2.1391E-05   1002.70c 2.4603E-09
       8016.70c 1.0693E-05   8017.70c 4.0648E-09
c          Total 9.6142E-02
mt22  grph.10t lwtr.10t hwtr.10t
c
```

```
c ------ OPyC ------
m23     6000.70c 9.4752E-02  47107.70c 5.4698E-10  47109.70c 5.0817E-10
        5010.70c 2.1160E-09   5011.70c 8.5172E-09  20040.70c 2.5548E-07
       20042.70c 1.7051E-09  20043.70c 3.5578E-10  20044.70c 5.4975E-09
       20046.70c 1.0542E-11  20048.70c 4.9283E-10  48106.70c 6.5181E-12
       48108.70c 4.6409E-12  48110.70c 6.5128E-11  48111.70c 6.6745E-11
       48112.70c 1.2582E-10  48113.70c 6.3721E-11  48114.70c 1.4981E-10
       48116.70c 3.9056E-11  17035.70c 3.6492E-08  17037.70c 1.1663E-08
       27059.70c 1.2553E-09  24050.70c 1.7215E-09  24052.70c 3.3197E-08
       24053.70c 3.7643E-09  24054.70c 9.3702E-10  66156.70c 2.1012E-14
       66158.70c 3.5021E-14  66160.70c 8.1949E-13  66161.70c 6.6224E-12
       66162.70c 8.9338E-12  66163.70c 8.7202E-12  66164.70c 9.8689E-12
       63151.70c 1.7904E-11  63153.70c 1.9545E-11  26054.70c 3.5142E-09
       26056.70c 5.5166E-08  26057.70c 1.2740E-09  26058.70c 1.6955E-10
       64152.70c 7.2380E-14  64154.70c 7.8894E-13  64155.70c 5.3561E-12
       64156.70c 7.4081E-12  64157.70c 5.6637E-12  64158.70c 8.9896E-12
       64160.70c 7.9111E-12   3006.70c 6.2230E-09   3007.70c 7.5766E-08
       25055.70c 8.9085E-09  28058.70c 6.6007E-09  28060.70c 2.5426E-09
       28061.70c 1.1052E-10  28062.70c 3.5240E-10  28064.70c 8.9746E-11
       16032.70c 1.8533E-10  16033.70c 1.4837E-12  16034.70c 8.3753E-12
       16036.70c 3.9046E-14  22046.70c 9.7495E-10  22047.70c 8.7923E-10
       22048.70c 8.7119E-09  22049.70c 6.3933E-10  22050.70c 6.1215E-10
       23000.70c 4.8372E-09   1001.70c 1.2634E-05   1002.70c 1.4531E-09
        8016.70c 6.3154E-06   8017.70c 2.4008E-09
c          Total 9.4772E-02
mt23  grph.10t lwtr.10t hwtr.10t
c
c ------ Fueled Zone ------
m24     6000.70c 8.6842E-02  47107.70c 5.0131E-10  47109.70c 4.6575E-10
        5010.70c 1.9393E-09   5011.70c 7.8061E-09  20040.70c 2.3415E-07
       20042.70c 1.5628E-09  20043.70c 3.2608E-10  20044.70c 5.0385E-09
       20046.70c 9.6616E-12  20048.70c 4.5168E-10  48106.70c 5.9739E-12
       48108.70c 4.2534E-12  48110.70c 5.9691E-11  48111.70c 6.1172E-11
       48112.70c 1.1532E-10  48113.70c 5.8401E-11  48114.70c 1.3730E-10
       48116.70c 3.5795E-11  17035.70c 3.3446E-08  17037.70c 1.0690E-08
       27059.70c 1.1505E-09  24050.70c 1.5778E-09  24052.70c 3.0426E-08
       24053.70c 3.4500E-09  24054.70c 8.5879E-10  66156.70c 1.9258E-14
       66158.70c 3.2097E-14  66160.70c 7.5107E-13  66161.70c 6.0695E-12
       66162.70c 8.1879E-12  66163.70c 7.9921E-12  66164.70c 9.0449E-12
       63151.70c 1.6409E-11  63153.70c 1.7913E-11  26054.70c 3.2208E-09
       26056.70c 5.0560E-08  26057.70c 1.1677E-09  26058.70c 1.5539E-10
       64152.70c 6.6337E-14  64154.70c 7.2307E-13  64155.70c 4.9089E-12
       64156.70c 6.7896E-12  64157.70c 5.1909E-12  64158.70c 8.2391E-12
       64160.70c 7.2506E-12   3006.70c 5.7034E-09   3007.70c 6.9441E-08
       25055.70c 8.1647E-09  28058.70c 6.0496E-09  28060.70c 2.3303E-09
       28061.70c 1.0130E-10  28062.70c 3.2298E-10  28064.70c 8.2253E-11
       16032.70c 1.6986E-10  16033.70c 1.3599E-12  16034.70c 7.6760E-12
       16036.70c 3.5786E-14  22046.70c 8.9355E-10  22047.70c 8.0582E-10
       22048.70c 7.9846E-09  22049.70c 5.8596E-10  22050.70c 5.6104E-10
       23000.70c 4.4334E-09   1001.70c 1.1579E-05   1002.70c 1.3318E-09
        8016.70c 5.7882E-06   8017.70c 2.2003E-09
c          Total 8.6859E-02
mt24  grph.10t lwtr.10t hwtr.10t
c
c ------ Unfueled Zone ------
m25     6000.70c 8.6842E-02  47107.70c 5.0131E-10  47109.70c 4.6575E-10
        5010.70c 1.9393E-09   5011.70c 7.8061E-09  20040.70c 2.3415E-07
       20042.70c 1.5628E-09  20043.70c 3.2608E-10  20044.70c 5.0385E-09
       20046.70c 9.6616E-12  20048.70c 4.5168E-10  48106.70c 5.9739E-12
       48108.70c 4.2534E-12  48110.70c 5.9691E-11  48111.70c 6.1172E-11
       48112.70c 1.1532E-10  48113.70c 5.8401E-11  48114.70c 1.3730E-10
       48116.70c 3.5795E-11  17035.70c 3.3446E-08  17037.70c 1.0690E-08
       27059.70c 1.1505E-09  24050.70c 1.5778E-09  24052.70c 3.0426E-08
       24053.70c 3.4500E-09  24054.70c 8.5879E-10  66156.70c 1.9258E-14
       66158.70c 3.2097E-14  66160.70c 7.5107E-13  66161.70c 6.0695E-12
       66162.70c 8.1879E-12  66163.70c 7.9921E-12  66164.70c 9.0449E-12
       63151.70c 1.6409E-11  63153.70c 1.7913E-11  26054.70c 3.2208E-09
       26056.70c 5.0560E-08  26057.70c 1.1677E-09  26058.70c 1.5539E-10
       64152.70c 6.6337E-14  64154.70c 7.2307E-13  64155.70c 4.9089E-12
       64156.70c 6.7896E-12  64157.70c 5.1909E-12  64158.70c 8.2391E-12
       64160.70c 7.2506E-12   3006.70c 5.7034E-09   3007.70c 6.9441E-08
       25055.70c 8.1647E-09  28058.70c 6.0496E-09  28060.70c 2.3303E-09
       28061.70c 1.0130E-10  28062.70c 3.2298E-10  28064.70c 8.2253E-11
       16032.70c 1.6986E-10  16033.70c 1.3599E-12  16034.70c 7.6760E-12
       16036.70c 3.5786E-14  22046.70c 8.9355E-10  22047.70c 8.0582E-10
       22048.70c 7.9846E-09  22049.70c 5.8596E-10  22050.70c 5.6104E-10
```

```
      23000.70c 4.4334E-09   1001.70c 1.1579E-05   1002.70c 1.3318E-09
       8016.70c 5.7882E-06   8017.70c 2.2003E-09
c         Total 8.6859E-02
mt25  grph.10t lwtr.10t hwtr.10t
c
c ------ Moderator Pebbles ------
m26    6000.70c 8.4434E-02   5010.70c 1.4193E-08   5011.70c 5.7130E-08
      20040.70c 3.1657E-06  20042.70c 2.1129E-08  20043.70c 4.4086E-09
      20044.70c 6.8121E-08  20046.70c 1.3062E-10  20048.70c 6.1067E-09
      48106.70c 3.3846E-11  48108.70c 2.4098E-11  48110.70c 3.3819E-10
      48111.70c 3.4658E-10  48112.70c 6.5336E-10  48113.70c 3.3088E-10
      48114.70c 7.7791E-10  48116.70c 2.0280E-10  17035.70c 4.0423E-07
      17037.70c 1.2920E-07  66156.70c 2.4350E-13  66158.70c 4.0583E-13
      66160.70c 9.4964E-12  66161.70c 7.6742E-11  66162.70c 1.0353E-10
      66163.70c 1.0105E-10  66164.70c 1.1436E-10  63151.70c 4.1496E-10
      63153.70c 4.5297E-10  26054.70c 6.2652E-09  26056.70c 9.8350E-08
      26057.70c 2.2713E-09  26058.70c 3.0227E-10  64152.70c 5.1616E-13
      64154.70c 5.6261E-12  64155.70c 3.8196E-11  64156.70c 5.2829E-11
      64157.70c 4.0389E-11  64158.70c 6.4107E-11  64160.70c 5.6416E-11
       3006.70c 9.7630E-09   3007.70c 1.1887E-07  28058.70c 9.1788E-09
      28060.70c 3.5357E-09  28061.70c 1.5369E-10  28062.70c 4.9004E-10
      28064.70c 1.2480E-10  16032.70c 4.2052E-06  16033.70c 3.3666E-08
      16034.70c 1.9004E-07  16036.70c 8.8595E-10  14028.70c 1.1661E-06
      14029.70c 5.9212E-08  14030.70c 3.9033E-08  62144.70c 1.7815E-11
      62147.70c 8.6986E-11  62148.70c 6.5225E-11  62149.70c 8.0197E-11
      62150.70c 4.2826E-11  62152.70c 1.5523E-10  62154.70c 1.3202E-10
      22046.70c 1.7486E-08  22047.70c 1.5770E-08  22048.70c 1.5625E-07
      22049.70c 1.1467E-08  22050.70c 1.0979E-08  23000.70c 2.5891E-07
       1001.70c 1.1262E-05   1002.70c 1.2953E-09   8016.70c 5.6296E-06
       8017.70c 2.1401E-09
c         Total 8.4461E-02
mt26  grph.10t lwtr.10t hwtr.10t
c
c --- Graphite Fillers -----------------------------------------------------------
c ------ Long Plugs/Rods (Radial Reflector C-Driver Positions) ------
m27    5010.70c 2.3422E-08   5011.70c 9.4278E-08   6000.70c 8.8496E-02
c         Total 8.8496E-02
mt27  grph.10t
c
c ------ Long Plugs/Rods (Radial Reflector ZEBRA Positions) ------
m28    5010.70c 2.3621E-08   5011.70c 9.5079E-08   6000.70c 8.9248E-02
c         Total 8.9248E-02
mt28  grph.10t
c
c ------ Short Plugs/Rods (Axial Reflectors) ------
m29    5010.70c 2.3356E-08   5011.70c 9.4011E-08   6000.70c 8.8245E-02
c         Total 8.8245E-02
mt29  grph.10t
c
c ------ Source Plug (Lower Axial Reflector) ------
m30    5010.70c 2.3356E-08   5011.70c 9.4011E-08   6000.70c 8.8245E-02
c         Total 8.8245E-02
mt30  grph.10t
c
c ------ Axial Modifiers ------
m31    5010.70c 2.1869E-08   5011.70c 8.8027E-08   6000.70c 8.2629E-02
c         Total 8.2629E-02
mt31  grph.10t
c
c ------ Lattice Spacers ------
c    *Lattice Spacers Not Used
c
c ------ Cavity Floor ------
c    *Cavity Floor Fillers Not Used
c
c --- Water Ingress Simulation --------------------------------------------------
c ------ Polyethylene Rods ------
m34    5010.70c 5.2797E-09   5011.70c 2.1252E-08   1001.70c 8.2835E-02
       1002.70c 9.5271E-06   6000.70c 4.0810E-02
c         Total 1.2365E-01
mt34  poly.10t
c
c ------ Copper Wire ------
c    *Copper Wire Not Used
c
c --- Auxiliary Components -------------------------------------------------------
```

```
c ------ Start-Up Source ------
c    *Start-Up Source Information Unknown
c
c ------ Detectors ------
c    *Detector Information Unknown
c
c ------ Temperature Sensors ------
c    *Temperature Sensor Information Unknown
c
c *** Control Cards ************************************************************
mode  n
kcode 100000 1 150 1650
ksrc  0 0  80  40 40  80  40 -40  80  -40 -40  80  -40 40  80
      0 0  90  40 40  90  40 -40  90  -40 -40  90  -40 40  90
      0 0 100  40 40 100  40 -40 100  -40 -40 100  -40 40 100
      0 0 110  40 40 110  40 -40 110  -40 -40 110  -40 40 110
      0 0 120  40 40 120  40 -40 120  -40 -40 120  -40 40 120
      0 0 130  40 40 130  40 -40 130  -40 -40 130  -40 40 130
      0 0 140  40 40 140  40 -40 140  -40 -40 140  -40 40 140
      0 0 150  40 40 150  40 -40 150  -40 -40 150  -40 40 150
      0 20  80  20 0  80  -20 0  80  0 -20  80
      0 20  90  20 0  90  -20 0  90  0 -20  90
      0 20 100  20 0 100  -20 0 100  0 -20 100
      0 20 110  20 0 110  -20 0 110  0 -20 110
      0 20 120  20 0 120  -20 0 120  0 -20 120
      0 20 130  20 0 130  -20 0 130  0 -20 130
      0 20 140  20 0 140  -20 0 140  0 -20 140
      0 20 150  20 0 150  -20 0 150  0 -20 150
      0 50  80  50 0  80  -50 0  80  0 -50  80
      0 50  90  50 0  90  -50 0  90  0 -50  90
      0 50 100  50 0 100  -50 0 100  0 -50 100
      0 50 110  50 0 110  -50 0 110  0 -50 110
      0 50 120  50 0 120  -50 0 120  0 -50 120
      0 50 130  50 0 130  -50 0 130  0 -50 130
      0 50 140  50 0 140  -50 0 140  0 -50 140
      0 50 150  50 0 150  -50 0 150  0 -50 150
c
kopts  blocksize=10 kinetics=yes precursor=yes
c print
c
```

APPENDIX D: HTR-PROTEUS HISTORICAL DATA

D.1 Validation of Safety Related Physics Calculations for Low Enriched HTGRs

The IARA CRP on Validation of Safety Related Physics Calculations for Low Enriched HTGRs (established in 1990) represented a collaboration between China, France, Japan, Switzerland, Germany, the Netherlands, the USA, and the Russian Federation to fill the gaps in validation data for physics methods used in the core design of gas-cooled reactors fueled with low enriched uranium. An international team of researchers assembled at the PROTEUS critical experiment facility of the Paul Scherrer Institute in Villigen, Switzerland to plan, conduct, and analyze a new series of critical experiments focused on the needs of the participating countries.

The following institutes participated in this CRP:

- Paul Scherrer Institute (PSI), Villigen, Switzerland
- Institute for Nuclear Energy Technology (INET), Tsinghua University, Beijing, China
- Forschungzentrum Jülich (FZJ), Jülich, Germany
- Japan Atomic Energy Research Institute (JAERI), Tokai-mura, Japan
- Interfaculty Reactor Institute, Delft University, Delft, the Netherlands
- Centre d'Etudes de Cadarache (CEA), St. Paul les Durance-Cedex, France
- Oak Ridge National Laboratory (ORNL), Oak Ridge, USA
- Russian Research Center Kurchatov Institute (RRC-KI), Moscow, Russia
- Energy Research Center, Petten, the Netherlands
- General Atomics (GA), San Diego, USA
- Experimental Machine Building Design Bureau (OKBM), Nizhny Novgorod, Russia

The PROTEUS graphite moderated LEU critical experiments were planned to fill gaps in the base of validation data. The constraints included room temperature and 5500 LEU fuel pebbles supplied by the KFA Research Center in Jülich, Germany. Specifically, the experiments which could be conducted at the PROTEUS facility with available AVR LEU fuel are summarized in Table D.1-1. The experimental conditions achievable at PROTEUS are summarized in Table D.1-2 (Ref. 3).

Table D.1-1. Summary of PROTEUS Critical Experiments (Ref. 3).

- Clean critical cores.
- LEU pebble-type fuel with 16.76 % ^{235}U enrichment.
- A range of C/U atom ratios from 946 to 1890 (achieved by varying the moderator-to-fuel pebble ratio from 0.5 to 2.0).
- Core (equivalent) diameter = 1.25 m.
- Core height = 0.843 m to 1.73 m (with simulated water ingress smaller core heights possible).
- Core H/D from 0.7 to 1.4.
- Flux distribution measurements and spectral distribution measurements (including measurements in side reflector).
- Kinetic parameter measurements.
- Worth of reflector control rods (partially and fully inserted).
- Worth of in-core control rod (partially and fully inserted).
- Effects of moisture ingress over range of water density up to 0.25 g H_2O/cm^3 void (corresponds to 0.065 g H_2O/cm^3 core for PROTEUS). Water is simulated with polyethylene inserts.
  - Effect on core reactivity.
  - Effect on worth of reflector control rods.
  - Effect on worth of in-core control rod.
  - Effect on burnable poison worth.
  - Effect on prompt neutron lifetime.
  - Effect on flux and power distributions.

Table D.1-2. Experimental Conditions Achievable at PROTEUS (Ref. 3).

- The PROTEUS critical provide validation data for low-enriched uranium fuel with an enrichment near to that planned for advanced GCR designs.
- PROTEUS moisture ingress experiments will investigate the effects which are important for advanced GCR designs (i.e., reactivity worth of moisture, and the effect of moisture on control rod and burnable poison worth and on reaction rate distributions) over the range of moisture densities of interest.
- The achievable range of C/U atom ratios at PROTEUS is near to, but higher than, that of advanced GCR designs (this ratio is an important factor in determining the neutron energy spectrum).
- PROTEUS provides the validation data
  - For the worth of reflector control rods.
  - For the worth of an in-core control rod.
  - For the worth of small samples of burnable poison (B_4C).
  - For fission rate distributions in core and reflector.

D.2 PROTEUS Critical Experiment Facility History and HTR Reconfiguration

The zero-power reactor facility PROTEUS is a part of the Paul Scherrer Institute (formerly EIR) and is situated near Würenlingen in the canton of Aargau in northern Switzerland. In the past it had been configured as a multi-zone (driven) system for reactor physics investigations of gas-cooled fast breeder and high conversion reactors. Various test configurations were built into a central, subcritical test zone which was driven critical by means of annular, thermal driver zones. PROTEUS was configured, for the first time, as a single zone for the HTR experiments with a pebble bed system surrounded radially and axially by a thick graphite reflector (Ref. 3).

A brief history of the facility is as follows (Ref. 3):[a]

- January 1968 – September 1970
  - Operation as a "zero-reactivity experiment" with a thermal, D_2O moderated test-lattice and a graphite driver.
- September 1970 – April 1972
  - Mixed fast-thermal system with a "buffer-zone" and reduced size test-zone.
- April 1972 – April 1979
  - Sixteen different configurations of the gas-cooled fast reactor type.
- January 1980 – August 1980
  - Preliminary HTR experiments.
- August 1980 – May 1981
  - Rebuild of the test-zone to accommodate light-water high conversion reactor experiments.
- May 1981 – October 1982
  - Phase I of the advanced light-water reactor experiments. Six configurations were investigated.
- February 1983 – May 1985
  - Re-configuration of the test-zone for Phase II of the light-water high conversion reactor experiments.

[a] PROTEUS Home Page, http://proteus.web.psi.ch/, Paul Scherrer Institut, Villigen, Switzerland (Accessed January 11, 2011).

- June 1985 – December 1990
  - Phase II of the advanced light-water experiments. Fourteen different test-zones, containing more representative fuel than in Phase I.
- January 1991 – July 1991
  - Rebuild for the LEU-HTR experiments.
- July 1992 – October 1996
  - HTR-PROTEUS critical experiments. Ten core configurations, some with multiple reference states.
- 1996 – 1997
  - Rebuild for LWR-PROTEUS experiments for validation of LWR fuel design and analysis tools.
- 1997 – 2001
  - Phase I – SVEA96+ BWR fuel: fission rates and reactivity worths.
- 2001 – 2003
  - Phase II – PWR fuel: reactivity of burnt fuel segments.
- 2003 – 2005
  - Phase III – SVEA-96 Optima2 BWR fuel: fission rates and moderator density effects.
- 2005 – 2011
  - LIFE@PROTEUS experimental program (Large-scale Irradiated Fuel Experiments): power distributions and mismatch, reaction rates, reactivity effects, and characterization of burnt fuel.

A brief summary of the work performed to rebuild the PROTEUS for the HTR-PROTEUS experiments is as follows (Ref. 3):

- All driver and buffer fuel discharged and stored.
- Fuel in test-zone discharged and stored.
- All installations inside graphite reflector removed.
- Construction of upper reflector assembly for HTR, an aluminum tank containing an annular region of old graphite and a central cylinder of new graphite.
- Filling of ~50 % of the ~300 C-Driver holes with new graphite rods. The other ~50 % were filled with existing graphite rods.
- Renewal of the safety/shutdown rods – increased length to allow for greater core height and better characterization of material properties – for improved benchmark quality of experiments.
- Increased height of radial reflector by 12 cm.
- Reconstruction of lower axial reflector, including central part of new graphite.
- Mounting of graphite panels in core cavity to modify the cavity shape to accommodate deterministic loadings.
- Fuel and moderator pebbles loaded.
- After the rest worths of the original ZEBRA control rods were found to be unacceptably high, these rods were replaced with conventional withdrawable control rods.

D.3 HTR-PROTEUS Timeline and Test Matrix

The time periods spanned by each configuration is provided in Figure D.3-1. A summary of the test matrix parameters investigated as part of each configuration is presented in Table D.3-3.

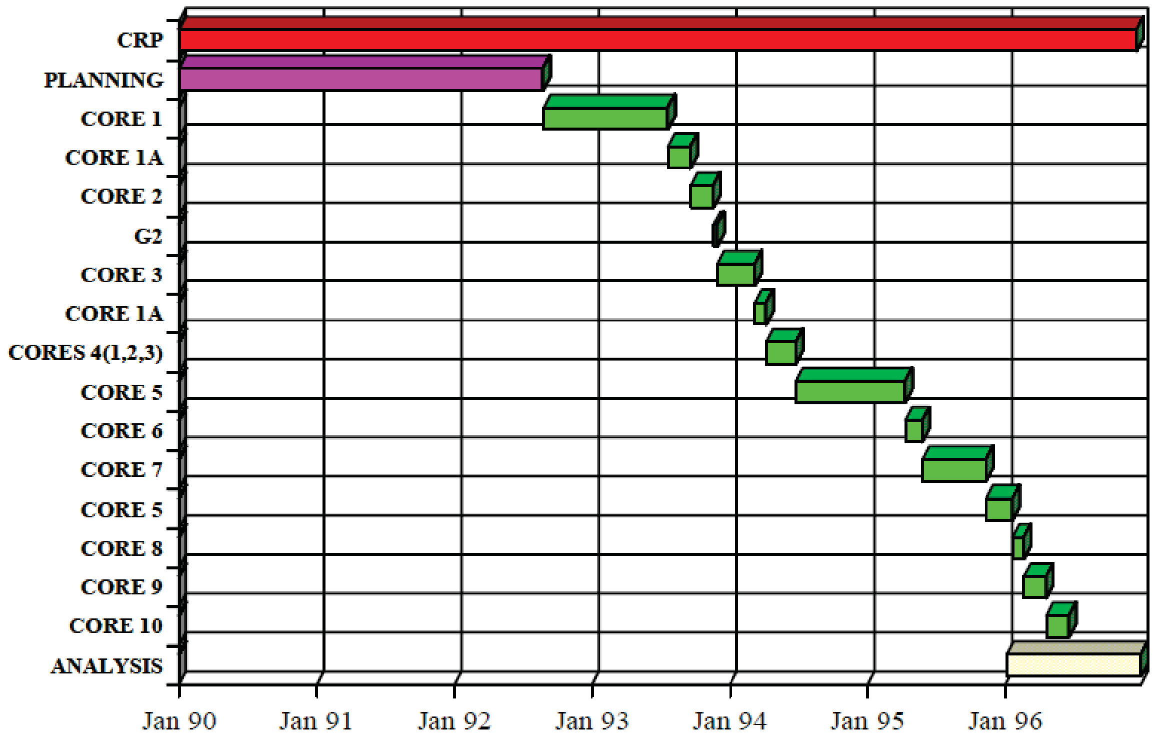

Figure D.3-1. Time Allocation for HTR-PROTEUS Experiments (Ref. 3).

Table D.3-1. Test Matrix for Cores 1 through 10 (Ref. 3).

CORE \ METHOD	CRITICAL LOADING	Σ_a	SUBCRIT CORE	SHUTDOWN RODS		CONTROL RODS		UPPER REFL.	β/A	MEAS. RODS	CENT. CONT. ROD	TEMP. COEFF	COM-PONENT WORTHS	MISC	REACTION RATE DISTRIBUTIONS					REACTION RATE RATIOS		
															IN CORE			IN PEBBLE		AT CORE CENTRE		
	PEBBLE COUNT	PNS	PNS	PNS	IK	SP	PNS	PNS (SP)	PNS	PNS	PNS	COMP	COMP	-	FOILS	FISSION CHAMBER.	γ SCAN	FOILS	PARTICLE FOILS	FOILS	PARTICLE FOILS	WHOLE PEBBLE
G1		✓													F: 5 C: 8	F: 5, 8, 7, 9, 2, 1						
1	✓		✓	✓	✓	✓	✓		✓	✓			✓		F: 5,8 C: 8	F: 5, 8, 7						
1A	✓				✓	✓										F: 5, 8, 7						
2	✓			✓	✓	✓	✓	✓	✓						F: 5,8 C: 8	F: 5, 8, 7						
G2		✓														F: 5, 8						
3	✓		✓	✓	✓	✓	✓		✓													
1A	✓			✓		✓																
4(1)	✓					✓																
4(2)	✓			✓	✓	✓																
4(3)	✓			✓		✓																
5	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	water/ CH_2 CH_2 in lower axial reflector	F:5,8 C8	F:5,8,7	C8, Ftot	F:5,8,9 C8	Ftot C8	F:5,8,9 C8	C8/Ftot	C8/Ftot
6	✓					✓																
7	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓		water/ CH_2 CH_2 in lower axial reflector	F:5,8 C8	F:5,8,7	C8, Ftot	F:5,8,9 C8	Ftot C8	F:5,8,9 C8	C8/Ftot	C8/Ftot
8	✓						✓															
9	✓				✓	✓	✓	✓	✓	✓					F:5	F:5,8,7,9	C8, Ftot	F:5,8,9 C8				
10	✓		✓		✓	✓	✓	✓	✓	✓				subcriticality with CH_2 removed	F:5	F:5,8,7,9	C8, Ftot	F:5,8,9 C:8				

✓ F: 5 = PLANNED AND EXECUTED

F=fission, C=capture, 5=U-235, 8=U-238, 9=Pu-239, 7=Np-237, 2=Pu-242, G1,2=graphite (no fuel in core), COMP. = compensation with calibrated control rods

APPENDIX E: Data from the 16th edition chart of the Nuclides[a]

E.1 Isotopic Abundances and Atomic Weights

This evaluation incorporated atomic weights and isotopic abundances found in the 16th edition of the Chart of the Nuclides. A list of the values used in the benchmark model or in the generation of the MCNP input deck is compiled in Table E.1-1.

[a] E. M. Baum, H. D. Knox, and T. R. Miller, *Nuclides and Isotopes: 16th Edition*, Knolls Atomic Power Laboratory (2002).

Table E.1-1. Summary of Data Employed from the 16th Ed. of the Chart of the Nuclides.

Isotope or Element	Atomic Weight (g/mol)	Isotopic Abundance (at.%)	Isotope or Element	Atomic Weight (g/mol)	Isotopic Abundance (at.%)
H	1.00794	--	S	32.065	--
^{1}H	--	99.9885	^{32}S	--	94.93
^{2}H	--	0.0115	^{33}S	--	0.76
He	4.002602	--	^{34}S	--	4.29
^{3}He	--	0.000137	^{36}S	--	0.02
^{4}He	--	99.999863	Cl	35.453	--
Li	6.941	--	^{35}Cl	--	75.78
^{6}Li	--	7.59	^{37}Cl	--	24.22
^{7}Li	--	92.41	Ar	39.948	--
B	10.811	--	^{36}Ar	--	0.3365
^{10}B	10.012937	19.9	^{38}Ar	--	0.0632
^{11}B	11.0093055	80.1	^{40}Ar	--	99.6003
C[a]	12.0107	--	Ca	40.078	--
N	14.0067	--	^{40}Ca	--	96.941
^{14}N	--	99.632	^{42}Ca	--	0.647
^{15}N	--	0.368	^{43}Ca	--	0.135
O	15.9994	--	^{44}Ca	--	2.086
^{16}O	--	99.757	^{46}Ca	--	0.004
^{17}O	--	0.038	^{48}Ca	--	0.187
^{18}O[a]	--	0.205	Ti	47.867	--
Ne	20.1797	--	^{46}Ti	--	8.25
Mg	24.3050	--	^{47}Ti	--	7.44
^{24}Mg	--	78.99	^{48}Ti	--	73.72
^{25}Mg	--	10	^{49}Ti	--	5.41
^{26}Mg	--	11.01	^{50}Ti	--	5.18
Al	26.981538	--	V[a]	50.9415	--
Si	28.0855	--	Cr	51.9961	--
^{28}Si	--	92.2297	^{50}Cr	--	4.345
^{29}Si	--	4.6832	^{52}Cr	--	83.789
^{30}Si	--	3.0872	^{53}Cr	--	9.501
P	30.973761	--	^{54}Cr	--	2.365

Table E.1-1. (cont'd.). Summary of Data Employed from the 16th Ed. of the Chart of the Nuclides.

Isotope or Element	Atomic Weight (g/mol)	Isotopic Abundance (at.%)	Isotope or Element	Atomic Weight (g/mol)	Isotopic Abundance (at.%)
Mn	54.938049	--	Mo	95.94	--
Fe	55.845	--	^{92}Mo	--	14.84
^{54}Fe	--	5.845	^{94}Mo	--	9.25
^{56}Fe	--	91.754	^{95}Mo	--	15.92
^{57}Fe	--	2.119	^{96}Mo	--	16.68
^{58}Fe	--	0.282	^{97}Mo	--	9.55
Co	58.933200	--	^{98}Mo	--	24.13
Ni	58.6934	--	^{100}Mo	--	9.63
^{58}Ni	--	68.0769	Ag	107.8682	--
^{60}Ni	--	26.2231	^{107}Ag	--	51.839
^{61}Ni	--	1.1399	^{109}Ag	--	48.161
^{62}Ni	--	3.6345	Cd	112.411	--
^{64}Ni	--	0.9256	^{106}Cd	--	1.25
Cu	63.546	--	^{108}Cd	--	0.89
^{63}Cu	--	69.17	^{110}Cd	--	12.49
^{65}Cu	--	30.83	^{111}Cd	--	12.8
Zn[(a)]	65.409	--	^{112}Cd	--	24.13
Ga	69.723	--	^{113}Cd	--	12.22
^{69}Ga	--	60.108	^{114}Cd	--	28.73
^{71}Ga	--	39.892	^{116}Cd	--	7.49
Kr	83.798	--	Sn	118.710	--
^{78}Kr	--	0.35	^{112}Sn	--	0.97
^{80}Kr	--	2.28	^{114}Sn	--	0.66
^{82}Kr	--	11.58	^{115}Sn	--	0.34
^{83}Kr	--	11.49	^{116}Sn	--	14.54
^{84}Kr	--	57	^{117}Sn	--	7.68
^{86}Kr	--	17.3	^{118}Sn	--	24.22
			^{119}Sn	--	8.59
			^{120}Sn	--	32.58
			^{122}Sn	--	4.63
			^{124}Sn	--	5.79

Table E.1-1. (cont'd.). Summary of Data Employed from the 16th Ed. of the Chart of the Nuclides.

Isotope or Element	Atomic Weight (g/mol)	Isotopic Abundance (at.%)	Isotope or Element	Atomic Weight (g/mol)	Isotopic Abundance (at.%)
Ba	137.327	--	Gd	157.25	--
^{130}Ba	--	0.106	^{152}Gd	--	0.2
^{132}Ba	--	0.101	^{154}Gd	--	2.18
^{134}Ba	--	2.417	^{155}Gd	--	14.8
^{135}Ba	--	6.592	^{156}Gd	--	20.47
^{136}Ba	--	7.854	^{157}Gd	--	15.65
^{137}Ba	--	11.232	^{158}Gd	--	24.84
^{138}Ba	--	71.698	^{160}Gd	--	21.86
Sm	150.36	--	Dy	162.500	--
^{144}Sm	--	3.07	^{156}Dy	--	0.06
^{147}Sm	--	14.99	^{158}Dy	--	0.1
^{148}Sm	--	11.24	^{160}Dy	--	2.34
^{149}Sm	--	13.82	^{161}Dy	--	18.91
^{150}Sm	--	7.38	^{162}Dy	--	25.51
^{152}Sm	--	26.75	^{163}Dy	--	24.9
^{154}Sm	--	22.75	^{164}Dy	--	28.18
Eu	151.964	--	Pb	207.2	--
^{151}Eu	--	47.81	^{204}Pb	--	1.4
^{153}Eu	--	52.19	^{206}Pb	--	24.1
			^{207}Pb	--	22.1
			^{208}Pb	--	52.4
			Bi	208.98038	--
			^{234}U	234.040946	0.0055[(b)]
			^{235}U	235.043923	0.7200[(b)]
			^{238}U	238.050783	99.2745[(b)]

a. Natural element without isotopic breakdown.
b. Neutronically, ^{18}O is treated as ^{16}O.
c. Natural isotopic abundance of U.

APPENDIX F: MODELS SPECIFICATION FOR SCALED REACTIVITY EFFECTS DATA

F.1 Evaluated Measurements (NOT BENCHMARK MEASUREMENTS)

As discussed in Section 2.4, various reported reactivity effects measurements were actually measured on other HTR-PROTEUS core configurations and then scaled via a ratio of control rod bank worths for the core on which the original measurement was performed and the core on which the measurement was applied to allow for model simplifications. Where sufficient information was available, these scaled measurements were evaluated but not considered appropriate to use as benchmark data. A summary of the evaluated scaled measurements in provided in Table F.1-1 for Core 9 and Table F.1-2 for Core 10. Means to model the scaled measurements and sample calculations are provided in subsequent sections of this appendix.

Table F.1-1. Adjusted Experimental Reactivity Effects Scaled Measurements (Core 9).

Case	Measured Parameter	Benchmark Measurement?	Experimental Worth		
			ρ($)	**±**	**σ**
1.F-1	Autorod Rest Worth	No	-0.13	±	0.01
1.F-2	Graphite in Control Rod Channels	No	-0.026	±	0.003
1.F-3	Graphite in Empty Channels: R2-15, -47, & -63	No	-0.05	±	0.01

Table F.1-2. Adjusted Experimental Reactivity Effects Scaled Measurements (Core 10).

Case	Measured Parameter	Benchmark Measurement?	Experimental Worth		
			ρ($)	**±**	**σ**
2.F-1	Autorod Rest Worth	No	-0.081	±	0.005
2.F-2	Graphite in Control Rod Channels	No	-0.021	±	0.002
2.F-3	Graphite in Empty Channels: R2-15, -47, & -63	No	-0.04	±	0.01

F.2 Modeling Specifications

Simplifications and discussions provided in Section 3.4 also apply to the models discussed in Appendix F. Only information unique to the simulation of the scaled measurements provided in Table F.1-1 are included herein; all other details for model development are provided as benchmark models in Section 3.1 and 3.4.

F.2.1 Dimensions Supplemental Data

F.2.1.1 Autorod Worths

The rest worth of the autorod is obtained by fully withdrawing the autorod and then comparing this condition with a similar configuration in which the autorod is replaced with void.

F.2.1.2 Graphite Plug Worths

The locations of the control rod channels and channels R2-15, -47, and -63 are shown in Figure F.1-1. The x-y positions are shown in the figure. The worth of the graphite plugs in the four control rod channels is obtained by taking the benchmark critical configurations (Section 3.1), replacing the control rod components with void, and comparing the condition of voided control rod channels with one in which the channels are filled with graphite. The worth of the graphite plugs in the three R2 positions is obtained by taking the benchmark critical configurations and adding in the three, void-filled, R2 channels that have a diameter of 2.743 cm and run through the full height of the radial reflector. The modified configurations are then compared with the condition where the three voided channels are filled with graphite.

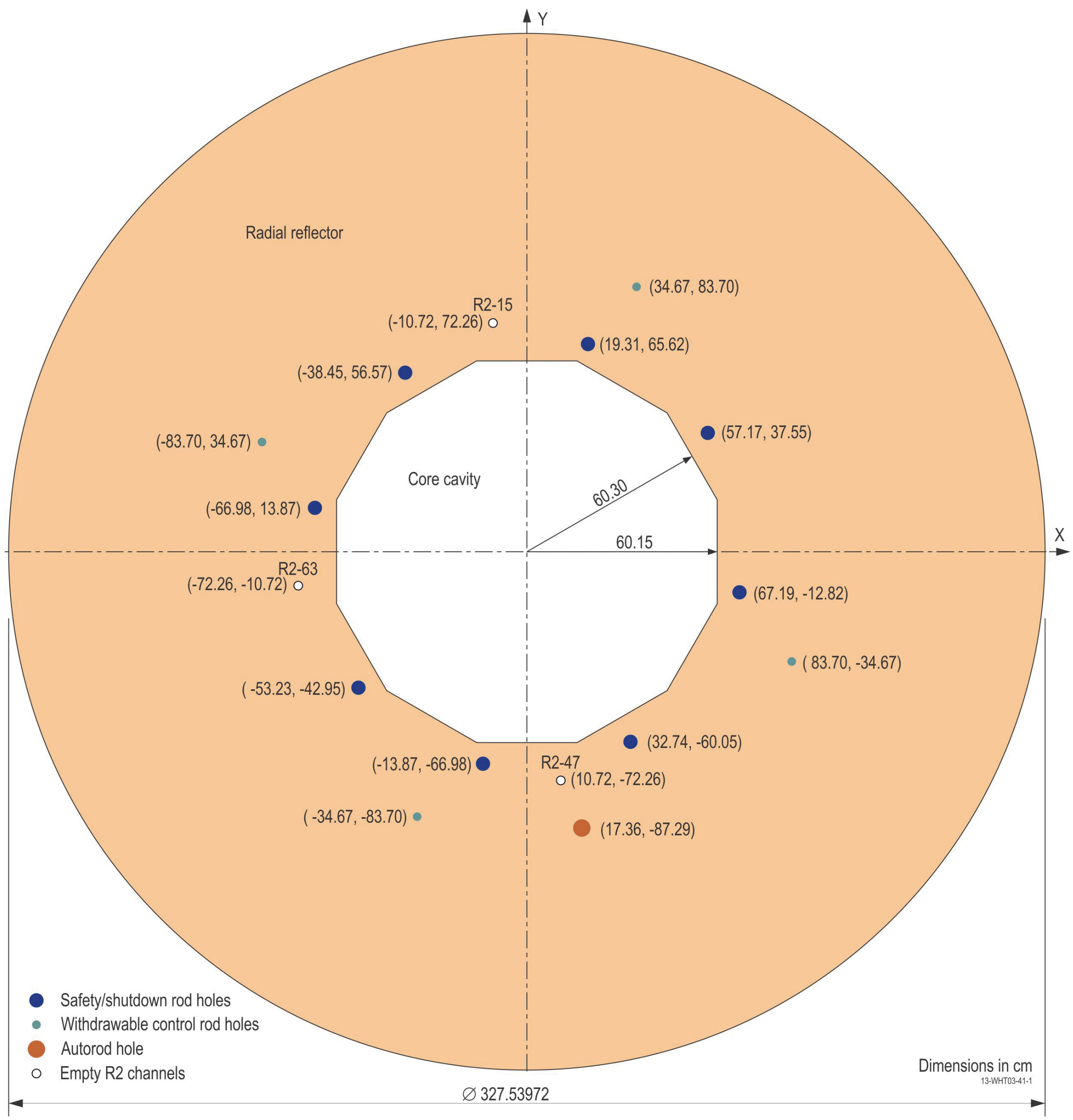

Figure F.1-1. Radial Reflector Surrounding Core Cavity Region Including Empty R2 Channel Positions.

F.2.2 Material Data Supplemental Data

F.2.2.1 Graphite Plug Worths

The graphite plugs have the compositions provided in Table F.1-2, which is the same plug graphite used in the upper axial reflector in Section 3.1.3.2.

Table F.1-2. Graphite Plug Compositions.

Component	Plugs in Radial Reflector
Isotope/Element	**Atoms/barn-cm**
^{10}B	2.3422E-08
^{11}B	9.4278E-08
C	8.8496E-02
Total	8.8496E-02
Mass Density (g/cm^3)	1.765

F.3 Sample Calculations for Scaled Measurements

The benchmark models described in Section 3.1 were modified as discussed in this appendix and used with MCNP5-1.60 (see Appendix A.1 and A.4 for input deck descriptions) and ENDF/B-VII.0 neutron cross section data. For additional details regarding how the TRISO particles were modeled, see Section 4.1. Monte Carlo calculations were performed with 1,650 generations with 100,000 neutrons per generation. The k_{eff} estimates are based on 150 skipped generations and a total of 150,000,000 neutron histories each.

The difference between various configurations, as described in Section 3.4.2, were simulated to calculate reactivity worths ($\Delta k/k$). These worths were then converted into units of ρ($) using a β_{eff} value of 0.00693 ± 0.00035 (5 %, 1σ) for Core 9 and 0.00685 ± 0.00034 (5 %, 1σ) for Core 10. The Monte Carlo statistical uncertainty is approximately $0.01. The uncertainty in the calculated values provided in this section also include the uncertainty in β_{eff}; therefore, calculations using additional neutron cross section libraries were not performed.

The worth of a control rod is calculated using the following equation:

$$\rho(\$) = \frac{k_{inserted} - k_{withdrawn}}{k_{inserted} \times k_{withdrawn}} \times \frac{1}{\beta_{eff}}.$$

Worth calculations for other parameters are similarly calculated by comparing the eigenvalues for configurations both with and without a given reactor component.

Results are provided in Table F.1-3 for Core 9 and Table F.1-4 for Core 10. There is generally good agreement between calculated and scaled worths. Most calculations are within 1σ to 2σ of the scaled experimental values. At the time of this evaluation the statistical uncertainty in MCNP calculations of the HTR-PROTEUS models is ~1 ¢; it is not practical to further reduce this uncertainty with currently available computing resources.

Table F.1-3. Sample Calculations for Reactivity Effects Scaled Measurements (Core 9).

Case	**Measured Parameter**	**Scaled Worth**			**Calculated Worth**			$\frac{C-E}{E}(\%)$	**±**	**σ**[(a)]
		ρ($)	**±**	**σ**	**ρ($)**	**±**	**σ**			
1.F-1	Autorod Rest Worth	-0.13	±	0.01	-0.13	±	0.02	0	±	17
1.F-2	Graphite in Control Rod Channels	-0.026	±	0.003	-0.02	±	0.01	-23	±	39
1.F-3	Graphite in Empty Channels: R2-15, -47, & -63	-0.05	±	0.01	-0.04	±	0.01	-20	±	26

(a) The uncertainty in $\frac{C-E}{E}(\%)$ is calculated by propagating the uncertainties in both the calculated and scaled experiment eigenvalues using the following equation: $\sigma = 100\% \times \sqrt{\left(\frac{\sigma_C}{E}\right)^2 + \left(\frac{\sigma_E C}{E^2}\right)^2}$.

Table F.1-4. Sample Calculations for Reactivity Effects Scaled Measurements (Core 10).

Case	**Measured Parameter**	**Scaled Worth**			**Calculated Worth**			$\frac{C-E}{E}(\%)$	**±**	**σ**[(a)]
		ρ($)	**±**	**σ**	**ρ($)**	**±**	**σ**			
2.F-1	Autorod Rest Worth	-0.081	±	0.005	-0.09	±	0.01	11	±	14
2.F-2	Graphite in Control Rod Channels	-0.021	±	0.002	-0.01	±	0.01	-52	±	48
2.F-3	Graphite in Empty Channels: R2-15, -47, & -63	-0.04	±	0.01	-0.05	±	0.01	25	±	40

(a) The uncertainty in $\frac{C-E}{E}(\%)$ is calculated by propagating the uncertainties in both the calculated and scaled experiment eigenvalues using the following equation: $\sigma = 100\% \times \sqrt{\left(\frac{\sigma_C}{E}\right)^2 + \left(\frac{\sigma_E C}{E^2}\right)^2}$.