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Rev. 1

HTR-Proteus Pebble Bed Experimental Program Cores 1, 1A, 2, and 3: Hexagonal Close Packing with a 1:2 Moderator-to-Fuel Pebble Ratio

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Gas Cooled (Thermal) Reactor – GCR

PROTEUS-GCR-EXP-001
CRIT

HTR-PROTEUS PEBBLE BED EXPERIMENTAL PROGRAM CORES 1, 1A, 2, and 3: HEXAGONAL CLOSE PACKING WITH A 1:2 MODERATOR-TO-FUEL PEBBLE RATIO

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Gas Cooled (Thermal) Reactor – GCR

PROTEUS-GCR-EXP-001
CRIT

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	NA	NA	NA	NA
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	NA	NA	NA	NA
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	NA	NA	NA	NA
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	NA	NA	NA	NA
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 1, 1A, 2, and 3: HEXAGONAL CLOSE PACKING WITH A 1:2 MODERATOR-TO-FUEL PEBBLE RATIO

IDENTIFICATION NUMBER: PROTEUS-GCR-EXP-001
CRIT

KEY WORDS: 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) 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. Reference 4 documents the measured reactivity effects associated with the initial critical assembly, Core 1. 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.

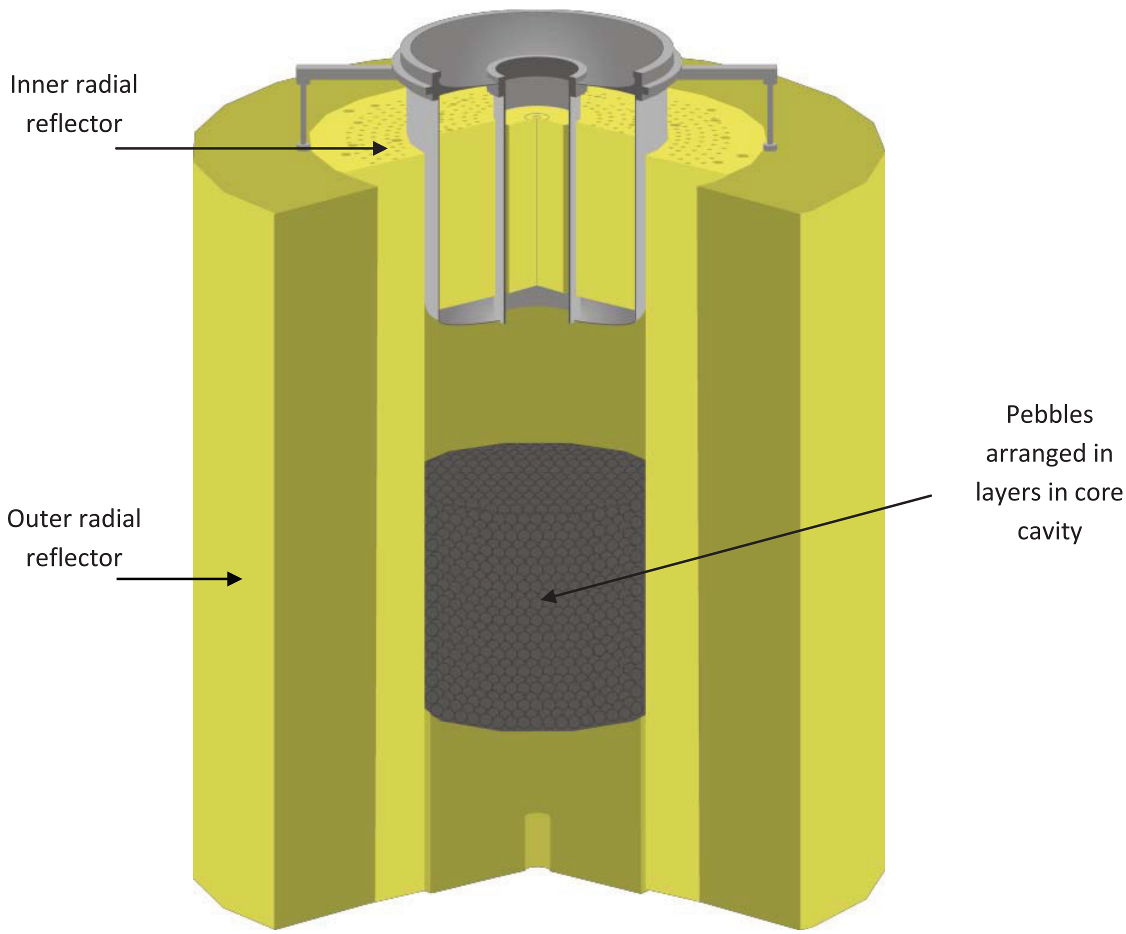

Figure 1.0-1. Generic HTR-PROTEUS configuration (derived from Ref. 2).

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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).

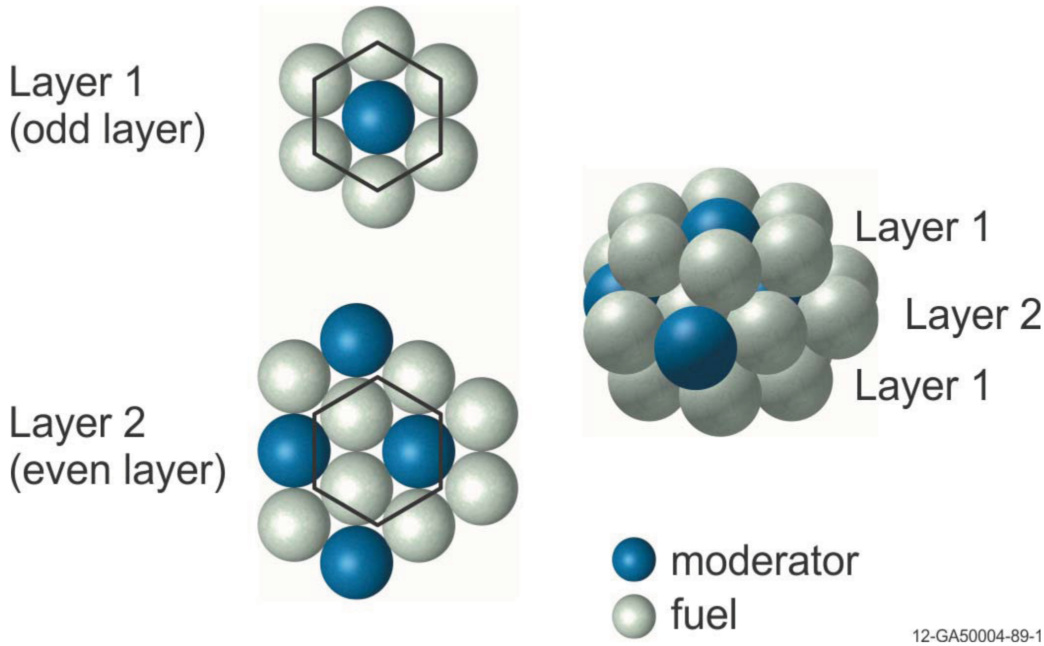

Figure 1.0-2. Subunit for Construction of the Hexagonal Close-Packed (HCP) Cell.

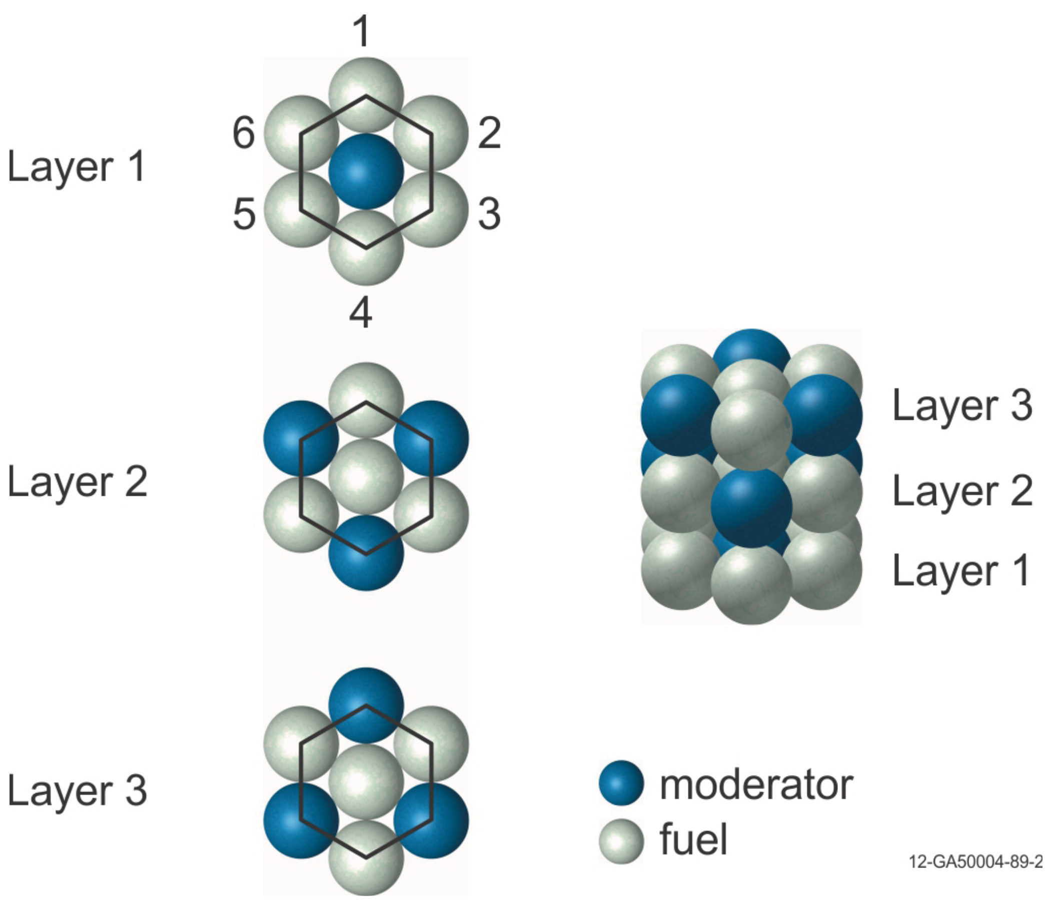

Figure 1.0-3. Subunit for Construction of the Columnar Hexagonal Point-On-Point (CHPOP) Cell.

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.

1.1 Description of the Critical and / or Subcritical Configuration

1.1.1 Overview of Experiment

Only Cores 1, 1A, 2, and 3 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 1, 1A, 2, and 3 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.

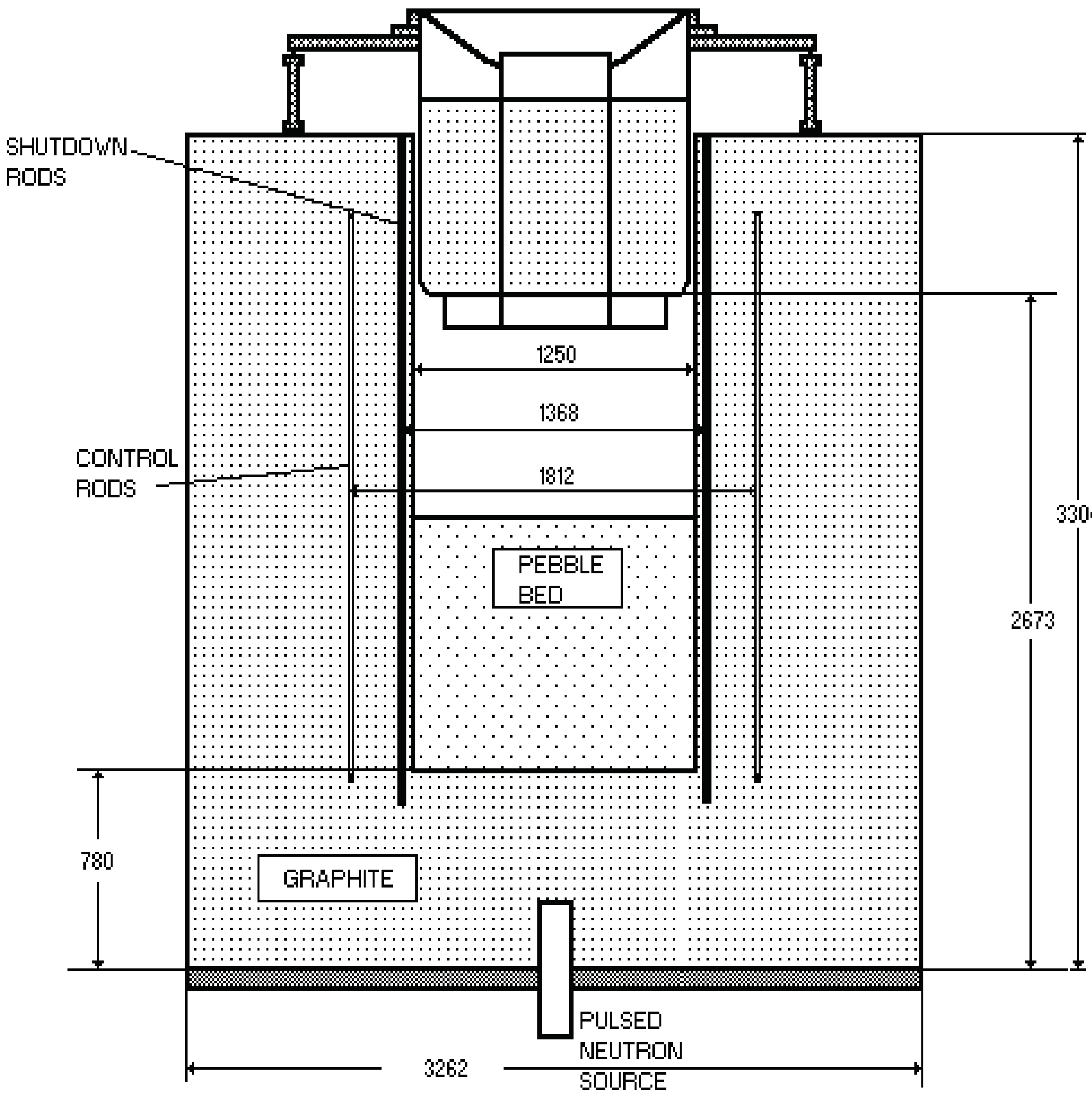

Figure 1.1-1. Schematic side view of the HTR-PROTEUS facility (dimensions in mm), (Ref. 2 and 3).

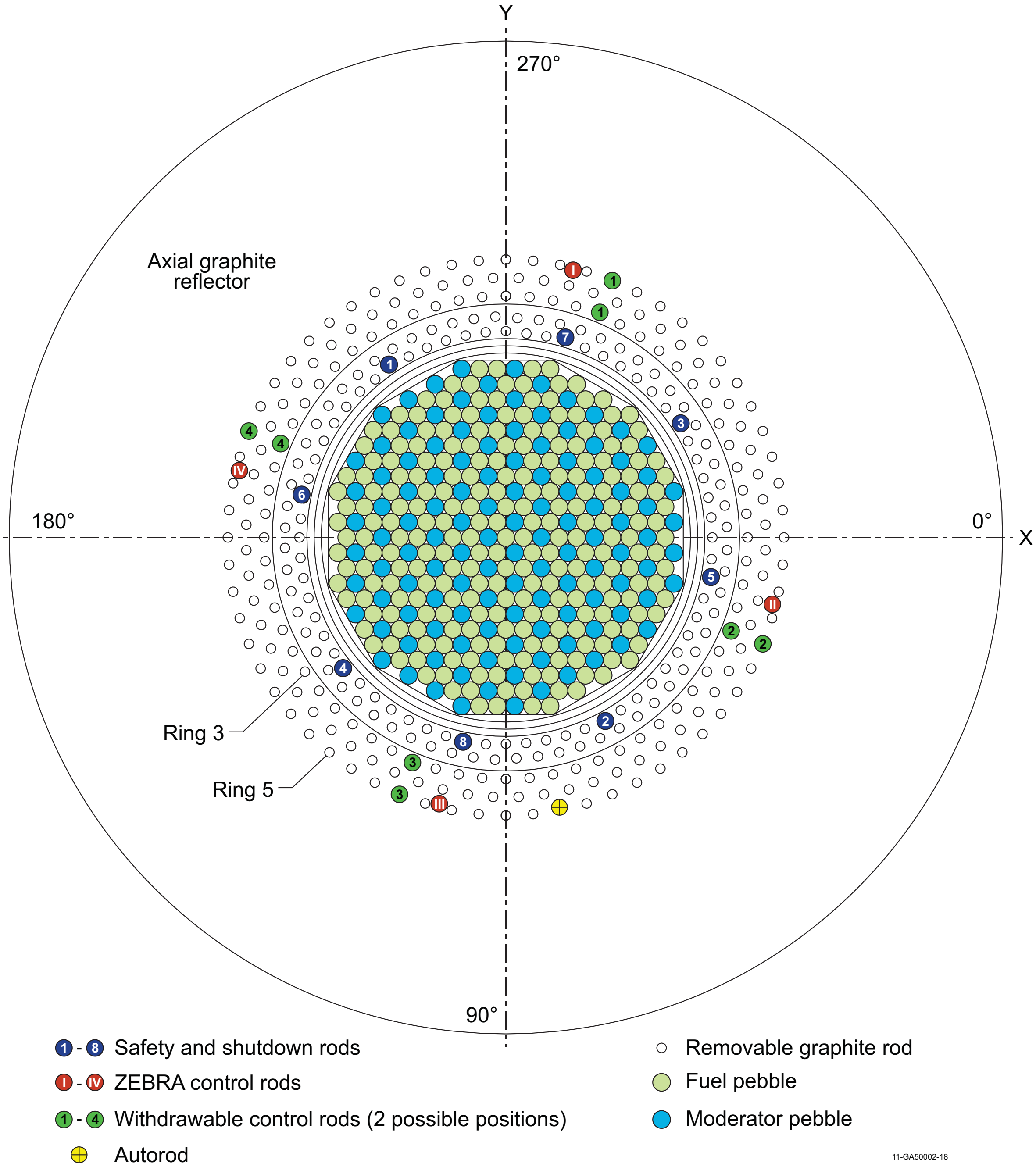

Figure 1.1-2a. HTR-PROTEUS control rod positions and bore hole locations (derived from Ref. 2).

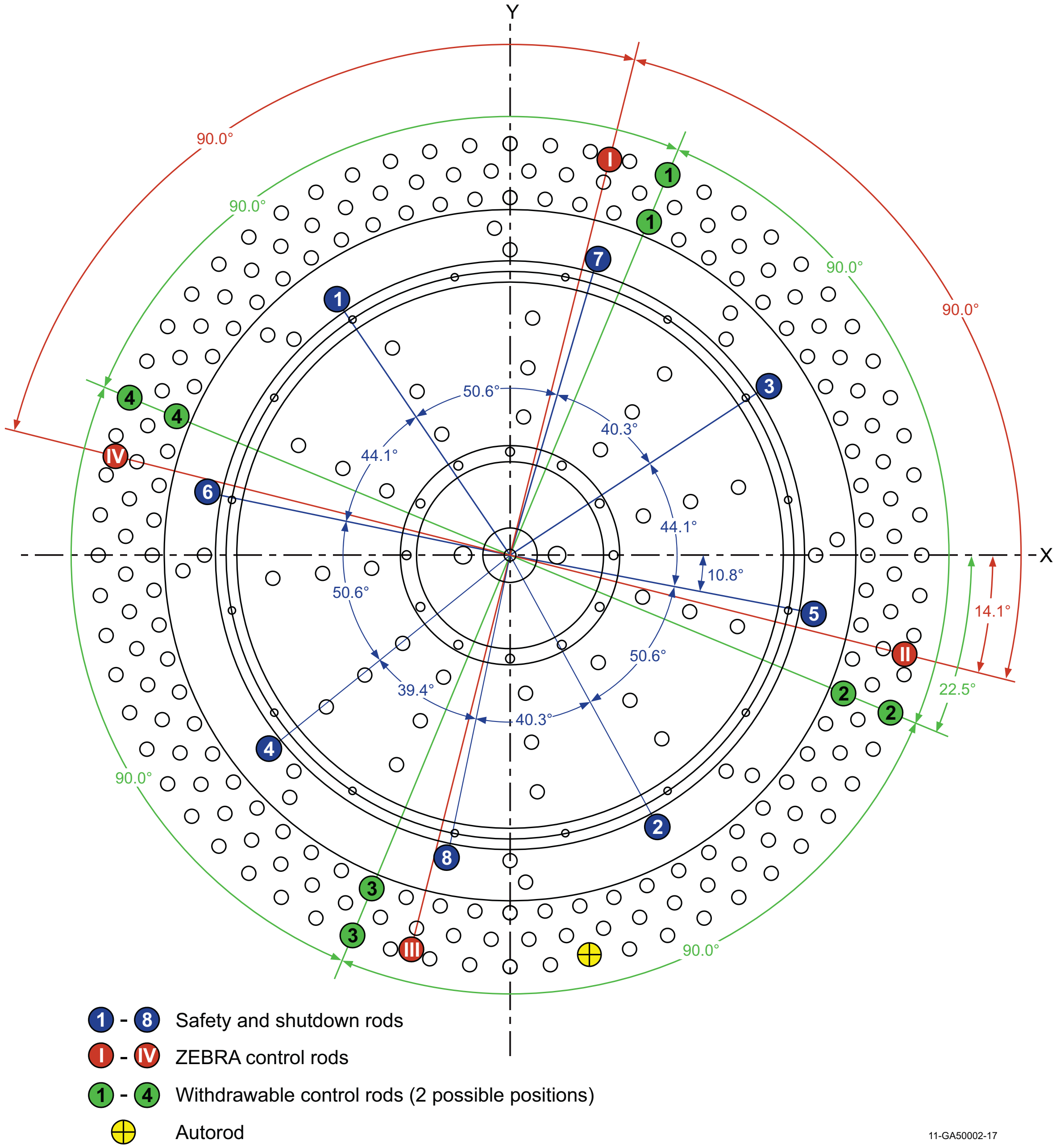

Figure 1.1-2b . HTR-PROTEUS control rod positions and bore hole locations (Ref. 2).

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 (Ref. 4).

Steel Plate Pedestal

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

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.[a]

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.[b]

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] 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).

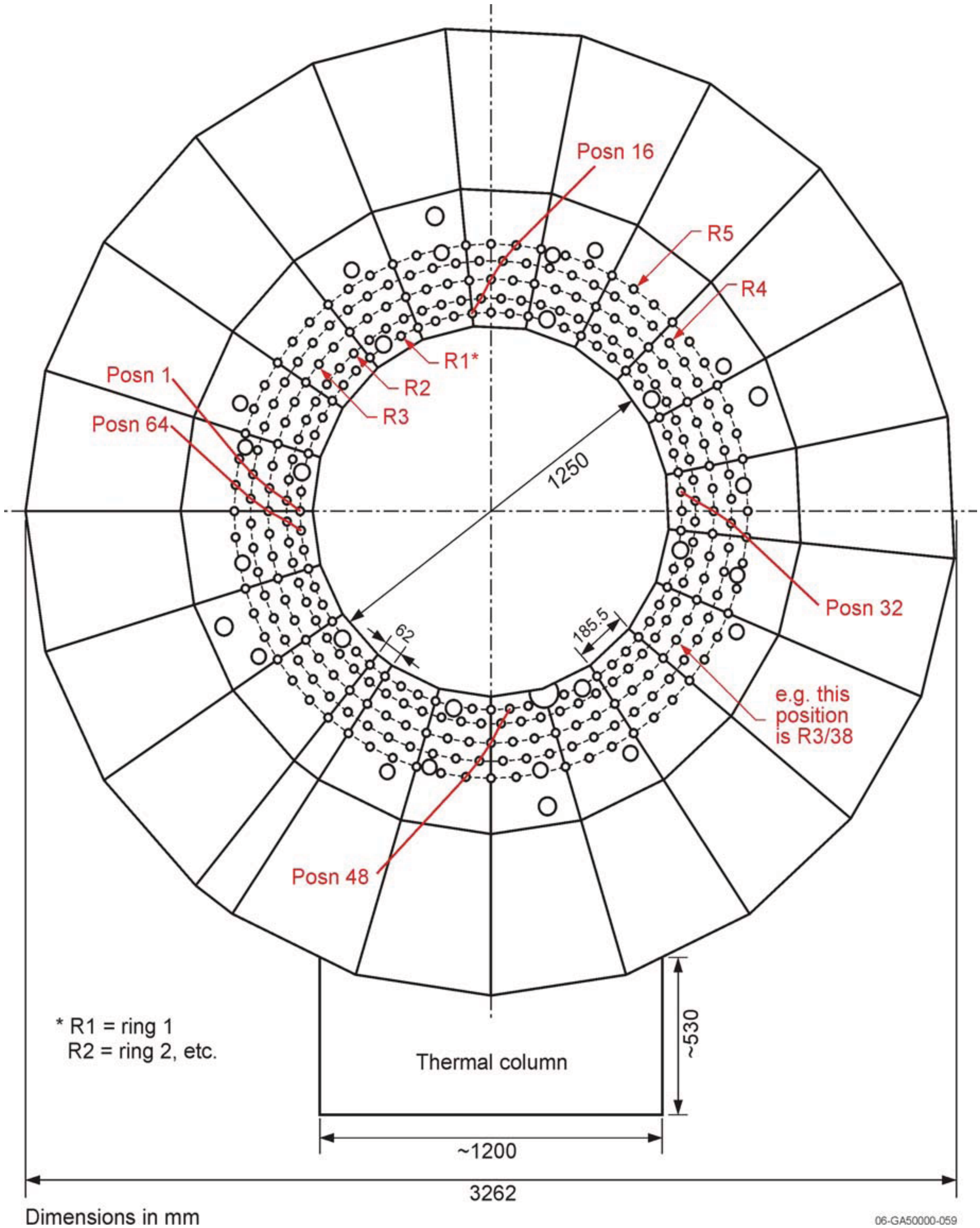

Figure 1.1-3. Cross section view of the radial reflector (Ref. 2).

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).

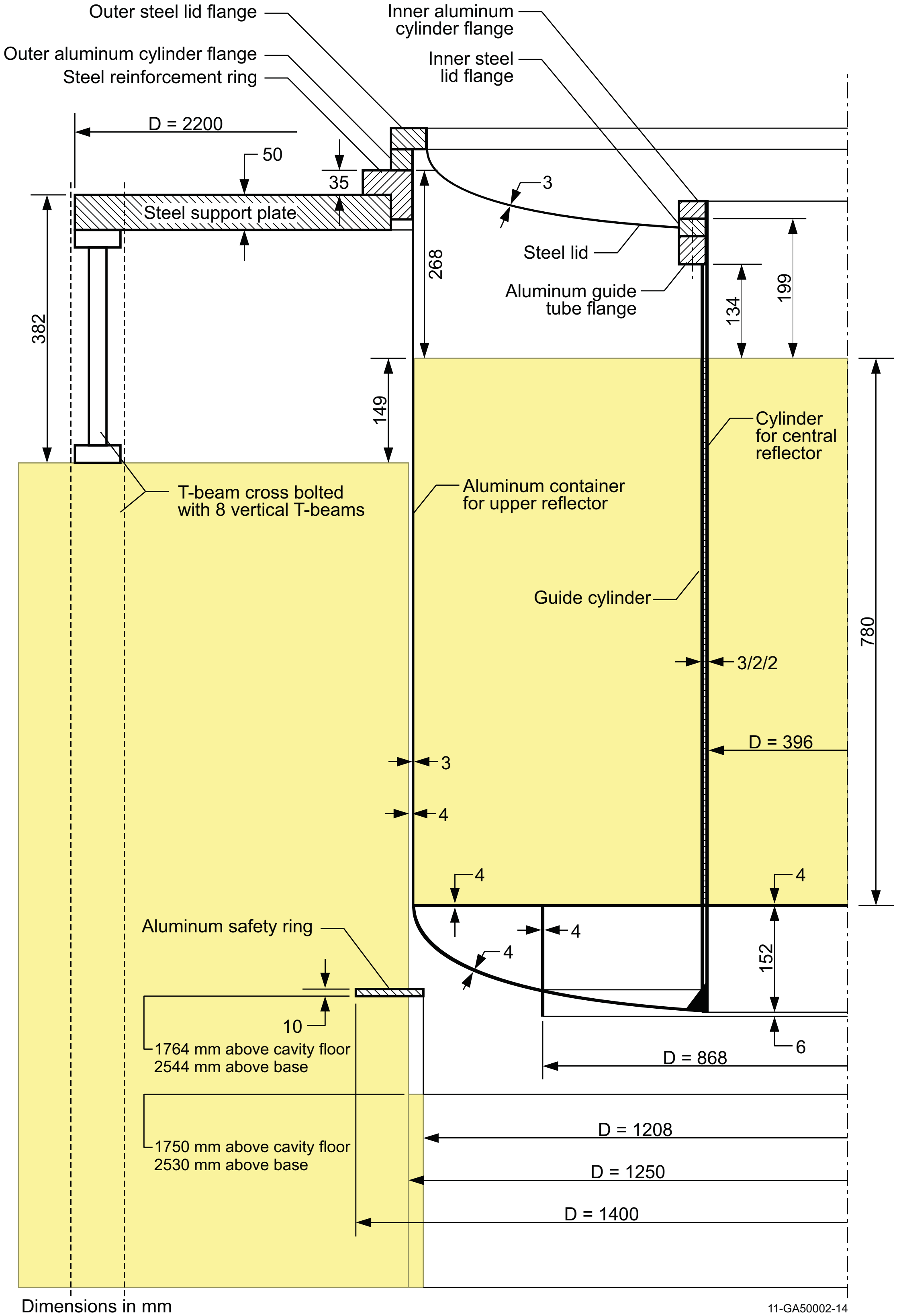

Figure 1.1-4. Placement of the upper axial reflector (Ref. 2).

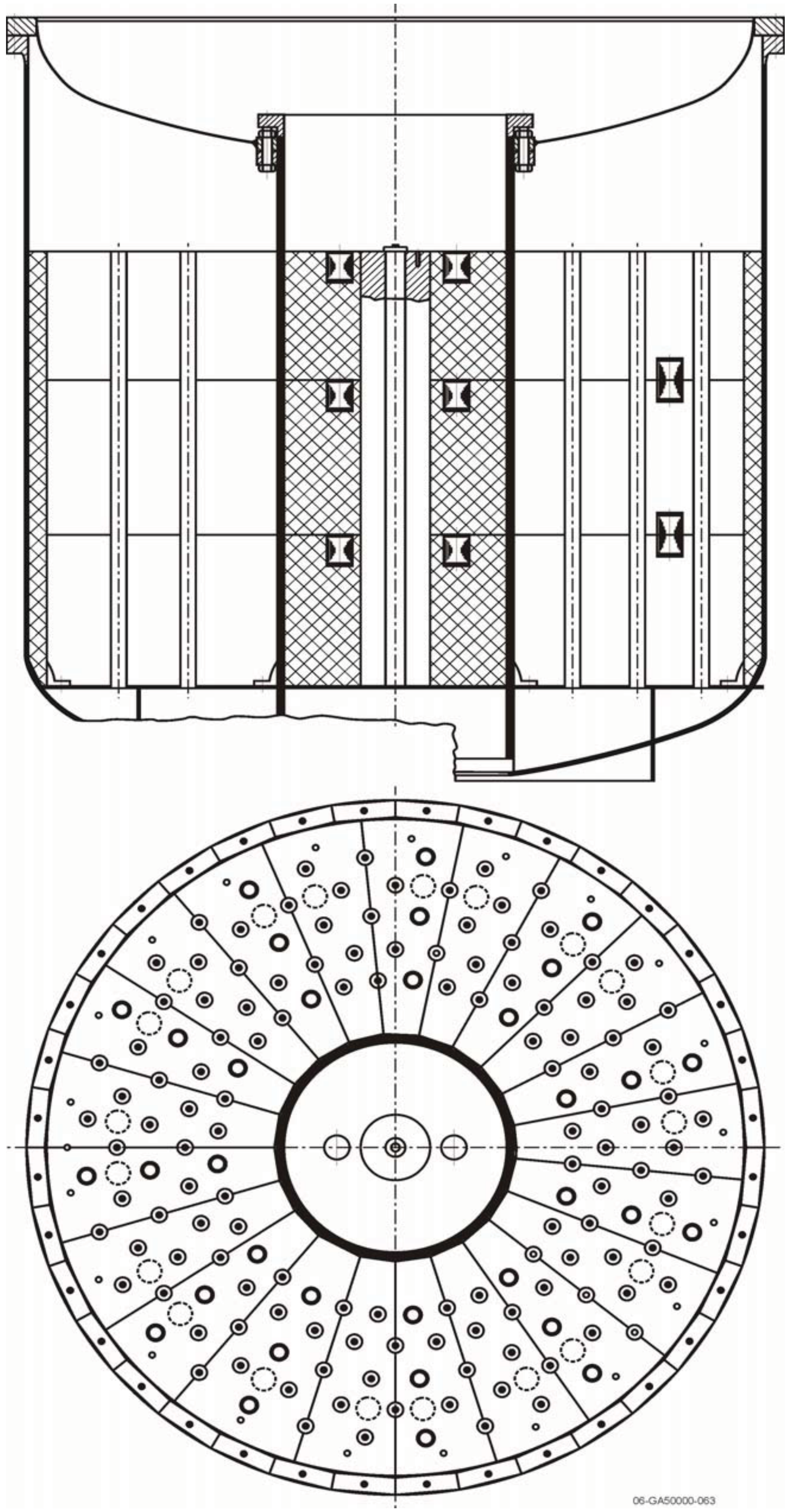

Figure 1.1-5. Non-dimensional cross sections of the upper axial reflector (Ref. 2).

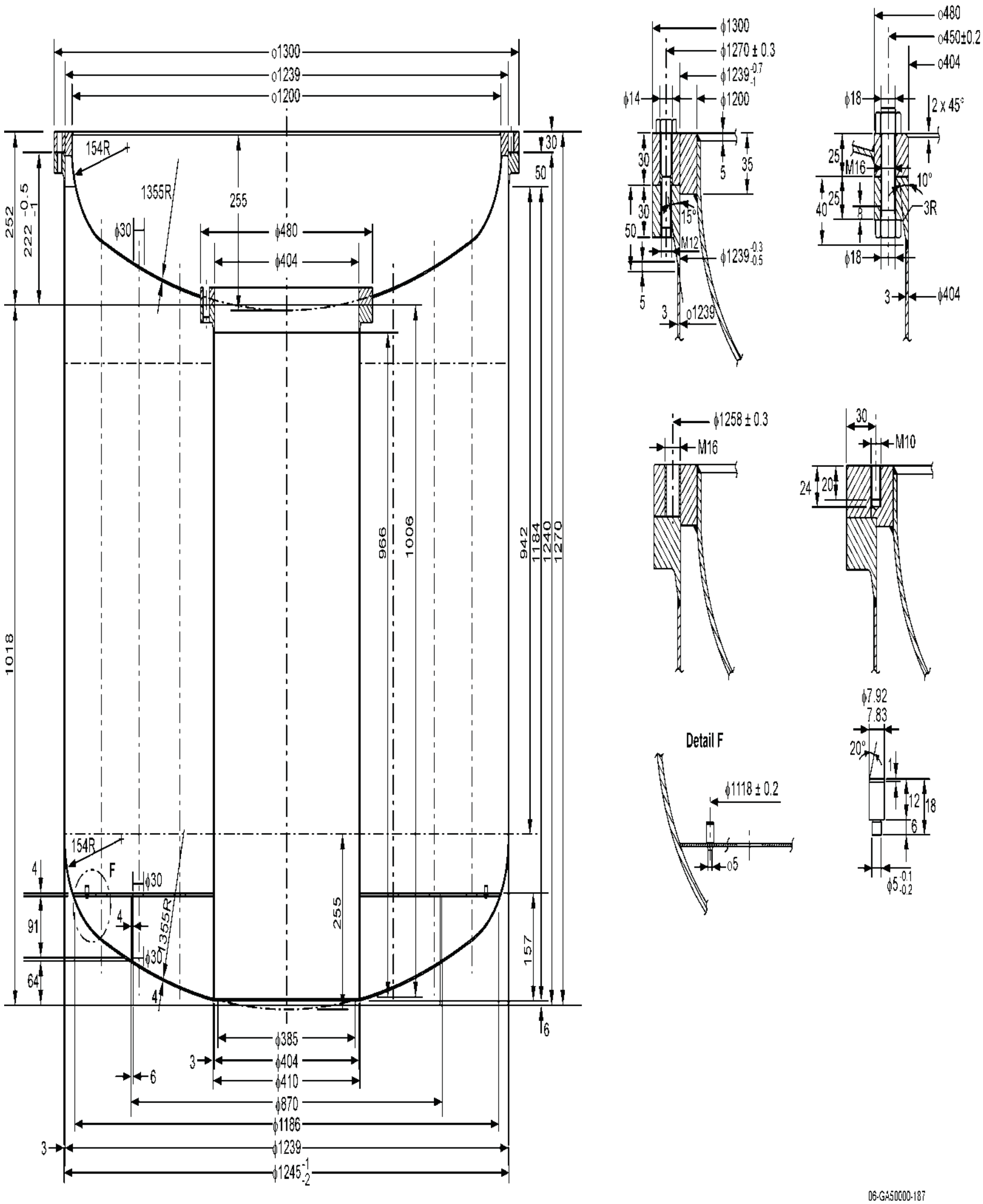

Figure 1.1-6. Details of the main aluminum structure of the upper axial reflector (Ref. 2).
Units are in millimeters.

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).

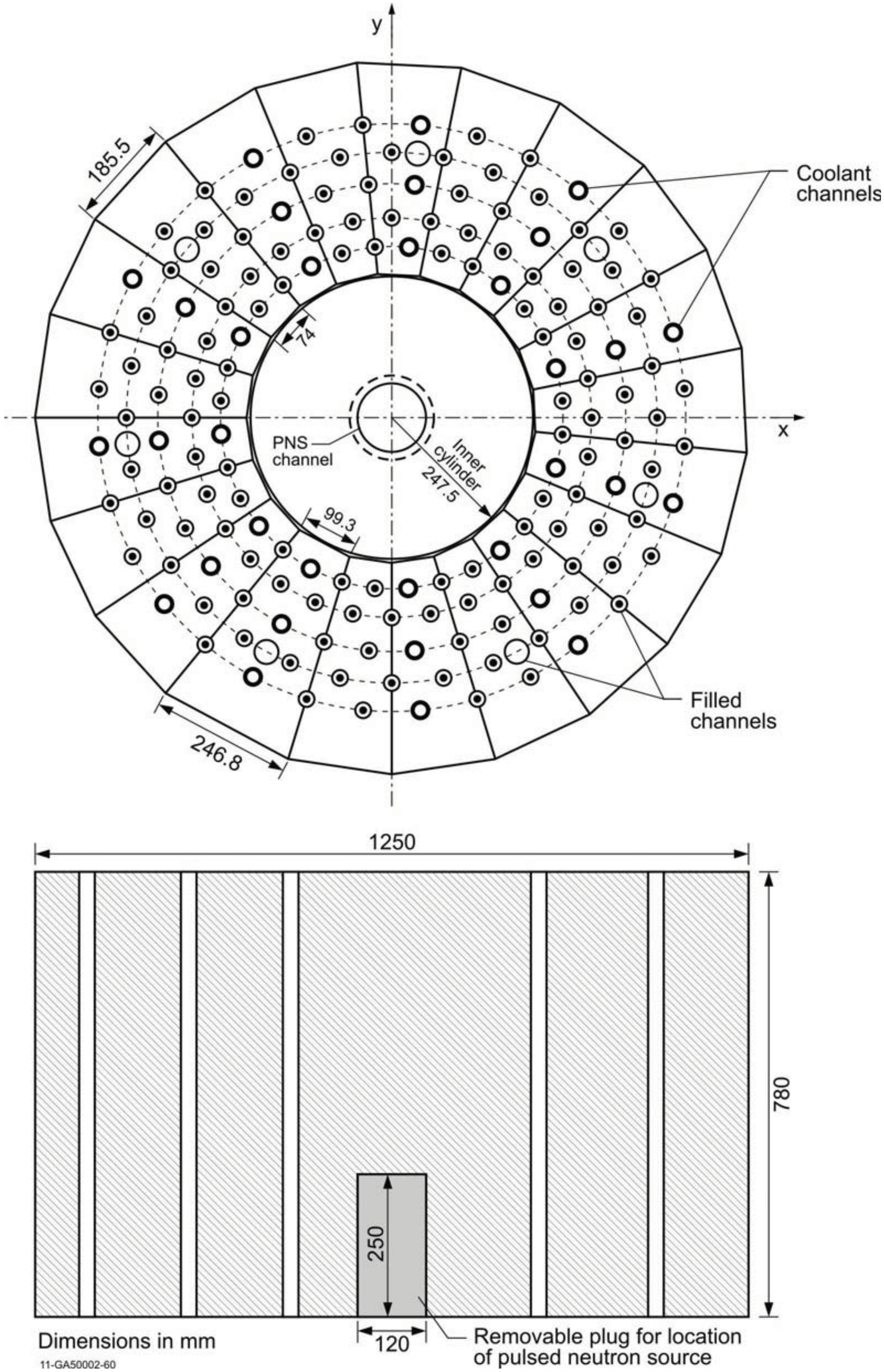

Figure 1.1-7. Details of the lower axial reflector. Note the 33 coolant channels, the small air gap between outer and inner parts, and the position of the pulsed source channel (Ref. 2).

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]

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[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).

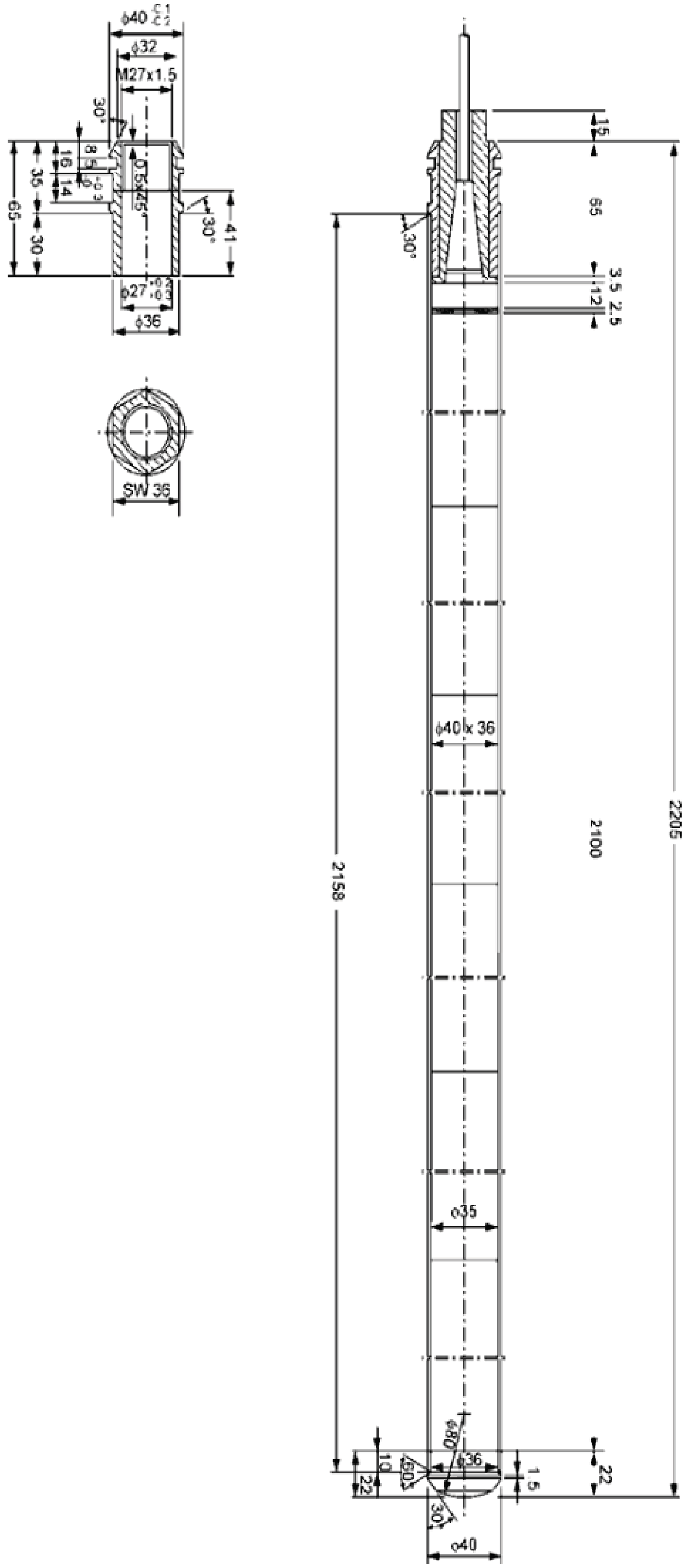

Figure 1.1-8. Details of safety/shutdown rods (Ref. 2). Units are in millimeters.

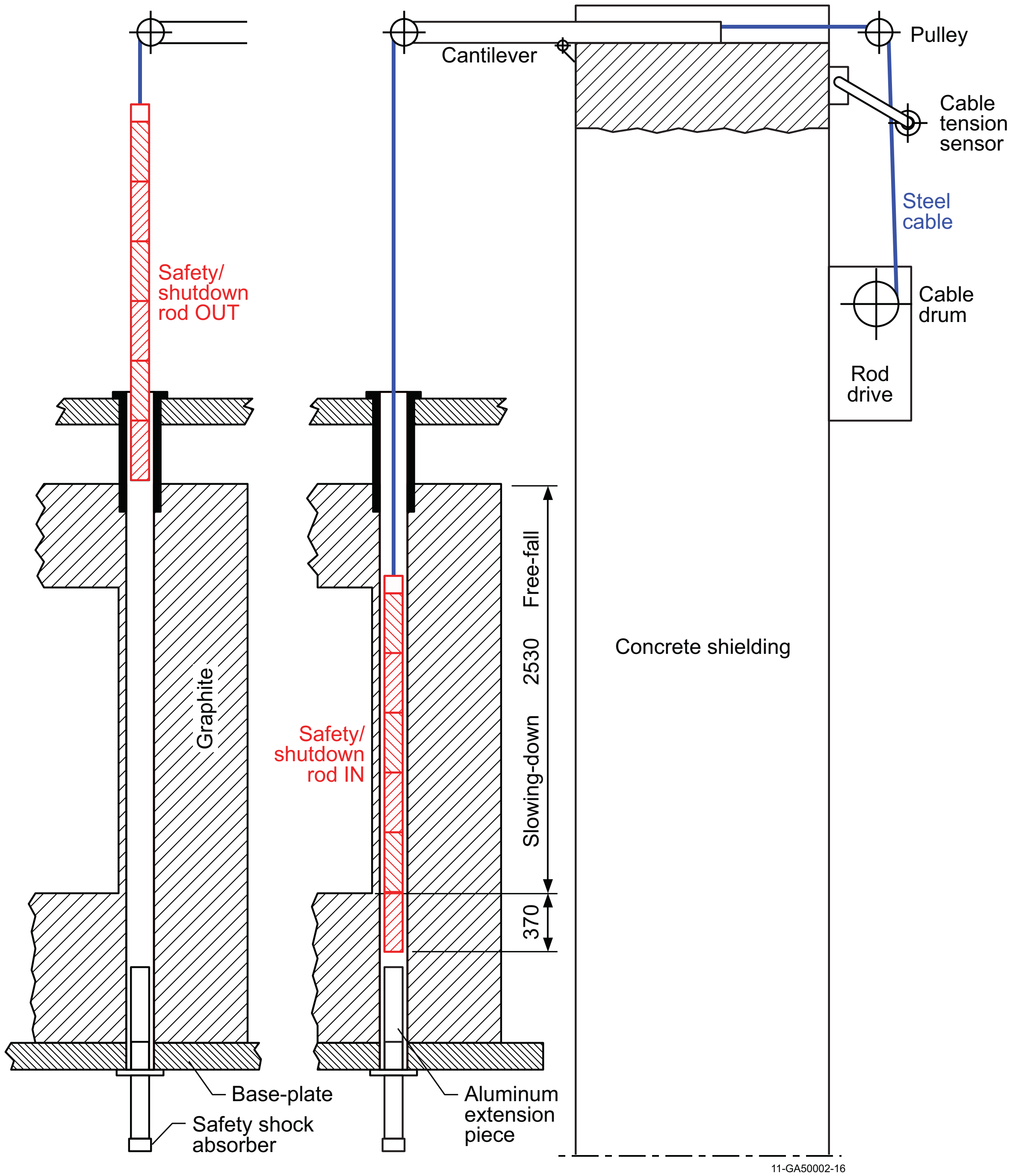

Figure 1.1-9. Safety/shutdown rod movement (Ref. 2). Units are in millimeters.

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 ($\beta_{eff} = 0.00723$) and an uncertainty of around 5 %. The autorod response was intercalibrated with the ZEBRA (and later withdrawable) control rods (Ref. 4).

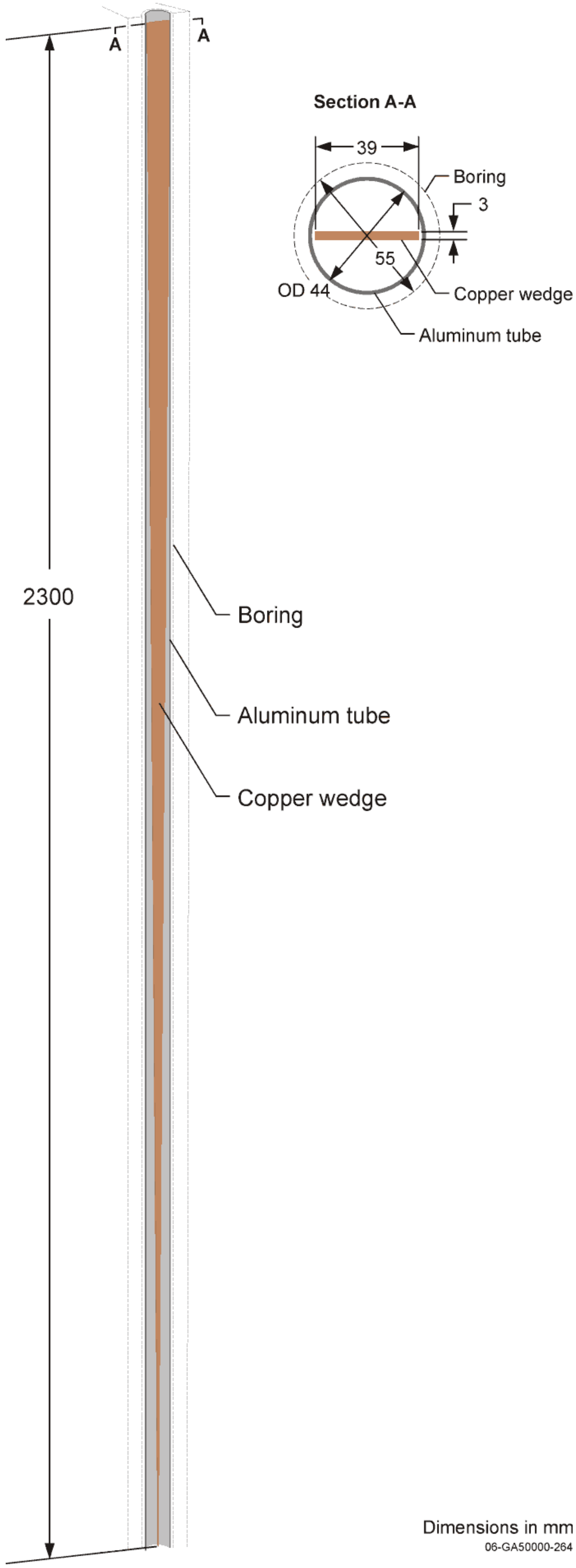

Figure 1.1-10. Automatic control rod (derived from Ref. 2).

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).

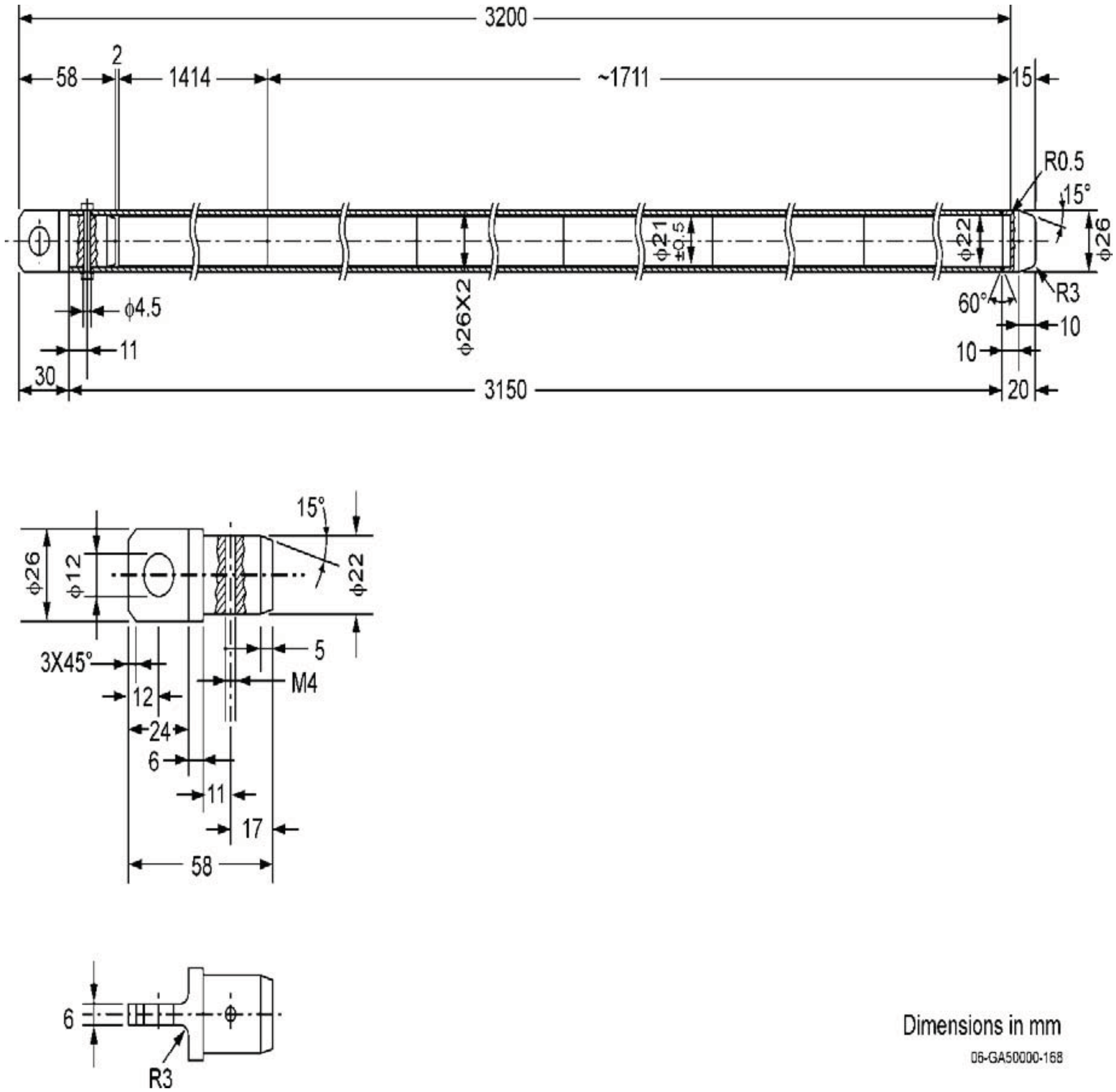

Figure 1.1-11. Details of the long static measurement rod (Ref. 2).

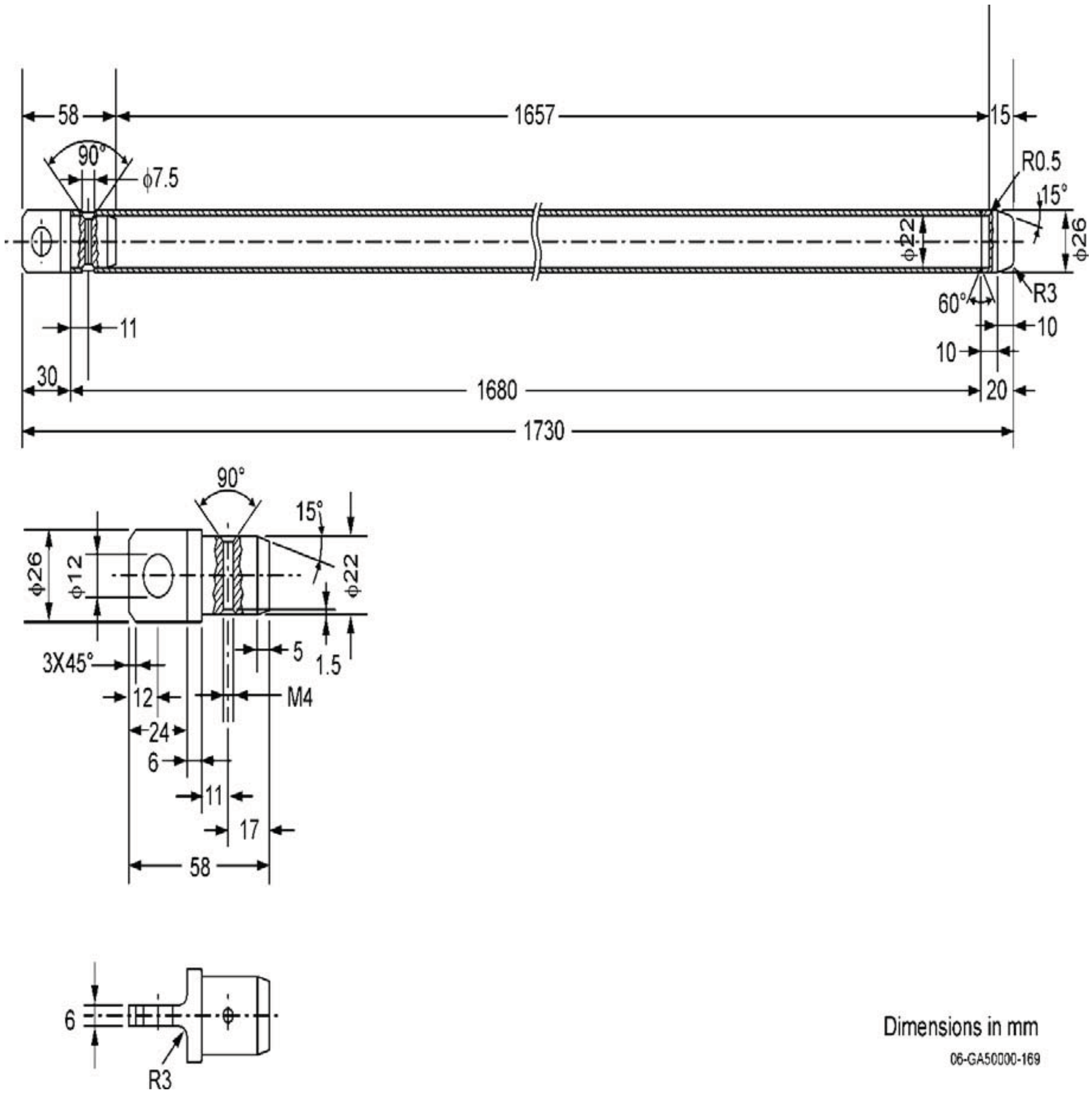

Figure 1.1-12. Details of the short static measurement rod (Ref. 2).

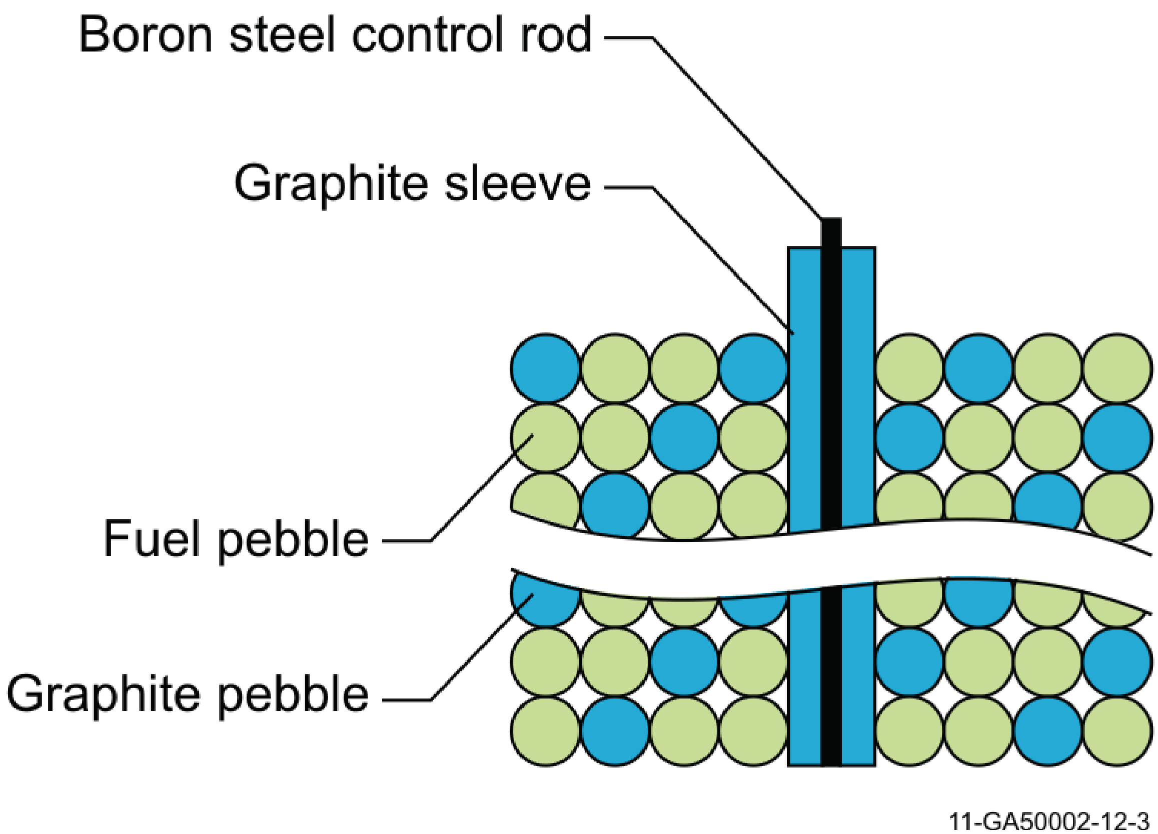

Figure 1.1-13. Graphite sleeve for short static measurement rod (Ref. 2).

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.

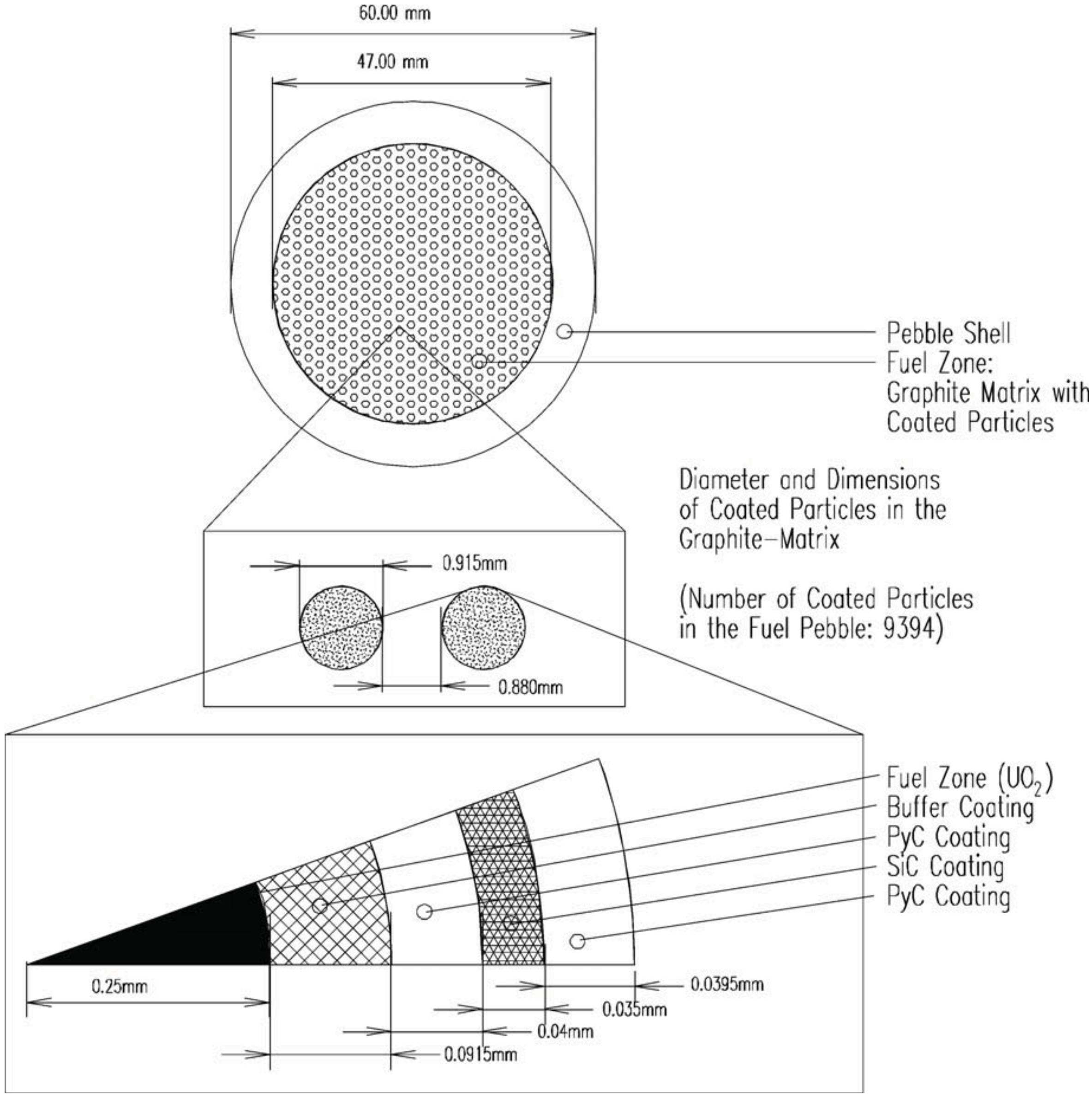

Figure 1.1-14. HTR-PROTEUS fuel pebble and coated fuel particle (Ref. 2 and 3).

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 (Refs. 3 and 4).

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 (Refs. 3 and 4).

Temperature Sensors

There are typically four separate temperature sensors in the system: two in the core and two in the radial reflector (Refs. 3 and 4).

1.1.2.2 Components Unique to Cores 1, 1A, 2, and 3

The following components are unique to core configurations 1, 1A, 2, and 3.

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 1, 1A, 2, and 3.

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 and 1.1-16 (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]

In addition to the aforementioned twelve panels, every even layer, namely 2, 4, 6, etc., in this type of configuration required six additional horizontal pieces to replace the missing partial pebbles at the core reflector interface. These graphite filler pieces serve as lattice supports. The six pieces are grouped into two different types, three of each; the characteristics of these pieces are shown in Figures 1.1-16 and 1.1-17 (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] Difilippo, F. C., "Applications of Monte Carlo Simulations of Thermalization Processes to the Nondestructive Assay of Graphite," *Nucl. Sci. Eng.*, **133**, 163-177 (1999).

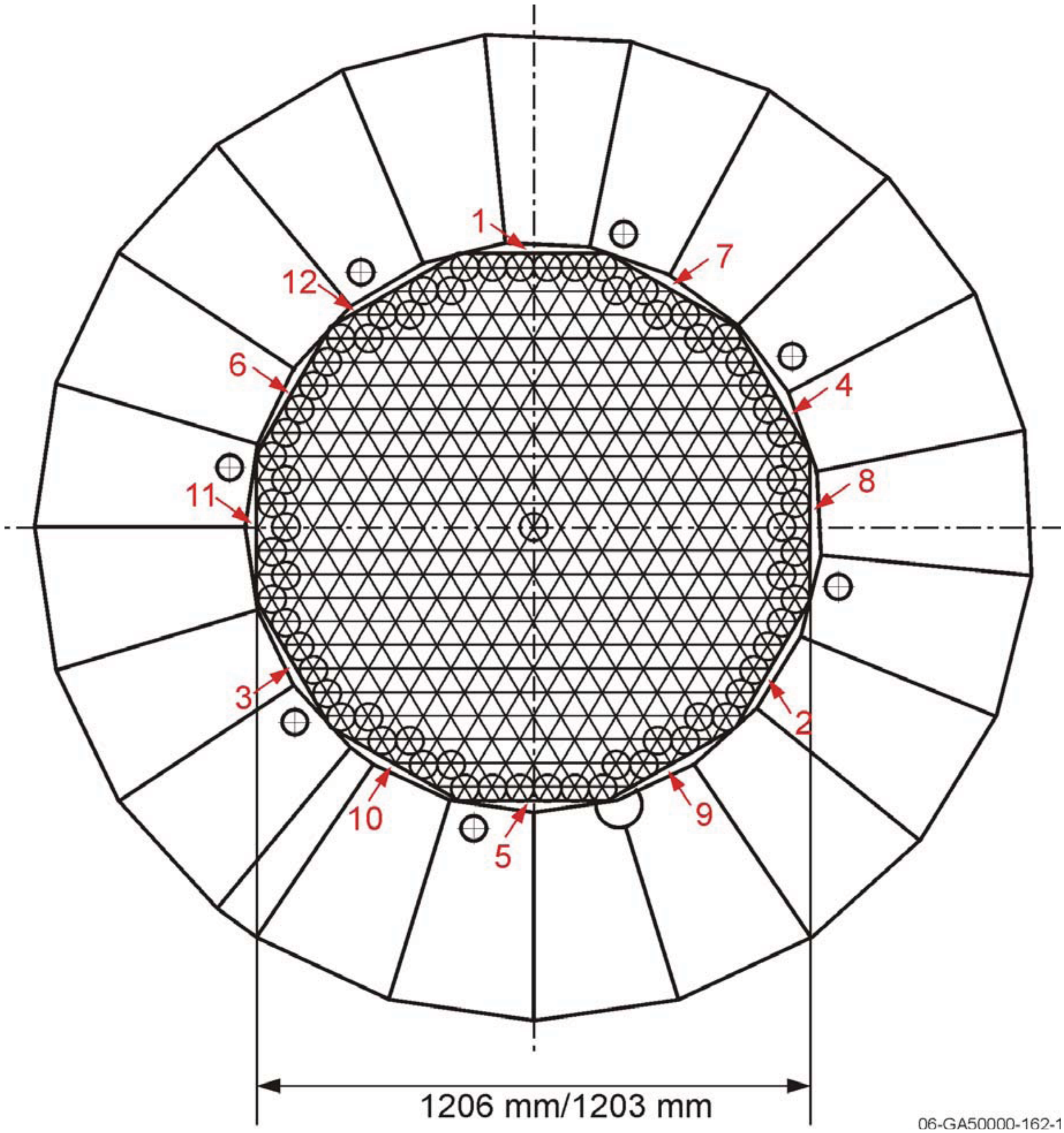

Figure 1.1-15. Positioning of the graphite filler pieces used in the deterministic cores (Ref. 2).

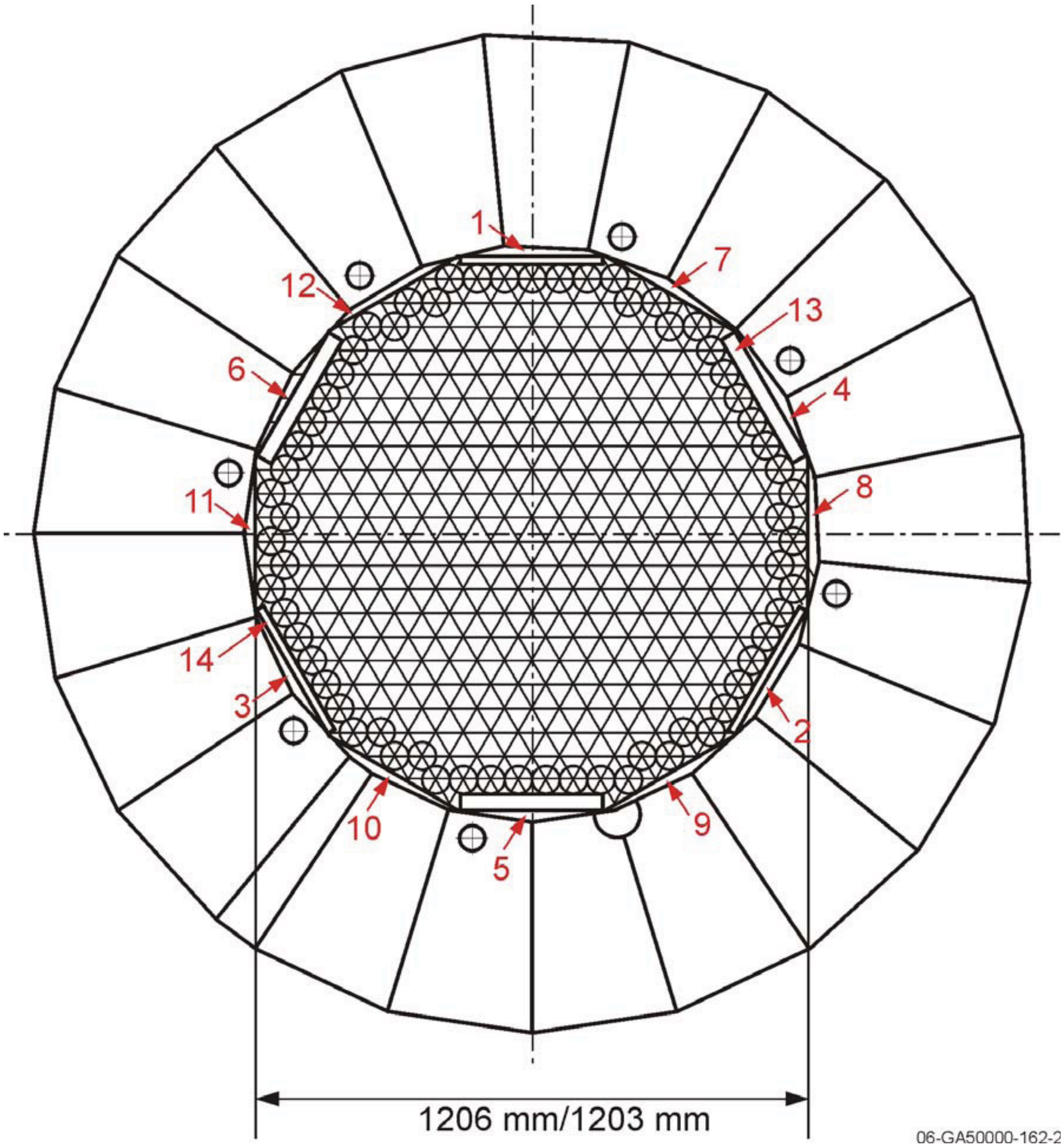

Figure 1.1-16. Positioning of the additional graphite filler pieces used in the even layers of the deterministic, hexagonal close packed cores (Ref. 2).

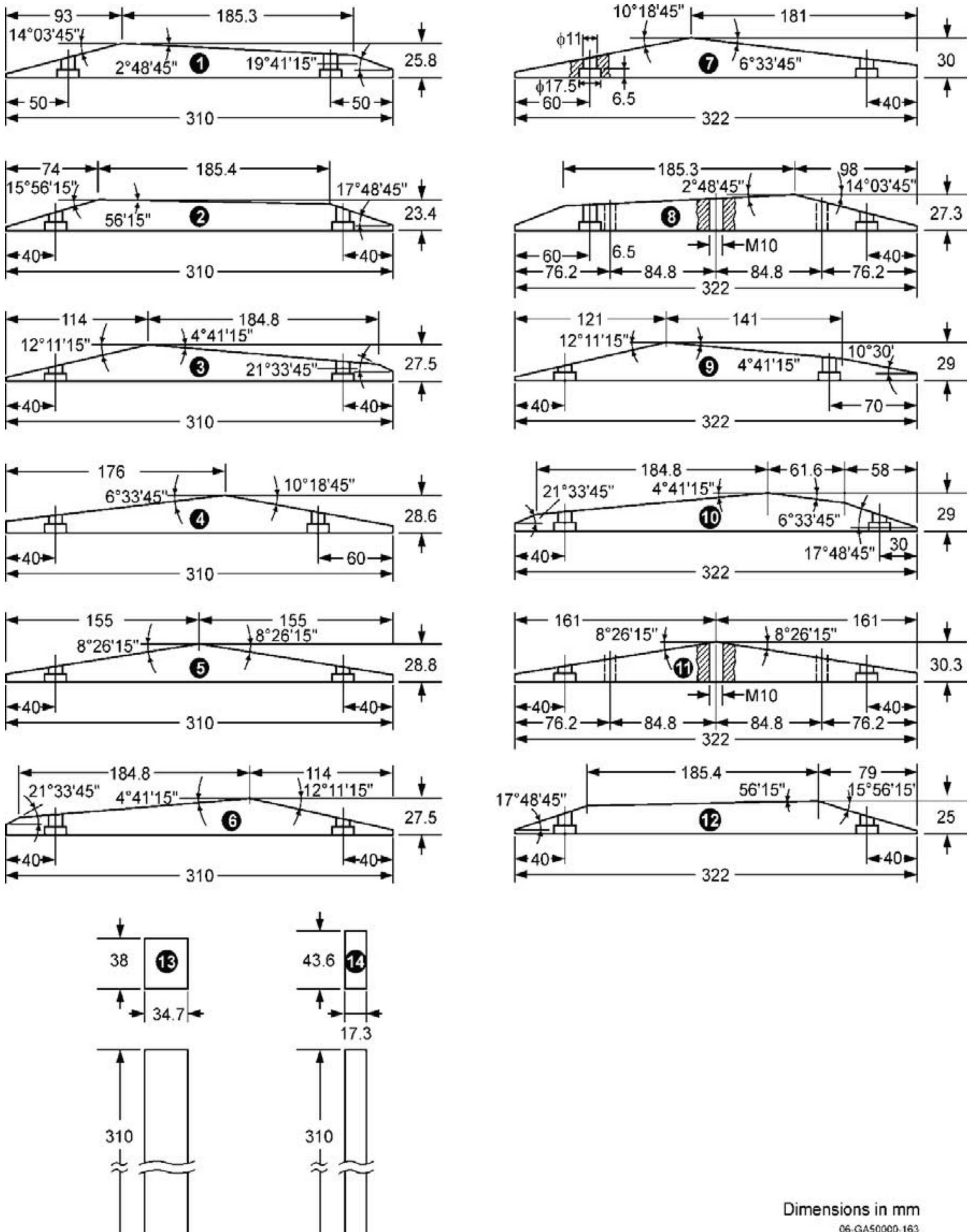

Figure 1.1-17. Graphite filler pieces used in the deterministic cores (Ref. 2). The position numbers are engraved into the top of each graphite filler piece.

ZEBRA Control Rods

Four Cd/Al control rods, ZEBRA type, were used in Core 1. This type of control rod had the advantage of causing minimal perturbations in the axial flux distributions at the price of a significant minimum (rest) reactivity worth. This minimum reactivity worth varies with core configurations and is time consuming to determine experimentally; therefore, these rods were replaced with withdrawable stainless steel control rods for Cores 1A through 10 (Ref. 2 and 3). Due to the extreme complexity of these control rods, they were never intended to play a part in the code validation exercise. Two types of ZEBRA rods were fabricated for these experiments (26 mm outer diameter rods and 42 mm outer diameter rods), but only the 42 mm outer diameter rods were ever used in the HTR-PROTEUS. Both types of rods used six sets of cadmium sleeves instead of five sets, such as was used in the previous PROTEUS "FDWR" experiments, because of the greater reactor core heights in the HTR-PROTEUS configurations (Ref. 2).

The ZEBRA control rods, shown in Figures 1.1-18 and 1.1-19, consisted of two concentric Peraluman R-257 tubes. The inner tube had an inside diameter of 30 mm and a thickness of 5 mm; the outer tube had an inside diameter of 35.7 mm and a thickness of 6.3 mm. Each rod had, fitted flush to its outer surface, 6 sheaths of cadmium with a length of 160 mm, thickness of 0.5 mm, and spacing of 240 mm, to achieve an active length of 2400 mm.[a] When the rods are "fully withdrawn", the cadmium on the inner aluminum tube is obscured by the outer cadmium sheath and the control panel indicates 200 mm. When the rods are "fully inserted", the cadmium on the inner tube is "visible" to neutrons in the gap between the sheaths on the outer tube and the control panel indicates 0 mm. The gap between the sheaths is greater than the actual sheath length; there is a relatively dead region between 0 and ~40 mm in which only a small reactivity effect was observed. The total length of the exposed cadmium portions of the ZEBRA type control rods was 960 mm in the overlapped position and 1920 mm in the non-overlapped position (Ref. 2).

The aluminum tubes were fixed onto lower and upper steel support plates while the inner tubes were driven from below. The four assemblies were situated symmetrically in 45 mm diameter channels in the radial reflector at a radius of 896.3 mm, as shown in Figure 1.1-2. The total length of the active section of the ZEBRA rods was 2160 mm in the overlapped condition and 2360 mm in the non-overlapped condition (top of uppermost cadmium sleeve to bottom of lowermost cadmium sleeve). The lower end of the outer, fixed (non-moveable) cadmium sleeve is 278 mm below the plane of the bottom of the reactor cavity. The lower end of the inner (moveable) cadmium sleeve is 478 mm below the bottom of the reactor cavity in the non-overlapped position (Ref. 2).

[a] As discussed further in Section 2.1.15, the reported thicknesses of 5, 6.3, and 0.25 mm for the inner tube, outer tube, and cadmium represent the difference between diameters and not the actual thickness. These values need divided in half so as to match the dimensions reported in Figure 1-21 and such that the ZEBRA rods could physically be assembled in placed into channels within the graphite radial reflector.

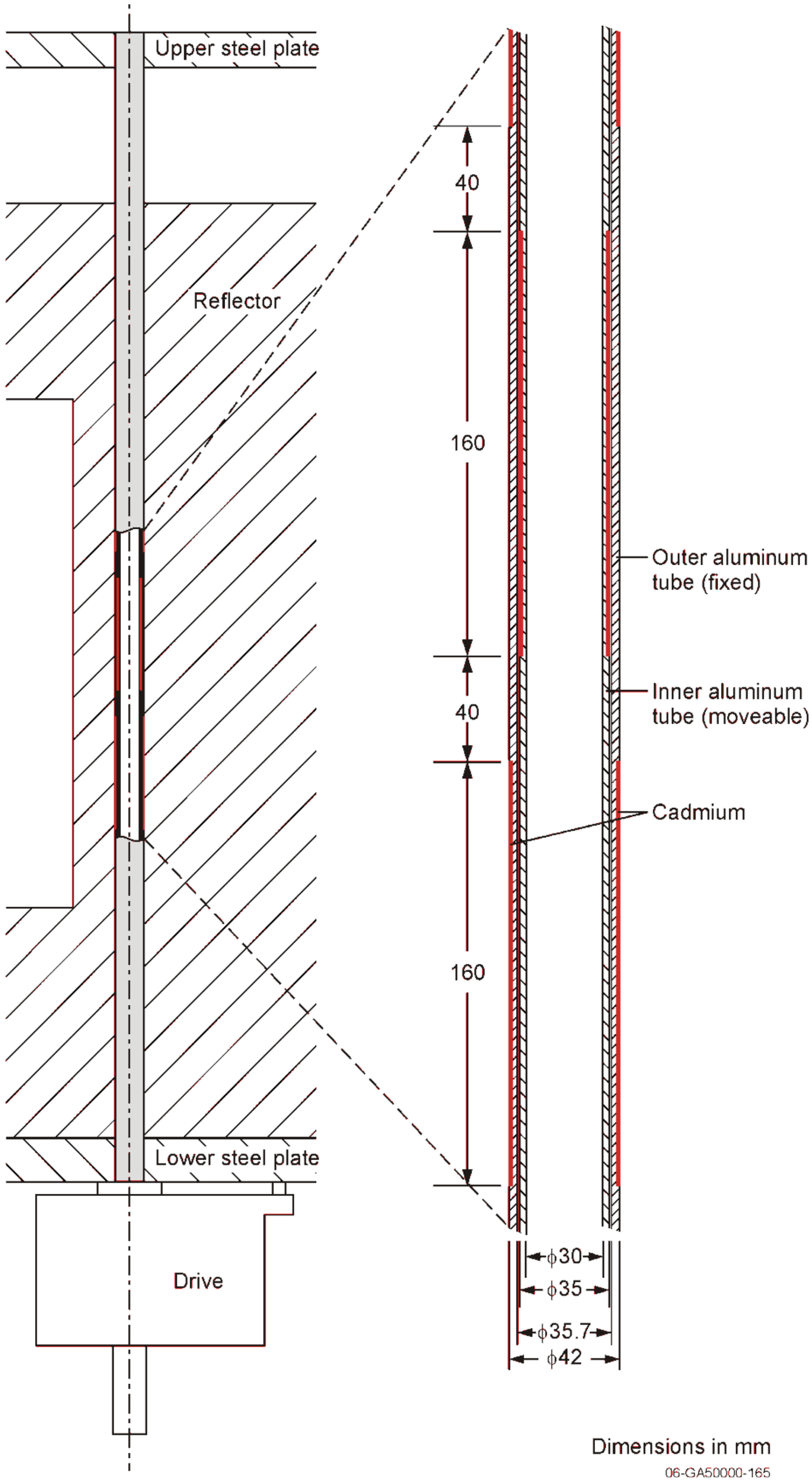

Figure 1.1-18. Details of the ZEBRA control rods (Ref. 2).

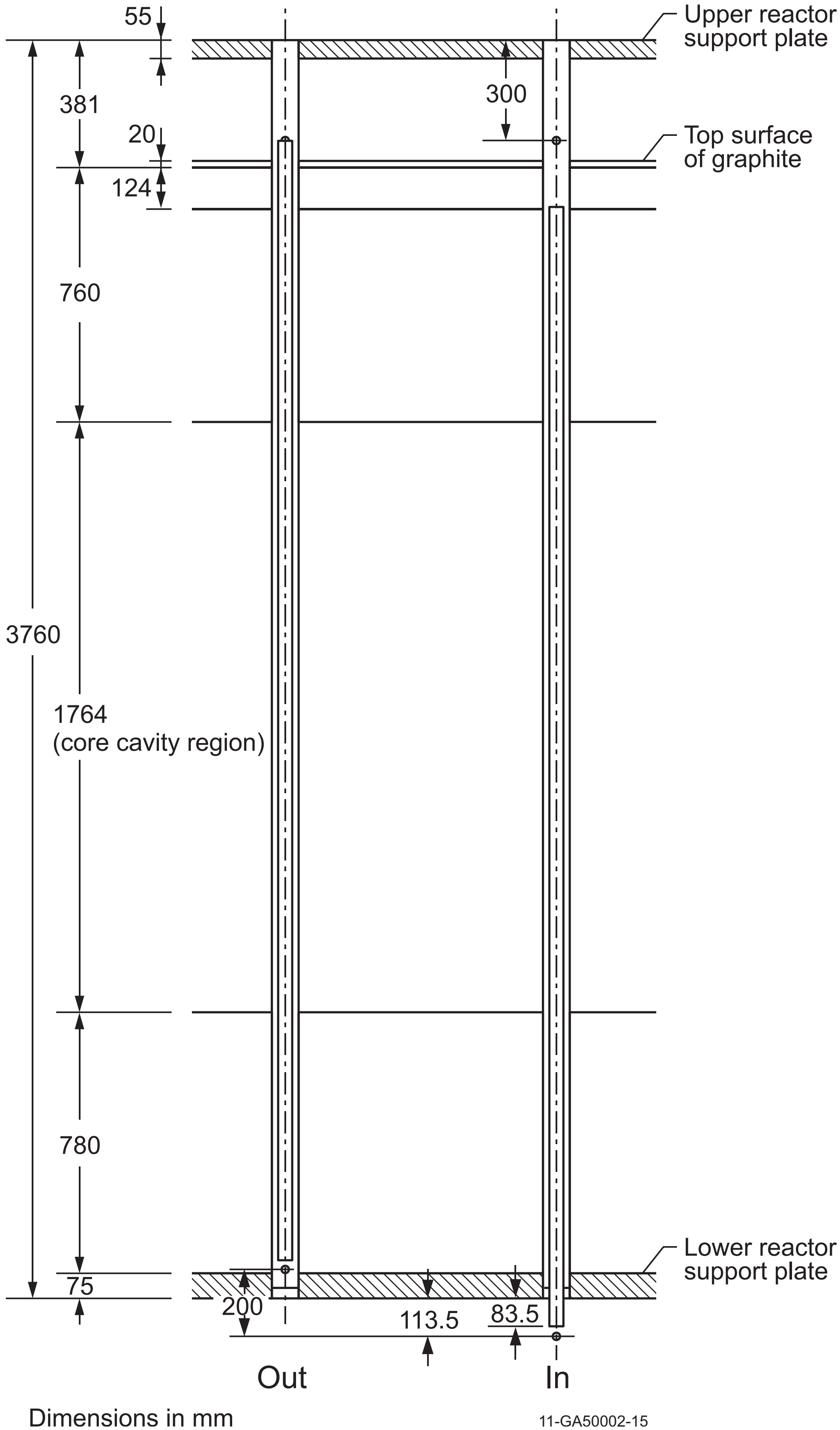

Figure 1.1-19. Location and operation of the ZEBRA control rods (Ref. 2).

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).

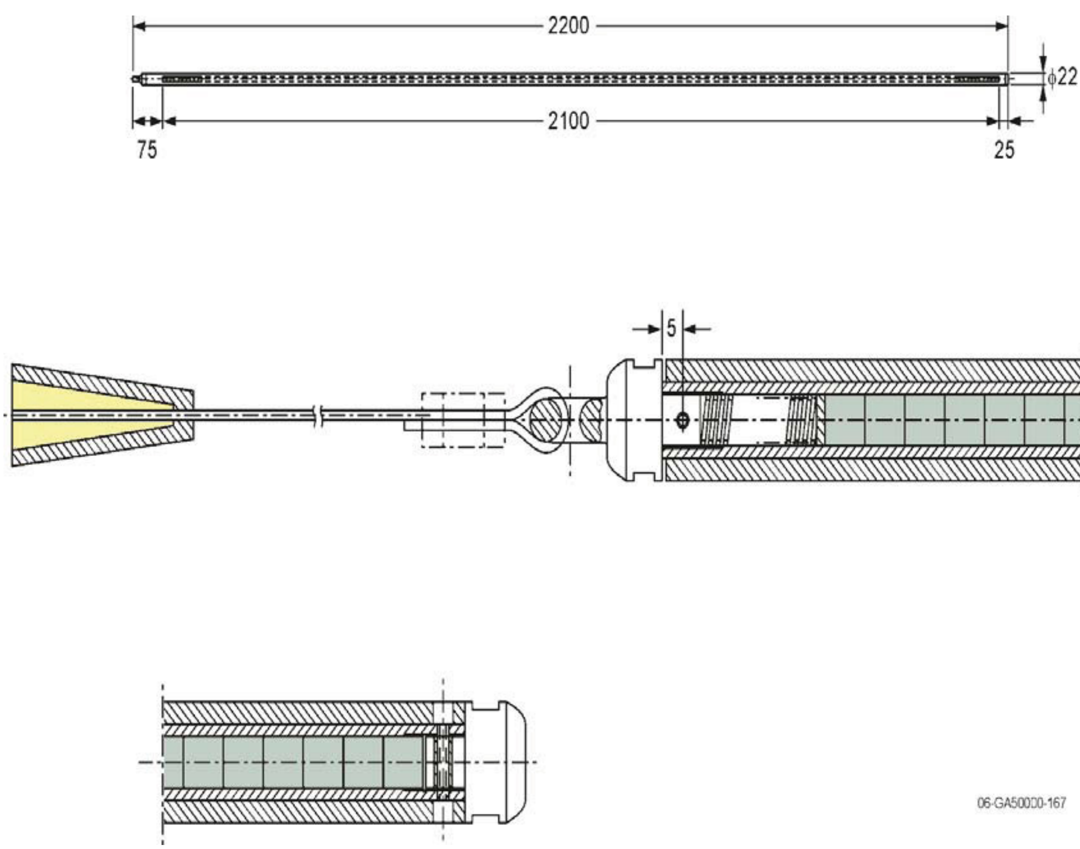

Figure 1.1-20. Details of the withdrawable stainless steel control rods (Ref. 2). Units are in millimeters.

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 1.1-21. 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 Cores 1, 1A, and 2. A total of 327 polyethylene rods were placed in the inter-pebble channels (no edge channels) of Core 3. Each rod had a diameter of 8.9 mm (see Figure 1.1-21) and a length of 860 mm for the 17 layer configuration described in Table 1.1-7. A partial 18^{th} layer with 37 additional pebbles was loaded to achieve an operational core with more convenient control rod positions; the inter-pebble channels in this central region had a length of 910 mm (Ref. 1).

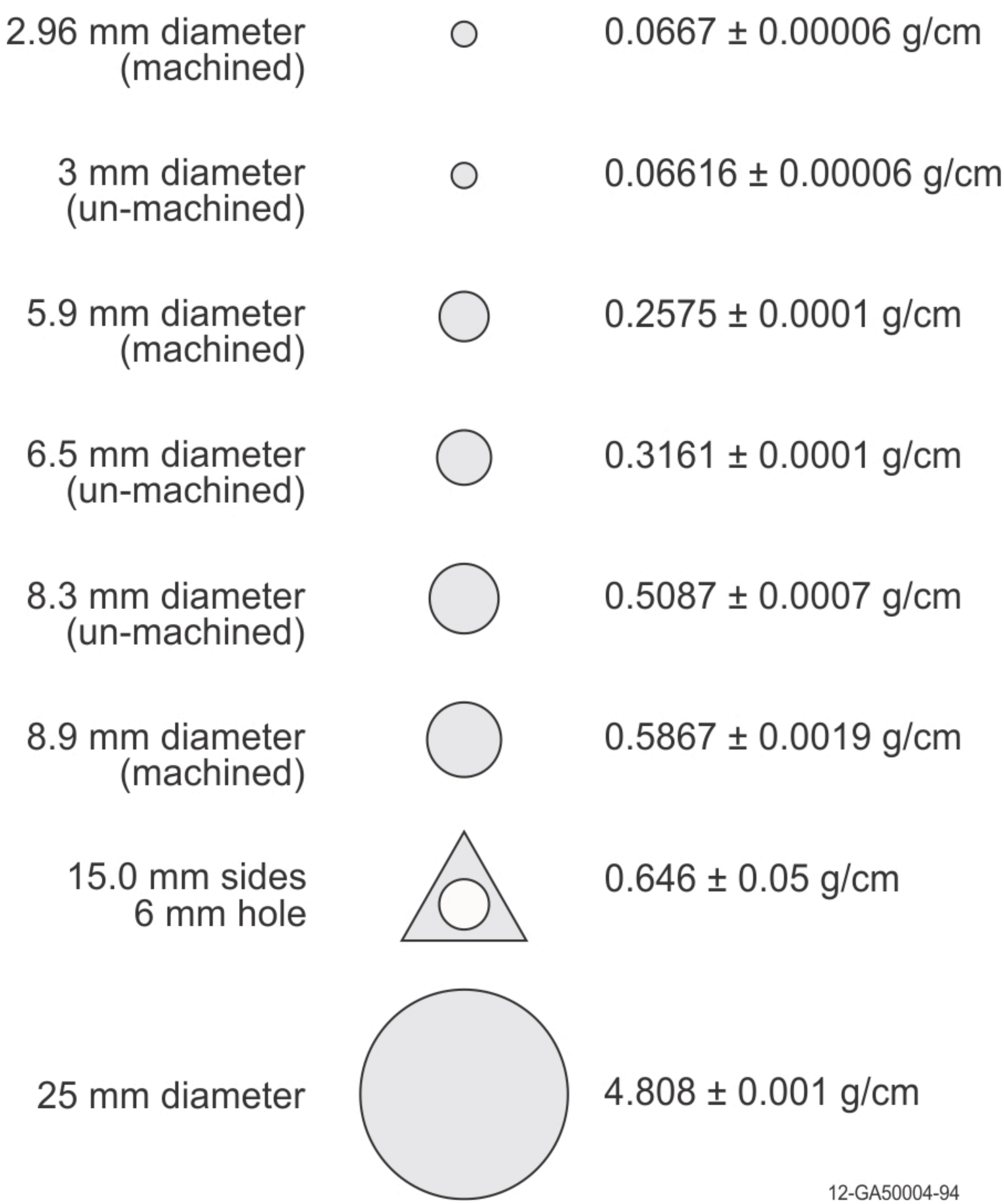

Figure 1.1-21. Physical properties of available polyethylene rods (Ref. 2 and 3). Reference 3 states that the sides of the triangular rod are 13.5 mm; however, the resultant mass density calculates to be ~1.3 g/cm^3, much greater than a typical density of 0.94 g/cm^3.

Copper Wire

Copper wire was not used in the experiments with Cores 1, 1A, 2, and 3.

Core Pebble Packing

Cores 1, 1A, 2, and 3 were deterministically stacked in Hexagonal Close-Packed (HCP) cells, as shown in Figure 1.0-2.

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. The loading of the hexagonal close packed lattices was relatively simple since the pebbles located themselves readily in the depressions between the pebbles in the layer below (Ref. 3).

Core Configurations

Tables 1.1-3 through 1.1-7 provide detailed summaries of the core description and critical balance information for Cores 1, 1A, 2, and 3. Figures 1.1-22 through 1.1-29 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 1 (reference state #1): Table 1.1-3 and Figures 1.1-22 and 1.1-23
- Core 1A (reference state #1): Table 1.1-4 and Figures 1.1-22 and 1.1-23
- Core 1A (reference state #2): Table 1.1-5 and Figures 1.1-22 and 1.1-23
- Core 2 (reference state #1): Table 1.1-6 and Figures 1.1-22 through 1.1-25
- Core 3 (reference state #1): Table 1.1-7 and Figures 1.1-26 through 1.1-29

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 1 (Reference State #1) Critical Information (Ref. 1 and 3).[(a)]

Core Description			
1st Criticality	July 7, 1992		
Unloaded	June 7, 1993	Only partially to Core 1A	
Nominal Pebble Ratio	1:2 moderator:fuel		
Pebble Count	2585 moderator, 5181 fuel		
Pebble Packing	Hexagonal Close Packed ABABAB…		
Polyethylene Loading	None		
Critical Balance			
Date	May 18, 1993		
Critical Loading	22 layers	**M**[(b)]	See Figure 1.1-22 and 1.1-23
Critical Height	1.0888 m	**M**	2×(3)+21×(4.898) cm[(c)]
Rod Positions (Control/Autorod)	148/418 mm	**M**	200/1000 mm = fully out[(d)]
Nominal Flux	5×10^7 n/cm^2/s	**M**	
Hall Temperature	21 ºC	**M**	
Core Temperatures (Center/Edge)	19.4/19.9 ºC	**M**	
Reflector Temperatures (R2,47/R2,15)[(e)]	20.2/20.1 ºC	**M**	
Air Pressure	975.6 mbar	**M**	
Air Humidity	50 %	**M**	

(a) The magnitude of the reactivity excess in the core, predominantly caused by the relatively high negative rest worths of the ZEBRA control rods, was undesirable and led to their replacement with conventional withdrawable control rods with lower negative rest worths.
(b) Directly measured experimental measurements are indicated with an **M**; sometimes a few values were estimated, and indicated with an **E**.
(c) In the hexagonal close packed cores the layer repeat distance is ~4.898 cm, based on the height of a tetrahedron formed from four adjacent pebbles with a radius of 3 cm; there are two “partial” layers at the top and bottom of the packed core of a half-pebble each (3 cm), because a complete tetrahedron is not formed by the addition of another layer. See further discussion in Section 2.1.19.6 and Figure 1.1-1.
(d) The ZEBRA control rods and autorod are considered fully withdrawn when their positions indicate 200 and 1000 mm, respectively.
(e) The nomenclature for the channels in the radial reflector is described in Figure 1.1-5.

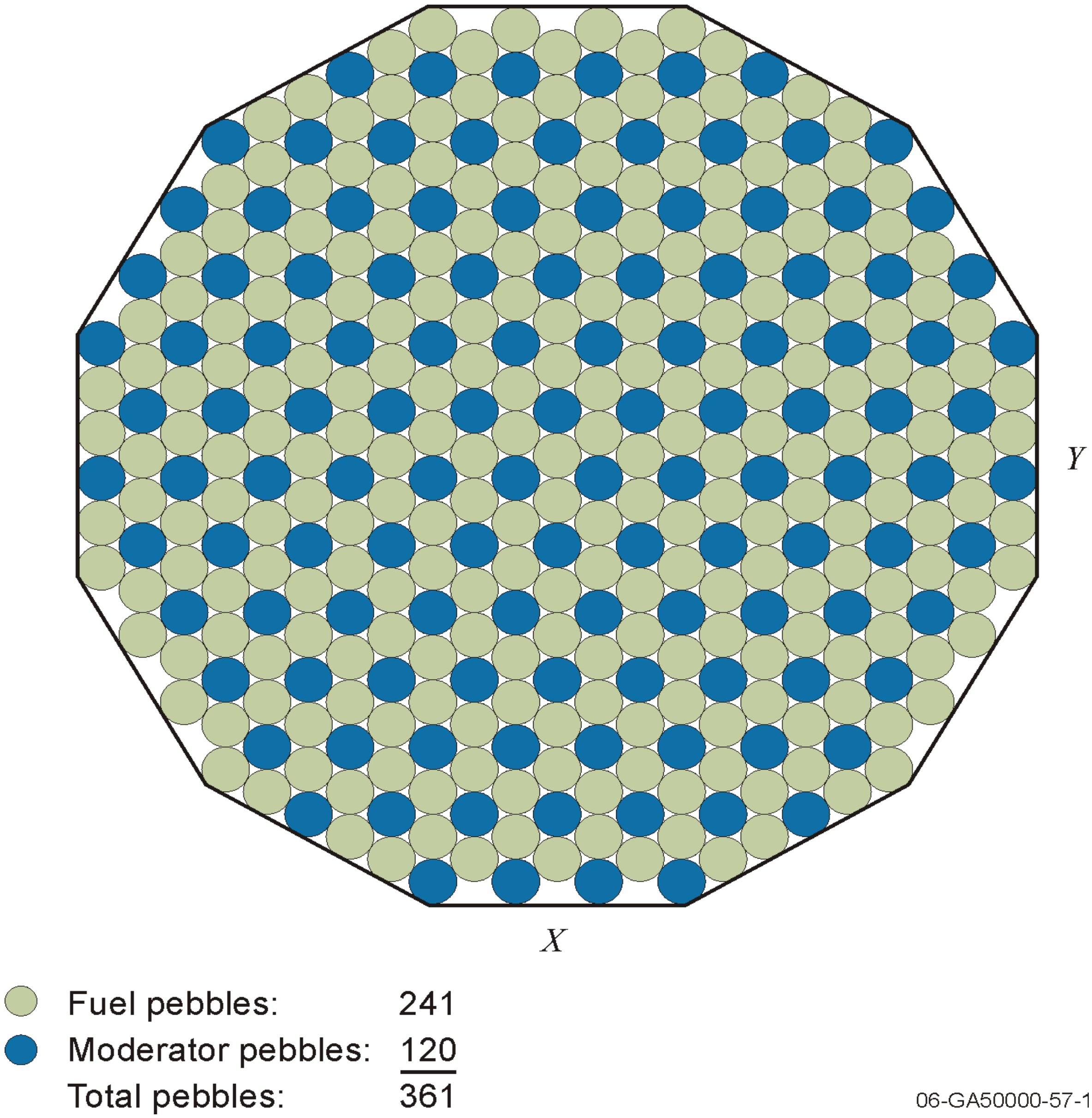

Figure 1.1-22. Odd fueled layers (1, 3, 5, 7, etc.) of Cores 1, 1A, and 2 (Ref. 1).

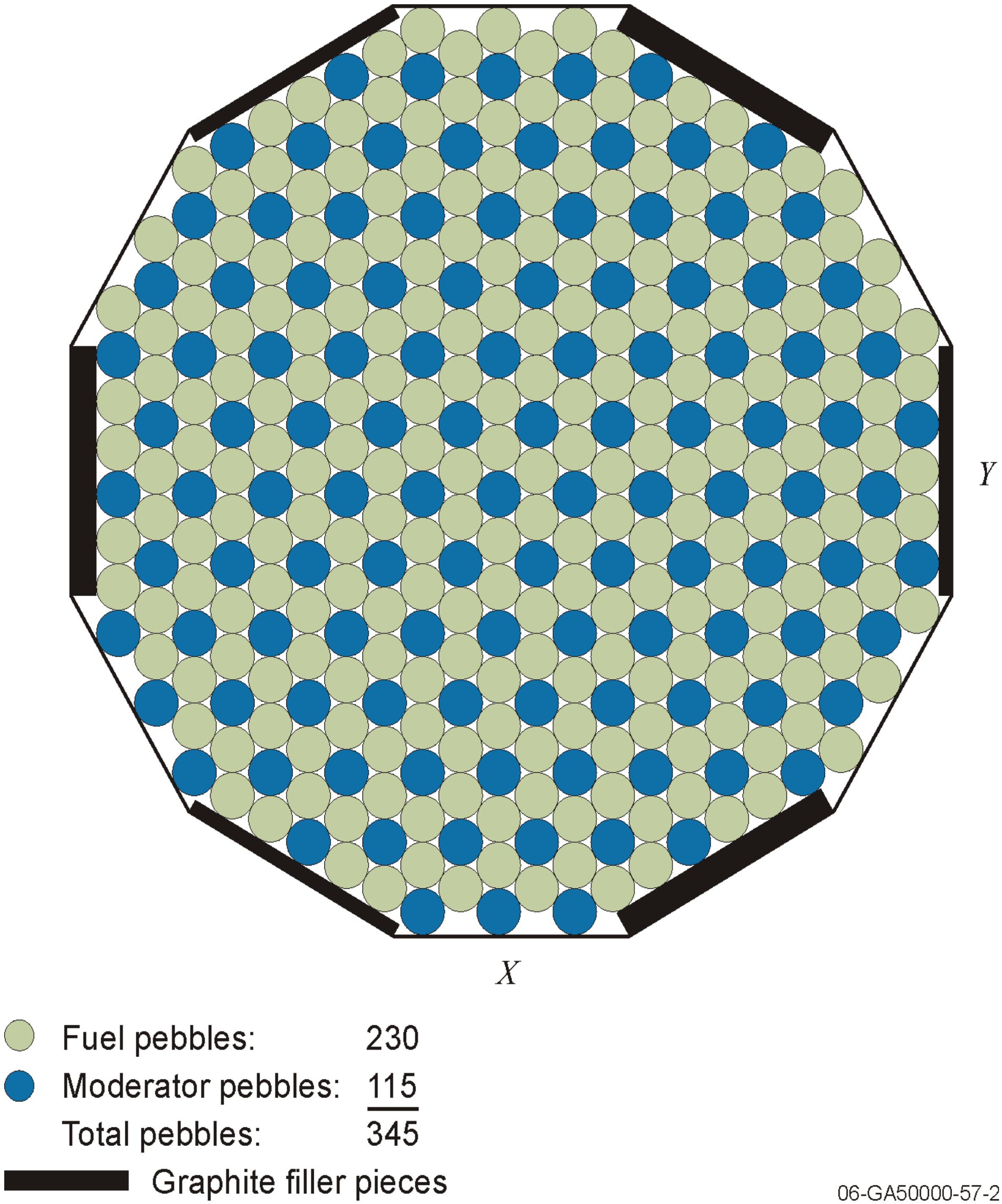

Figure 1.1-23. Even fueled layers (2, 4, 6, 8, etc.) of Cores 1, 1A, and 2 (Ref. 1).

Table 1.1-4. Core 1A (Reference State #1) Critical Information (Ref. 1 and 3).(a)

Core Description			
1st Criticality	June 8, 1993		
Unloaded	August 17, 1993		
Nominal Pebble Ratio	1:2 moderator:fuel		
Pebble Count	2470 moderator, 4951 fuel		
Pebble Packing	Hexagonal Close Packed ABABAB…		
Polyethylene Loading	None		
Critical Balance			
Date	June 14, 1993		
Critical Loading	21 layers	**M**[(b)]	See Figure 1.1-22 and 1.1-23
Critical Height	1.0398 m	**M**	2×(3)+20×(4.898) cm[(c)]
Rod Positions (Control/Autorod)	2183/482 mm	**M**	0/1000 mm = fully out[(d)]
Nominal Flux	5×10^7 n/cm^2/s	**M**	
Hall Temperature	20.2 ºC	**M**	
Core Temperatures (Center/Edge)	20.7/21.1 ºC	**M**	
Reflector Temperatures (R2,47/R2,15)[(e)]	21.2/21.2 ºC	**M**	
Air Pressure	980 mbar	**E**	
Air Humidity	50 %	**E**	

(a) Core 1A is equivalent to Core 1 with the ZEBRA rods replaced by withdrawable control rods in Ring 5 and the core height reduced by one layer. The new rods are hollow (i.e., ,contain no B_4C pellets). In this case the reactivity excess is still ~2 dollars, but ~1.25 dollars is due to only three components (control rods, safety and shutdown channels, and channels in the lower reflector). Apart from the control rod, no component worths were measured in this core, it was reasoned that the direct use of the Core 1 values would introduce minimal error.

(b) Directly measured experimental measurements are indicated with an **M**; sometimes a few values were estimated, and indicated with an **E**.

(c) In the hexagonal close packed cores the layer repeat distance is ~4.898 cm, based on the height of a tetrahedron formed from four adjacent pebbles with a radius of 3 cm; there are two "partial" layers at the top and bottom of the packed core of a half-pebble each (3 cm), because a complete tetrahedron is not formed by the addition of another layer. See further discussion in Section 2.1.19.6 and Figure 1.1-1.

(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.

Table 1.1-5. Core 1A (Reference State #2) Critical Information (Ref. 1 and 3).[(a)]

Core Description			
1st Criticality	February 21, 1994		
Unloaded	March 22, 1994		
Nominal Pebble Ratio	1:2 moderator:fuel		
Pebble Count	2470 moderator, 4951 fuel		
Pebble Packing	Hexagonal Close Packed ABABAB…		
Polyethylene Loading	None		
Critical Balance			
Date	February 22, 1994		
Critical Loading	21 layers	**M**[(b)]	See Figure 1.1-22 and 1.1-23
Critical Height	1.0398 m	**M**	$2\times(3)+20\times(4.898)$ cm[(c)]
Rod Positions (Control/Autorod)	2350/130 mm	**M**	0/1000 mm = fully out[(d)]
Nominal Flux	5×10^7 n/cm^2/s	**M**	
Hall Temperature	20 ºC	**M**	
Core Temperatures (Center/Edge)	--/19.4 ºC	**M**	
Reflector Temperatures (R2,47/R2,15/R2,63)[(e)]	19.0/18.9/18.8 ºC	**M**	
Air Pressure	980 mbar	**E**	
Air Humidity	50 %	**E**	

(a) This was a repeat of Core 1A to check reproducibility. This state is arguably more reliable than the reference state #1 since here the old ZEBRA channels are filled, and the 12 aluminum support tubes, present in state #1, have been removed. Comparing the clean k_{eff} values of the two states, an excellent correspondence was noted, confirming the reproducibility of this configuration and giving some increased confidence in the uncertainty estimate.

(b) Directly measured experimental measurements are indicated with an **M**; sometimes a few values were estimated, and indicated with an **E**.

(c) In the hexagonal close packed cores the layer repeat distance is ~4.898 cm, based on the height of a tetrahedron formed from four adjacent pebbles with a radius of 3 cm; there are two "partial" layers at the top and bottom of the packed core of a half-pebble each (3 cm), because a complete tetrahedron is not formed by the addition of another layer. See further discussion in Section 2.1.19.6 and Figure 1.1-1.

(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 1.1-5.

Table 1.1-6. Core 2 (Reference State #1) Critical Information (Ref. 1 and 3).[a]

Core Description			
1st Criticality	August 20, 1993		
Unloaded	October 4, 1993		
Nominal Pebble Ratio	1:2 (bottom 16 layers) 1:0 (top 17 layers)- moderator:fuel		
Pebble Count	Fuelled region: 1880 moderator, 3768 fuel Moderator region: 6009 moderator, 0 fuel		
Pebble Packing	Hexagonal Close Packed ABABAB…		
Polyethylene Loading	None		
Critical Balance			
Date	August 20, 1993		
Critical Loading	16 layers with fuel 17 layers moderator	**M**[b]	See Figure 1.1-22 through 1.1-25
Critical Height	1.627 m	**M**	2×(3)+32×(4.898) cm[c]
Rod Positions (Control/Autorod)	1936/316 mm	**M**	0/1000 mm = fully out[d]
Nominal Flux	5×10^7 n/cm^2/s	**M**	
Hall Temperature	20 ºC	**M**	
Core Temperatures (Center/Edge)	N/A		
Reflector Temperatures (R2,47/R2,15)[e]	22.5/22.4 ºC	**M**	
Air Pressure	988.1 mbar	**M**	
Air Humidity	55 %	**M**	

(a) In order to eliminate the void space above the core, the height of Core 1A was reduced to 16 layers and then 17 layers of moderator pebble also in an ABABAB hexagonal close packed geometry were loaded on top. The upper reflector assembly was in place but its worth was negligible.
(b) Directly measured experimental measurements are indicated with an **M**; sometimes a few values were estimated, and indicated with an **E**.
(c) In the hexagonal close packed cores the layer repeat distance is ~4.898 cm, based on the height of a tetrahedron formed from four adjacent pebbles with a radius of 3 cm; there are two "partial" layers at the top and bottom of the packed core of a half-pebble each (3 cm), because a complete tetrahedron is not formed by the addition of another layer. See further discussion in Section 2.1.19.6 and Figure 1.1-1.
(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 1.1-5.

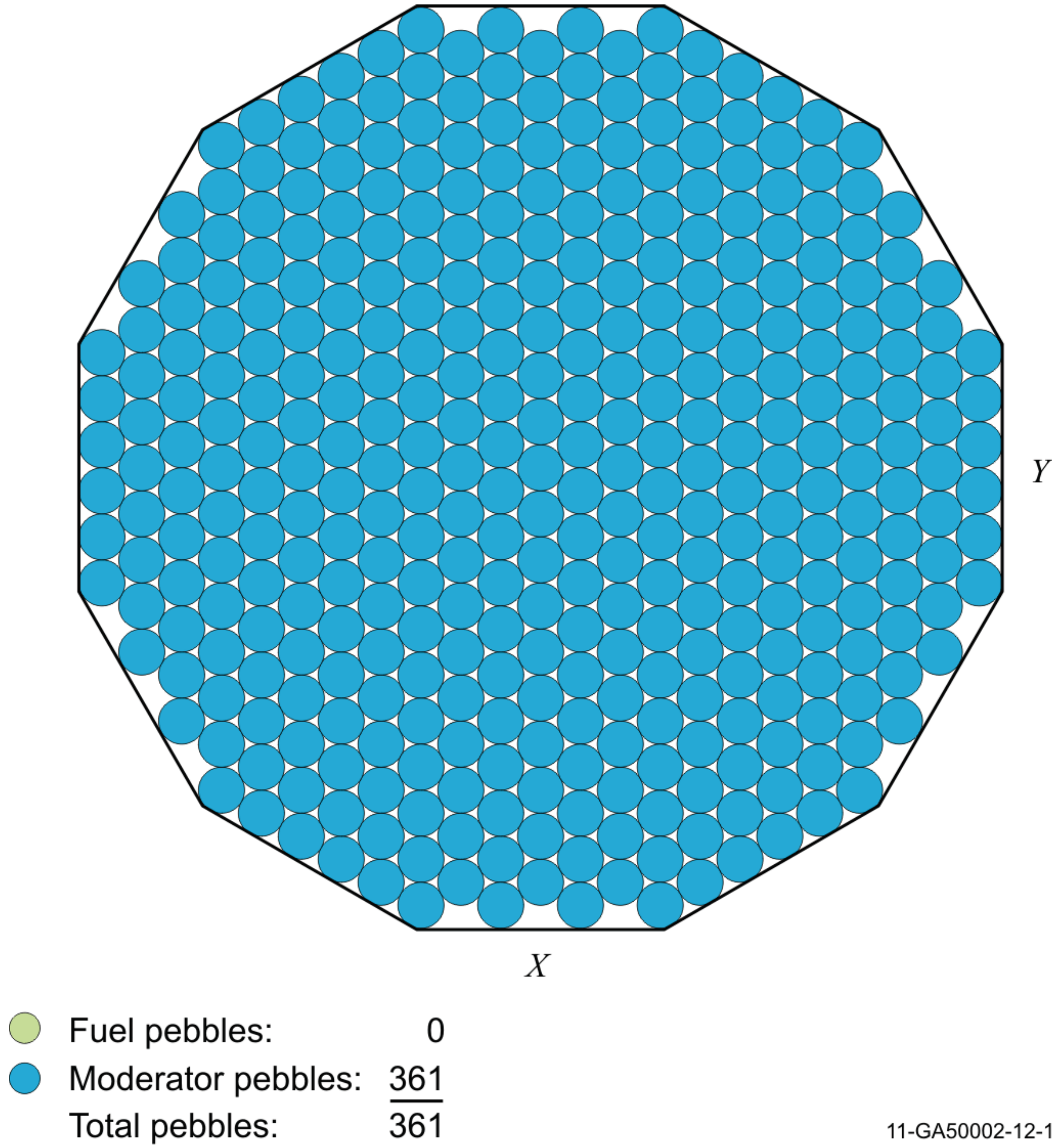

Figure 1.1-24. Odd moderator layers (17, 19, 21, etc.) of Core 2 (derived from Ref. 1).

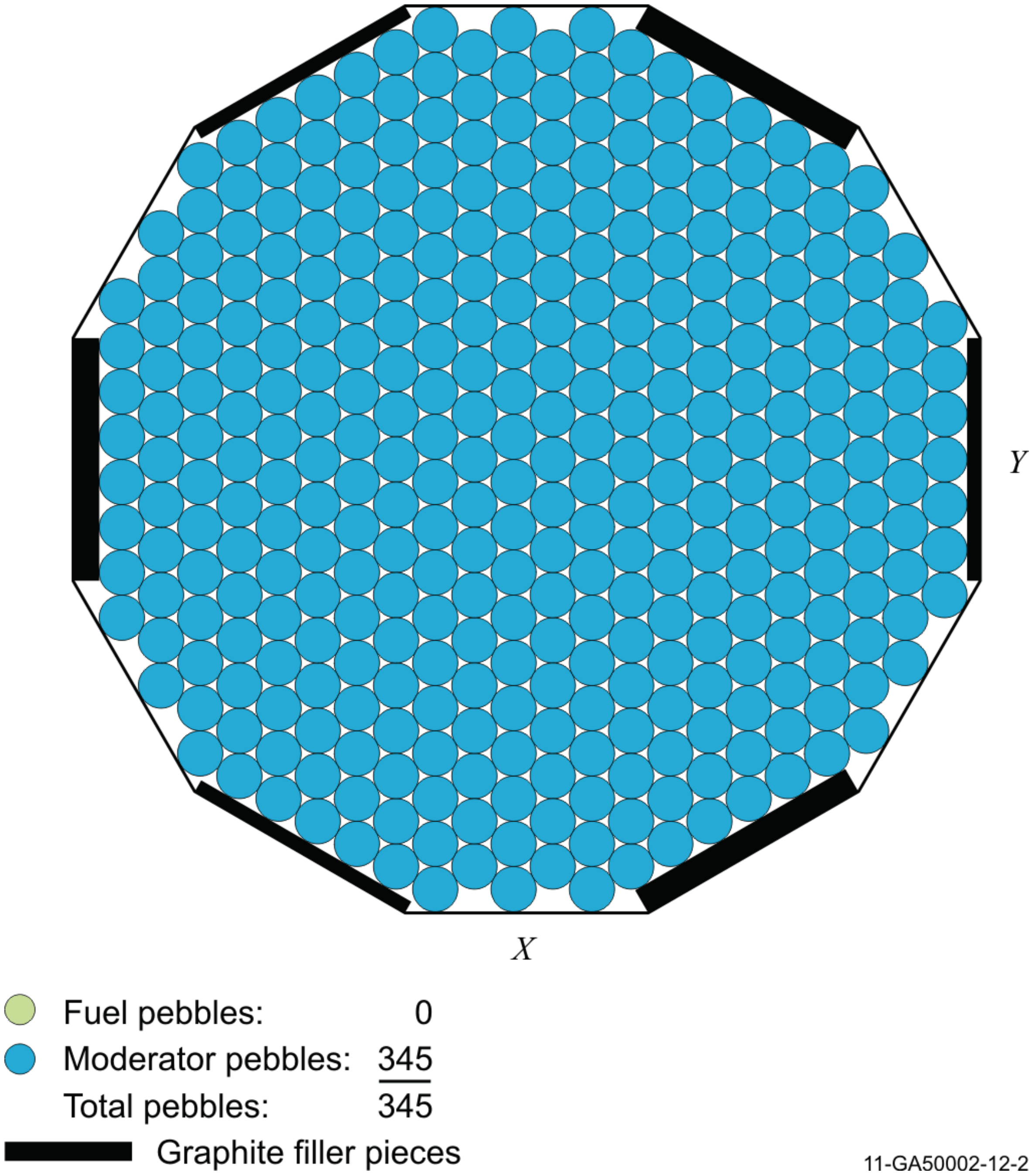

Figure 1.1-25. Even moderator layers (18, 20, 22, etc.) of Core 2 (derived from Ref. 1).

Table 1.1-7. Core 3 (Reference State #1) Critical Information (Ref. 1 and 3).(a)

Core Description			
1st Criticality	October 20, 1993		
Unloaded	February 17, 1994		
Nominal Pebble Ratio	1:2 moderator:fuel		
Pebble Count	2000 moderator, 4009 fuel		
Pebble Packing	Hexagonal Close Packed ABABAB…		
Polyethylene Loading[(b)]	327, 8.9 mm polyethylene rods, one in every available channel and each one cut to slightly more than core height		
Critical Balance			
Date	October 20, 1993		
Critical Loading	17 layers	**M**[(c)]	See Figure 1.1-26 through 1.1-
Critical Height	0.843 m	**M**	2×(3)+16×(4.898) cm[(d)]
Rod Positions (Control/Autorod)	0/685 mm	**M**	0/1000 mm = fully out[(e)]
Nominal Flux	1×10^7 n/cm^2/s	**M**	
Hall Temperature	20 ºC	**M**	
Core Temperatures (Center/Edge)	N/A		
Reflector Temperatures (R2,47/R2,15)[(f)]	N/A		
Air Pressure	986.7 mbar	**M**	
Air Humidity	40 %	**M**	

(a) This is not the operational loading. After this critical balance, chosen for its small reactivity excess, 25 fuel and 12 moderator pebbles were added centrally, in a partial 18th layer (Figures 1.1-28 and 1.1-29), to provide more convenient control rod positions for the routine operation of the reactor.

(b) In this critical balance, with 17 layers of pebbles, each of the 327 inter-pebble channels (i.e., no edge channels) contained one, 8.9 mm diameter, 860 mm long polyethylene rod. In the operational configuration described in footnote (a), the channels in the central region around the 37 pebbles in the 18th layer contained 910 mm long polyethylene rods.

(c) Directly measured experimental measurements are indicated with an **M**; sometimes a few values were estimated, and indicated with an **E**.

(d) In the hexagonal close packed cores the layer repeat distance is ~4.898 cm, based on the height of a tetrahedron formed from four adjacent pebbles with a radius of 3 cm; there are two "partial" layers at the top and bottom of the packed core of a half-pebble each (3 cm), because a complete tetrahedron is not formed by the addition of another layer. See further discussion in Section 2.1.19.6 and Figure 1.1-1.

(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 1.1-5.

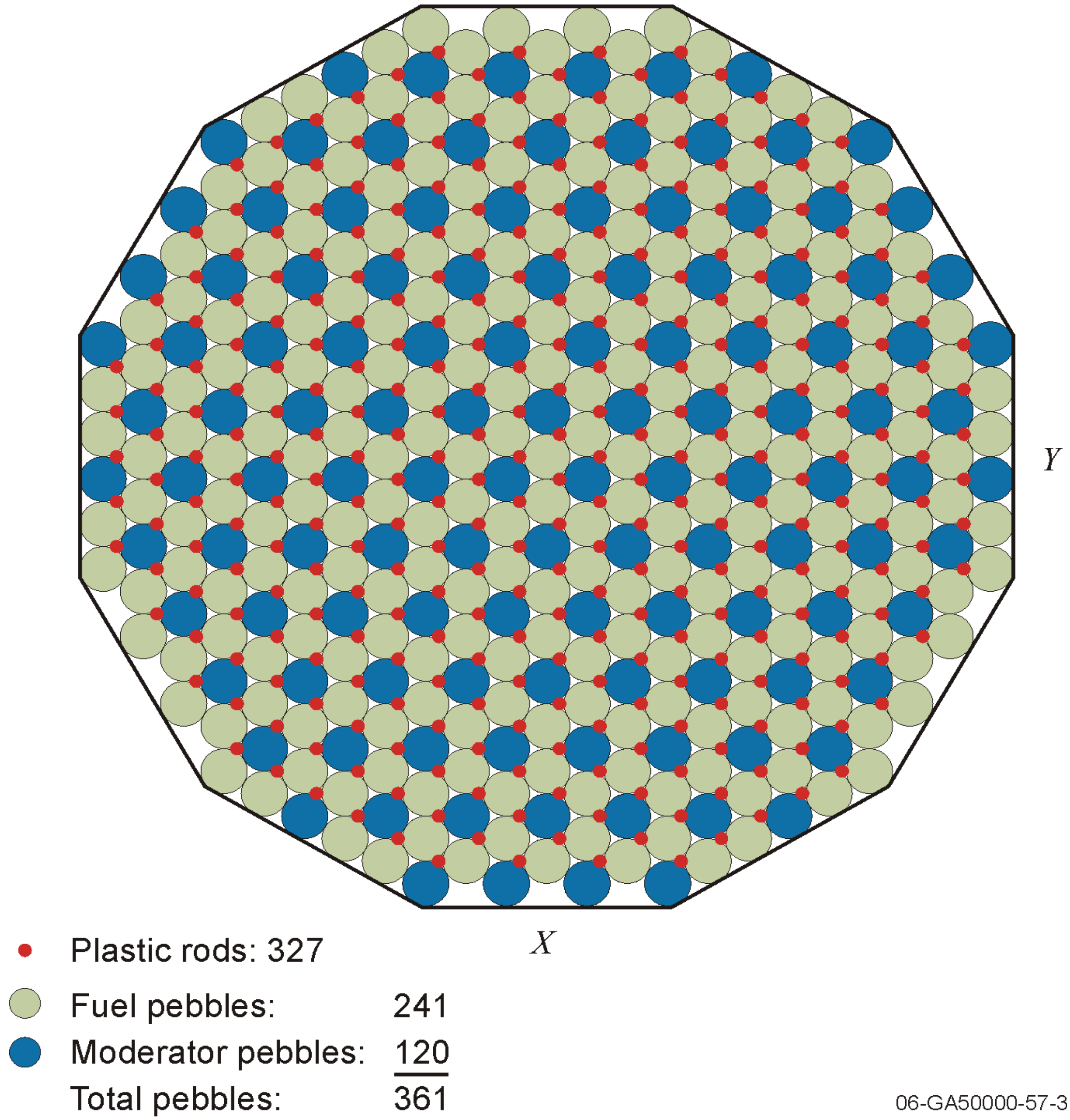

Figure 1.1-26. Odd fueled layers (1, 3, 5, 7, etc.) of Core 3 (Ref. 1).

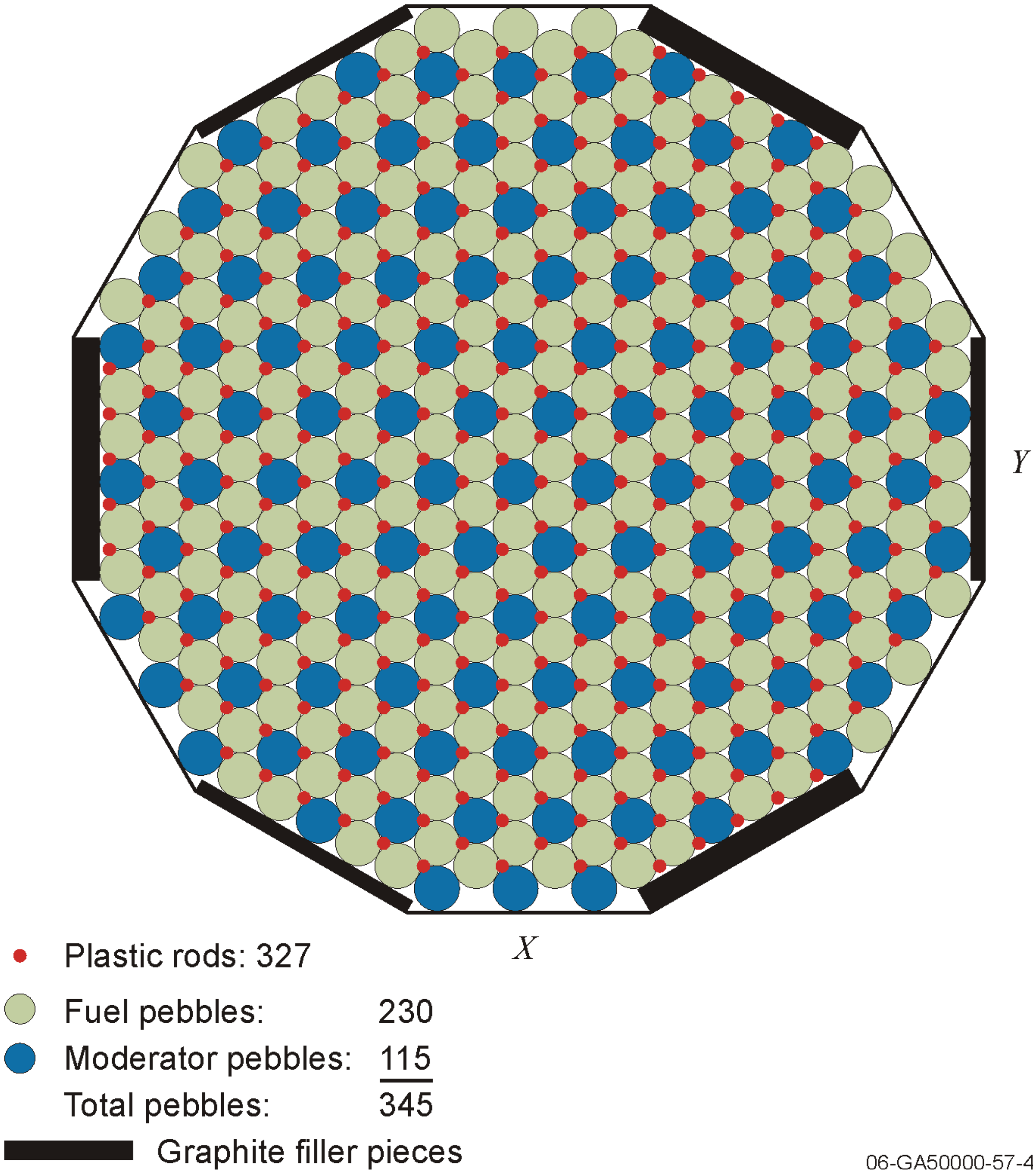

Figure 1.1-27. Even fueled layers (2, 4, 6, 8, etc.) of Core 3 (Ref. 1).

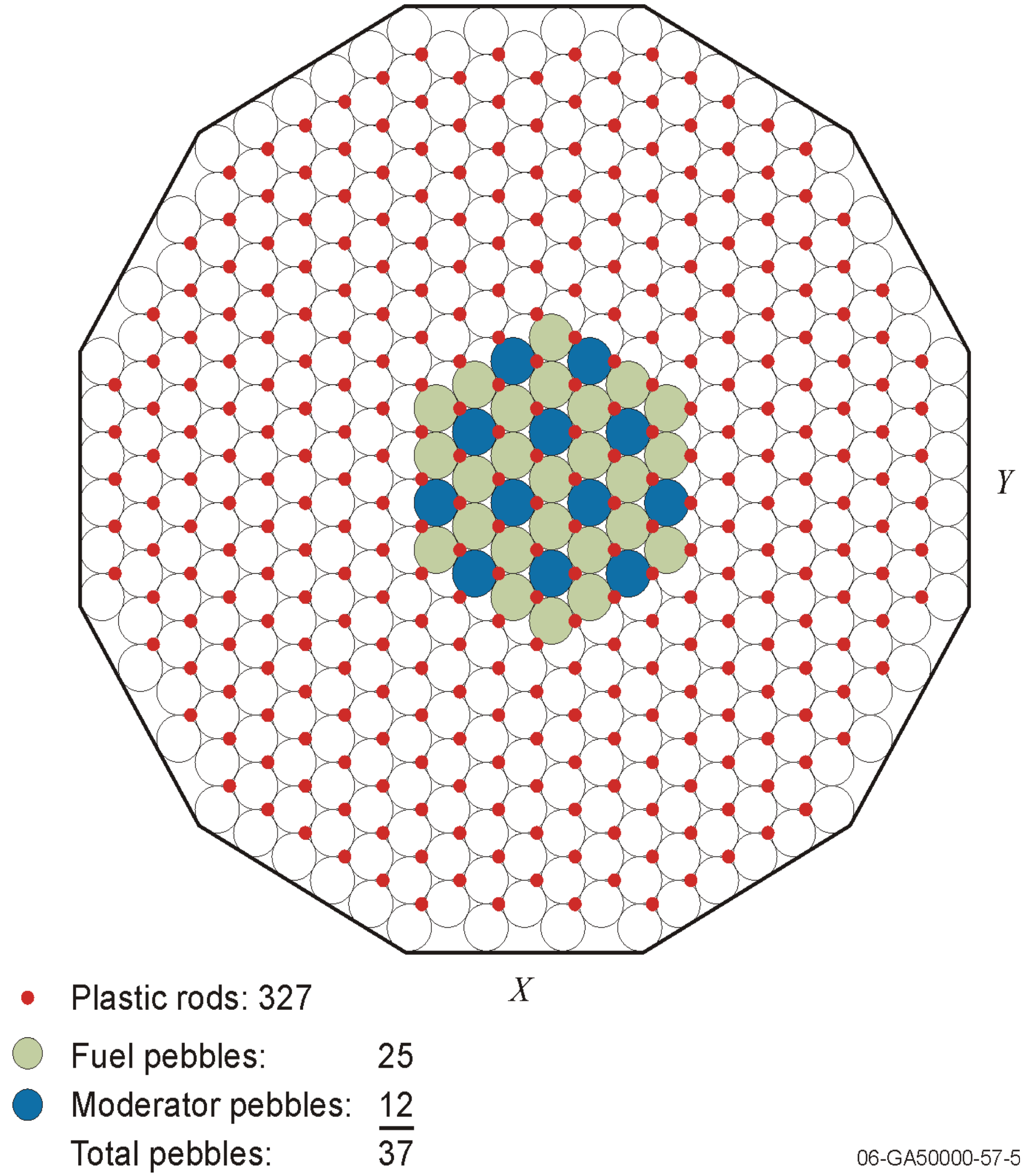

Figure 1.1-28. Fueled layer 18 of Core 3 operational loading (Ref. 1).

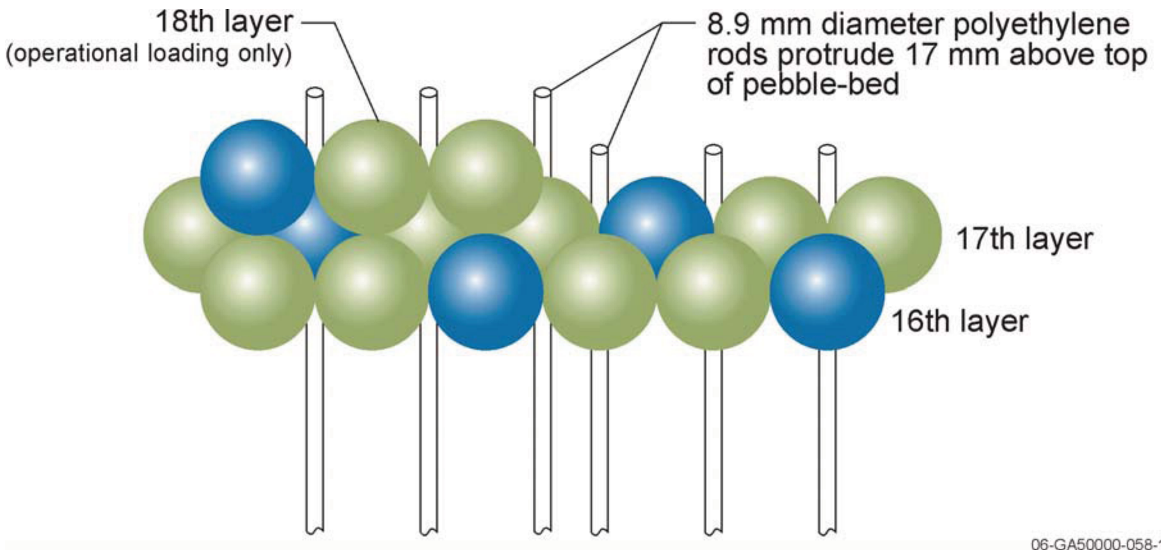

Figure 1.1-29. Side view of layer 18 of Core 3 operational loading (Ref. 1).

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 made 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.

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.

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

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

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 1.1-8 (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]

[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 1.1-8. 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 1.1-9. 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 1.1-9. 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)	**(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 1.1-10) and had a total mass of 10.42 kg (Ref. 2).

Table 1.1-10. 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 1.1-8.

The aluminum housing consisted of Peraluman-300, shown in Table 1.1-10. 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 1.1-8.

Graphite Plugs

New graphite was used for the graphite plugs placed into holes in the reflectors (Table 1.1-8).

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 1.1-11. The 18/8 stainless steel cladding material (Table 1.1-12) 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 1.1-11. 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 1.1-12. 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.

[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.

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 1.1-13. 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 1.1-11). 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 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 1.1-13. 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 1.1-14. 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 1.1-15. 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 1.1-14. 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 1.1-15. 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 1.1-16, 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 1.1-16. 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 1, 1A, 2, and 3

The following components are unique to core configurations 1, 1A, 2, and 3.

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).

The total mass of the six filler pieces used to replace missing partial pebbles at the core reflector interface was 3.36 kg (Ref. 2).

ZEBRA Control Rods

The Peraluman R-257 tubes had the composition shown in Table 1.1-13. No further information regarding the cadmium sheaths was available but the authors of Ref. 2 recommended a density of 8.65 g/cm^3.

Withdrawable Stainless Steel Control Rods

The inner tube of the withdrawable stainless steel control rods was St1.4301 (Table 1.1-17) and the outer tube was St1.4541 (Table 1.1-18). Both steels had a density of 7.9 g/cm^3 (Ref. 2).

Table 1.1-17. 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 1.1-18. 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 1.1-21 (Ref. 2).

Copper Wire

Copper wire was not used in the experiments with Cores 1, 1A, 2, and 3.

Ambient Air

Ambient (hall) temperatures, air pressure, and humidity for HTR-PROTEUS critical experiments, Cores 1, 1A, 2, and 3, are provided in the following tables:

- Core 1 (reference state #1): Table 1.1-3
- Core 1A (reference state #1): Table 1.1-4
- Core 1A (reference state #2): Table 1.1-5
- Core 2 (reference state #1): Table 1.1-6
- Core 3 (reference state #1): Table 1.1-7

1.1.4 Temperature Data

Room (hall), core, and reflector temperatures for HTR-PROTEUS critical experiments, Cores 1, 1A, 2, and 3, are provided in the following tables:

- Core 1 (reference state #1): Table 1.1-3
- Core 1A (reference state #1): Table 1.1-4
- Core 1A (reference state #2): Table 1.1-5
- Core 2 (reference state #1): Table 1.1-6
- Core 3 (reference state #1): Table 1.1-7

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 for Core 1 (Ref. 4). Reactivity corrections for Cores 1 through 3, provided in the original references, are summarized in the following tables:

- Core 1 (reference state #1): Table 1.1-19
- Core 1A (reference state #1): Table 1.1-20
- Core 1A (reference state #2): Table 1.1-21
- Core 2 (reference state #1): Table 1.1-22
- Core 3 (reference state #1): Table 1.1-23

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 (Refs. 3 and 4).

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[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).

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 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 made 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 made 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 1.1-19. Core 1 (Reference State #1) Reactivity Corrections (Ref. 1, 3, and 4).

Reactivity Corrections to Critical Loading	**No.**		**Total ¢**			**Comments**
ZEBRA Rest Worths[(a)]	4	M	-264	±	1	Ref. 4[(h)]
ZEBRA Insertion (148 mm)	4	M	-39	±	0.2	
ZEBRA Rod Channels	4	M	-2	±	0.6	
Autorod Rest Worth	1	M	-7.7	±	0.1	
Autorod Insertion (418 mm)	1	M	-3.7	±	0.3	
Autorod Channel	1	M	-0.5	±	0.15	
Safety and Shutdown Rod Channels[(b)]	8	C	-24	±	4	
Empty Channels R2[(c)]	2	M	-2.7	±	0.3	
Empty Channels R3[(c)]	4	M	-3.8	±	0.6	
Air Gaps in C-Driver Holes[(d)]	320	C	-8.1			
Channels in Upper Reflector	34[(f)]	M	-3.6	±	0.9	
Channels in Lower Reflector	33	M	-23	±	6	
Aluminum Plugs in Lower Reflector[(e)]	12	M	-15.3	±	0.2	
Start-up Sources	2	M	-3.3	±	0.01	
Start-up Source Penetrations	2	M	-1	±	0.1[(i)]	
Pulsed Neutron Source and Missing Graphite	1	M	-4.3	±	0.1	
Nuclear Instrumentation (Ionization)	6	M	-8.4	±	1.8	
Nuclear Instrumentation (Fission)	2	M	-0.8	±	0.6	
Temperature Instrumentation Reflector	2	M	-10.6	±	0.3	
Temperature Instrumentation Core	0					
Total Correction			426[(j)]	±	10[(g)]	
Corrected k_{eff} (β_{eff} = 0.00723)			1.0318	±	0.0006	

(a) This was the only configuration having ZEBRA fine control rods.
(b) 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 cents for this core.
(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) In all the deterministic cores, some 12 pebbles lie directly over one of the 33 cooling channels in the lower axial reflector. In order to avoid pebble displacement in these cases, special aluminum plugs were developed to support the pebbles. In later cores, simple graphite rods were used.
(f) The number of channels in the upper reflector was reported as 33 in Ref. 3.
(g) This uncertainty is reported as 8¢ in Ref. 3 and 4.
(h) Details regarding reactivity corrections are reported Ref. 4.
(i) This uncertainty is listed as 0.6 in Ref. 4.
(j) This value is listed as 417 in Ref. 4; however, the effect of air gaps in the C-Driver holes had not been included in the summary of measured effects.

Table 1.1-20. Core 1A (Reference State #1) Reactivity Corrections (Ref. 1 and 3).

Reactivity Corrections to Critical Loading	No.		Total ¢			Comments
Control Rod Insertion (2183 mm)[(a)]	4	M	-77.9	±	0.1	[(h)]
Control Rod Channels[(b)]	4	E	-2	±	1	Zebra Rod Channels in Core 1
Old ZEBRA Rod Channels[(c)]	4	M	-2	±	0.6	Core 1 Value
Autorod Rest Worth	1	M	-7.7	±	0.1	Core 1 Value
Autorod Insertion (482 mm)	1	M	-3.2	±	0.3	Scaled from Core 1
Autorod Channel	1	M	-0.5	±	0.15	Core 1 Value
Safety and Shutdown Rod Channels[(d)]	8	C	-24	±	4	Core 1 Value
Empty Channels R2[(e)]	2	M	-2.7	±	0.3	Core 1 Value
Air Gaps in C-Driver Holes[(f)]	320	C	-8.3			
Channels in Upper Reflector	34	M	-3.6	±	0.9	Core 1 Value
Channels in Lower Reflector	33	M	-23	±	6	Core 1 Value
Aluminum Plugs in Lower Reflector[(g)]	12	M	-15.3	±	0.2	Core 1 Value
Start-up Sources	2	M	-3.3	±	0.01	Core 1 Value
Start-up Source Penetrations	2	M	-1	±	0.1	Core 1 Value
Nuclear Instrumentation (Ionization)	6	M	-8.4	±	1.8	Core 1 Value
Nuclear Instrumentation (Fission)	2	M	-0.8	±	0.6	Core 1 Value
Temperature Instrumentation Reflector	2	M	-10.6	±	0.3	Core 1 Value
Temperature Instrumentation Core	2	M	-0.9	±	0.3	Core 1 Value
Total Correction			195	±	8	
Corrected k_{eff} (β_{eff} = 0.00723)			1.0143	±	0.0006	

(a) The control rods are fully inserted when 2500 mm is indicated.
(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) At the time of loading Core 1A, no filler pieces were available for the now vacant ZEBRA rod channels.
(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) In all the deterministic cores, some 12 pebbles lie directly over one of the 33 cooling channels in the lower axial reflector. In order to avoid pebble displacement in these cases, special aluminum plugs were developed to support the pebbles. In later cores, simple graphite rods were used.
(h) Details regarding ZEBRA control rod replacement are reported in T. Williams, "HTR PROTEUS Core 1A: The Replacement of ZEBRA Control Rods by Conventional Control Rods," TM-41-93-25, Paul Sherrer Institut, Villigen, August 20, 1993

Table 1.1-21. Core 1A (Reference State #2) Reactivity Corrections (Ref. 1 and 3).

Reactivity Corrections to Critical Loading	**No.**		**Total ¢**			**Comments**
Control Rod Insertion (2350 mm)[a]	4	M	-94.3	±	0.5	
Control Rod Channels[b]	4	E	-2	±	1	Zebra Rod Channels in Core 1
Autorod Rest Worth	1	M	-7.7	±	0.1	Core 1 Value
Autorod Insertion (130 mm)	1	M	-5.4	±	0.3	Scaled from Core 1
Autorod Channel	1	S	-0.5	±	0.15	Core 1 Value
Safety and Shutdown Rod Channels[c]	8	C	-24	±	4	Core 1 Value
Empty Channels R2[d]	2	M	-2.7	±	0.3	Core 1 Value
Air Gaps in C-Driver Holes[e]	320	C	-8.3			
Channels in Upper Reflector	34	M	-3.6	±	0.9	Core 1 Value
Channels in Lower Reflector	29	S	-20	±	6	Scaled from Core 1
Start-up Sources	2	S	-3.3	±	0.01	Core 1 Value
Start-up Source Penetrations	2	S	-1	±	0.1	Core 1 Value
Nuclear Instrumentation (Ionization)	7	S	-9.8	±	2.0	Core 1 Value
Nuclear Instrumentation (Fission)	2	S	-0.8	±	0.6	Core 1 Value
Temperature Instrumentation Reflector	3	S	-15.9	±	0.9	Scaled from Core 1
Temperature Instrumentation Core	1	S	-0.5	±	0.3	Scaled from Core 1
Total Correction			199.8	±	8	
Corrected k_{eff} (β_{eff} = 0.00723)			1.0147	±	0.0006	

(a) The control rods are fully inserted when 2500 mm is indicated.
(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) 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.

Table 1.1-22. Core 2 (Reference State #1) Reactivity Corrections (Ref. 1 and 3).

Reactivity Corrections to Critical Loading	No.		Total ¢			Comments
Control Rod Insertion (1936 mm)[a,b]	4	M	-43.6	±	0.2	
Control Rod Channels[c]	4	M	-2	±	1	Zebra Rod Channels in Core 1
Autorod Rest Worth[d]	1	S	-6.7	±	0.5	Scaled from Core 1A
Autorod Insertion (316 mm)[d]	1	S	-3.7	±	0.3	Scaled from Core 1A
Autorod Channel	1	M	-0.5	±	0.15	Core 1A Value
Safety and Shutdown Rod Channels[e]	8	C	-21	±	4	Core 1A Value
Empty Channels R2[d,f]	2	M	-2.3	±	0.3	Scaled from Core 1A
Air Gaps in C-Driver Holes[g]	320	C	-8.7			
Channels in Upper Reflector[h]	34		0.0			No Reflector Worth
Channels in Lower Reflector	33	M	-23	±	6	Core 1A Value
Aluminum Plugs in Lower Reflector[i]	12	M	-15.3	±	0.2	Core 1A Value
Start-up Source Penetrations	2	M	-1	±	0.1	Core 1A Value
Nuclear Instrumentation (Ionization)[d]	6	S	-7.3	±	1.8	Scaled from Core 1A
Nuclear Instrumentation (Fission)	2	S	-0.8	±	0.6	Core 1 Value
Temperature Instrumentation Reflector[d]	2	S	-9.2	±	0.3	Scaled from Core 1A
Total Correction			145	±	8	
Corrected k_{eff} (β_{eff} = 0.00723)			1.0106	±	0.0006	

(a) The control rods are fully inserted when 2500 mm is indicated.
(b) The measurement of the differential worths of the control rods in Core 2 has not been published anywhere, but the method was the same as was performed for Core 1A. The bank worth in Core 2 is 1.0 dollar compared with some 1.13 dollars in Core 1A.
(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) The values of those components residing in the radial reflector have been scaled from the Core 1A value by the ratio of the control rod bank worths in the two cores (~0.88).
(e) 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 17.5 cents for this core.
(f) R2 indicates the second ring of the C-Driver channels.
(g) 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.
(h) The upper reflector assembly has no appreciable reactivity worth in this configuration.
(i) In all the deterministic cores, some 12 pebbles lie directly over one of the 33 cooling channels in the lower axial reflector. In order to avoid pebble displacement in these cases, special aluminum plugs were developed to support the pebbles. In later cores, simple graphite rods were used.

Table 1.1-23. Core 3 (Reference State #1) Reactivity Corrections (Ref. 1 and 3).

Reactivity Corrections to Critical Loading	**No.**		**Total ¢**			**Comments**
Control Rod Insertion (0 mm)[(a)]	0					
Control Rod Channels[(b,c)]	4	S	-1.3	±	1	Scaled from Core 1A
Autorod Rest Worth[(c)]	1	S	-5.0	±	0.5	Scaled from Core 1A
Autorod Insertion (685 mm)[(c)]	1	S	-2.0	±	0.5	Scaled from Core 1A
Autorod Channel	1	S	-0.5	±	0.15	Core 1A Value
Safety and Shutdown Rod Channels[(c,d)]	8	C	-16	±	4	Scaled from Core 1A
Empty Channels R2[(c,e)]	2	S	-1.8	±	0.3	Scaled from Core 1A
Air Gaps in C-Driver Holes[(f)]	320	C	-6.8			
Channels in Upper Reflector[(g)]	33	S	-3.6	±	2.0	Core 1A Value
Channels in Lower Reflector[(h)]	1	S	-0.7	±	0.2	Graphite Filled
Start-up Source Penetrations	2	S	-1	±	0.1	Core 1A Value
Nuclear Instrumentation (Ionization)[(c)]	6	S	-5.6	±	1.8	Scaled from Core 1A
Nuclear Instrumentation (Fission)	2	S	-0.8	±	0.6	Core 1A Value
Total Correction			45.1	±	5	
Corrected k_{eff} (β_{eff} = 0.00727)			1.0033	±	0.0004	

(a) The control rods are fully inserted when 2500 mm is indicated.
(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) The values of those components residing in the radial reflector have been scaled from the Core 1A value by the ratio of the control rod bank worths in the two cores (~0.67).
(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 14 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) Although, as a result of the increased core moderation and reduced core height, the worth of the upper reflector, and hence the channels therein, will be reduced compared to Core 1A. The small size of the effect does not warrant any serious attention. Instead, the Core 1A value has been adopted, but with an increased uncertainty.
(h) In contrast to previous cores, all but one of the coolant channels in the lower axial reflector were filled with graphite plugs.

1.2 Description of Buckling and Extrapolation Length Measurements

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

1.3 Description of Spectral Characteristics Measurements

Spectral characteristics measurements were not made.

1.4 Description of Reactivity Effects Measurements

Reactivity effects measurements were made but have not yet been evaluated.

1.5 Description of Reactivity Coefficient Measurements

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

1.6 Description of Kinetics Measurements

Kinetics measurements were made but have not yet been evaluated.

1.7 Description of Reaction-Rate Distribution Measurements

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

1.8 Description of Power Distribution Measurements

Power distribution measurements were not made.

1.9 Description of Isotopic Measurements

Isotopic measurements were not made.

1.10 Description of Other Miscellaneous Types of Measurements

Other miscellaneous types of measurements were not made.

2.0 EVALUATION OF EXPERIMENTAL DATA

2.1 Evaluation of Critical and / or Subcritical Configuration Data

Four benchmark experiments were evaluated in this report: Cores 1, 1A, 2, and 3. These core configurations represent the hexagonal close packing (HCP) configurations of the HTR-PROTEUS experiment with a moderator-to-fuel pebble ratio of 1:2. Core 1 represents the only configuration utilizing ZEBRA control rods. Cores 1A, 2, and 3 use withdrawable, hollow, stainless steel control rods. Cores 1 and 1A are similar except for the use of different control rods; Core 1A also has one less layer of pebbles (21 layers instead of 22). Core 1A has two reference states: one in which the ZEBRA rod channels are empty and another where the channels are filled with graphite. The second reference state has been selected to represent the benchmark experiment configuration for Core 1A as it is most similar to Cores 2 and 3, which also have graphite fillers placed in the ZEBRA rod channels. Core 2 retains the first 16 layers of pebbles from Cores 1 and 1A; however, an additional 17 layers of moderator pebbles were loaded in order to eliminate the void space between the core region and the upper axial reflector. Core 3 retains the first 17 layers of pebbles from Cores 1 and 1A but has polyethylene rods inserted between pebbles to simulate water ingress. Only a single reference state was recorded for Cores 1, 2, and 3 benchmark experiment configurations. The additional partial pebble layer (layer 18) for Core 3 was not included as it was used for core operations and not the reported critical configuration.

The benchmark critical configurations for Cores 1, 1A, 2, and 3 will be referred to as Cases 1, 2, 3, and 4, 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.

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] cross section data was also used in this evaluation. The statistical uncertainty in k_{eff} and Δk_{eff} is ≤0.00010 and ≤0.00014, respectively. Calculations were performed with 1,650 generations with 50,000 neutrons per generation. The k_{eff} estimates (with the first 150 generations skipped) are the result of 75,000,000 neutron histories.

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,

[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).

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 2.1-172 through 2.1-176. 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.

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 2.1.22; 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. 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).

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

- Radial Reflector
  - C-Driver Positions
  - C-Driver Hole Diameter
  - ZEBRA Rod 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
  - Lattice Support Width
  - Lattice Support Length
  - Lattice Support Height
- ZEBRA Control Rods
  - Inner Tube Diametrical Thickness
  - Outer Tube Diametrical Thickness
  - Vertical Alignment of Tubes
  - Cadmium Thickness
  - Cadmium Length
- 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
  - ZEBRA Rod Positions
  - Withdrawable Control Rod Positions
  - Core Height

2.1.1 Concrete

Little information was available regarding geometry and composition of the concrete shielding surrounding the assembly. For analysis purposes, concrete was modeled only along the four sides of the assembly in a rectangular shape directly in contact with the outer surface of the radial reflector and thermal column, similar to models previously investigated for some PROTEUS configurations.[a] The wall spanned from the bottom of the steel plate pedestal to a total height of approximately 6300 mm, sufficient to allow for the full withdrawal of the safety/shutdown rods (see Figure 1.1-9). A concrete floor and ceiling were not modeled. The effective bias for voiding the concrete was determined to be negligible (Section 3.1.1.1), as was determined experimentally in Reference 4.

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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).

2.1.1.1 Thickness

The nominal thickness of the concrete shielding surrounding the assembly was 800 mm. The uncertainty in the wall thickness was assumed to be 100 mm (bounding limit with uniform probability distribution). A single-sided perturbation was performed in which the wall thickness was increased by 200 mm to estimate the uncertainty in k_{eff} due to the uncertainty in concrete thickness. The calculated results were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-1. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-1. Effect of Uncertainty in Concrete Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±200 mm	<0.00001	±	0.00014	2√3	<0.00001	±	0.00004
2 (1A)	±200 mm	<0.00001	±	0.00014	2√3	<0.00001	±	0.00004
3 (2)	±200 mm	<0.00001	±	0.00014	2√3	<0.00001	±	0.00004
4 (3)	±200 mm	<0.00001	±	0.00013	2√3	<0.00001	±	0.00004

2.1.1.2 Density

The density of the concrete shielding surrounding the assembly was not reported. A literature value of 3.45683 g/cm^3 has been used previously to model the Ba concrete walls of PROTEUS.[a] The uncertainty in the concrete density was assumed to be 20 % (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the concrete density was perturbed by ±20 % to estimate the uncertainty in k_{eff} due to the uncertainty in concrete density. 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 2.1-2. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-2. Effect of Uncertainty in Concrete Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±20 %	-0.00001	±	0.00007	√3	-0.00001	±	0.00004
2 (1A)	±20 %	0.00010	±	0.00007	√3	0.00005	±	0.00004
3 (2)	±20 %	0.00011	±	0.00007	√3	0.00006	±	0.00004
4 (3)	±20 %	0.00011	±	0.00007	√3	0.00006	±	0.00004

2.1.1.1 Composition

The composition of the concrete shielding surrounding the assembly was not reported. A reference composition has been used previously to model the Ba concrete walls of PROTEUS (see Table 2.1-3). Because the effective bias and uncertainties in neglecting the concrete is negligible, no additional uncertainty analysis in regards to the composition was performed since the resulting calculations would also be negligible.

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

Table 2.1-3. Composition of Ba Concrete Walls.[(a)]

Element	Composition (wt.%)	Atoms/barn-cm
Ba	44.868	6.8015E-03
O	10.443	1.3588E-02
S	32.978	2.1410E-02
Ca	4.869	2.5291E-03
Fe	4.604	1.7162E-03
Si	1.018	7.5456E-04
H	0.703	1.4519E-02
Al	0.402	3.1016E-04
Mg	0.114	9.7642E-05
Total	99.999	6.1726E-02

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

2.1.2 Steel Plate Pedestal

2.1.2.1 Thickness

The nominal thickness of the steel plate pedestal beneath the assembly was 75 mm (see Figure 1.1-19). The uncertainty in the plate thickness was assumed to be 1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the plate thickness was perturbed by ±3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in steel plate thickness. 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. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-4. Effect of Uncertainty in Support Plate Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	-0.00004	±	0.00007	3√3	-0.00001	±	0.00001
2 (1A)	±3 mm	0.00006	±	0.00007	3√3	0.00001	±	0.00001
3 (2)	±3 mm	-0.00003	±	0.00007	3√3	-0.00001	±	0.00001
4 (3)	±3 mm	0.00010	±	0.00007	3√3	0.00002	±	0.00001

2.1.2.2 Density

The density of the steel plate pedestal beneath the assembly was assumed to be that of nominal stainless steel, 7.92 g/cm^3, such as was reported for the 18/8 stainless steel cladding material for the safety/shutdown rods. The uncertainty in the steel density was assumed to be 0.01 g/cm^3 (1σ). A double-sided perturbation was performed in which the plate density was perturbed by ±0.03 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in steel plate density. 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. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-5. Effect of Uncertainty in Support Plate Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.03 g/cm^3	-0.00007	±	0.00007	3	-0.00002	±	0.00002
2 (1A)	±0.03 g/cm^3	0.00009	±	0.00007	3	0.00003	±	0.00002
3 (2)	±0.03 g/cm^3	0.00007	±	0.00007	3	0.00002	±	0.00002
4 (3)	±0.03 g/cm^3	-0.00009	±	0.00007	3	-0.00003	±	0.00002

2.1.2.3 Composition

The composition of the steel plate pedestal beneath the assembly was assumed to be that of nominal stainless steel, Types 301/302/304 (see Table 2.1-6). A double-sided perturbation was performed in which the plate 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 plate 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. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-6. Composition of Steel Plate Pedestal
(Stainless Steel Type 301/302/304).[(a)]

Element	Minimum wt.%	Maximum wt.%	Nominal wt.%	Nominal Atoms/barn-cm
Cr	16	20	18	1.6511E-02
Fe	Balance		72.425	6.1855E-02
Ni	6	10	8	6.5099E-03
C	--	0.15	0.075	2.9783E-04
Si	--	1	0.5	8.4910E-04
Mn	--	2	1	8.6816E-04
Total	--	--	100	8.6882E-02

(a) Perry, R. H., and Green, D. W., Eds., Perry's Chemical Engineers' Handbook (7th Edition), Mc-Graw-Hill, New York, NY (1997).

Table 2.1-7. Effect of Uncertainty in Support Plate Composition.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	Min/Max Fe	-0.00006	±	0.00007	√3	-0.00003	±	0.00004
2 (1A)	Min/Max Fe	-0.00009	±	0.00007	√3	-0.00005	±	0.00004
3 (2)	Min/Max Fe	0.00006	±	0.00007	√3	0.00003	±	0.00004
4 (3)	Min/Max Fe	-0.00007	±	0.00007	√3	-0.00004	±	0.00004

2.1.3 Radial Reflector and Thermal Column

2.1.3.1 Inner Equivalent Diameter

The radial reflector is comprised of an unknown quantity of finely machined graphite blocks. These blocks are placed in a radial pattern surrounding the cavity region, approximating a nearly circular annulus (Figure 1.1-3). The radial reflector is an irregularly-shaped icosikaidigon (22-sided polygon). Available information regarding the dimensions of the radial reflector were utilized to estimate the location of the vertices to form the annular shape (see Figure 2.1-1). A perfect polygon could not be generated using all the dimensions provided. Various dimensions had to be estimated and the smallest dimension on the smallest piece, 62 mm, was too small to fill the gap between the other pieces. Possible gaps in assembly may have contributed to slight measurement discrepancies. The smallest dimension on the smallest piece was modeled as 66.5981 mm. The impact of dimensional discrepancies is negligible.

The dimensions shown in Figure 2.1-1 were used to calculate the total area encompassed by the inner polygon (~1.24 m^2) and then the radius and diameter of a circle encompassing this equivalent area (~628 and ~1257 mm, respectively).

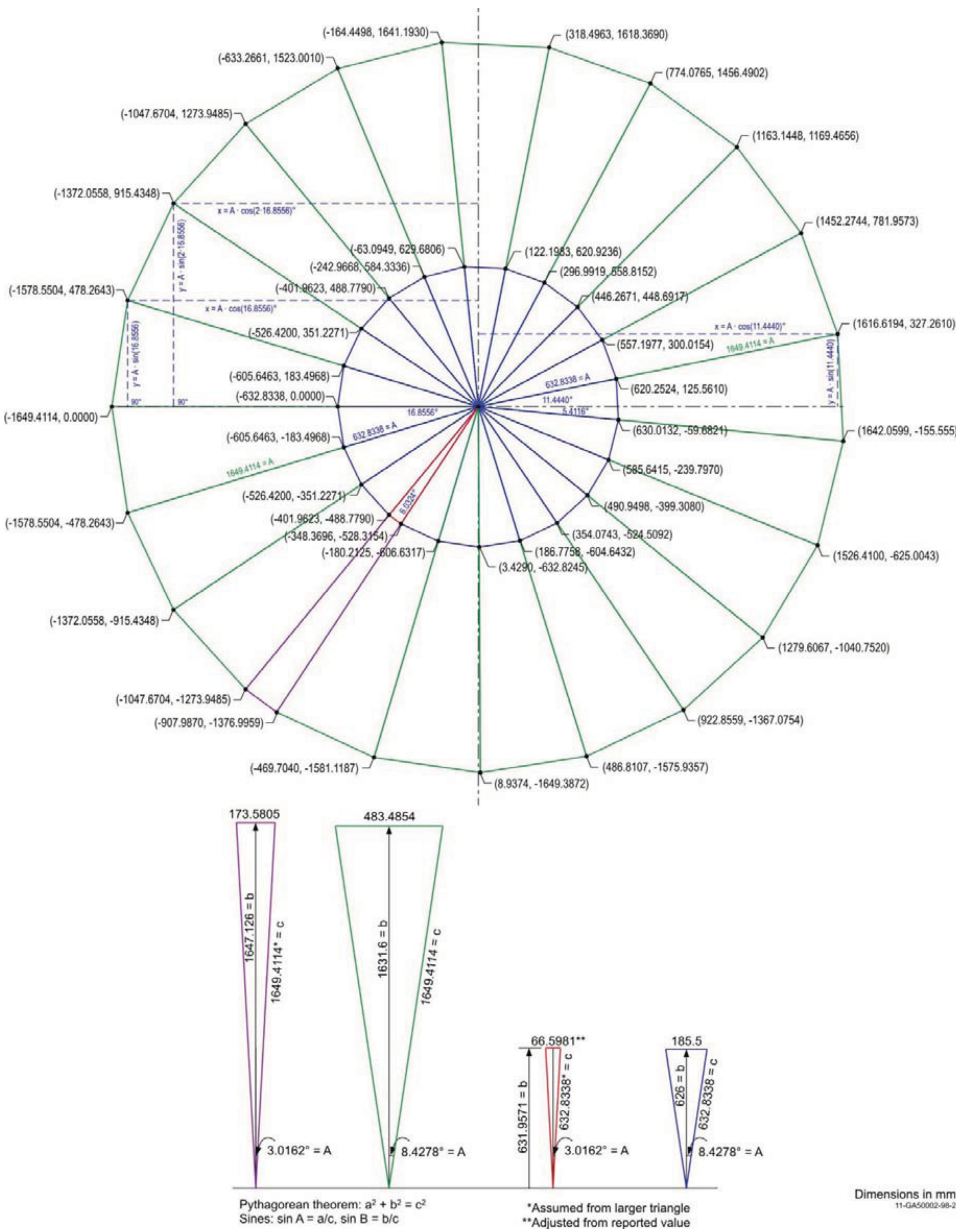

Figure 2.1-1. Vertices and dimensions of the radial reflector.

The calculated inner equivalent diameter of the radial reflector surrounding the core is ~1257 mm. The uncertainty in the diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the diameter was perturbed by ±3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in inner equivalent diameter 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 2.1-8. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-8. Effect of Uncertainty in Inner Equivalent Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	-0.00036	±	0.00007	3√3	-0.00007	±	0.00001
2 (1A)	±3 mm	-0.00031	±	0.00007	3√3	-0.00006	±	0.00001
3 (2)	±3 mm	-0.00045	±	0.00007	3√3	-0.00009	±	0.00001
4 (3)	±3 mm	-0.00043	±	0.00006	3√3	-0.00008	±	0.00001

2.1.3.2 Outer Equivalent Diameter

The dimensions shown in Figure 2.1-1 were used to calculate the total area encompassed by the outer polygon describing the radial reflector (~8.43 m^2) and then the radius and diameter of a circle encompassing this equivalent area (~1638 and ~3275 mm, respectively).

The calculated outer equivalent diameter of the radial reflector surrounding the core is ~3275 mm. The uncertainty in the diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the diameter was perturbed by ±3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in outer equivalent diameter 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 2.1-9. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-9. Effect of Uncertainty in Outer Equivalent Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	-0.00002	±	0.00007	3√3	<0.00001	±	0.00001
2 (1A)	±3 mm	-0.00012	±	0.00007	3√3	-0.00002	±	0.00001
3 (2)	±3 mm	<0.00001	±	0.00007	3√3	<0.00001	±	0.00001
4 (3)	±3 mm	0.00007	±	0.00006	3√3	0.00001	±	0.00001

2.1.3.3 Height

The radial reflector (see Figures 1.1-1 and 1.1-2) 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 radial reflector surrounding the core was 3304 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 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 2.1-10. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-10. Effect of Uncertainty in Height.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	-0.00002	±	0.00007	3√3	<0.00001	±	0.00001
2 (1A)	±3 mm	-0.00002	±	0.00007	3√3	<0.00001	±	0.00001
3 (2)	±3 mm	-0.00004	±	0.00007	3√3	-0.00001	±	0.00001
4 (3)	±3 mm	0.00004	±	0.00006	3√3	0.00001	±	0.00001

2.1.3.4 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 1.1-8), 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 2.1-11.

Table 2.1-11. Effect of Uncertainty in Graphite Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.036 g/cm^3	0.00292	±	0.00007	3	0.00097	±	0.00002
2 (1A)	±0.036 g/cm^3	0.00268	±	0.00007	3	0.00089	±	0.00002
3 (2)	±0.036 g/cm^3	0.00273	±	0.00007	3	0.00091	±	0.00002
4 (3)	±0.036 g/cm^3	0.00229	±	0.00006	3	0.00076	±	0.00002

2.1.3.5 Graphite Impurities

Various values were reported for the nominal absorption cross section or boron content for the graphite material used in the core (Table 1.1-8). 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 2.1-12.

Table 2.1-12. Effect of Uncertainty in Graphite Impurity Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.24 ppma	-0.00207	±	0.00007	3	-0.00069	±	0.00002
2 (1A)	±0.24 ppma	-0.00233	±	0.00007	3	-0.00078	±	0.00002
3 (2)	±0.24 ppma	-0.00236	±	0.00007	3	-0.00078	±	0.00002
4 (3)	±0.24 ppma	-0.00186	±	0.00007	3	-0.00062	±	0.00002

2.1.3.6 C-Driver Hole Positions

Information regarding the radial distance of the C-Driver channels from the center of the assembly were not provided. From Figure 1.1-3 it can be concluded that they were spaced equidistantly surrounding the core and roughly equidistant in the distance between the five rings. The withdrawable control rods were used exclusively in ring 5 but could have been used in ring 3; the radial distance of 906 and 789 mm, respectively, were reported for these two rings. An average distance was computed to obtain the radial position of the other three rings. Equidistant holes within a ring are 5.625° apart with positions located in one ring halfway between holes in an adjacent ring (2.8125°). Due to the uncertainty in the exact radial

[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).

placement of each C-Driver ring, an uncertainty of ±5 mm is assumed sufficient to encompass that uncertainty. This uncertainty also encompasses the uncertainty in the angular placement within a ring (assumed negligible) and the uncertainty in displacing the withdrawable control rods in Cases 2 through 4).

The positions of the C-Driver holes within the radial reflector surrounding the core were approximately 672, 730.5, 789, 847.5, and 906 mm radially from the core center. The uncertainty in these positions was 5 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which all positions were simultaneously perturbed by ±15 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the positions of the C-Driver holes within 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 2.1-13. The calculated uncertainty is negligible (≤0.00010). As can be seen by the calculated values, there is no significant difference between the perturbation of the C-Driver positions in the cores with withdrawable control rods (Cases 2 through 4) and the core using ZEBRA control rods (Case 1).

Table 2.1-13. Effect of Uncertainty in C-Driver Positions.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±15 mm	-0.00013	±	0.00007	3√3	-0.00003	±	0.00001
2 (1A)	±15 mm	-0.00011	±	0.00007	3√3	-0.00002	±	0.00001
3 (2)	±15 mm	0.00014	±	0.00007	3√3	0.00003	±	0.00001
4 (3)	±15 mm	<0.00001	±	0.00007	3√3	<0.00001	±	0.00001

2.1.3.7 C-Driver Hole Diameter

The diameter of the C-Driver holes within the radial reflector surrounding the core was 27.43 mm. The uncertainty in hole diameter was assumed to be 0.01 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the diameter of all positions were simultaneously perturbed by ±0.03 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the diameter of the C-Driver holes within 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 2.1-14. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-14. Effect of Uncertainty in C-Driver Hole Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.03 mm	-0.00011	±	0.00007	3√3	-0.00002	±	0.00001
2 (1A)	±0.03 mm	-0.00007	±	0.00007	3√3	-0.00001	±	0.00001
3 (2)	±0.03 mm	-0.00008	±	0.00007	3√3	-0.00001	±	0.00001
4 (3)	±0.03 mm	-0.00003	±	0.00007	3√3	-0.00001	±	0.00001

2.1.3.8 Autorod Hole Position

The position of the autorod is shown in Figure 1.1-2b, where it encompasses a C-Driver position in the 5^{th} ring. A radial distance of 890 mm from core center at a position ~80° clockwise from the x-axis is reported. To properly displace the C-Driver position in the radial reflector, as shown in Figure 1.1-2b, an angle of 78.75° was selected for the autorod position. The x,y-coordinates for the autorod position are (17.36, -87.29 cm). The uncertainty in the autorod position is assumed to be the same as the uncertainty used to evaluate the position of the C-Driver channels (±5 mm). Angular displacement of the autorod is assumed to have a negligible effect compared to its radial distance from the core center.

The positions of the autorod hole within the radial reflector surrounding the core was 890 mm radially from the core center. The uncertainty in this position was 5 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the position was perturbed by ±15 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the position of the autorod hole within 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 2.1-15. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-15. Effect of Uncertainty in Autorod Position.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±15 mm	0.00010	±	0.00007	3√3	0.00002	±	0.00001
2 (1A)	±15 mm	0.00016	±	0.00007	3√3	0.00003	±	0.00001
3 (2)	±15 mm	0.00006	±	0.00007	3√3	0.00001	±	0.00001
4 (3)	±15 mm	-0.00003	±	0.00007	3√3	-0.00001	±	0.00001

2.1.3.9 Autorod Hole Diameter

The diameter of the autorod hole within the radial reflector surrounding the core was 55 mm. The uncertainty in hole diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the hole diameter was perturbed by ±3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the diameter of the autorod hole within 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 2.1-16. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-16. Effect of Uncertainty in Autorod Hole Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	0.00003	±	0.00007	3√3	0.00001	±	0.00001
2 (1A)	±3 mm	-0.00004	±	0.00007	3√3	-0.00001	±	0.00001
3 (2)	±3 mm	-0.00004	±	0.00007	3√3	-0.00001	±	0.00001
4 (3)	±3 mm	-0.00006	±	0.00007	3√3	-0.00001	±	0.00001

2.1.3.10 ZEBRA Rod Hole Positions

The position of the ZEBRA rods is shown in Figure 1.1-2b. A radial distance of 896.3 mm from core center is reported. The x,y-coordinates for the ZEBRA positions are (±21.84, ±86.93 cm). The uncertainty in the ZEBRA rod positions is assumed to be the same as the uncertainty used to evaluate the position of the C-Driver channels (±5 mm). Angular displacement of the ZEBRA rod positions is assumed to have a negligible effect compared to its radial distance from the core center.

The position of the ZEBRA rod holes within the radial reflector surrounding the core was 896.3 mm radially from the core center. The uncertainty in these positions was 5 mm (bounding limit with uniform probability distribution). A single-sided perturbation was performed in which all positions were simultaneously increased by 15 mm radially from the core center to estimate the uncertainty in k_{eff} due to the uncertainty in the positions of the ZEBRA rod holes within the radial reflector. The calculated results were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-17. The uncertainty in Cases 2 through 4 (Cores 1A, 2, and 3) are negligible because ZEBRA rods were not utilized in these configurations; the holes were filled with graphite filler rods.

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 divided by √4 to account for the perturbation of multiple positions. The final adjusted Δk_{eff} uncertainty was obtained by summing under quadrature the systematic and random uncertainties.

Table 2.1-17. Effect of Uncertainty in ZEBRA Rod Hole Positions.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (1)	+15 mm	0.00184	±	0.00014	3√3	0.00035	±	0.00003	0.00016
2 (1A)	+15 mm	-0.00004	±	0.00014	3√3	-0.00001	±	0.00003	<0.00001
3 (2)	+15 mm	-0.00009	±	0.00014	3√3	-0.00002	±	0.00003	<0.00001
4 (3)	+15 mm	0.00016	±	0.00013	3√3	0.00003	±	0.00002	<0.00001

2.1.3.11 ZEBRA Rod Hole Diameter

The diameter of the ZEBRA rod holes within the radial reflector surrounding the core was 45 mm. The uncertainty in hole diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A single-sided perturbation was performed in which the diameter of all positions were simultaneously increased by 3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the diameter of the ZEBRA rod holes within the radial reflector. The calculated results were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-18.

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 divided by √4 to account for the perturbation of multiple positions. The final adjusted Δk_{eff} uncertainty was obtained by summing under quadrature the systematic and random uncertainties. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-18. Effect of Uncertainty in ZEBRA Rod Hole Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (1)	+3 mm	-0.00056	±	0.00014	3√3	-0.00011	±	0.00003	0.00005
2 (1A)	+3 mm	-0.00017	±	0.00014	3√3	-0.00003	±	0.00003	0.00001
3 (2)	+3 mm	-0.00008	±	0.00014	3√3	-0.00002	±	0.00003	0.00001
4 (3)	+3 mm	0.00028	±	0.00013	3√3	0.00005	±	0.00003	0.00002

2.1.3.12 ZEBRA Rod Hole Filler Diameter

Dimensional information for the ZEBRA rod hole fillers was unavailable. It was assumed that these fillers would fill most of the ZEBRA rod hole with sufficient dimensional tolerance to easily allow for their insertion and removal. The ZEBRA rod hole diameter is 45 mm; a diameter of 44 mm was assumed for the fillers. The fillers would have also extended the full length of the radial reflector.

The diameter of the ZEBRA rod hole fillers within the radial reflector surrounding the core was assumed to be 44 mm. The uncertainty in hole diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A single-sided perturbation was performed in which the diameter of all positions were simultaneously increased by 1 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the diameter of the ZEBRA rod hole fillers within the radial reflector. The calculated results were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-19.

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 divided by √4 to account for the perturbation of multiple positions. The final adjusted Δk_{eff} uncertainty was obtained by summing under quadrature the systematic and random uncertainties. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-19. Effect of Uncertainty in ZEBRA Rod Hole Filler Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (1)	NA	NA			NA	NA			NA
2 (1A)	+1 mm	-0.00017	±	0.00014	√3	-0.00010	±	0.00008	0.00004
3 (2)	+1 mm	0.00015	±	0.00014	√3	0.00009	±	0.00008	0.00004
4 (3)	+1 mm	-0.00013	±	0.00013	√3	-0.00019	±	0.00008	0.00009

2.1.3.13 ZEBRA Rod Hole Filler Length

Perturbation of the length of the ZEBRA Rod Hole Fillers, which would have extended the full length of the radial reflector (3304 mm), was performed as part of the uncertainty analysis of the radial reflector height (see Section 2.1.3.3). The effective uncertainty in perturbing the radial reflector height was negligible; therefore, the effective uncertainty in perturbing the length of the ZEBRA rod hole fillers would also be negligible.

2.1.3.14 ZEBRA Rod Hole Filler Density

The filler rods for the ZEBRA rod channels are reported to have a density of 1.78 g/cm^3. No uncertainty was provided. It is assumed that the measured density uncertainty of 0.012 g/cm^3 (1σ), discussed in Section 2.1.3.4, 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 ZEBRA rod hole filler graphite within the radial reflector surrounding the core was 1.78 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 ZEBRA rod hole filler graphite. 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 2.1-20. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-20. Effect of Uncertainty in ZEBRA Rod Hole Filler Density.

Case (Core)	**Deviation**	**Δk$_p$**	**±**	**σ$_{Δkp}$**	**Scaling Factor**	**Δk$_{eff}$ (1σ)**	**±**	**σ$_{Δkeff}$**
1 (1)	NA	NA			NA	NA		
2 (1A)	±0.036 g/cm^3	<0.00001	±	0.00007	3	<0.00001	±	0.00002
3 (2)	±0.036 g/cm^3	0.00003	±	0.00007	3	0.00001	±	0.00002
4 (3)	±0.036 g/cm^3	-0.00001	±	0.00006	3	<0.00001	±	0.00002

2.1.3.15 ZEBRA Rod Hole Filler Impurities

It is assumed that the EBC of 1.33 ± 0.08 ppm (by at.%), discussed in Section 2.1.3.5, sufficiently described the impurity content in the filler rods used in the ZEBRA rod holes.

The impurity content of the ZEBRA rod hole filler graphite within the radial reflector surrounding the core 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 ZEBRA rod hole filler graphite. 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 uncertainty is negligible (≤0.00010).

Table 2.1-21. Effect of Uncertainty in ZEBRA Rod Hole Filler Graphite Impurity Content.

Case (Core)	**Deviation**	**Δk$_p$**	**±**	**σ$_{Δkp}$**	**Scaling Factor**	**Δk$_{eff}$ (1σ)**	**±**	**σ$_{Δkeff}$**
1 (1)	NA	NA			NA	NA		
2 (1A)	±0.24 ppma	-0.00001	±	0.00007	3	<0.00001	±	0.00002
3 (2)	±0.24 ppma	0.00003	±	0.00007	3	0.00001	±	0.00002
4 (3)	±0.24 ppma	-0.00001	±	0.00006	3	<0.00001	±	0.00002

2.1.3.16 Safety/Shutdown Rod Hole Positions

The position of the safety/shutdown rods is shown in Figure 1.1-2b. A radial distance of 684 mm from core center is reported. The x,y-coordinates for the safety/shutdown rod positions are as follows:

1. -38.45, 56.57
2. 32.74, -60.05
3. 57.17, 37.55
4. -53.23, -42.95
5. 67.19, -12.82
6. -66.98, 13.87
7. 19.31, 65.62
8. -13.87, -66.98 cm

The uncertainty in the safety/shutdown rod positions is assumed to be the same as the uncertainty used to evaluate the position of the C-Driver channels (±5 mm). Angular displacement of the safety/shutdown rod positions is assumed to have a negligible effect compared to its radial distance from the core center.

The positions of the safety/shutdown rod within the radial reflector surrounding the core were 684 mm radially from the core center. The uncertainty in these positions was 5 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which all positions were simultaneously perturbed by ±15 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the positions of the safety/shutdown rod holes within 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 2.1-22. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-22. Effect of Uncertainty in Safety/Shutdown Rod Positions.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	+15 mm	0.00006	±	0.00007	3√3	0.00001	±	0.00001
2 (1A)	+15 mm	0.00011	±	0.00007	3√3	0.00002	±	0.00001
3 (2)	+15 mm	0.00007	±	0.00007	3√3	0.00001	±	0.00001
4 (3)	+15 mm	0.00024	±	0.00006	3√3	0.00005	±	0.00001

2.1.3.17 Safety/Shutdown Rod Hole Diameter

The diameter of the safety/shutdown rod holes within the radial reflector surrounding the core was 45 mm. The uncertainty in hole diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the diameter of all positions were simultaneously perturbed by ±3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the diameter of the safety/shutdown holes within 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 2.1-23. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-23. Effect of Uncertainty in Safety/Shutdown Hole Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	-0.00051	±	0.00007	3√3	-0.00010	±	0.00001
2 (1A)	±3 mm	-0.00049	±	0.00007	3√3	-0.00009	±	0.00001
3 (2)	±3 mm	-0.00037	±	0.00007	3√3	-0.00007	±	0.00001
4 (3)	±3 mm	-0.00041	±	0.00007	3√3	-0.00008	±	0.00001

2.1.3.18 Thermal Column Width

The width of the thermal column was ~1200 mm (Figure 1.1-3). The uncertainty in the width was assumed to be 10 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the width was perturbed by ±30 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the width of the thermal column. 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. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-24. Effect of Uncertainty in Thermal Column Width.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±30 mm	-0.00004	±	0.00007	3√3	-0.00001	±	0.00001
2 (1A)	±30 mm	0.00009	±	0.00007	3√3	0.00002	±	0.00001
3 (2)	±30 mm	-0.00003	±	0.00007	3√3	-0.00001	±	0.00001
4 (3)	±30 mm	0.00002	±	0.00006	3√3	<0.00001	±	0.00001

2.1.3.19 Thermal Column Depth

The depth of the thermal column was ~530 mm (Figure 1.1-3). The uncertainty in the depth was assumed to be 10 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the depth was perturbed by ±30 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the depth of the thermal column. 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 2.1-25. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-25. Effect of Uncertainty in Thermal Column Depth.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±30 mm	-0.00005	±	0.00007	3√3	-0.00001	±	0.00001
2 (1A)	±30 mm	-0.00003	±	0.00007	3√3	-0.00001	±	0.00001
3 (2)	±30 mm	<0.00001	±	0.00007	3√3	<0.00001	±	0.00001
4 (3)	±30 mm	0.00001	±	0.00007	3√3	<0.00001	±	0.00001

2.1.3.20 Thermal Column Height

The height of the thermal column was 1200 mm. The uncertainty in the height was assumed to be 10 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the height was perturbed by ±30 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the height of the thermal column. 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 2.1-26. The calculated uncertainty is negligible (≤0.00010). Perturbation of the vertical location of the thermal column with respect to the core cavity region was also assumed to be negligible.

Table 2.1-26. Effect of Uncertainty in Thermal Column Height.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±30 mm	0.00005	±	0.00007	3√3	0.00001	±	0.00001
2 (1A)	±30 mm	0.00003	±	0.00007	3√3	0.00001	±	0.00001
3 (2)	±30 mm	-0.00001	±	0.00007	3√3	<0.00001	±	0.00001
4 (3)	±30 mm	-0.00006	±	0.00006	3√3	-0.00001	±	0.00001

2.1.3.21 Safety Ring Vertical Thickness

The safety ring (Figure 1.1-4) is located 1764 mm above the floor of the cavity; any uncertainty in its position is assumed to be negligible and included within the uncertainty in the thickness of the ring itself. The vertical thickness of the safety ring was 10 mm. 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 to estimate the uncertainty in k_{eff} due to the uncertainty in the vertical thickness of the safety ring. 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 2.1-27. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-27. Effect of Uncertainty in Safety Ring Vertical Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	-0.00050	±	0.00007	3√3	-0.00010	±	0.00001
2 (1A)	±3 mm	-0.00050	±	0.00007	3√3	-0.00010	±	0.00001
3 (2)	±3 mm	0.00001	±	0.00007	3√3	<0.00001	±	0.00001
4 (3)	±3 mm	-0.00045	±	0.00006	3√3	-0.00009	±	0.00001

2.1.3.22 Safety Ring Diametrical Thickness

The diametrical thickness of the safety ring is defined as the distance between its inner diameter (1208 mm) and outer diameter (1400 mm) shown in Figure 1.1-4.

The diametrical thickness of the safety ring was 96 mm. 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 (split 1.5 mm apiece between the inner and outer diameters) to estimate the uncertainty in k_{eff} due to the uncertainty in the diametrical thickness of the safety ring. 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 2.1-28. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-28. Effect of Uncertainty in Safety Ring Diametrical Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	-0.00001	±	0.00007	3√3	<0.00001	±	0.00001
2 (1A)	±3 mm	-0.00009	±	0.00007	3√3	-0.00002	±	0.00001
3 (2)	±3 mm	-0.00004	±	0.00007	3√3	-0.00001	±	0.00001
4 (3)	±3 mm	-0.00022	±	0.00007	3√3	-0.00004	±	0.00001

2.1.3.23 Safety Ring Density

The mass of the Peraluman-300 safety ring was reported to be 10.42 kg. It is assumed this mass was measured prior to punching holes in the ring to accommodate graphite plugs in the C-Driver positions of the 1st ring in the radial reflector. The safety ring has a volume of ~3475 cm^3 and mass density of ~3.00 g/cm^3 if the volume of the holes are removed from the total volume before calculating the density. The volume of the ring without removing holes, and the associated mass density, are ~3933 cm^3 and 2.65 g/cm^3. This latter mass density matches the reported density for Peraluman R-257 that is used in the ZEBRA control rods. Therefore a mass density of 2.65 g/cm^3 is selected as the density of the safety ring. An uncertainty in the mass measurement was not reported and is expected to be quite small. An uncertainty of ±0.01 g/cm^3 is equivalent to ~40 g, and is assumed to represent a 1σ uncertainty in the mass of the safety ring.

The density of the safety ring was 2.65 g/cm^3. The uncertainty in the density was assumed to be 0.01 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.03 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in the density of the safety ring. 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. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-29. Effect of Uncertainty in Safety Ring Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.03 g/cm^3	-0.00005	±	0.00007	3	-0.00002	±	0.00002
2 (1A)	±0.03 g/cm^3	0.00006	±	0.00007	3	0.00002	±	0.00002
3 (2)	±0.03 g/cm^3	-0.00007	±	0.00007	3	0.00002	±	0.00002
4 (3)	±0.03 g/cm^3	0.00001	±	0.00007	3	<0.00001	±	0.00002

2.1.3.24 Safety Ring Composition

The composition specifications for Peraluman-300 is provided in Table 1.1-10. 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 2.1-30.

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 2.1-31.

Table 2.1-30. 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 2.1-31. Effect of Uncertainty in Safety Ring Composition.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	Min/Max Al	0.00012	±	0.00007	√3	0.00007	±	0.00004
2 (1A)	Min/Max Al	0.00011	±	0.00007	√3	0.00006	±	0.00004
3 (2)	Min/Max Al	0.00001	±	0.00007	√3	<0.00001	±	0.00004
4 (3)	Min/Max Al	0.00018	±	0.00006	√3	0.00011	±	0.00004

2.1.3.25 C-Driver Plug Diameter

The diameter of the C-Driver plugs within the radial reflector surrounding the core was 26.5 mm. The uncertainty in hole diameter was assumed to be 0.1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the diameter of all plugs were simultaneously perturbed by ±0.3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the diameter of the C-Driver plugs within 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 2.1-32. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-32. Effect of Uncertainty in C-Driver Plug Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.3 mm	0.00054	±	0.00007	3√3	0.00010	±	0.00001
2 (1A)	±0.3 mm	0.00037	±	0.00007	3√3	0.00007	±	0.00001
3 (2)	±0.3 mm	0.00048	±	0.00007	3√3	0.00009	±	0.00001
4 (3)	±0.3 mm	0.00018	±	0.00007	3√3	0.00003	±	0.00001

2.1.3.26 C-Driver Plug Length

Perturbation of the length of the C-Driver plugs, which would have extended the full length of the radial reflector (3304 mm), was performed as part of the uncertainty analysis of the radial reflector height (see Section 2.1.3.3). The effective uncertainty in perturbing the radial reflector height was negligible; therefore, the effective uncertainty in perturbing the length of the C-Driver plugs would also be negligible.

2.1.3.27 C-Driver Plug Density

The C-Driver plugs were reported in Table 1.1-8 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 2.1.3.4, 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 2.1-33.

Table 2.1-33. 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 (1)	±0.036 g/cm^3	0.00027	±	0.00007	3	0.00009	±	0.00002
2 (1A)	±0.036 g/cm^3	0.00024	±	0.00007	3	0.00008	±	0.00002
3 (2)	±0.036 g/cm^3	0.00033	±	0.00007	3	0.00011	±	0.00002
4 (3)	±0.036 g/cm^3	0.00024	±	0.00007	3	0.00008	±	0.00002

2.1.3.28 C-Driver Plug Impurities

It is assumed that the EBC of 1.33 ± 0.08 ppm (by at.%), discussed in Section 2.1.3.5, sufficiently described the impurity content in the filler rods used in the C-Driver holes.

The impurity content of the C-Driver plugs within the radial reflector surrounding the core 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 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 2.1-34. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-34. Effect of Uncertainty in C-Driver Plug Impurity Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.24 ppma	-0.00015	±	0.00007	3	-0.00005	±	0.00002
2 (1A)	±0.24 ppma	-0.00005	±	0.00007	3	-0.00002	±	0.00002
3 (2)	±0.24 ppma	-0.00024	±	0.00007	3	-0.00008	±	0.00002
4 (3)	±0.24 ppma	-0.00014	±	0.00007	3	-0.00005	±	0.00002

2.1.4 Upper Axial Reflector

2.1.4.1 Central Cylinder Diameter

The diameter of the central graphite cylinder of the upper axial reflector was 394 mm (Figure 1.1-4). The uncertainty in the diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A single-sided perturbation was performed in which the diameter was decreased 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 2.1-35. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-35. Effect of Uncertainty in Central Cylinder Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	-2 mm	-0.00007	±	0.00014	2√3	-0.00002	±	0.00004
2 (1A)	-2 mm	0.00002	±	0.00014	2√3	0.00001	±	0.00004
3 (2)	-2 mm	-0.00015	±	0.00014	2√3	-0.00004	±	0.00004
4 (3)	-2 mm	0.00002	±	0.00013	2√3	0.00001	±	0.00004

2.1.4.2 Annulus Inner Diameter

The inner diameter of the annulus of the upper axial reflector was reported to be 418.6 mm. It is apparent from Figure 1.1-5, that the annulus consisted of 21 graphite blocks forming an irregular icosikaihenagon (21-sided polygon) and then surrounded by 36 tightly-packed rectangular graphite blocks. Dimensions for these individual graphite blocks were unavailable. However, the exact mass of the upper reflector was measured and there was not a significant bias for cylinderizing the annulus of the lower axial reflector, which is very similar in dimensions and formation. A slightly larger uncertainty was used to evaluate the uncertainty in the annulus inner diameter compared to what was typically assumed for other graphite component of PROTEUS to determine whether there would be any significant effect on the uncertainty in k_{eff}.

The annulus inner diameter of the upper axial reflector was 418.6 mm. The uncertainty in the diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the diameter was perturbed by ±6 mm to estimate the uncertainty in k_{eff} due to the uncertainty in annulus inner diameter. 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 2.1-36. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-36. Effect of Uncertainty in Annulus Inner Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±6 mm	0.00005	±	0.00007	6√3	<0.00001	±	0.00001
2 (1A)	±6 mm	0.00013	±	0.00007	6√3	0.00001	±	0.00001
3 (2)	±6 mm	0.00001	±	0.00007	6√3	<0.00001	±	0.00001
4 (3)	±6 mm	<0.00001	±	0.00006	6√3	<0.00001	±	0.00001

2.1.4.3 Annulus Outer Diameter

The discussion provided in Section 2.1.4.2 regarding the reported dimensions of the upper axial reflector annulus apply for the computation of the uncertainty in the 1234 mm outer diameter. A larger perturbation in the outer diameter could not be performed due to spatial limitations from the aluminum support structure.

The annulus outer diameter of the upper axial reflector was 1234 mm. The uncertainty in the diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A single-sided perturbation was performed in which the diameter was decreased by 2 mm to estimate the uncertainty in k_{eff} due to the uncertainty in annulus outer diameter. Mass was conserved. The calculated results were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-37. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-37. Effect of Uncertainty in Annulus Outer Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	-2 mm	0.00018	±	0.00015	2√3	0.00005	±	0.00004
2 (1A)	-2 mm	0.00027	±	0.00014	2√3	0.00008	±	0.00004
3 (2)	-2 mm	0.00016	±	0.00014	2√3	0.00005	±	0.00004
4 (3)	-2 mm	-0.00030	±	0.00013	2√3	-0.00009	±	0.00004

2.1.4.4 Annulus Geometry

As discussed in Section 2.1.4.2, the annulus of the upper axial reflector consists of multiple graphite blocks. Slight gaps would exist between these blocks. These streaming paths would be negligible compared to those of the open coolant channels and annuli between the graphite components and the aluminum support structure. Furthermore, the upper axial reflector is suspended above the core cavity with either air (Cases 1, 2, and 4) or moderator pebbles (Case 3) between it and the fueled region. Any additional uncertainty due to homogenization of these graphite blocks into a single annulus is considered negligible.

The orientation of the upper axial reflector is assumed to match that of the lower axial reflector such that the open coolant channels in both reflectors are coaxial. Rotation of either axial reflector is assumed to have negligible impact on the uncertainty in k_{eff}.

2.1.4.5 Graphite Height

The upper axial reflector (see Figure 1.1-5) has penetrations, many of which were 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 upper 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 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 2.1-38. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-38. Effect of Uncertainty in Height.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	-0.00010	±	0.00007	3√3	-0.00002	±	0.00001
2 (1A)	±3 mm	-0.00002	±	0.00007	3√3	<0.00001	±	0.00001
3 (2)	±3 mm	-0.00009	±	0.00007	3√3	-0.00002	±	0.00001
4 (3)	±3 mm	0.00002	±	0.00006	3√3	<0.00001	±	0.00001

2.1.4.6 Location above Core

The bottom surface of the graphite in the upper axial reflector is location 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 single-sided perturbation was performed in which the location was increased by 30 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the location of the upper axial reflector. The calculated results were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-39. The uncertainty in the position for Case 3 is much smaller than in the other core configurations due to the large quantity of moderator pebbles between the fueled core and the upper axial reflector.

Table 2.1-39. 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 (1)	+30 mm	-0.01015	±	0.00014	6√3	-0.00098	±	0.00001
2 (1A)	+30 mm	-0.01147	±	0.00014	6√3	-0.00110	±	0.00001
3 (2)	+30 mm	-0.00111	±	0.00014	6√3	-0.00011	±	0.00001
4 (3)	+30 mm	-0.01079	±	0.00013	6√3	-0.00104	±	0.00001

2.1.4.7 Graphite Mass

The graphite used in the upper axial reflector is comprised of both old and new graphite (see Table 1.1-8). The central cylinder was new graphite with a reported mass density of 1.75 ± 0.007 g/cm^3. The graphite blocks forming the annulus was old graphite with a reported mass density of 1.76 ± 0.01 g/cm^3. The total mass of the graphite in the upper axial reflector was reported as 1585.64 kg. Computation of the mass density using the reported mass and volume of the cylinder and annulus produces a mass density of ~1.87 g/cm^3. The measured mass is reduced by the mass of the 127 graphite plugs (~96.16 kg assuming a mass density of 1.76 g/cm^3) located in coolant channels within the upper axial reflector. The corrected mass of the upper axial reflector is ~1489.48 kg. This total mass was distributed between the cylinder and annulus by calculating the nominal mass of each component based on the nominal densities for new and old graphite, respectively, and then scaling the total mass allocated to each graphite component. The mass of the cylinder and annulus were ~165.70 and ~1323.78 kg, respectively (mass density of 1.750896 and 1.760901 g/cm^3, respectively). It is assumed that the measured density uncertainty of 0.012 g/cm^3 (1σ), discussed in Section 2.1.3.4, sufficiently encompasses the uncertainty in the density of the graphite in the upper axial reflector. This uncertainty equates to a mass uncertainty of ~1.14 kg in the central cylinder and ~9.02 kg in the annulus, a total of ~10.16 kg uncertainty in the mass of the upper axial reflector (excluding the 127 graphite plugs).

The mass of the upper axial reflector was ~1489.48 kg (effective mass density of ~1.751 and ~1.761 in the central cylinder and annulus, respectively). The assumed uncertainty in the density was 0.012 g/cm^3 (±10.16 kg, 1σ). A double-sided perturbation was performed in which the density was perturbed by

[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).

±0.036 g/cm^3 (±30.47 kg) to estimate the uncertainty in k_{eff} due to the uncertainty in the density 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 2.1-40. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-40. Effect of Uncertainty in Upper Axial Reflector Mass.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.036 g/cm^3 (±30.47 kg)	0.00012	±	0.00007	3	0.00004	±	0.00002
2 (1A)	±0.036 g/cm^3 (±30.47 kg)	0.00021	±	0.00007	3	0.00007	±	0.00002
3 (2)	±0.036 g/cm^3 (±30.47 kg)	-0.00001	±	0.00007	3	<0.00001	±	0.00002
4 (3)	±0.036 g/cm^3 (±30.47 kg)	-0.00003	±	0.00007	3	-0.00001	±	0.00002

2.1.4.8 Graphite Impurities

It is assumed that the EBC of 1.33 ± 0.08 ppm (by at.%), discussed in Section 2.1.3.5, sufficiently described the impurity content in the cylinder and annulus of the upper axial reflector.

The impurity content of the upper 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 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 2.1-41. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-41. Effect of Uncertainty in Graphite Impurity Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.24 ppma	-0.00002	±	0.00007	3	0.00001	±	0.00002
2 (1A)	±0.24 ppma	-0.00002	±	0.00007	3	0.00001	±	0.00002
3 (2)	±0.24 ppma	0.00001	±	0.00007	3	<0.00001	±	0.00002
4 (3)	±0.24 ppma	-0.00010	±	0.00007	3	-0.00003	±	0.00002

2.1.4.9 Coolant Channel Positions

The radial location of the 33 typically open coolant channels are reported to have radial distances from the core center of 300, 410, and 515 mm, representing the 1st, 3rd, and 5th rings (see Figures 1.1-2b and 1.1-7) for the lower axial reflector. It is assumed that the channels in the upper axial reflector are located in the same positions both radially and azimuthally. It is assumed that the placement of the coolant channel rings was roughly equidistant, such that the 2nd and 4th rings would be located at radii of 355 and 462.5 mm, respectively. Equidistant holes within a ring are 11.25° apart with positions located in one ring halfway between holes in an adjacent ring (5.625°).

Due to the uncertainty in the exact radial placement of each coolant channel ring, an uncertainty of ±5 mm is assumed sufficient to encompass that uncertainty. This uncertainty also encompasses the uncertainty in the angular placement within a ring (assumed negligible). Because the channels in the upper and lower axial reflectors are assumed to be coaxial, the position of the channels in both reflectors was perturbed simultaneously. Perturbation of the center coolant channel (upper axial reflector only) was not performed as any additional uncertainty would be negligible.

The positions of the coolant channel holes within the axial reflectors were approximately 300, 355, 410, 462.5, and 515 mm radially from the core center. The uncertainty in these positions was 5 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which all positions were simultaneously perturbed by ±15 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the positions of the coolant channel holes within the axial reflectors. 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 Coolant Channel Positions.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±15 mm	0.00004	±	0.00007	3√3	0.00001	±	0.00001
2 (1A)	±15 mm	-0.00005	±	0.00007	3√3	-0.00001	±	0.00001
3 (2)	±15 mm	0.00020	±	0.00007	3√3	0.00004	±	0.00001
4 (3)	±15 mm	0.00017	±	0.00007	3√3	0.00003	±	0.00001

2.1.4.10 Coolant Channel Diameter

The diameter of the coolant channel holes within the upper axial reflector was 27.43 mm. The uncertainty in hole diameter was assumed to be 0.01 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the diameter of all positions were simultaneously perturbed by ±0.03 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the diameter of the coolant channel holes within 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 2.1-43. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-43. Effect of Uncertainty in Coolant Channel Hole Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.03 mm	-0.00014	±	0.00007	3√3	-0.00003	±	0.00001
2 (1A)	±0.03 mm	0.00002	±	0.00007	3√3	<0.00001	±	0.00001
3 (2)	±0.03 mm	0.00001	±	0.00007	3√3	<0.00001	±	0.00001
4 (3)	±0.03 mm	-0.00003	±	0.00006	3√3	0.00001	±	0.00001

2.1.4.11 Plug Diameter

The same graphite plugs were used in the coolant channels of both the upper and lower axial reflectors. Therefore evaluation of this uncertainty included simultaneous perturbation of the plug diameter in both reflectors.

The diameter of the coolant channel plugs within the axial reflectors was 26.5 mm. The uncertainty in hole diameter was assumed to be 0.1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the diameter of all positions were simultaneously perturbed by ±0.3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the diameter of the coolant channel plugs within the axial reflectors. 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 2.1-44. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-44. Effect of Uncertainty in Coolant Channel Plug Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.3 mm	0.00006	±	0.00007	3√3	0.00001	±	0.00001
2 (1A)	±0.3 mm	0.00006	±	0.00007	3√3	0.00001	±	0.00001
3 (2)	±0.3 mm	0.00008	±	0.00007	3√3	0.00002	±	0.00001
4 (3)	±0.3 mm	0.00007	±	0.00006	3√3	0.00001	±	0.00001

2.1.4.12 Plug Length

Perturbation of the length of the coolant channel plugs, which would have extended the full length of the upper axial reflector (780 mm), was performed as part of the uncertainty analysis of the upper axial reflector height (see Section 2.1.4.5). The effective uncertainty in perturbing the upper axial reflector height was negligible; therefore, the effective uncertainty in perturbing the length of the coolant channel plugs would also be negligible.

2.1.4.13 Plug Density

The density of the coolant channel plugs was not reported in Table 1.1-6. The coolant channel plugs are assumed to have a density of 1.76 ± 0.01 g/cm^3 (old graphite) because they are not explicitly listed in Table 1.1-6 as graphite components constructed from the new graphite material. It is assumed that the measured density uncertainty of 0.012 g/cm^3 (1σ), discussed in Section 2.1.3.4, sufficiently encompasses the uncertainty in the plug density. The same graphite plugs were used in the coolant channels of both the upper and lower axial reflectors. Therefore evaluation of this uncertainty included simultaneous perturbation of the plug density in both reflectors.

The density of the coolant channel plugs within the axial reflectors 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 coolant channel 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 2.1-45. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-45. Effect of Uncertainty in Coolant Channel Plug Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.036 g/cm^3	-0.00003	±	0.00007	3	-0.00001	±	0.00002
2 (1A)	±0.036 g/cm^3	0.00013	±	0.00007	3	0.00004	±	0.00002
3 (2)	±0.036 g/cm^3	0.00009	±	0.00007	3	0.00002	±	0.00002
4 (3)	±0.036 g/cm^3	0.00007	±	0.00007	3	0.00002	±	0.00002

2.1.4.14 Plug Impurities

It is assumed that the EBC of 1.33 ± 0.08 ppm (by at.%), discussed in Section 2.1.3.5, sufficiently described the impurity content in the graphite plugs used in the axial reflector coolant channels. The same graphite plugs were used in the coolant channels of both the upper and lower axial reflectors. Therefore evaluation of this uncertainty included simultaneous perturbation of the plug density in both reflectors.

The impurity content of the coolant channel plugs within the axial reflectors 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 coolant channel 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 2.1-46. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-46. Effect of Uncertainty in Coolant Channel Plug Impurity Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.24 ppma	-0.00021	±	0.00007	3	-0.00007	±	0.00002
2 (1A)	±0.24 ppma	-0.00013	±	0.00007	3	-0.00004	±	0.00002
3 (2)	±0.24 ppma	-0.00001	±	0.00007	3	<0.00001	±	0.00002
4 (3)	±0.24 ppma	-0.00007	±	0.00006	3	-0.00002	±	0.00002

2.1.4.15 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 2.1-47. The uncertainty in the aluminum dimensions for Case 3 is much smaller than in the other core configurations due to the large quantity of moderator pebbles between the fueled core and the upper axial reflector.

Table 2.1-47. Effect of Uncertainty in Aluminum Dimensions.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	-2 mm	-0.00123	±	0.00014	2√3	-0.00036	±	0.00004
2 (1A)	-2 mm	-0.00120	±	0.00014	2√3	-0.00035	±	0.00004
3 (2)	-2 mm	-0.00013	±	0.00014	2√3	-0.00004	±	0.00004
4 (3)	-2 mm	-0.00114	±	0.00013	2√3	-0.00033	±	0.00004

2.1.4.16 Aluminum Density

The mass of the aluminum housing below the upper surface of the graphite in the upper axial reflector was reported as 71.48 kg. It is difficult to exactly calculate the exact volume of the aluminum components from Figures 1.1-4 through 1.1-6. However, the structure is comprised of Peraluman-300, the same material used in the safety ring. It is assumed that the density of the aluminum would be the same, 2.65 g/cm^3. It is also assumed that a variation of ±0.01 g/cm^3 would be greater than the actual uncertainty in the measured mass of the aluminum support structure.

The density of the aluminum support structure was assumed to be a nominal 2.65 g/cm^3. The uncertainty in the density was 0.01 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.03 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in the density of the safety ring. 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 2.1-48. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-48. Effect of Uncertainty in Support Structure Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.03 g/cm^3	-0.00001	±	0.00007	3	<0.00001	±	0.00002
2 (1A)	±0.03 g/cm^3	-0.00016	±	0.00007	3	-0.00005	±	0.00002
3 (2)	±0.03 g/cm^3	-0.00008	±	0.00007	3	-0.00003	±	0.00002
4 (3)	±0.03 g/cm^3	-0.00009	±	0.00006	3	-0.00003	±	0.00002

2.1.4.17 Aluminum Composition

The composition specifications for Peraluman-300 is provided in Table 1.1-10. 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 2.1-30.

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 2.1-49. The uncertainty in the aluminum composition for Case 3 is smaller than in the other core configurations due to the large quantity of moderator pebbles between the fueled core and the upper axial reflector.

Table 2.1-49. Effect of Uncertainty in Support Structure Composition.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	Min/Max Al	0.00033	±	0.00007	√3	0.00019	±	0.00004
2 (1A)	Min/Max Al	0.00054	±	0.00007	√3	0.00031	±	0.00004
3 (2)	Min/Max Al	-0.00003	±	0.00007	√3	-0.00001	±	0.00004
4 (3)	Min/Max Al	0.00048	±	0.00006	√3	0.00028	±	0.00004

2.1.5 Lower Axial Reflector

2.1.5.1 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 double-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. 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 2.1-50.

Table 2.1-50. Effect of Uncertainty in Central Cylinder Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±2 mm	<0.00001	±	0.00007	2√3	<0.00001	±	0.00002
2 (1A)	±2 mm	0.00041	±	0.00007	2√3	0.00012	±	0.00002
3 (2)	±2 mm	0.00021	±	0.00007	2√3	0.00006	±	0.00002
4 (3)	±2 mm	0.00028	±	0.00006	2√3	0.00008	±	0.00002

2.1.5.2 Annulus Inner Equivalent Diameter

The lower axial reflector is comprised of at least 21finely machined graphite blocks. These blocks are placed in a radial pattern surrounding a central cylinder, approximating a nearly circular annulus (Figure 1.1-7). The reflector is an irregularly-shaped icosikaihenagon (21-sided polygon). Available information regarding the dimensions of the lower axial reflector were utilized to estimate the location of the vertices to form the annular shape (see Figure 2.1-2). A perfect polygon could not be generated using all the dimensions provided. Various dimensions had to be estimated from available information with adjustments made to complete the annulus. Possible gaps in assembly may have contributed to slight measurement discrepancies. The inside dimension on most of the inside surfaces was modeled as 74.0380 mm instead of 74 mm. The single outside dimension of 246.8 mm was instead modeled as

248.6 mm such that a dimension of the other outer surfaces could be 185.3558 mm (slightly less than the reported value of 185.5 mm). The impact of dimensional discrepancies is negligible.

The dimensions shown in Figure 2.1-2 were used to calculate the total area encompassed by the inner polygon (~0.20 m^2) and then the radius and diameter of a circle encompassing this equivalent area (~251 and ~501 mm, respectively).

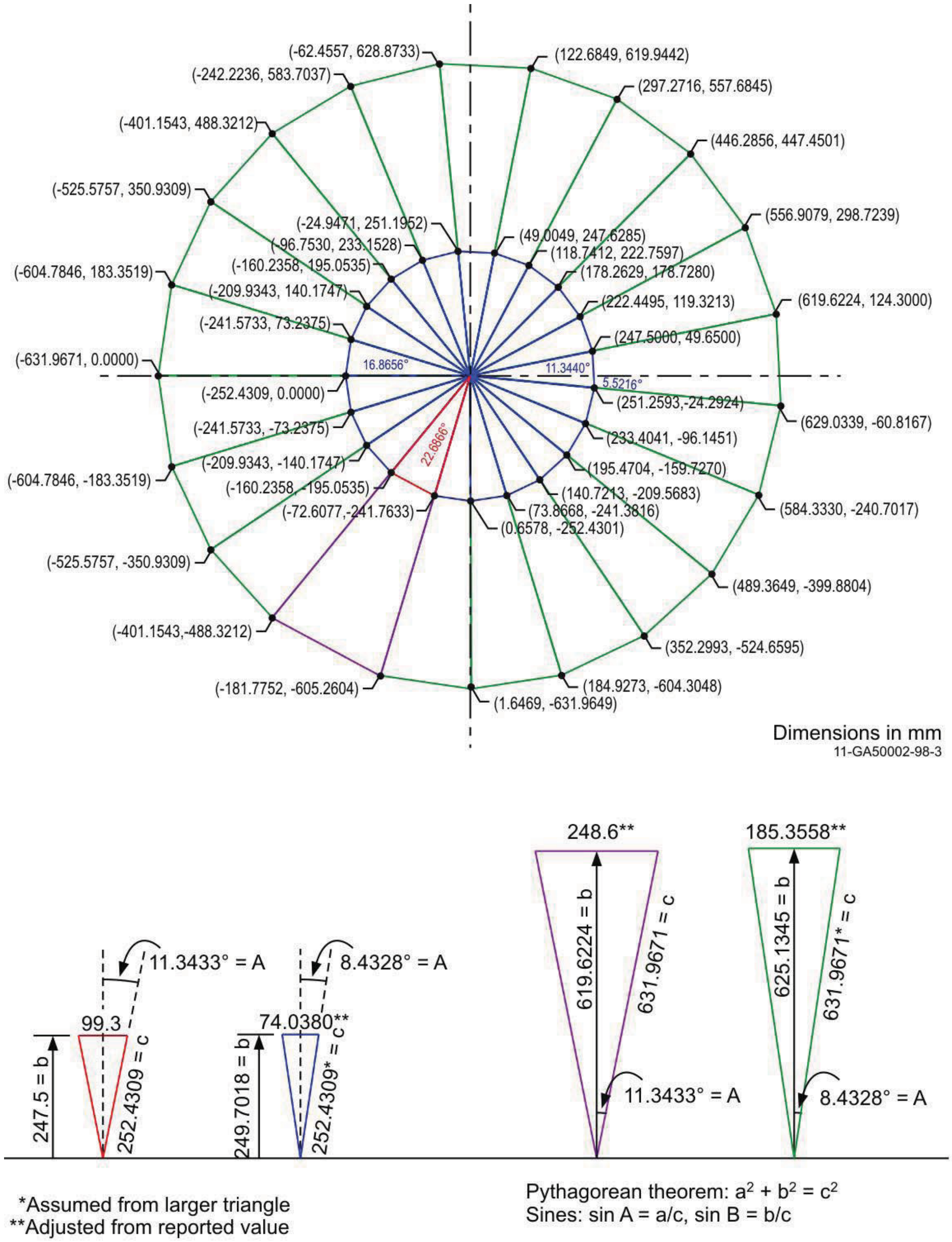

Figure 2.1-2. Vertices and dimensions of the lower axial reflector.

The calculated inner equivalent diameter of the lower axial reflector is ~501 mm. The uncertainty in the diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A double-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 inner equivalent diameter 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 2.1-51. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-51. Effect of Uncertainty in Inner Equivalent Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±2 mm	<0.00001	±	0.00007	2√3	<0.00001	±	0.00002
2 (1A)	±2 mm	<0.00001	±	0.00007	2√3	<0.00001	±	0.00002
3 (2)	±2 mm	<0.00001	±	0.00007	2√3	<0.00001	±	0.00002
4 (3)	±2 mm	<0.00001	±	0.00007	2√3	<0.00001	±	0.00002

2.1.5.3 Annulus Outer Equivalent Diameter

The dimensions shown in Figure 2.1-2 were used to calculate the total area encompassed by the outer polygon describing the lower axial reflector (~1.23 m^2) and then the radius and diameter of a circle encompassing this equivalent area (~627 and ~1253 mm, respectively).

The calculated outer equivalent diameter of the lower axial reflector is ~1254 mm. The uncertainty in the diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A double-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 outer equivalent diameter 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 2.1-52. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-52. Effect of Uncertainty in Outer Equivalent Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±2 mm	<0.00001	±	0.00007	2√3	<0.00001	±	0.00002
2 (1A)	±2 mm	<0.00001	±	0.00007	2√3	<0.00001	±	0.00002
3 (2)	±2 mm	<0.00001	±	0.00007	2√3	<0.00001	±	0.00002
4 (3)	±2 mm	<0.00001	±	0.00007	2√3	<0.00001	±	0.00002

2.1.5.4 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 single-sided perturbation was performed in which the height was decreased by 3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the height of the lower axial reflector. The calculated results were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-53.

Table 2.1-53. Effect of Uncertainty in Height.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	-3 mm	-0.00098	±	0.00014	3√3	-0.00019	±	0.00003
2 (1A)	-3 mm	-0.00046	±	0.00014	3√3	-0.00009	±	0.00003
3 (2)	-3 mm	-0.00074	±	0.00014	3√3	-0.00014	±	0.00003
4 (3)	-3 mm	-0.00071	±	0.00013	3√3	-0.00014	±	0.00002

2.1.5.5 Central Cylinder Density

New graphite was used for the central cylinder of the lower axial reflector (Table 1.1-8) with a reported density of 1.75 ± 0.007 g/cm^3. It is assumed that the measured density uncertainty of 0.012 g/cm^3 (1σ), discussed in Section 2.1.3.4, sufficiently encompasses the uncertainty in the new graphite density.

The density of the central cylinder of the lower axial reflector was 1.75 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 central cylinder 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 2.1-54. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-54. Effect of Uncertainty in Central Cylinder Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.036 g/cm^3	0.00012	±	0.00007	3	0.00004	±	0.00002
2 (1A)	±0.036 g/cm^3	0.00008	±	0.00007	3	0.00003	±	0.00002
3 (2)	±0.036 g/cm^3	0.00027	±	0.00007	3	0.00009	±	0.00002
4 (3)	±0.036 g/cm^3	0.00021	±	0.00006	3	0.00007	±	0.00002

2.1.5.6 Annulus Density

Old graphite was used for the annulus of the lower axial reflector (Table 1.1-8) 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 2.1.3.4, 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 2.1-55.

Table 2.1-55. Effect of Uncertainty in Annulus Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.036 g/cm^3	0.00075	±	0.00007	3	0.00025	±	0.00002
2 (1A)	±0.036 g/cm^3	0.00063	±	0.00007	3	0.00021	±	0.00002
3 (2)	±0.036 g/cm^3	0.00090	±	0.00007	3	0.00030	±	0.00002
4 (3)	±0.036 g/cm^3	0.00062	±	0.00006	3	0.00021	±	0.00002

2.1.5.7 Central Cylinder Impurities

It is assumed that the EBC of 1.33 ± 0.08 ppm (by at.%), discussed in Section 2.1.3.5, sufficiently described the impurity content in the central cylinder of the lower axial reflector.

The impurity content of the central cylinder 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 central cylinder. 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 2.1-56. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-56. Effect of Uncertainty in Central Cylinder Impurity Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.24 ppma	-0.00017	±	0.00007	3	-0.00006	±	0.00002
2 (1A)	±0.24 ppma	-0.00020	±	0.00007	3	-0.00007	±	0.00002
3 (2)	±0.24 ppma	-0.00016	±	0.00007	3	-0.00005	±	0.00002
4 (3)	±0.24 ppma	-0.00016	±	0.00007	3	-0.00005	±	0.00002

2.1.5.8 Annulus Impurities

It is assumed that the EBC of 1.33 ± 0.08 ppm (by at.%), discussed in Section 2.1.3.5, 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 2.1-57.

Table 2.1-57. Effect of Uncertainty in Annulus Impurity Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.24 ppm	-0.00035	±	0.00007	3	-0.00012	±	0.00002
2 (1A)	±0.24 ppm	-0.00039	±	0.00007	3	-0.00013	±	0.00002
3 (2)	±0.24 ppm	-0.00040	±	0.00007	3	-0.00013	±	0.00002
4 (3)	±0.24 ppm	-0.00056	±	0.00007	3	-0.00019	±	0.00002

2.1.5.9 Coolant Channel Positions

The channels in the upper and lower axial reflectors are assumed to be coaxial, the position of the channels in both reflectors was perturbed simultaneously (see Section 2.1.4.9).

2.1.5.10 Coolant Channel Diameter

The diameter of the coolant channel holes within the lower axial reflector was 27.42 mm. The uncertainty in hole diameter was assumed to be 0.01 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the diameter of all positions were simultaneously perturbed by ±0.03 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the diameter of the coolant channel holes within 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 2.1-58. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-58. Effect of Uncertainty in Coolant Channel Hole Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.03 mm	<0.00001	±	0.00007	$3\sqrt{3}$	<0.00001	±	0.00001
2 (1A)	±0.03 mm	0.00005	±	0.00007	$3\sqrt{3}$	0.00001	±	0.00001
3 (2)	±0.03 mm	-0.00001	±	0.00007	$3\sqrt{3}$	<0.00001	±	0.00001
4 (3)	±0.03 mm	0.00006	±	0.00007	$3\sqrt{3}$	0.00001	±	0.00001

2.1.5.11 Plug Diameter

The same graphite plugs were used in the coolant channels of both the upper and lower axial reflectors. Therefore evaluation of this uncertainty included simultaneous perturbation of the plug diameter in both reflectors (see Section 2.1.4.11).

2.1.5.12 Plug Length

Perturbation of the length of the coolant channel plugs, which would have extended the full length of the lower axial reflector (780 mm), was performed as part of the uncertainty analysis of the lower axial reflector height (see Section 2.1.5.4). The effective uncertainty in perturbing the lower axial reflector height was small; therefore, the effective uncertainty in perturbing the length of the coolant channel plugs would be negligible.

2.1.5.13 Plug Density

The same graphite plugs were used in the coolant channels of both the upper and lower axial reflectors. Therefore evaluation of this uncertainty included simultaneous perturbation of the plug density in both reflectors (see Section 2.1.4.13).

2.1.5.14 Plug Impurities

The same graphite plugs were used in the coolant channels of both the upper and lower axial reflectors. Therefore evaluation of this uncertainty included simultaneous perturbation of the plug density in both reflectors (see section 2.1.4.14).

2.1.5.15 Source Position Diameter

The diameter of the source plug position was 121 mm. The uncertainty in hole diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A single-sided perturbation was performed in which the diameter was increased by 3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the diameter of the neutron source position. The calculated results were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-59. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-59. Effect of Uncertainty in Source Position Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	+3 mm	0.00022	±	0.00014	3√3	0.00004	±	0.00003
2 (1A)	+3 mm	-0.00006	±	0.00014	3√3	-0.00001	±	0.00003
3 (2)	+3 mm	-0.00002	±	0.00014	3√3	<0.00001	±	0.00003
4 (3)	+3 mm	0.00010	±	0.00013	3√3	0.00002	±	0.00002

2.1.5.16 Source Position Length

The length of the source plug position was 250 mm. The uncertainty in hole length was assumed to be 1 mm (bounding limit with uniform probability distribution). A single-sided perturbation was performed in which the diameter was increased by 3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the length of the neutron source position. The calculated results were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-60. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-60. Effect of Uncertainty in Source Position Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	+3 mm	0.00003	±	0.00014	3√3	0.00001	±	0.00003
2 (1A)	+3 mm	-0.00019	±	0.00014	3√3	-0.00004	±	0.00003
3 (2)	+3 mm	<0.00001	±	0.00014	3√3	<0.00001	±	0.00003
4 (3)	+3 mm	-0.00009	±	0.00013	3√3	-0.00002	±	0.00002

2.1.5.17 Source Plug Diameter

The diameter of the source channel plug was 120 mm (Figure 1.1-7). The uncertainty in plug diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A single-sided perturbation was performed in which the diameter was decreased by 3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the diameter of the source plug. The calculated results were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-61. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-61. Effect of Uncertainty in Source Plug Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	-3 mm	-0.00014	±	0.00014	3√3	-0.00003	±	0.00003
2 (1A)	-3 mm	0.00013	±	0.00014	3√3	0.00003	±	0.00003
3 (2)	-3 mm	-0.00007	±	0.00014	3√3	-0.00001	±	0.00003
4 (3)	-3 mm	-0.00009	±	0.00013	3√3	-0.00002	±	0.00002

2.1.5.18 Source Plug Length

The length of the source channel plug was 250 mm (Figure 1.1-7). The uncertainty in plug length was assumed to be 1 mm (bounding limit with uniform probability distribution). A single-sided perturbation was performed in which the diameter was decreased by 3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the length of the source plug. The calculated results were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-62. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-62. Effect of Uncertainty in Source Plug Length.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	-3 mm	-0.00018	±	0.00014	3√3	-0.00003	±	0.00003
2 (1A)	-3 mm	0.00012	±	0.00014	3√3	0.00002	±	0.00003
3 (2)	-3 mm	-0.00005	±	0.00014	3√3	-0.00001	±	0.00003
4 (3)	-3 mm	-0.00008	±	0.00013	3√3	-0.00002	±	0.00002

2.1.5.19 Source Plug Density

Old graphite was used for the source plug of the lower axial reflector (Table 1.1-8) 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 2.1.3.4, sufficiently describes the uncertainty in the graphite density of the source plug.

The density of the source plug 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 source plug. 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 2.1-63. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-63. Effect of Uncertainty in Source Plug Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.036 g/cm^3	-0.00004	±	0.00007	3	-0.00001	±	0.00002
2 (1A)	±0.036 g/cm^3	-0.00011	±	0.00007	3	-0.00004	±	0.00002
3 (2)	±0.036 g/cm^3	-0.00004	±	0.00007	3	-0.00001	±	0.00002
4 (3)	±0.036 g/cm^3	-0.00005	±	0.00006	3	-0.00002	±	0.00002

2.1.5.20 Source Plug Impurities

It is assumed that the EBC of 1.33 ± 0.08 ppm (by at.%), discussed in Section 2.1.3.5, sufficiently described the impurity content in the source plug of the lower axial reflector.

The impurity content of the source plug 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 source plug. 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 2.1-64. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-64. Effect of Uncertainty in Source Plug Impurity Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.24 ppma	0.00006	±	0.00007	3	0.00002	±	0.00002
2 (1A)	±0.24 ppma	0.00006	±	0.00007	3	0.00002	±	0.00002
3 (2)	±0.24 ppma	-0.00004	±	0.00007	3	-0.00001	±	0.00002
4 (3)	±0.24 ppma	-0.00009	±	0.00006	3	-0.00003	±	0.00002

2.1.5.21 Aluminum Plugs

Details regarding the dimensions, composition, and mass of the aluminum plugs used in some of the PROTEUS cores to prevent pebble displacement within the coolant channels of the lower axial reflector were unavailable. The effective bias and bias uncertainty for removing these plugs was experimentally measured (see Section 1.1.5) and accounted for (see Section 3.1.1.1) in the evaluation of the benchmark model. It is assumed that any uncertainty in the dimensions, composition, or mass of the plugs is already included in the reported bias uncertainty.

2.1.6 Safety/Shutdown Rods

2.1.6.1 Borated Steel Rod Diameter

The diameter of the borated steel safety/shutdown rods was 35 mm (Figure 1.1-8). The uncertainty in the diameter was assumed to be 1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the diameter of all positions were simultaneously perturbed by ±3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the diameter of the borated steel 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 2.1-65. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-65. Effect of Uncertainty in Borated Steel Rod Diameter.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	-0.00002	±	0.00007	3√3	-0.00001	±	0.00004
2 (1A)	±3 mm	0.00001	±	0.00007	3√3	0.00001	±	0.00004
3 (2)	±3 mm	-0.00002	±	0.00007	3√3	-0.00001	±	0.00004
4 (3)	±3 mm	-0.00007	±	0.00007	3√3	-0.00004	±	0.00004

2.1.6.2 Borated Steel Rod Length

The length of the borated steel rod was 2100 mm (Figure 1.1-8). The uncertainty in length was assumed to be 1 mm (bounding limit with uniform probability distribution). Because the safety/shutdown rods are fully withdrawn, an uncertainty in the length of the borated steel rod would be negligible.

2.1.6.3 Borated Steel Density

An uncertainty in the borated steel density for the safety/shutdown rods was not reported. The uncertainty in the density of the borated steel used in the static measurement rods was ±0.029 g/cm^3. It is assumed that the uncertainty was the same for the borated steel density in the safety/shutdown rods.

The density of the borated steel safety/shutdown rods was 6.878 g/cm^3. The uncertainty in the density was 0.029 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.087 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in the density of the borated steel 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 2.1-66. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-66. Effect of Uncertainty in Borated Steel Rod Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.087 g/cm^3	-0.00002	±	0.00007	3	-0.00001	±	0.00004
2 (1A)	±0.087 g/cm^3	0.00001	±	0.00007	3	0.00001	±	0.00004
3 (2)	±0.087 g/cm^3	-0.00002	±	0.00007	3	-0.00001	±	0.00004
4 (3)	±0.087 g/cm^3	-0.00007	±	0.00007	3	-0.00004	±	0.00004

2.1.6.4 Boron Content

The borated steel was reported to have a boron content of 4.95 % before final casting and machining (processes that could incur loss of boron) and a final measured boron content of 4.70 %. Details regarding what measurement method was used, the uncertainty in that measurement, and whether the values were in at.% or wt.% were not provided. The authors of Reference 2 indicated that these values were believed to be in wt.%. The composition of the borated steel (Table 1.1-11) also reports a content of 4.70 wt.%. A boron content of ~5 wt.% is equal to ~20 at.%; therefore, the assumption that the original measurements were reported in wt.% is correct.

Renormalization of the reported content to ~100 % (see Table 2.1-68) increases the effective boron content to 4.75 wt.%. An uncertainty of 0.25 wt.% is assumed to adequately encompass the uncertainty in the boron content in the borated steel. Whereas the safety/shutdown rods are fully withdrawn, there is no impact on k_{eff}.

The boron content of the borated steel safety/shutdown rods was ~4.75 wt.%. The uncertainty in the boron content was 0.25 wt.% (1σ). A double-sided perturbation was performed in which the boron content was perturbed by ±0.75 wt.% to estimate the uncertainty in k_{eff} due to the uncertainty in the boron content of the borated steel 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 2.1-67. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-67. Effect of Uncertainty in Borated Steel Rod Boron Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.75 wt.%	0.00007	±	0.00007	3	0.00002	±	0.00002
2 (1A)	±0.75 wt.%	-0.00006	±	0.00007	3	-0.00002	±	0.00002
3 (2)	±0.75 wt.%	<0.00001	±	0.00007	3	<0.00001	±	0.00002
4 (3)	±0.75 wt.%	-0.00010	±	0.00007	3	-0.00003	±	0.00002

2.1.6.5 Borated Steel Composition

The borated steel composition reported in Table 1.1-11 was renormalized prior to the computation of atom densities for perturbation calculations. Whereas the safety/shutdown rods are fully withdrawn, and the effective uncertainty in perturbing the boron content is negligible, any variation in the other constituents of the borated steel composition would produce a negligible effect.

Table 2.1-68. Composition of Borated Steel.

Element	Reported wt.%	Normalized wt.%	Atoms/barn-cm
^{10}B	0.94	0.949	3.9257E-03
^{11}B	3.76	3.796	1.4282E-02
Si	1.02	1.030	1.5187E-03
Cr	40.4	40.787	3.2491E-02
Mn	1.3	1.312	9.8952E-04
Fe	41.8	42.201	3.1300E-02
Ni	9.83	9.924	7.0036E-03
Total	99.05	99.999[(a)]	9.1511E-02

(a) The total normalized value is slightly less than 100 % due to rounding in the reported table values.

2.1.6.6 Steel Tube Diametrical Thickness

The diametrical thickness of the steel tube is defined as the distance between its inner diameter (36 mm) and outer diameter (40 mm) as shown in Figure 1.1-8.

The diametrical thickness of the steel tube containing the borated steel was 2 mm. 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 ±2 mm (split 1 mm apiece between the inner and outer diameters) to estimate the uncertainty in k_{eff} due to the uncertainty in the diametrical thickness of the steel tube. 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 2.1-69. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-69. Effect of Uncertainty in Steel Tube Diametrical Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±2 mm	-0.00010	±	0.00007	2√3	-0.00003	±	0.00002
2 (1A)	±2 mm	0.00002	±	0.00007	2√3	0.00001	±	0.00002
3 (2)	±2 mm	-0.00008	±	0.00007	2√3	-0.00002	±	0.00002
4 (3)	±2 mm	0.00004	±	0.00007	2√3	0.00001	±	0.00002

2.1.6.7 Steel Tube Length

The total length of the steel tube and end plugs was 2220 mm (Figure 1.1-8). The uncertainty in length was assumed to be 10 mm (bounding limit with uniform probability distribution). Because the safety/shutdown rods are fully withdrawn, an uncertainty in the length of the steel tube would be negligible.

2.1.6.8 Steel Tube Density

The density of the steel tube containing the borated steel was assumed to be that of nominal stainless steel, 7.92 g/cm^3. The uncertainty in the steel density was assumed to be 0.01 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.03 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in steel tube density. 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 2.1-70. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-70. Effect of Uncertainty in Steel Tube Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.03 g/cm^3	0.00001	±	0.00007	3	<0.00001	±	0.00002
2 (1A)	±0.03 g/cm^3	-0.00009	±	0.00007	3	-0.00003	±	0.00002
3 (2)	±0.03 g/cm^3	-0.00017	±	0.00007	3	-0.00006	±	0.00002
4 (3)	±0.03 g/cm^3	0.00006	±	0.00007	3	0.00002	±	0.00002

2.1.6.9 Steel Tube Composition

The steel tube containing the borated steel was reported to be Type 18/8 with the composition shown in Table 1.1-12. This steel is similar to stainless steel Types 301, 302, and 304; the composition of the steel tubes was adjusted to represent an average composition of these steel types. No additional uncertainty or bias due to this assumption is expected.

The composition of the steel tube containing the borated steel was stainless steel Type 18/8 (see Table 2.1-71). 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 2.1-72. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-71. Composition of Stainless Steel 18/8.[(a)]

Element	Minimum wt.%	Maximum wt.%	Nominal wt.%	Nominal Atoms/barn-cm
Cr	16	20	18	1.6511E-02
Fe	Balance		72.425	6.1855E-02
Ni	6	10	8	6.5009E-03
C	--	0.15	0.075	2.9783E-04
Si	--	1	0.5	8.4910E-04
Mn	--	2	1	8.6816E-04
Total	--	--	100	8.6882E-02

(a) Assumed to be an average composition of Types 301, 302, and 304 stainless steel; compositions obtained from Perry, R. H., and Green, D. W., Eds., *Perry's Chemical Engineers' Handbook (7th Edition)*, Mc-Graw-Hill, New York, NY (1997).

Table 2.1-72. Effect of Uncertainty in Steel Tube Composition.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	Min/Max Fe	0.00006	±	0.00007	√3	0.00003	±	0.00004
2 (1A)	Min/Max Fe	-0.00009	±	0.0007	√3	-0.00005	±	0.00004
3 (2)	Min/Max Fe	0.00007	±	0.00007	√3	0.00004	±	0.00004
4 (3)	Min/Max Fe	0.00006	±	0.00007	√3	0.00003	±	0.00004

2.1.6.10 Aluminum Shock Damper Dimensions

Shock damper reference dimensions were used to include them in a detailed model of the PROTEUS cores (see Appendix C). No uncertainties in the dimensions were provided and the bias for their removal is negligible (see Section 3.1.1.1). Therefore any uncertainties in the dimensions of the aluminum shock dampers are assumed to also be negligible.

2.1.6.11 Aluminum Mass

The mass of an aluminum shock damper was reported to be 633.65 g. However, using the reported dimensions, the calculated mass density is ~3.68 g/cm^3. The bias for their removal is negligible (see Section 3.1.1.1) and the shock dampers are located near the base of the radial reflector, therefore an attempt to adjust their dimensions to decrease the mass density was not performed. It is also assumed that a variation of ±0.01 g/cm^3 would be greater than the actual uncertainty in the measured mass of the aluminum shock dampers.

The mass of an aluminum shock damper was 633.65 g (effective mass density of ~3.68 g/cm^3). The assumed uncertainty in the density was 0.01 g/cm^3 (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the density was perturbed by ±0.03 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in the mass of the aluminum shock dampers. 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 2.1-73. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-73. Effect of Uncertainty in Shock Damper Mass.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.03 g/cm^3	0.00005	±	0.00007	3√3	0.00001	±	0.00001
2 (1A)	±0.03 g/cm^3	-0.00004	±	0.00007	3√3	-0.00001	±	0.00001
3 (2)	±0.03 g/cm^3	0.00005	±	0.00007	3√3	0.00001	±	0.00001
4 (3)	±0.03 g/cm^3	-0.00004	±	0.00006	3√3	-0.00001	±	0.00001

2.1.6.12 Aluminum Composition

The aluminum shock dampers were reported to be pure aluminum alloy. It is assumed that the aluminum is Type 1100 with the composition shown in Table 2.1-74 (see footnote to table for reference information). Typically aluminum compositions are reported as having additional impurities with a maximum content of 0.15 wt.% with no single impurity greater than 0.05 wt.%. Impurities of cobalt, nickel, and tin are assumed.

A double-sided perturbation was performed in which the shock damper composition was perturbed by minimizing and maximizing the aluminum content in the aluminum alloy, 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 shock damper 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 2.1-75. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-74. Composition of the Aluminum 1100.[a]

Element	Minimum wt.%	Maximum wt.%	Nominal wt.%	Nominal Atoms/barn-cm[b]
Si	--	1	0.5	3.9442E-04
Fe	--	1	0.5	1.9836E-04
Cu	0.05	0.2	0.125	4.3580E-05
Mn	--	0.05	0.025	1.0082E-05
Zn	--	0.1	0.05	1.6936E-05
Co	--	0.5	0.25	9.3983E-05
Ni	--	0.5	0.25	9.4367E-05
Sn	--	0.5	0.25	4.6658E-05
Al	99	--	98.05	8.0510E-02
Total	--	--	100	8.1409E-02

(a) Alloy Information Report for Aluminum 1100, All Metals & Forge, http://www.steelforge.com/forgings/alloys/aluminum1100report.html (Accessed 8/31/2011).
(b) The atom densities provided here apply only to the aluminum shock dampers. A mass density of 3.67893 g/cm^3 was used.

Table 2.1-75. Effect of Uncertainty in Shock Damper Composition.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	Min/Max Al	<0.00001	±	0.00007	√3	<0.00001	±	0.00004
2 (1A)	Min/Max Al	-0.00004	±	0.00007	√3	-0.00002	±	0.00004
3 (2)	Min/Max Al	<0.00001	±	0.00007	√3	<0.00001	±	0.00004
4 (3)	Min/Max Al	-0.00016	±	0.00007	√3	-0.00009	±	0.00004

2.1.7 Autorod

2.1.7.1 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 2.1-76.

Table 2.1-76. Effect of Uncertainty in Copper Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	-0.00038	±	0.00007	3√3	-0.00007	±	0.00001
2 (1A)	±3 mm	-0.00057	±	0.00007	3√3	-0.00011	±	0.00001
3 (2)	±3 mm	-0.00046	±	0.00007	3√3	-0.00009	±	0.00001
4 (3)	±3 mm	-0.00015	±	0.00006	3√3	-0.00003	±	0.00001

2.1.7.2 Copper Length

Perturbation of the length of the copper wedge also perturbs the angle at which the wedge diminishes from the top surface to bottom point. It is assumed that the uncertainty in the width of the top of the wedge (39 mm) is negligible compared to the uncertainty in the length of the copper wedge. It is assumed that the wedge diminishes to a point equally on both sides, forming an isosceles triangle; any uncertainty in the straightness of this wedge is also assumed to be negligible.

The length of the copper was 2300 mm (Figure 1.1-10). The uncertainty in the length was assumed to be 10 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the length was perturbed by ±30 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the length 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 2.1-77. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-77. Effect of Uncertainty in Copper Length.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±30 mm	0.00007	±	0.00007	3√3	0.00001	±	0.00001
2 (1A)	±30 mm	0.00009	±	0.00007	3√3	0.00002	±	0.00001
3 (2)	±30 mm	-0.00002	±	0.00007	3√3	<0.00001	±	0.00001
4 (3)	±30 mm	-0.00002	±	0.00006	3√3	<0.00001	±	0.00001

2.1.7.3 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 2.1-78.

Table 2.1-78. Effect of Uncertainty in Copper Orientation.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	Rotate 90°	-0.00016	±	0.00010	√3	-0.00009	±	0.00006
2 (1A)	Rotate 90°	-0.00002	±	0.00010	√3	-0.00001	±	0.00006
3 (2)	Rotate 90°	-0.00002	±	0.00010	√3	-0.00001	±	0.00006
4 (3)	Rotate 90°	0.00007	±	0.00010	√3	0.00004	±	0.00006

2.1.7.4 Copper Density

Material properties for the copper wedge used in the autorod was not reported. It was assumed that the copper was Type C110 with a mass density of 8.89 g/cm^3 and the composition shown in Table 2.1-80 (see footnote to table for reference information).

The density of the copper was assumed to be that of nominal copper, 8.89 g/cm^3. The uncertainty in the copper density was assumed to be 0.01 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.03 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in copper density. 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 2.1-79. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-79. Effect of Uncertainty in Copper Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.03 g/cm^3	0.00005	±	0.00007	3	0.00001	±	0.00001
2 (1A)	±0.03 g/cm^3	-0.00009	±	0.00007	3	-0.00002	±	0.00001
3 (2)	±0.03 g/cm^3	-0.00007	±	0.00007	3	-0.00001	±	0.00001
4 (3)	±0.03 g/cm^3	0.00007	±	0.00006	3	0.00001	±	0.00001

2.1.7.5 Copper Composition

Material properties for the copper wedge used in the autorod was not reported. It was assumed that the copper was Type C110 with a mass density of 8.89 g/cm^3 and the composition shown in Table 2.1-80 (see footnote to table for reference information).

The composition of the copper autorod was assumed to be that of nominal copper, Type C110 (see Table 2.1-80). A double-sided perturbation was performed in which the copper composition was perturbed by minimizing and maximizing the copper content in the autorod (metallic impurities were perturbed by ±100% of their nominal content), 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 copper 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 2.1-81. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-80. Composition of Copper C110.[(a)]

Element	Minimum wt.%	Maximum wt.%	Nominal wt.%
Cu	99.9	--	99.95
O	--	0.04	0.02
Ag	--	--	0.0075
S	--	--	0.0075
Ni	--	--	0.0075
Fe	--	--	0.0075
Total	--	--	100

(a) Copper-110, Bohler Uddeholm Australia, http://www.buau.com.au/english/files/110.pdf (Accessed 8/30/2011).

Table 2.1-81. Effect of Uncertainty in Copper Composition.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	Min/Max Cu	0.00006	±	0.00007	√3	0.00003	±	0.00004
2 (1A)	Min/Max Cu	0.00005	±	0.00007	√3	0.00003	±	0.00004
3 (2)	Min/Max Cu	0.00006	±	0.00007	√3	0.00003	±	0.00004
4 (3)	Min/Max Cu	-0.00002	±	0.00007	√3	-0.00001	±	0.00004

2.1.7.6 Aluminum Diametrical Thickness

The diametrical thickness of the autorod aluminum tube is defined as the distance between its inner diameter (assumed to be 40 mm) and outer diameter (44 mm) as shown in Figure 1.1-10.

The diametrical thickness of the aluminum tube containing the autorod was 2 mm. 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 (split 1.5 mm apiece between the inner and outer diameters) to estimate the uncertainty in k_{eff} due to the uncertainty in the diametrical thickness of the aluminum tube. The top portion of the copper wedge (width of 39 mm) was truncated to accommodate the perturbation of the aluminum tube when the inner diameter was reduced. 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 2.1-82. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-82. Effect of Uncertainty in Aluminum Tube Diametrical Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	-0.00006	±	0.00007	3√3	-0.00001	±	0.00001
2 (1A)	±3 mm	-0.00009	±	0.00007	3√3	-0.00002	±	0.00001
3 (2)	±3 mm	-0.00013	±	0.00007	3√3	-0.00003	±	0.00001
4 (3)	±3 mm	-0.00007	±	0.00007	3√3	-0.00001	±	0.00001

2.1.7.7 Aluminum Length

Perturbation of the length of the autorod aluminum tube, which would have extended the full length of the radial reflector (3304 mm), was performed as part of the uncertainty analysis of the radial reflector height (see Section 2.1.3.3). The effective uncertainty in perturbing the radial reflector height was negligible; therefore, the effective uncertainty in perturbing the length of the autorod aluminum tube would also be negligible.

2.1.7.8 Aluminum Density

The density of the aluminum tube containing the autorod was assumed to be that of typical aluminum, 2.70 g/cm^3. The uncertainty in the aluminum density was assumed to be 0.01 g/cm^3 (1σ). A double-sided perturbation was performed in which the tube density was perturbed by ±0.03 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in aluminum tube density. 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 2.1-83. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-83. Effect of Uncertainty in Aluminum Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.03 g/cm^3	0.00002	±	0.00007	3	0.00001	±	0.00002
2 (1A)	±0.03 g/cm^3	-0.00012	±	0.00007	3	-0.00004	±	0.00002
3 (2)	±0.03 g/cm^3	0.00001	±	0.00007	3	<0.00001	±	0.00002
4 (3)	±0.03 g/cm^3	0.00007	±	0.00006	3	0.00002	±	0.00002

2.1.7.9 Aluminum Composition

The composition of the aluminum tube was not reported. It is assumed that the aluminum is Type 1100 with the composition shown in Table 2.1-74 (see footnote to table for reference information). Typically aluminum compositions are reported as having additional impurities with a maximum content of 0.15 wt.% with no single impurity greater than 0.05 wt.%. Impurities of cobalt, nickel, and tin are assumed. The atom density values provided in Table 2.1-74 do not apply to the composition of the aluminum tube for the autorod since the mass density of the shock dampers were modeled at a higher density.

A double-sided perturbation was performed in which the aluminum tube composition was perturbed by minimizing and maximizing the aluminum content in the aluminum alloy, 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 aluminum 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 2.1-84. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-84. Effect of Uncertainty in Aluminum Tube Composition.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	Min/Max Al	0.00011	±	0.00007	√3	0.00006	±	0.00004
2 (1A)	Min/Max Al	0.00012	±	0.00007	√3	0.00007	±	0.00004
3 (2)	Min/Max Al	0.00001	±	0.00007	√3	0.00001	±	0.00004
4 (3)	Min/Max Al	0.00007	±	0.00007	√3	0.00004	±	0.00004

2.1.8 Static Measurement Rods

Static measurement rods were not used in the core during the conduct of these critical experiments.

2.1.9 Fuel Pebbles

2.1.9.1 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 2.1-85.

Table 2.1-85. Number of Fuel Pebbles.

Case (Core)	# Fuel Pebbles
1 (1)	5181
2 (1A)	4951
3 (2)	3768
4 (3)	4009

2.1.9.2 Pebble Packing Fraction

The theoretical packing fraction for an infinite hexagonal close-packed (HCP) configuration is 0.7405.[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 69 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 2.1.19.6.

Table 2.1-86. Pebble Packing Fraction.

Case (Core)	Total # Pebbles	Pebble Volume (m^3)	Pebble Stack Height (m)	Core Volume (m^3)	Packing Fraction (vol.%)[(a)]
1 (1)	7766	~0.8783	~1.0888	~1.2698	~69.17
2 (1A)	7421	~0.8393	~1.0398	~1.2126	~69.21
3 (2)	11657	~1.3184	~1.6277	~1.8982	~69.45
4 (3)	6009	~0.6796	~0.8438	~0.9841	~69.06

(a) An infinite hexagonal close-packed (rhombohedral) lattice has a theoretical filling factor of 0.7405.

2.1.9.3 Pebble Random Packing

The pebbles were placed in exact positions, there is negligible uncertainty in the pebble locations due to the small uncertainties in the diameters of the pebbles and dimensions of the graphite reflector. Therefore, the uncertainty in the randomness of pebble packing is negligible.

2.1.9.4 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 2.1.9.16.

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

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 2.1-87. The uncertainty is small and within the 2σ statistical uncertainty. Similar results were shown for random particle placement in an analysis of the HTR-10.[b]

Table 2.1-87. Effect of Uncertainty in TRISO Random Packing.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	Random Particle Placement	0.00021	±	0.00014	1	0.00021	±	0.00014
2 (1A)	Random Particle Placement	0.00006	±	0.00014	1	0.00006	±	0.00014
3 (2)	Random Particle Placement	0.00002	±	0.00014	1	0.00002	±	0.00014
4 (3)	Random Particle Placement	-0.00016	±	0.00013	1	-0.00016	±	0.00013

2.1.9.5 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 2.1-88.

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).
[b] Uner, C. and Seker, V., "Monte Carlo Criticality Calculations for a Pebble Bed Reactor with MCNP," *Nucl. Sci. Eng.*, **149**, 131-137 (2005).

Table 2.1-88. 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 (1)	±0.0015 cm	-0.00187	±	0.00007	2.5	-0.00075	±	0.00003	-0.00011
2 (1A)	±0.0015 cm	-0.00187	±	0.00007	2.5	-0.00075	±	0.00003	-0.00011
3 (2)	±0.0015 cm	-0.00154	±	0.00007	2.5	-0.00062	±	0.00003	-0.00009
4 (3)	±0.0015 cm	-0.00052	±	0.00007	2.5	-0.00021	±	0.00003	-0.00003

2.1.9.6 Buffer Thickness

The thickness of the buffer layer was 0.00915 cm (Table 1.1-1). The uncertainty in the thickness was 0.00125 cm (1σ). A double-sided perturbation was performed in which the thickness was perturbed by ±0.00375 cm to estimate the uncertainty in k_{eff} due to the uncertainty in the thickness of the buffer layer. 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 2.1-89.

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 2.1-89. Effect of Uncertainty in Buffer Layer Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (1)	±0.00375 cm	-0.00085	±	0.00007	3	-0.00028	±	0.00002	-0.00004
2 (1A)	±0.00375 cm	-0.00081	±	0.00007	3	-0.00027	±	0.00002	-0.00004
3 (2)	±0.00375 cm	-0.00081	±	0.00007	3	-0.00027	±	0.00002	-0.00004
4 (3)	±0.00375 cm	-0.00075	±	0.00007	3	-0.00025	±	0.00002	-0.00004

2.1.9.7 IPyC Thickness

The thickness of the IPyC layer was 0.00399 cm (Table 1.1-1). The uncertainty in the thickness was 0.0005 cm (1σ). A double-sided perturbation was performed in which the thickness was perturbed by ±0.0015 cm to estimate the uncertainty in k_{eff} due to the uncertainty in the thickness of the IPyC layer. 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 2.1-90.

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 2.1-90. Effect of Uncertainty in IPyC Layer Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (1)	±0.0015 cm	-0.00019	±	0.00007	3	-0.00006	±	0.00002	-0.00001
2 (1A)	±0.0015 cm	-0.00009	±	0.00007	3	-0.00003	±	0.00002	<0.00001
3 (2)	±0.0015 cm	-0.00020	±	0.00007	3	-0.00007	±	0.00002	-0.00001
4 (3)	±0.0015 cm	-0.00012	±	0.00006	3	-0.00004	±	0.00002	-0.00001

2.1.9.8 SiC Thickness

The thickness of the SiC layer was 0.00353 cm (Table 1.1-1). The uncertainty in the thickness was 0.0002 cm (1σ). A double-sided perturbation was performed in which the thickness was perturbed by ±0.0006 cm to estimate the uncertainty in k_{eff} due to the uncertainty in the thickness of the SiC layer. 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 2.1-91.

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 2.1-91. Effect of Uncertainty in SiC Layer Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (1)	±0.0006 cm	-0.00055	±	0.00007	3	-0.00018	±	0.00002	-0.00003
2 (1A)	±0.0006 cm	-0.00051	±	0.00007	3	-0.00017	±	0.00002	-0.00003
3 (2)	±0.0006 cm	-0.00052	±	0.00007	3	-0.00017	±	0.00002	-0.00003
4 (3)	±0.0006 cm	-0.00044	±	0.00007	3	-0.00015	±	0.00002	-0.00002

2.1.9.9 OPyC Thickness

The thickness of the OPyC layer was 0.00400 cm (Table 1.1-1). The uncertainty in the thickness was 0.0004 cm (1σ). A double-sided perturbation was performed in which the thickness was perturbed by ±0.0012 cm to estimate the uncertainty in k_{eff} due to the uncertainty in the thickness of the OPyC layer. 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 2.1-92.

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 2.1-92. Effect of Uncertainty in OPyC Layer Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (1)	±0.0012 cm	0.00011	±	0.00007	3	0.00004	±	0.00002	0.00001
2 (1A)	±0.0012 cm	0.00009	±	0.00007	3	0.00003	±	0.00002	<0.00001
3 (2)	±0.0012 cm	0.00004	±	0.00007	3	0.00001	±	0.00002	<0.00001
4 (3)	±0.0012 cm	0.00006	±	0.00006	3	0.00002	±	0.00002	<0.00001

2.1.9.10 Fueled Zone Radius

The radius of the fueled zone was 2.350 cm (Table 1.1-1). The uncertainty in the radius was 0.025 cm (1σ). A double-sided perturbation was performed in which the radius was perturbed by ±0.075 cm to estimate the uncertainty in k_{eff} due to the uncertainty in the radius of the fueled zone. The placement of TRISO particles within the model (see Figure 4.1-1 with associated textual discussion) was adjusted to uniformly fill the perturbed fueled region without truncating TRISO particles. 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 2.1-93.

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 2.1-93. Effect of Uncertainty in the Fueled Zone Radius.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (1)	±0.075 cm	-0.00011	±	0.00007	3	-0.00004	±	0.00002	-0.00001
2 (1A)	±0.075 cm	0.00011	±	0.00007	3	0.00004	±	0.00002	0.00001
3 (2)	±0.075 cm	0.00005	±	0.00007	3	0.00002	±	0.00002	<0.00001
4 (3)	±0.075 cm	0.00035	±	0.00007	3	0.00012	±	0.00002	0.00002

2.1.9.11 Pebble Radius

The outer radius of the fuel pebbles was reported as 3.0006 ± 0.002 cm and the outer radius of the moderator pebbles was reported as 2.9979 ± 0.0015 cm (Tables 1.1-1 and 1.1-2, respectively). To simplify modeling of the core configurations, all pebbles were modeled with a radius of 3.000 cm; the total pebble mass for each pebble type was conserved. Whereas the effective uncertainty in perturbing the radius of the pebbles (Tables 2.1-94 and 2.1-117) is negligible, any associated bias and bias uncertainty associated with this simplification of the model and uncertainty evaluation are also considered to be negligible.

The nominal radius of the fuel pebbles was 3.000 cm. The uncertainty in the radius was 0.002 cm (1σ). A single-sided perturbation was performed in which the radius was decreased by 0.006 cm to estimate the uncertainty in k_{eff} due to the uncertainty in the radius of the fuel pebble. Pebble mass was conserved. Results are shown in Table 2.1-94.

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 2.1-94. Effect of Uncertainty in the Fuel Pebble Radius.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (1)	-0.006 cm	0.00001	±	0.00014	3	<0.00001	±	0.00005	<0.00001
2 (1A)	-0.006 cm	0.00024	±	0.00014	3	0.00008	±	0.00005	0.00001
3 (2)	-0.006 cm	0.00036	±	0.00014	3	0.00012	±	0.00005	0.00002
4 (3)	-0.006 cm	0.00014	±	0.00013	3	0.00005	±	0.00004	0.00001

2.1.9.12 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 2.1-95).

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 2.1-96.

Table 2.1-95. 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 2.1-96. 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 (1)	±0.003 g (~0.050 wt.%)	-0.00047	±	0.00007	3	-0.00016	±	0.00002
2 (1A)	±0.003 g (~0.050 wt.%)	-0.00060	±	0.00007	3	-0.00020	±	0.00002
3 (2)	±0.003 g (~0.050 wt.%)	-0.00065	±	0.00007	3	-0.00022	±	0.00002
4 (3)	±0.003 g (~0.050 wt.%)	-0.00038	±	0.00007	3	-0.00013	±	0.00002

2.1.9.13 Isotopic Content (Mass) ^{235}U

See discussion in Section 2.1.9.12 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 2.1-97.

Table 2.1-97. 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 (1)	±0.030 g (~0.50 wt.%)	0.00668	±	0.00007	3	0.00223	±	0.00002
2 (1A)	±0.030 g (~0.50 wt.%)	0.00678	±	0.00007	3	0.00226	±	0.00002
3 (2)	±0.030 g (~0.50 wt.%)	0.00682	±	0.00007	3	0.00227	±	0.00002
4 (3)	±0.030 g (~0.50 wt.%)	0.00801	±	0.00006	3	0.00267	±	0.00002

2.1.9.14 Isotopic Content (Mass) ^{236}U

See discussion in Section 2.1.9.12 regarding the isotopic content of the uranium fuel.

The mass of ^{236}U reported was 0.005 g per pebble (Table 1.1-1). The uncertainty in the ^{236}U mass was 0.001 g (~0.017 wt.%, 1σ). A double-sided perturbation was performed in which the ^{236}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 ^{236}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 2.1-98. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-98. Effect of Uncertainty in the ^{236}U content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.003 g (~0.050 wt.%)	-0.00012	±	0.00007	3	-0.00004	±	0.00002
2 (1A)	±0.003 g (~0.050 wt.%)	-0.00014	±	0.00007	3	-0.00005	±	0.00002
3 (2)	±0.003 g (~0.050 wt.%)	-0.00009	±	0.00007	3	-0.00003	±	0.00002
4 (3)	±0.003 g (~0.050 wt.%)	-0.00017	±	0.00007	3	-0.00006	±	0.00002

2.1.9.15 Isotopic Content (Mass) ^{238}U

The mass of ^{238}U reported was 4.953 ± 0.050 g per pebble (Table 1.1-1). It appears that the uncertainty in ^{238}U mass was estimated by multiplying the uncertainty in ^{235}U mass by the mass ratio of ^{238}U to ^{235}U, which is ~5. The uncertainty in the isotopic content of ^{234}U, ^{235}U, and ^{236}U was evaluated by adjusting the ^{238}U content to compensate for perturbations and conserve the total uranium mass. No additional uncertainty analysis was performed to investigate this large, and possible wrong, uncertainty reported for the mass of ^{238}U. The uncertainty in the isotopic content (mass) of ^{238}U is assumed to be negligible.

2.1.9.16 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 2.1-99.

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 2.1-99. 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 (1)	±0.065 g (0.12 g/cm^3)	0.00197	±	0.00007	12/11	0.00181	±	0.00006	0.00027
2 (1A)	±0.065 g (0.12 g/cm^3)	0.00184	±	0.00007	12/11	0.00169	±	0.00006	0.00025
3 (2)	±0.065 g (0.12 g/cm^3)	0.00190	±	0.00007	12/11	0.00174	±	0.00006	0.00026
4 (3)	±0.065 g (0.12 g/cm^3)	0.00254	±	0.00006	12/11	0.00233	±	0.00006	0.00035

(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.

2.1.9.17 Carbon Mass

The total carbon mass per fuel pebble was reported to be 193.1 ± 0.2 g, with a total fuel pebble mass of 202.22 ± 0.18 g (Table 1.1-1). The footnote to the reported total mass indicates that there is a discrepancy of 0.86 g between the measured fuel pebble mass and the mass of 201.4 g obtained by summing the mass of the individual components within the pebble. Calculation of the TRISO particle mass using the densities provided indicate a mass difference of approximately 0.854 g. Subtraction of the carbon in the TRISO particles from the total carbon mass provides a value of 188.52 g; this value seems slightly lower than the measured mass of a solid graphite moderator pebble (190.54 ± 1.44 g, Table 1.1-2). Whereas the total uranium mass and fuel pebble masses should be more accurately known, and the volumetric displacement of TRISO particles in the graphite matrix of the fuel pebble is negligible, the total mass of graphite in the fuel pebble should be greater than what was reported. Therefore, the mass of the TRISO particles are subtracted from the total measured mass of the fuel pebbles and a carbon mass of 189.4 g is obtained. The uncertainty of ±0.2 g is retained as the uncertainty in the reported carbon mass per pebble and is greater than the uncertainty in the fuel pebble mass. No additional uncertainty for the correction of the carbon mass is included.

The total mass of carbon per fuel pebble was 189.4 g (excluding TRISO carbon). The uncertainty in the mass was 0.2 g (0.0018 g/cm^3, 1σ). A double-sided perturbation was performed in which the carbon mass was perturbed by ±0.6 g (0.0055 g/cm^3) to estimate the uncertainty in k_{eff} due to the uncertainty in the carbon mass per fuel pebble. The radius of the fuel 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 2.1-100.

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 2.1-100. Effect of Uncertainty in the Fuel Pebble Carbon Mass.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (1)	±0.6 g (0.0055 g/cm^3)	0.00084	±	0.00007	3	0.00028	±	0.00002	0.00004
2 (1A)	±0.6 g (0.0055 g/cm^3)	0.00085	±	0.00007	3	0.00028	±	0.00002	0.00004
3 (2)	±0.6 g (0.0055 g/cm^3)	0.00057	±	0.00007	3	0.00019	±	0.00002	0.00003
4 (3)	±0.6 g (0.0055 g/cm^3)	0.00051	±	0.00006	3	0.00017	±	0.00002	0.00003

2.1.9.18 Total Pebble Mass

The total fuel pebble mass reported was 202.22 ± 0.18 g (Table 1.1-1). An additional uncertainty in the total fuel pebble mass was not performed since the masses of the individual components within the fuel pebbles were investigated separately. Any additional uncertainty due to the weighing of individual pebbles, beyond what was already accounted for in the mass of the fuel pebble components, is assumed to be negligible.

2.1.9.19 Kernel Density

An additional uncertainty in the fuel kernel density was not performed. See Section 2.1.9.16 regarding the evaluation of uncertainty in the uranium fuel mass.

2.1.9.20 Buffer Density

The buffer density is reported as ≤1.1 g/cm^3 with a one-sided 10 % uncertainty assumed by the authors of the reference documentation (Table 1.1-1). A density of 1.05 ± 0.05 g/cm^3 (1σ) seemed more appropriate since the manufacturing parameters for TRISO particles are normally distributed and the true uncertainty in the buffer density is unknown. The uncertainty in the buffer layer of TRISO particles used in the HTTR (HTTR-GCR-RESR-001) is 0.10 g/cm^3; however, the uncertainties in the density in the other layers forming the PROTEUS TRISO particles are roughly half those reported for the HTTR.

The buffer density used was 1.05 g/cm^3. The selected uncertainty in the density was 0.05 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.15 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in the buffer density. 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 2.1-101. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-101. Effect of Uncertainty in the Buffer Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.15 g/cm^3	0.00024	±	0.00007	3	0.00008	±	0.00002
2 (1A)	±0.15 g/cm^3	0.00018	±	0.00007	3	0.00006	±	0.00002
3 (2)	±0.15 g/cm^3	0.00013	±	0.00007	3	0.00004	±	0.00002
4 (3)	±0.15 g/cm^3	0.00016	±	0.00006	3	0.00005	±	0.00002

2.1.9.21 IPyC Density

The IPyC density was 1.90 g/cm^3 (Table 1.1-1). The uncertainty in the density was 0.05 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.15 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in the IPyC density. 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 2.1-102. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-102. Effect of Uncertainty in the IPyC Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.15 g/cm^3	0.00007	±	0.00007	3	0.00002	±	0.00002
2 (1A)	±0.15 g/cm^3	0.00021	±	0.00007	3	0.00007	±	0.00002
3 (2)	±0.15 g/cm^3	0.00009	±	0.00007	3	0.00003	±	0.00002
4 (3)	±0.15 g/cm^3	0.00007	±	0.00007	3	0.00002	±	0.00002

2.1.9.22 SiC Density

The SiC density was 3.20 g/cm^3 (Table 1.1-1). The uncertainty in the density was 0.02 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.06 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in the SiC density. 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 2.1-103. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-103. Effect of Uncertainty in the SiC Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.06 g/cm^3	-0.00014	±	0.00007	3	-0.00005	±	0.00002
2 (1A)	±0.06 g/cm^3	-0.00001	±	0.00007	3	<0.00001	±	0.00002
3 (2)	±0.06 g/cm^3	0.00010	±	0.00007	3	0.00003	±	0.00002
4 (3)	±0.06 g/cm^3	-0.00004	±	0.00006	3	-0.00001	±	0.00002

2.1.9.23 OPyC Density

The OPyC density was 1.89 g/cm^3 (Table 1.1-1). The uncertainty in the density was 0.05 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.15 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in the OPyC density. 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 2.1-104. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-104. Effect of Uncertainty in the OPyC Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.15 g/cm^3	0.00029	±	0.00007	3	0.00010	±	0.00002
2 (1A)	±0.15 g/cm^3	0.00022	±	0.00007	3	0.00007	±	0.00002
3 (2)	±0.15 g/cm^3	0.00013	±	0.00007	3	0.00004	±	0.00002
4 (3)	±0.15 g/cm^3	0.000010	±	0.00006	3	0.00003	±	0.00002

2.1.9.24 Kernel Impurities

The reported impurity content for UO_2 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 kernel composition is normalized such that the total composition adds up to 100 %. The nominal impurity content used for evaluation of the uncertainty in the kernel impurities is in Table 2.1-105.

The nominal kernel impurity content is shown in Table 2.1-105. 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 kernel impurity 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 2.1-106. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-105. Kernel Impurities.

Element	Minimum ppm (wt.%)	Maximum ppm (wt.%)	Nominal ppm (wt.%)
Ag	--	0.2	0.1
B	0.085	0.085	0.085
Ca	51	51	51
Cd	--	0.2	0.1
Cl	--	3	1.5
Co	--	1	0.5
Cr	23	23	23
Dy	--	0.02	0.01
Eu	--	0.02	0.01
Fe	28	28	28
Gd	--	0.02	0.01
Li	--	1	0.5
Mn	7.5	7.5	7.5
Mo	--	3	1.5
Ni	2.5	2.5	2.5
S	--	0.04	0.02
Ti	--	10	5
V	--	10	5
Total	--	--	126.335

Table 2.1-106. Effect of Uncertainty in the Kernel Impurities.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±50 %	-0.00005	±	0.00007	1	-0.00005	±	0.00007
2 (1A)	±50 %	-0.00006	±	0.00007	1	-0.00006	±	0.00007
3 (2)	±50 %	-0.00006	±	0.00007	1	-0.00006	±	0.00007
4 (3)	±50 %	-0.00004	±	0.00007	1	-0.00004	±	0.00007

2.1.9.25 Buffer Impurities

The reported impurity content for the fuel pebbles is listed in Table 1.1-15, and is assumed to apply to the impurity content of the TRISO particle layers. The composition values listed as less than a given value are taken at half this maximum value in the nominal material composition. The buffer composition is adjusted such that the total composition adds up to 100 %. The nominal impurity content used for evaluation of the uncertainty in the buffer impurities is in Table 2.1-107.

The nominal buffer impurity content is shown in Table 2.1-107. 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 buffer impurity 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 2.1-108. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-107. 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 2.1-108. Effect of Uncertainty in the Buffer Impurities.

Case (Core)	**Deviation**	**Δk_p**	**±**	**$\sigma_{\Delta kp}$**	**Scaling Factor**	**Δk_{eff} (1σ)**	**±**	**$\sigma_{\Delta keff}$**
1 (1)	±50 %	<0.00001	±	0.00007	1	<0.00001	±	0.00007
2 (1A)	±50 %	0.00002	±	0.00007	1	0.00002	±	0.00007
3 (2)	±50 %	-0.00001	±	0.00007	1	-0.00001	±	0.00007
4 (3)	±50 %	-0.00004	±	0.00007	1	-0.00004	±	0.00007

2.1.9.26 IPyC Impurities

The reported impurity content for the fuel pebbles is listed in Table 1.1-15, and is assumed to apply to the impurity content of the TRISO particle layers. The composition values listed as less than a given value are taken at half this maximum value in the nominal material composition. The IPyC composition is adjusted such that the total composition adds up to 100 %. The nominal impurity content used for evaluation of the uncertainty in the IPyC impurities is in Table 2.1-107.

The nominal IPyC impurity content is shown in Table 2.1-107. 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 IPyC impurity 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 2.1-109. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-109. Effect of Uncertainty in the IPyC Impurities.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±50 %	0.00007	±	0.00007	1	0.00007	±	0.00007
2 (1A)	±50 %	0.00005	±	0.00007	1	0.00005	±	0.00007
3 (2)	±50 %	0.00006	±	0.00007	1	0.00006	±	0.00007
4 (3)	±50 %	0.00008	±	0.00006	1	0.00008	±	0.00006

2.1.9.27 SiC Impurities

The reported impurity content for the fuel pebbles is listed in Table 1.1-15, and is assumed to apply to the impurity content of the TRISO particle layers. The composition values listed as less than a given value are taken at half this maximum value in the nominal material composition. The SiC composition is adjusted such that the total composition adds up to 100 %. The nominal impurity content used for evaluation of the uncertainty in the SiC impurities is in Table 2.1-107.

The nominal SiC impurity content is shown in Table 2.1-107. 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 SiC impurity 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 2.1-110. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-110. Effect of Uncertainty in the SiC Impurities.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±50 %	-0.00009	±	0.00007	1	-0.00009	±	0.00007
2 (1A)	±50 %	-0.00009	±	0.00007	1	-0.00009	±	0.00007
3 (2)	±50 %	0.00005	±	0.00007	1	0.00005	±	0.00007
4 (3)	±50 %	0.00004	±	0.00006	1	0.00004	±	0.00006

2.1.9.28 OPyC Impurities

The reported impurity content for the fuel pebbles is listed in Table 1.1-15, and is assumed to apply to the impurity content of the TRISO particle layers. The composition values listed as less than a given value are taken at half this maximum value in the nominal material composition. The OPyC composition is adjusted such that the total composition adds up to 100 %. The nominal impurity content used for evaluation of the uncertainty in the OPyC impurities is in Table 2.1-107.

The nominal OPyC impurity content is shown in Table 2.1-107. 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 OPyC impurity 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 2.1-111. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-111. Effect of Uncertainty in the OPyC Impurities.

Case (Core)	**Deviation**	**Δk_p**	**±**	**$\sigma_{\Delta kp}$**	**Scaling Factor**	**Δk_{eff} (1σ)**	**±**	**$\sigma_{\Delta keff}$**
1 (1)	±50 %	0.00003	±	0.00007	1	0.00003	±	0.00007
2 (1A)	±50 %	0.00004	±	0.00007	1	0.00004	±	0.00007
3 (2)	±50 %	0.00008	±	0.00007	1	0.00008	±	0.00007
4 (3)	±50 %	0.00005	±	0.00006	1	0.00005	±	0.00006

2.1.9.29 Fueled Zone Impurities

The reported impurity content for the fuel pebbles is listed in Table 1.1-15. 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 2.1-107.

The nominal fueled zone impurity content is shown in Table 2.1-107. 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 2.1-112.

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

Table 2.1-112. 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 (1)	±50 %	-0.00043	±	0.00007	1/0.53	-0.00023	±	0.00004
2 (1A)	±50 %	-0.00035	±	0.00007	1/0.53	-0.00019	±	0.00004
3 (2)	±50 %	-0.00036	±	0.00007	1/0.53	-0.00019	±	0.00004
4 (3)	±50 %	-0.00034	±	0.00007	1/0.53	-0.00018	±	0.00004

2.1.9.30 Unfueled Zone Impurities

The reported impurity content for the fuel pebbles is listed in Table 1.1-15. It is assumed that the unfueled zone impurities are the same as the fueled zone impurities in Section 2.1.9.29. 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 2.1-107.

The nominal unfueled zone impurity content is shown in Table 2.1-107. 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 2.1-113.

Table 2.1-113. 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 (1)	±50 %	-0.00041	±	0.00007	1/0.53	-0.00021	±	0.00004
2 (1A)	±50 %	-0.00055	±	0.00007	1/0.53	-0.00029	±	0.00004
3 (2)	±50 %	-0.00055	±	0.00007	1/0.53	-0.00029	±	0.00004
4 (3)	±50 %	-0.00048	±	0.00007	1/0.53	-0.00025	±	0.00004

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

2.1.9.31 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 2.1-114.

A second perturbation analysis was performed 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 this perturbation analysis were negligible. Because it is unclear how or when water was retained within the pebbles, the larger 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 2.1-114. Effect of Uncertainty in the Water Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.01 wt.%	0.00048	±	0.00007	√3	0.00028	±	0.00004
2 (1A)	±0.01 wt.%	0.00032	±	0.00007	√3	0.00018	±	0.00004
3 (2)	±0.01 wt.%	0.00052	±	0.00007	√3	0.00030	±	0.00004
4 (3)	±0.01 wt.%	0.00015	±	0.00007	√3	0.00008	±	0.00004

2.1.9.32 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 2.1-115.

Table 2.1-115. 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 (1)	±0.03	-0.00028	±	0.00007	3	-0.00009	±	0.00002
2 (1A)	±0.03	-0.00029	±	0.00007	3	-0.00010	±	0.00002
3 (2)	±0.03	-0.00024	±	0.00007	3	-0.00008	±	0.00002
4 (3)	±0.03	-0.00038	±	0.00007	3	-0.00013	±	0.00002

2.1.10 Moderator Pebbles

2.1.10.1 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 2.1-116.

Table 2.1-116. Number of Moderator Pebbles.

Case (Core)	# Moderator Pebbles
1 (1)	2585
2 (1A)	2470
3 (2)	1880 (fueled region) 6009 (moderator region)
4 (3)	2000

2.1.10.2 Radius

The outer radius of the fuel pebbles was reported as 3.0006 ± 0.002 cm and the outer radius of the moderator pebbles was reported as 2.9979 ± 0.0015 cm (Tables 1.1-1 and 1.1-2, respectively). To simplify modeling of the core configurations, all pebbles were modeled with a radius of 3.000 cm; the total pebble mass for each pebble type was conserved. Whereas the effective uncertainty in perturbing the radius of the pebbles (Tables 2.1-94 and 2.1-117) is negligible, any associated bias and bias uncertainty associated with this simplification of the model and uncertainty evaluation are also considered to be negligible.

The nominal radius of the moderator pebbles was 3.000 cm. The uncertainty in the radius was 0.0015 cm (1σ). A single-sided perturbation was performed in which the radius was decreased by 0.0045 cm to estimate the uncertainty in k_{eff} due to the uncertainty in the radius of the moderator pebble. Pebble mass was conserved. Results are shown in Table 2-1.117. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-117. Effect of Uncertainty in the Moderator Pebble Radius.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	-0.0045 cm	-0.00014	±	0.00014	3	-0.00005	±	0.00005
2 (1A)	-0.0045 cm	0.00017	±	0.00014	3	0.00006	±	0.00005
3 (2)	-0.0045 cm	-0.00016	±	0.00014	3	-0.00005	±	0.00005
4 (3)	-0.0045 cm	0.00010	±	0.00013	3	0.00003	±	0.00004

2.1.10.3 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 2.1-118.

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 2.1-118. 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 (1)	±4.32 g (0.038 g/cm^3)	0.00272	±	0.00007	3	0.00091	±	0.00002	0.00014
2 (1A)	±4.32 g (0.038 g/cm^3)	0.00282	±	0.00007	3	0.00094	±	0.00002	0.00014
3 (2)	±4.32 g (0.038 g/cm^3)	0.00322	±	0.00007	3	0.00107	±	0.00002	0.00016
4 (3)	±4.32 g (0.038 g/cm^3)	0.00196	±	0.00007	3	0.00065	±	0.00002	0.00010

2.1.10.4 Impurities

The reported impurity content for the moderator pebbles is listed in Table 1.1-16. 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 2.1-119.

The nominal moderator pebble impurity content is shown in Table 2.1-119. 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 2.1-120.
The uncertainty in Case 3 (Core 2) is significantly greater than the other three configurations; this is because 17 additional layers of moderator pebbles were placed between the core region and the upper axial reflector.

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

Table 2.1-119. 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 2.1-120. 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 (1)	50 %	-0.00193	±	0.00007	1/0.52	-0.00100	±	0.00004
2 (1A)	50 %	-0.00207	±	0.00007	1/0.52	-0.00108	±	0.00004
3 (2)	50 %	-0.00369	±	0.00007	1/0.52	-0.00192	±	0.00004
4 (3)	50 %	-0.00173	±	0.00007	1/0.52	-0.00090	±	0.00004

2.1.10.5 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 2.1-121.

A second perturbation analysis was performed 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 this perturbation analysis were negligible. Because it is unclear how or when water was retained within the pebbles, the larger uncertainty, obtained using uniform distribution of water content throughout the pebble, is utilized to represent the total uncertainty in the moderator pebble water content.

Table 2.1-121. Effect of Uncertainty in the Water Content.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.01 wt.%	0.00031	±	0.00007	√3	0.00018	±	0.00004
2 (1A)	±0.01 wt.%	0.00011	±	0.00007	√3	0.00006	±	0.00004
3 (2)	±0.01 wt.%	0.00005	±	0.00007	√3	0.00003	±	0.00004
4 (3)	±0.01 wt.%	-0.00003	±	0.00007	√3	-0.00002	±	0.00004

2.1.11 Start-Up Source

Details regarding the dimensions, composition, and mass of the start-up source, and its associated penetrations, used in the PROTEUS cores were unavailable. The effective bias and bias uncertainty for removing the start-up source was experimentally measured (see Section 1.1.5) and accounted for (see Section 3.1.1.1) in the evaluation of the benchmark model. It is assumed that any uncertainty in the dimensions, composition, or mass of the start-up source, and its associated penetrations, is already included in the reported bias uncertainty.

2.1.12 Detectors

Significant details regarding the dimensions, composition, and mass of the detectors used in the PROTEUS cores were unavailable. The effective bias and bias uncertainty for removing these detectors was experimentally measured (see Section 1.1.5) and accounted for (see Section 3.1.1.1) in the evaluation of the benchmark model. It is assumed that any uncertainty in the dimensions, composition, or mass of the detectors is already included in the reported bias uncertainty.

2.1.13 Temperature Sensors

Significant details regarding the dimensions, composition, and mass of the temperature sensors used in the PROTEUS cores were unavailable. The effective bias and bias uncertainty for removing these sensors was experimentally measured (see Section 1.1.5) and accounted for (see Section 3.1.1.1) in the evaluation of the benchmark model. It is assumed that any uncertainty in the dimensions, composition, or mass of the temperature sensors is already included in the reported bias uncertainty.

2.1.14 Graphite Fillers

2.1.14.1 Axial Modifier Thickness

Twelve graphite fillers served as axial modifiers in the core cavity to convert the irregular icosikaidigon (22-sided polygon) into a nearly uniform dodecagon (see Figures 1.1-15 and 1.1-16). Each of the 12 fillers were unique in shape (see Figure 1.1-17) with various angles, dimensions, penetrations, etc. The total mass of these 12 filler pieces was measured (211.2 kg). Exact dimensions were not used to model the axial reflectors; instead, the vertices of the dodecagon were used to create a graphite region between the axial core cavity and the radial reflector. This volume was then divided into the mass to create an average mass density for the axial modifier region. The uncertainty in the dimensions of these graphite parts was performed by perturbing the distance between the center of the core cavity and the inner walls of the axial modifier region (601.5 and 603 mm, at alternating sides). Since the individual parts described in Figure 1.1-17 have dimensions reported to the nearest 10^{th} of a millimeter, an uncertainty of 0.1 mm is used in assessment of the uncertainty in the thickness of the axial modifier components.

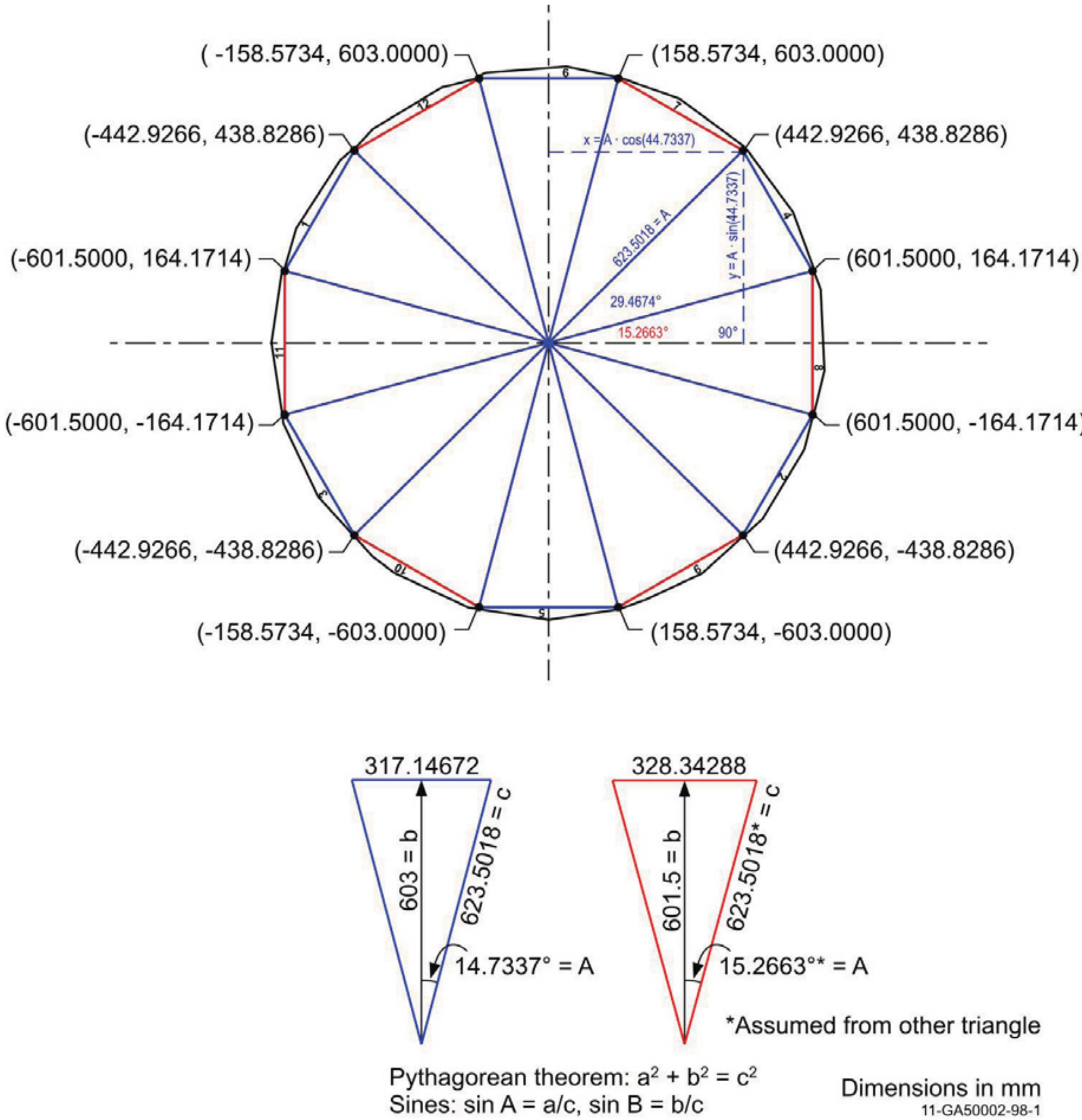

Figure 2.1-3. Vertices and Dimensions of the Axial Modifiers.

The axial modifier distance from the core center is shown in Figure 2.1-3, based upon part thicknesses shown in Figure 1.1-17. The uncertainty in the thickness was assumed to be 0.1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the thickness of all axial modifiers was simultaneously perturbed by ±0.3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the axial modifier thickness. 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 2.1-122. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-122. Effect of Uncertainty in the Axial Modifier Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.3 mm	0.00023	±	0.00007	3√3	0.00004	±	0.00001
2 (1A)	±0.3 mm	0.00014	±	0.00007	3√3	0.00003	±	0.00001
3 (2)	±0.3 mm	0.00018	±	0.00007	3√3	0.00003	±	0.00001
4 (3)	±0.3 mm	0.00007	±	0.00007	3√3	0.00001	±	0.00001

2.1.14.2 Axial Modifier Height

The height of the axial modifiers was reported as 1729 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 of all axial modifiers was simultaneously perturbed by ±3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the axial modifier height. 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 2.1-123. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-123. Effect of Uncertainty in the Axial Modifier Height.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	0.00005	±	0.00007	3√3	0.00001	±	0.00001
2 (1A)	±3 mm	0.00010	±	0.00007	3√3	0.00002	±	0.00001
3 (2)	±3 mm	0.00010	±	0.00007	3√3	0.00002	±	0.00001
4 (3)	±3 mm	-0.00008	±	0.00007	3√3	-0.00001	±	0.00001

2.1.14.3 Axial Modifier Mass

The mass of all 12 axial modifiers was reported as 211.2 kg; no uncertainty in the measurement was reported.

The total mass of the axial modifiers was 211.2 kg (average mass density of 1.6808 g/cm^3; see Section 2.1.14.1 for a description of how the volume of was determined). The uncertainty in the mass was assumed to be 0.1 kg (0.0008 g/cm^3, bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the total mass of the axial modifiers was perturbed by ±0.3 kg (0.0024 g/cm^3) to estimate the uncertainty in k_{eff} due to the uncertainty in the axial modifier mass. 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 2.1-124. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-124. Effect of Uncertainty in the Axial Modifier Mass.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.3 kg (0.0024 g/cm^3)	-0.00008	±	0.00007	3√3	-0.00002	±	0.00001
2 (1A)	±0.3 kg (0.0024 g/cm^3)	0.00006	±	0.00007	3√3	0.00001	±	0.00001
3 (2)	±0.3 kg (0.0024 g/cm^3)	-0.00004	±	0.00007	3√3	-0.00001	±	0.00001
4 (3)	±0.3 kg (0.0024 g/cm^3)	0.00001	±	0.00006	3√3	<0.00001	±	0.00001

2.1.14.4 Axial Modifier Impurities

It is assumed that the EBC of 1.33 ± 0.08 ppm (by at.%), discussed in Section 2.1.3.5, sufficiently described the impurity content in the graphite fillers serving as core axial modifiers.

The impurity content of the axial modifiers 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 axial modifiers. 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 2.1-125. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-125. Effect of Uncertainty in the Axial Modifier Impurities.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.24 ppma	-0.00022	±	0.00007	3	-0.00007	±	0.00002
2 (1A)	±0.24 ppma	-0.00005	±	0.00007	3	-0.00002	±	0.00002
3 (2)	±0.24 ppma	-0.00018	±	0.00007	3	-0.00006	±	0.00002
4 (3)	±0.24 ppma	-0.00011	±	0.00007	3	-0.00004	±	0.00002

2.1.14.5 Lattice Support Width

Additional graphite fillers were used in the even pebble layers (six per layer) to support the pebble lattice structure. These pieces are shown in-core in Figure 1.1-16 and the dimensions of the large and small fillers (pieces 13 and 14, respectively) in Figure 1.1-17. These fillers were placed flush against the axial modifier walls and the vertices were determined for use in models and analysis (see Figure 2.1-4).

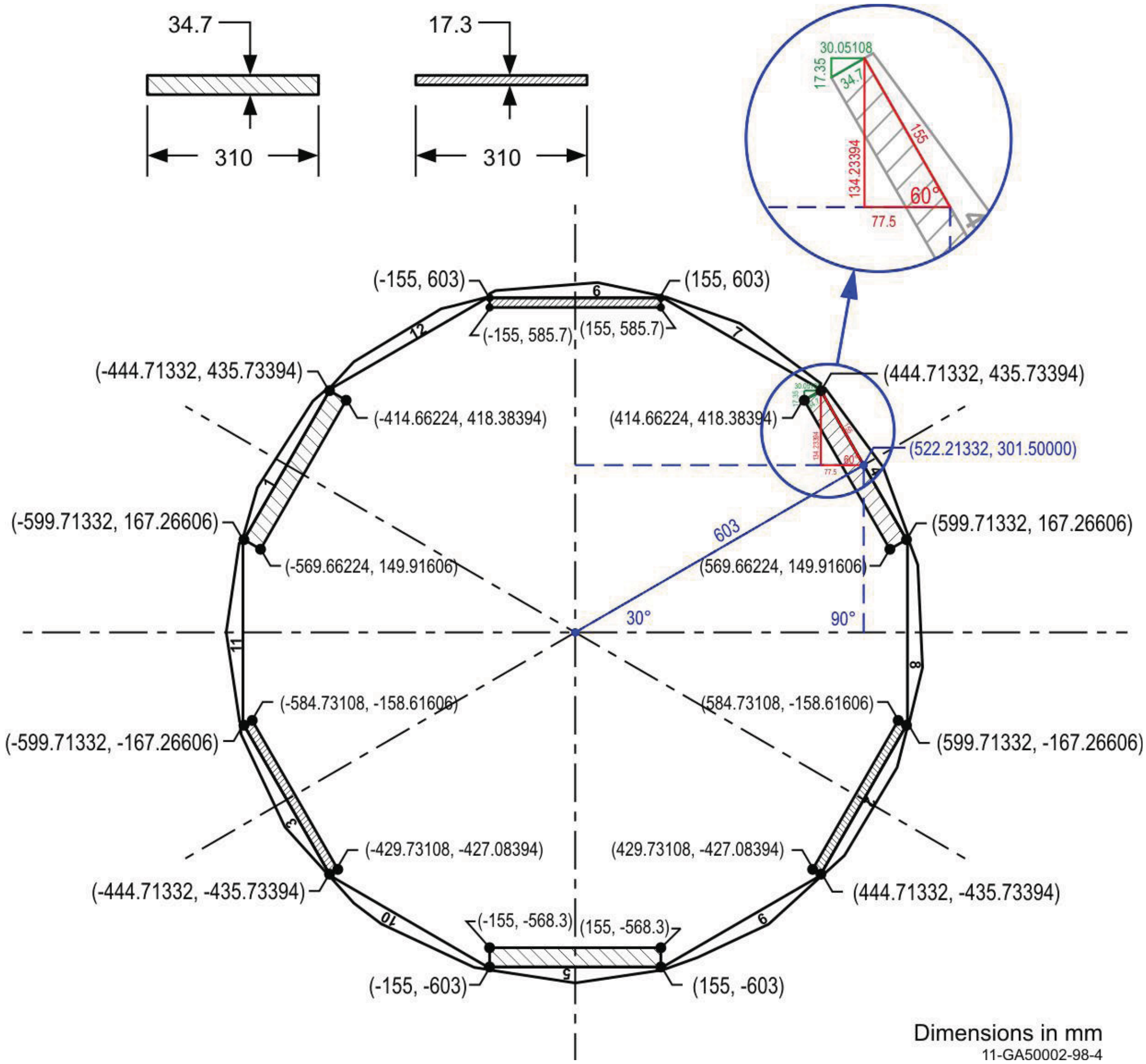

Figure 2.1-4. Vertices and Dimensions of the Lattice Supports (Even Layers Only).

The width of the lattice supports was either 17.3 or 34.7 mm (Figure 1.1-17). The uncertainty in the width was assumed to be 0.1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the width of all lattice supports was simultaneously perturbed by ±0.3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the lattice support width. Mass was conserved and the fillers were retained flush against the inner surface of the axial modifiers. 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 2.1-126. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-126. Effect of Uncertainty in the Lattice Support Width.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.3 mm	-0.00011	±	0.00007	3√3	-0.00002	±	0.00001
2 (1A)	±0.3 mm	-0.00028	±	0.00007	3√3	-0.00005	±	0.00001
3 (2)	±0.3 mm	-0.00014	±	0.00007	3√3	-0.00003	±	0.00001
4 (3)	±0.3 mm	0.00001	±	0.00007	3√3	<0.00001	±	0.00001

2.1.14.6 Lattice Support Length

The length of the lattice supports was 310 mm (Figure 1.1-17). The uncertainty in the length was assumed to be 0.1 mm. Whereas the uncertainty in both the width and height of these graphite pieces is negligible, a perturbation of the uncertainty in their length would also be negligible.

2.1.14.7 Lattice Support Height

The height of the lattice supports was either 43.6 or 38 mm (Figure 1.1-17). The uncertainty in the height was assumed to be 0.1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the height of all lattice supports was simultaneously perturbed by ±0.3 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the lattice support height. 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 2.1-127. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-127. Effect of Uncertainty in the Lattice Support Height.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.3 mm	0.00009	±	0.00007	3√3	0.00002	±	0.00001
2 (1A)	±0.3 mm	0.00005	±	0.00007	3√3	0.00001	±	0.00001
3 (2)	±0.3 mm	-0.00003	±	0.00007	3√3	-0.00001	±	0.00001
4 (3)	±0.3 mm	-0.00002	±	0.00007	3√3	<0.00001	±	0.00001

2.1.14.8 Lattice Support Mass

The total mass of six lattice supports (one pebble support layer) was 3.36 kg (average mass density of 1.7429 g/cm^3). The uncertainty in the mass was assumed to be 0.01 kg (0.0052 g/cm^3, bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the total mass of each pebble support layer was simultaneously perturbed by ±0.03 kg (0.0156 g/cm^3) to estimate the uncertainty in k_{eff} due to the uncertainty in the lattice support mass. 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 2.1-128. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-128. Effect of Uncertainty in the Lattice Support Mass.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.03 kg (0.0156 g/cm^3)	-0.00004	±	0.00007	3√3	-0.00001	±	0.00001
2 (1A)	±0.03 kg (0.0156 g/cm^3)	0.00006	±	0.00007	3√3	0.00001	±	0.00001
3 (2)	±0.03 kg (0.0156 g/cm^3)	0.00002	±	0.00007	3√3	<0.00001	±	0.00001
4 (3)	±0.03 kg (0.0156 g/cm^3)	-0.00005	±	0.00007	3√3	-0.00001	±	0.00001

2.1.14.9 Lattice Support Impurities

It is assumed that the EBC of 1.33 ± 0.08 ppm (by at.%), discussed in Section 2.1.3.5, sufficiently described the impurity content in the graphite fillers serving as pebble lattice supports.

The impurity content of the lattice supports 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 lattice supports. 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 2.1-129. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-129. Effect of Uncertainty in the Lattice Support Impurities.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.24 ppma	0.00022	±	0.00007	3	0.00007	±	0.00002
2 (1A)	±0.24 ppma	0.00013	±	0.00007	3	0.00004	±	0.00002
3 (2)	±0.24 ppma	-0.00002	±	0.00007	3	<0.00001	±	0.00002
4 (3)	±0.24 ppma	-0.00007	±	0.00006	3	-0.00002	±	0.00002

2.1.15 ZEBRA Control Rods

2.1.15.1 Inner Tube Diametrical Thickness

The diametrical thickness of the inner aluminum tube is defined as the distance between its inner diameter (30 mm) and outer diameter (35 mm) shown in Figure 1.1-18. Reference 2 reports a thickness of 5 mm. However, all thicknesses reported for the ZEBRA rods should be divided in half so as to match the dimensions reported in the accompanying figure and so that the ZEBRA rods could physically be assembled and placed into channels within the graphite radial reflector.

The diametrical thickness of the inner tube of the ZEBRA control rods was 2.5 mm. 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 ±2 mm (split 1 mm apiece between the inner and outer diameters) to estimate the uncertainty in k_{eff} due to the uncertainty in the diametrical thickness of the inner tube. 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 2.1-130. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-130. Effect of Uncertainty in the Inner Tube Diametrical Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±2 mm	-0.00014	±	0.00007	2√3	-0.00004	±	0.00002
2 (1A)	NA		NA		NA		NA	
3 (2)	NA		NA		NA		NA	
4 (3)	NA		NA		NA		NA	

2.1.15.2 Outer Tube Diametrical Thickness

The diametrical thickness of the outer aluminum tube is defined as the distance between its inner diameter (35.7 mm) and outer diameter (42 mm) shown in Figure 1.1-18. Reference 2 reports a thickness of 6.3 mm. However, all thicknesses reported for the ZEBRA rods should be divided in half so as to match the dimensions reported in the accompanying figure and so that the ZEBRA rods could physically be assembled and placed into channels within the graphite radial reflector.

The diametrical thickness of the outer tube of the ZEBRA control rods was 3.15 mm. The uncertainty in the thickness was assumed to be 0.1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the thickness was perturbed by ±0.3 mm (split 0.15 mm apiece between the inner and outer diameters) to estimate the uncertainty in k_{eff} due to the uncertainty in the diametrical thickness of the outer tube. 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 2.1-131. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-131. Effect of Uncertainty in the Outer Tube Diametrical Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.3 mm	-0.00006	±	0.00007	3√3	-0.00001	±	0.00001
2 (1A)	NA		NA		NA		NA	
3 (2)	NA		NA		NA		NA	
4 (3)	NA		NA		NA		NA	

2.1.15.3 Vertical Alignment of Tubes

The vertical placement of the outer (fixed) tube of the ZEBRA control rods is shown in Figure 1.1-19. It was assumed that an uncertainty of 10 mm in the vertical positioning of this tube adequately bounds any uncertainty in affixing the outer tubes within the radial reflectors, the reference location for the fixed cadmium sheaths when withdrawing the inner tube of the control rods, and the distance between individual sheaths on each control rod tube.

The uncertainty in the nominal location of the cadmium sleeves on the inner tube was 10 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the position of all the cadmium sleeves on the inner tube was simultaneously perturbed by ±30 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the vertical alignment of the tubes. 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 2.1-132.

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 divided by √4 to account for the perturbation of multiple positions. The final adjusted Δk_{eff} uncertainty was obtained by summing under quadrature the systematic and random uncertainties.

Table 2.1-132. Effect of Uncertainty in the Vertical Alignment of Tubes.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (1)	±30 mm	-0.00137	±	0.00007	3√3	-0.00026	±	0.00001	0.00012
2 (1A)	NA		NA		NA		NA		NA
3 (2)	NA		NA		NA		NA		NA
4 (3)	NA		NA		NA		NA		NA

2.1.15.4 Cadmium Thickness

Reference 2 reports a thickness of 0.5 mm. However, all thicknesses reported for the ZEBRA rods should be divided in half so as to match the dimensions reported in the accompanying figure and so that the ZEBRA rods could physically be assembled and placed into channels within the graphite radial reflector.

The thickness of the cadmium sleeves was 0.25 mm. The uncertainty in the thickness was assumed to be 0.1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the thickness of all sleeves was simultaneously perturbed by ±0.3 mm (only by perturbing the outer diameter) to estimate the uncertainty in k_{eff} due to the uncertainty in the thickness of the cadmium sleeves. 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 2.1-133. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-133. Effect of Uncertainty in the Cadmium Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.3 mm	-0.00034	±	0.00007	3√3	-0.00007	±	0.00001
2 (1A)	NA		NA		NA		NA	
3 (2)	NA		NA		NA		NA	
4 (3)	NA		NA		NA		NA	

2.1.15.5 Cadmium Length

The length of the cadmium sleeves was 160 mm (Figure 1.1-18). The uncertainty in the length was assumed to be 1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the thickness of all sleeves was simultaneously perturbed by ±3 mm (only by perturbing the outer diameter) to estimate the uncertainty in k_{eff} due to the uncertainty in the length of the cadmium sleeves. 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 2.1-134. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-134. Effect of Uncertainty in the Cadmium Length.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±3 mm	-0.00017	±	0.00007	3√3	-0.00003	±	0.00002
2 (1A)	NA	NA			NA	NA		
3 (2)	NA	NA			NA	NA		
4 (3)	NA	NA			NA	NA		

2.1.15.6 Aluminum Density

The density of the Peraluman tubes was 2.65 g/cm^3. The uncertainty in the density was 0.01 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.03 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in the density of the tubes. 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 2.1-135. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-135. Effect of Uncertainty in the Tube Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.03 g/cm^3	0.00013	±	0.00007	3	0.00004	±	0.00002
2 (1A)	NA	NA			NA	NA		
3 (2)	NA	NA			NA	NA		
4 (3)	NA	NA			NA	NA		

2.1.15.7 Aluminum Composition

The composition specifications for Peraluman R-257 is provided 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 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 ZEBRA rod aluminum tubes is in Table 2.1-136.

A double-sided perturbation was performed in which the composition of the aluminum tubes 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 (those elemental constituents with minimum and maximum content of equal amount were not perturbed), 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 2.1-137. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-136. Composition of the Peraluman R-257.

Element	Minimum wt.%	Maximum wt.%	Nominal wt.%
B	--	0.001	0.0005
Mg	--	2.8	1.4
Al	96.658	--	98.069
Si	0.2	0.2	0.2
Mn	--	0.01	0.005
Fe	0.2	0.2	0.2
Cu	0.02	0.02	0.02
Zn	0.1	0.1	0.1
Ga	--	0.01	0.005
Cd	--	0.001	0.0005
Total	--	--	100

Table 2.1-137. Effect of Uncertainty in the Tube Composition.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	Min/Max Al	0.00011	±	0.00007	√3	0.00002	±	0.00001
2 (1A)	NA	NA			NA	NA		
3 (2)	NA	NA			NA	NA		
4 (3)	NA	NA			NA	NA		

2.1.15.8 Cadmium Density

Material properties for the cadmium sheaths used in the ZEBRA rods was not reported. It was assumed that the cadmium was Type 5N with a mass density of 8.65 g/cm^3 and the composition shown in Table 2.1-139 (see footnote to table for reference information).

The density of the cadmium was assumed to be that of nominal cadmium, 8.65 g/cm^3. The uncertainty in the cadmium density was assumed to be 0.01 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.03 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in cadmium density. 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 2.1-138. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-138. Effect of Uncertainty in the Cadmium Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±0.03 g/cm^3	0.00003	±	0.00007	3	0.00001	±	0.00002
2 (1A)	NA	NA			NA	NA		
3 (2)	NA	NA			NA	NA		
4 (3)	NA	NA			NA	NA		

2.1.15.9 Cadmium Composition

Material properties for the cadmium sheaths used in the ZEBRA rods was not reported. It was assumed that the cadmium was Type 5N with a mass density of 8.65 g/cm^3 and the composition shown in Table 2.1-139 (see footnote to table for reference information).

The composition of the cadmium sleeves was assumed to be that of nominal cadmium, Type 5N (see Table2.1--139). A double-sided perturbation was performed in which the cadmium composition was perturbed by minimizing and maximizing the cadmium content in the sleeves, while simultaneously maximizing or minimizing the other elemental constituents within the specified limits (those elemental constituents with minimum and maximum content of equal amount were not perturbed), to estimate the uncertainty in k_{eff} due to the uncertainty in cadmium 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 2.1-140. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-139. Composition of Cadmium 5N.[(a)]

Element	Minimum ppm (wt.%)	Maximum ppm (wt.%)	Nominal wt.%
Cd	Balance		99.99911
Cu	--	0.1	0.000005
Fe	0.1	0.1	0.00001
Pb	2	2	0.0002
Mg	3	3	0.0003
Al	0.2	0.2	0.00002
Si	0.2	0.2	0.00002
Ag	--	0.1	0.000005
Ti	0.2	0.2	0.00002
Bi	3	3	0.0003
Ca	0.1	0.1	0.00001
Total	--	--	100

(a) High Purity Cadmium, ESPI Metals, http://www.espimetals.com/index.php/online-catalog/346-cadmium-cd (Accessed 9/1/2011).

Table 2.1-140. Effect of Uncertainty in the Cadmium Composition.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	Min/Max Cd	-0.00001	±	0.00007	√3	<0.00001	±	0.00004
2 (1A)	NA		NA		NA		NA	
3 (2)	NA		NA		NA		NA	
4 (3)	NA		NA		NA		NA	

2.1.16 Withdrawable Control Rods

2.1.16.1 Inner Tube Diametrical Thickness

The diametrical thickness of the inner tube is defined as the distance between its inner diameter (9.5 mm) and outer diameter (13.5 mm).

The diametrical thickness of the inner tube was 2 mm. The uncertainty in the thickness was assumed to be 0.1 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the thickness was perturbed by ±0.3 mm (split 0.15 mm apiece between the inner and outer diameters) to estimate the uncertainty in k_{eff} due to the uncertainty in the diametrical thickness of the steel tube. 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 2.1-141. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-141. Effect of Uncertainty in the Inner Tube Diametrical Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	NA	NA			NA	NA		
2 (1A)	±0.3 mm	-0.00012	±	0.00007	3√3	-0.00002	±	0.00001
3 (2)	±0.3 mm	-0.00009	±	0.00007	3√3	-0.00002	±	0.00001
4 (3)	±0.3 mm	0.00004	±	0.00007	3√3	0.00001	±	0.00001

2.1.16.2 Outer Tube Diametrical Thickness

The diametrical thickness of the outer tube is defined as the distance between its inner diameter (14 mm) and outer diameter (22 mm).

The diametrical thickness of the outer tube was 4 mm. 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 (split 1.5 mm apiece between the inner and outer diameters) to estimate the uncertainty in k_{eff} due to the uncertainty in the diametrical thickness of the steel tube. 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 2.1-142.

Table 2.1-142. Effect of Uncertainty in the Outer Tube Diametrical Thickness.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	NA	NA			NA	NA		
2 (1A)	±3 mm	-0.00115	±	0.00014	3√3	-0.00022	±	0.00003
3 (2)	±3 mm	-0.00050	±	0.00014	3√3	-0.00010	±	0.00003
4 (3)	±3 mm	0.00008	±	0.00013	3√3	0.00002	±	0.00002

2.1.16.3 Length of Tubes and End Plugs

The total length of the control rods is 2200 mm (Figure 1.1-20) with an assumed uncertainty of 10 mm. The rods are withdrawn from the core for coarse reactivity control and any uncertainty in the length of the control rods would be negligible.

2.1.16.4 Inner Tube Density

The density of the inner steel tube was 7.9 g/cm^3. The uncertainty in the steel density was assumed to be 0.01 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.03 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in steel tube density. 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 2.1-143. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-143. Effect of Uncertainty in the Inner Tube Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	NA	NA			NA	NA		
2 (1A)	±0.03 g/cm^3	-0.00002	±	0.00007	3	-0.00001	±	0.00002
3 (2)	±0.03 g/cm^3	0.00009	±	0.00007	3	0.00003	±	0.00002
4 (3)	±0.03 g/cm^3	0.00013	±	0.00007	3	0.00004	±	0.00002

2.1.16.5 Outer Tube and End Plug Density

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 different between using this material or the composition of the inner tube (St1.4301).

The density of the outer steel tube and end plugs was 7.9 g/cm^3. The uncertainty in the steel density was assumed to be 0.01 g/cm^3 (1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.03 g/cm^3 to estimate the uncertainty in k_{eff} due to the uncertainty in steel tube density. 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 2.1-144. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-144. Effect of Uncertainty in the Outer Tube Density.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	NA	NA			NA	NA		
2 (1A)	±0.03 g/cm^3	0.00016	±	0.00007	3	0.00005	±	0.00002
3 (2)	±0.03 g/cm^3	0.00010	±	0.00007	3	0.00003	±	0.00002
4 (3)	±0.03 g/cm^3	0.00002	±	0.00006	3	0.00001	±	0.00002

2.1.16.6 Inner Tube Composition

The composition of the inner steel tube was stainless steel Type St1.4301 (see Table 2.1-145). 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 2.1-146. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-145. Composition of Stainless Steel St1.4301.

Element	Minimum wt.%	Maximum wt.%	Nominal wt.%
C	--	0.07	0.035
Si	--	1	0.5
Mn	--	2	1
Cr	17	20	18.5
Ni	9	11.5	10.25
Fe	Balance		69.715
Total	--	--	100

Table 2.1-146. Effect of Uncertainty in Inner Steel Tube Composition.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	NA	NA			NA	NA		
2 (1A)	Min/Max Fe	-0.00001	±	0.00007	√3	<0.00001	±	0.00004
3 (2)	Min/Max Fe	0.00005	±	0.00007	√3	0.00003	±	0.00004
4 (3)	Min/Max Fe	0.00002	±	0.00006	√3	0.00001	±	0.00004

2.1.16.7 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 2.1-147). 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 2.1-148.

Table 2.1-147. 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 2.1-148. 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 (1)	NA	NA			NA	NA		
2 (1A)	Min/Max Fe	0.00023	±	0.00007	√3	0.00013	±	0.00004
3 (2)	Min/Max Fe	0.00011	±	0.00007	√3	0.00006	±	0.00004
4 (3)	Min/Max Fe	-0.00009	±	0.00007	√3	-0.00005	±	0.00004

2.1.17 Polyethylene Rods

2.1.17.1 Diameter

The diameter of the polyethylene rods was 8.9 mm (Figure 1.1-21). 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 2.1-149. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-149. 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 (1)	NA	NA			NA	NA		
2 (1A)	NA	NA			NA	NA		
3 (2)	NA	NA			NA	NA		
4 (3)	±0.3 mm	0.00049	±	0.00007	3√3	0.00009	±	0.00001

2.1.17.2 Length

The length of the polyethylene rods was 860 mm. The uncertainty in length was assumed to be 10 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the length was perturbed by ±30 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 2.1-150. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-150. 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 (1)	NA		NA		NA		NA	
2 (1A)	NA		NA		NA		NA	
3 (2)	NA		NA		NA		NA	
4 (3)	±30 mm	0.00011	±	0.00007	3√3	0.00002	±	0.00001

2.1.17.3 Density

The linear density of the polyethylene rods was 0.5867 g/cm (mass density: 0.9431 g/cm^3, Figure 1.1-21). The uncertainty in the linear density was 0.0019 g/cm (0.0031 g/cm^3, 1σ). A double-sided perturbation was performed in which the density was perturbed by ±0.0057 g/cm (0.0092 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 2.1-151.

Table 2.1-151. 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 (1)	NA		NA		NA		NA	
2 (1A)	NA		NA		NA		NA	
3 (2)	NA		NA		NA		NA	
4 (3)	±0.0057 g/cm (0.0092 g/cm^3)	0.00033	±	0.00007	3	0.00011	±	0.00002

2.1.17.4 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 2.1-152.

Table 2.1-152. 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 (1)	NA		NA		NA		NA	
2 (1A)	NA		NA		NA		NA	
3 (2)	NA		NA		NA		NA	
4 (3)	±0.09	0.00103	±	0.00006	3	0.00034	±	0.00002

2.1.17.5 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 2.1-153. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-153. Effect of Uncertainty in the Polyethylene Impurities.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	NA		NA		NA		NA	
2 (1A)	NA		NA		NA		NA	
3 (2)	NA		NA		NA		NA	
4 (3)	±0.5 ppm	-0.00004	±	0.00007	1	-0.00003	±	0.00004

2.1.18 Copper Wire

Copper wire was not used in the core during the conduct of these critical experiments.

2.1.19 Experimental Measurements

2.1.19.1 Measurement of keff

There is no additional information regarding the accuracy of the k_{eff} measurements for the critical core conditions. Detectors and the regulating rod position were all monitored for stability to confirm the critical state of the assembly. This uncertainty is typically very small and can be considered negligible.

Reproducibility experiments for Core 5 (Ref. 1) demonstrated that for deterministically studied cores, the difference in the measured k_{eff} values was ~0.0001, which is considered negligible.

2.1.19.2 Autorod Position

Autorod positions were obtained from Tables 1.1-1, 1.1-3, 1.1-4, and 1.1-5 for Cases 1, 2, 3, and 4, respectively. An uncertainty of 5 mm was assumed to bound any uncertainty in the position of the control rod. This uncertainty is approximately double the uncertainty applied for control rod positions within a TRIGA reactor (NRAD-FUND-RESR-001). The position of the autorod at criticality is shown in Table 2.1-154.

Table 2.1-154. Autorod Positions.

Case (Core)	**1 (1)**	**2 (1A)**	**3 (2)**	**4 (3)**
Control Rod	Withdrawn Distance (mm)			
Autorod	418	130	316	685

The withdrawn position of the autorod is in Table 2.1-154. The uncertainty in position was assumed to be 5 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the position was perturbed by ±15 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the withdrawn position of the autorod. 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 2.1-155. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-155. Effect of Uncertainty in the Autorod Position.

Case (Core)	**Deviation**	**Δk_p**	**±**	**$\sigma_{\Delta kp}$**	**Scaling Factor**	**Δk_{eff} (1σ)**	**±**	**$\sigma_{\Delta keff}$**
1 (1)	±15 mm	0.00006	±	0.00005	3√3	0.00001	±	0.00001
2 (1A)	±15 mm	0.00001	±	0.00005	3√3	<0.00001	±	0.00001
3 (2)	±15 mm	0.00006	±	0.00005	3√3	0.00001	±	0.00001
4 (3)	±15 mm	0.00001	±	0.00005	3√3	<0.00001	±	0.00001

2.1.19.3 Safety/Shutdown Rod Positions

The safety/shutdown rods were completely withdrawn (see Figure 1.1-9). An uncertainty of 5 mm was assumed to bound any uncertainty in the position of the control rods. This uncertainty is approximately double the uncertainty applied for control rod positions within a TRIGA reactor (NRAD-FUND-RESR-001). The position of the safety/shutdown rods at criticality is shown in Table 2.1-156.

Table 2.1-156. Safety/Shutdown Rod Positions.

Case (Core)	1 (1)	2 (1A)	3 (2)	4 (3)
Control Rod	Withdrawn Distance (mm)			
Safety/Shutdown Rod 1	2900	2900	2900	2900
Safety/Shutdown Rod 2	2900	2900	2900	2900
Safety/Shutdown Rod 3	2900	2900	2900	2900
Safety/Shutdown Rod 4	2900	2900	2900	2900
Safety/Shutdown Rod 5	2900	2900	2900	2900
Safety/Shutdown Rod 6	2900	2900	2900	2900
Safety/Shutdown Rod 7	2900	2900	2900	2900
Safety/Shutdown Rod 8	2900	2900	2900	2900

The withdrawn position of the safety/shutdown rods is in Table 2.1-156. The uncertainty in position was assumed to be 5 mm (bounding limit with uniform probability distribution). A single-sided perturbation was performed in which the positions were decreased by ±15 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the withdrawn position of the safety/shutdown rods. The calculated results were then scaled to obtain the 1σ uncertainty. Results are shown in Table 2.1-157. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-157. Effect of Uncertainty in the Safety/Shutdown Rod Positions.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±15 mm	-0.00008	±	0.00012	3√3	-0.00002	±	0.00002
2 (1A)	±15 mm	0.00004	±	0.00012	3√3	0.00001	±	0.00002
3 (2)	±15 mm	0.00007	±	0.00012	3√3	0.00001	±	0.00002
4 (3)	±15 mm	-0.00003	±	0.00011	3√3	-0.00001	±	0.00002

2.1.19.4 ZEBRA Rod Positions

ZEBRA rod positions were obtained from Table 1.1-1 for Case 1; they were not used in Cases 2 through 4. An uncertainty of 5 mm was assumed to bound any uncertainty in the position of the control rods. This uncertainty is approximately double the uncertainty applied for control rod positions within a TRIGA reactor (NRAD-FUND-RESR-001). The position of the ZEBRA rods at criticality is shown in Table 2.1-158.

Table 2.1-158. ZEBRA Rod Positions.

Case (Core)	1 (1)	2 (1A)	3 (2)	4 (3)
Control Rod	Withdrawn Distance (mm)			
ZEBRA Rod 1	148	NA	NA	NA
ZEBRA Rod 2	148	NA	NA	NA
ZEBRA Rod 3	148	NA	NA	NA
ZEBRA Rod 4	148	NA	NA	NA

The withdrawn position of the ZEBRA rods is in Table 2.1-158. The uncertainty in position was assumed to be 5 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the positions were perturbed by ±15 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the withdrawn positions of the ZEBRA 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 2.1-159.

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 divided by √4 to account for the perturbation of multiple positions. The final adjusted Δk_{eff} uncertainty was obtained by summing under quadrature the systematic and random uncertainties. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-159. Effect of Uncertainty in the ZEBRA Rod Positions.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$	Systematic Component of Δk_{eff} (1σ)
1 (1)	±15 mm	0.00059	±	0.00005	3√3	0.00011	±	0.00001	0.00005
2 (1A)	NA	NA			NA	NA			NA
3 (2)	NA	NA			NA	NA			NA
4 (3)	NA	NA			NA	NA			NA

2.1.19.5 Withdrawable Control Rod Positions

Withdrawable control rod positions were obtained from Tables 1.1-5, 1.1-6, and 1.1-7 for Cases 2, 3, and 4, respectively; they were not used in Case 1. The control rods were completely withdrawn in Case 4. An uncertainty of 5 mm was assumed to bound any uncertainty in the position of the control rods. This uncertainty is approximately double the uncertainty applied for control rod positions within a TRIGA reactor (NRAD-FUND-RESR-001). Rod position for the withdrawable control rods are reported opposite of the other control rods. For example, the withdrawable control rods are fully withdrawn when the reported position is ~6 mm and fully inserted when the position is reported as 2500 mm. The total rod range was 2494 mm. The position of the withdrawable rods at criticality is shown in Table 2.1-160; these values have been converted from the reported rod-position values to the actual vertical distance these rods were withdrawn from the core.

Table 2.1-160. Withdrawable Control Rod Positions.

Case (Core)	1 (1)	2 (1A)	3 (2)	4 (3)
Control Rod	Withdrawn Distance (mm)			
Withdrawable Control Rod 1	NA	150	564	2494
Withdrawable Control Rod 2	NA	150	564	2494
Withdrawable Control Rod 3	NA	150	564	2494
Withdrawable Control Rod 4	NA	150	564	2494

The withdrawn position of the withdrawable control rods is in Table 2.1-160. The uncertainty in position was assumed to be 5 mm (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the positions were perturbed by ±15 mm to estimate the uncertainty in k_{eff} due to the uncertainty in the withdrawn positions of the withdrawable control 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 2.1-161. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-161. Effect of Uncertainty in the Withdrawable Control Rod Positions.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	NA	NA			NA	NA		
2 (1A)	±15 mm	0.00010	±	0.00005	3√3	0.00002	±	0.00001
3 (2)	±15 mm	0.00020	±	0.00005	3√3	0.00004	±	0.00001
4 (3)	±15 mm	-0.00005	±	0.00005	3√3	-0.00001	±	0.00001

2.1.19.6 Stacked Pebble Height

The pebbles in Cores 1, 1A, 2, and 3 were stacked in HCP cells (see Figure 1.0-2) and thus the core height must be determined by calculating the height of pebbles stacked in tetrahedral arrangements. A tetrahedron connecting the centers of four pebbles (6.000 cm diameter each) has a height of ~4.899 cm, similar to what was reported in Tables 1.1-3 through 1.1-7. The difference in the reported values is due to round off of calculations. The total height of this stack would include the radii of the bottommost pebbles (3.000 cm) and the topmost pebble (3.000 cm) for a total height of ~10.899 cm. For each additional layer of pebbles, the total height is only increased by the tetrahedral distance of ~4.899 cm. The total stack height for each core configuration is provided in Table 2.1-162.

Table 2.1-162. Stacked Pebble Height.

Case (Core)	# Pebble Layers	Stack Height (m)
1 (1)	22	~1.0888
2 (1A)	21	~1.0398
3 (2)	33	~1.6277
4 (3)	17	~0.8438

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) 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 2.1-163.

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 2.1-163. 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 (1)	±0.06 % (pebble radii increased by 0.00175 cm)	-0.00090	±	0.00014	1	-0.00090	±	0.00014	-0.00014
2 (1A)	±0.06 % (pebble radii increased by 0.00175 cm)	-0.00091	±	0.00014	1	-0.00091	±	0.00014	-0.00014
3 (2)	±0.06 % (pebble radii increased by 0.00175 cm)	-0.00082	±	0.00014	1	-0.00082	±	0.00014	-0.00012
4 (3)	±0.06 % (pebble radii increased by 0.00175 cm)	-0.00073	±	0.00013	1	-0.00073	±	0.00013	-0.00011

2.1.19.7 Temperature (Excluding Air Density)

Measured temperatures for the room and assembly were reported in Table 1.1-3, 1.1-5, 1.1-6, and 1.1-7 for Cases 1, 2, 3, and 4, respectively, and are summarized in Table 2.1-164. There is little variation in the measured temperatures and an uncertainty of ~2 °C (1σ) would have negligible impact on the densities and cross sections of the critical assemblies.

Table 2.1-164. Recorded System Temperatures (°C).

Case (Core)	T_{Hall}	$T_{Core/Edge}$	$T_{Reflector}$
1 (1)	21	19.4 / 19.9	/ 20.1
2 (1A)	20	-- / 19.4	19.0 / 18.9 / 18.8
3 (2)	20	--	22.5 / 22.4
4 (3)	20	--	--

2.1.20 Ambient Air

The density of humid air is calculated using Equation 2-1, which neglects the small errors due to non-ideal gas compressibility and vapor pressure measurements not made over liquid water (σ < 0.2 % in the range of -10 to 50°C).[a]

$$\rho_h = \frac{p_d}{R_d \cdot T} + \frac{p_v}{R_v \cdot T}. \quad [2\text{-}1]$$

The density of the humid air, ρ_h (kg/m^3), is computed from the partial pressure of dry air, p_d (Pa); the pressure of water vapor, p_v (Pa); the specific gas constant for dry air, R_d (287.058 J/kg-K); the specific gas constant for water vapor, R_v (461.495 J/kg-K); and the temperature, T (K). The water vapor pressure is calculated from the relative humidity, φ, and the saturation vapor pressure, p_{sat}, using Equation 2-2.

$$p_v = \varphi \cdot p_{sat}. \quad [2\text{-}2]$$

The saturation vapor pressure is calculated using the empirical formula,[b] Equation 2-3.

$$p_{sat}[mbarn] = 6.1078 \cdot 10^{\frac{7.5 \cdot T - 2048.625}{T - 35.85}}. \quad [2\text{-}3]$$

The partial pressure of dry air is the difference between the absolute pressure and the vapor pressure of water (Equation 2-4).

$$p_d = p - p_v. \quad [2\text{-}4]$$

2.1.20.1 Temperature

The temperature of the ambient air is assumed to be adequately represented by the measured hall temperature in Table 2.1-164.

The uncertainty in temperature was assumed to be 2 °C (1σ). A double-sided perturbation was performed in which the temperature was perturbed by ±6 °C to estimate the uncertainty in k_{eff} due to the uncertainty in the temperature of the ambient air. 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 2.1-165. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-165. Effect of Uncertainty in the Temperature.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±6°C	0.00006	±	0.00005	3	0.00002	±	0.00002
2 (1A)	±6°C	0.00017	±	0.00005	3	-0.00001	±	0.00001
3 (2)	±6°C	0.00019	±	0.00005	3	0.00006	±	0.00001
4 (3)	±6°C	0.00012	±	0.00005	3	0.00004	±	0.00002

[a] F. E. Jones, *Techniques and Topics in Flow Measurement*, CRC Press, Boca Raton, FL (1995).
[b] Simplified regression empirical formula (http://en.wikipedia.org/wiki/Density_of_air) for discussions by R. Shelquist in "An Introduction to Air Density and Density Altitude Calculations," http://wahiduddin.net/calc/density_altitude.htm, accessed November 9, 2011.

2.1.20.2 Pressure

Measured ambient pressure during the experiments were reported in Table 1.1-3, 1.1-5, 1.1-6, and 1.1-7 for Cases 1, 2, 3, and 4, respectively, and are summarized in Table 2.1-166.

Table 2.1-166. Recorded System Pressure.

Case (Core)	Pressure (mbarn)
1 (1)	975.6
2 (1A)	980
3 (2)	988.1
4 (3)	986.7

The uncertainty in pressure was assumed to be 10 mbarn (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the pressure was perturbed by ±30 mbarn to estimate the uncertainty in k_{eff} due to the uncertainty in the pressure of the ambient air. 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 2.1-167. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-167. Effect of Uncertainty in the Pressure.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±30 mbarn	-0.00002	±	0.00005	3√3	<0.00001	±	0.00001
2 (1A)	±30 mbarn	-0.00005	±	0.00005	3√3	-0.00001	±	0.00001
3 (2)	±30 mbarn	-0.00016	±	0.00005	3√3	-0.00003	±	0.00001
4 (3)	±30 mbarn	-0.00010	±	0.00005	3√3	-0.00002	±	0.00001

2.1.20.3 Humidity

Measured ambient humidity during the experiments were reported in Table 1.1-3, 1.1-5, 1.1-6, and 1.1-7 for Cases 1, 2, 3, and 4, respectively, and are summarized in Table 2.1-168.

Table 2.1-168. Recorded System Humidity.

Case (Core)	Humidity (%)
1 (1)	50
2 (1A)	50
3 (2)	55
4 (3)	40

The uncertainty in humidity was assumed to be 5 % (bounding limit with uniform probability distribution). A double-sided perturbation was performed in which the humidity was perturbed by ±15 %

to estimate the uncertainty in k_{eff} due to the uncertainty in the humidity of the ambient air. 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 2.1-169. The calculated uncertainty is negligible (≤0.00010).

Table 2.1-169. Effect of Uncertainty in the Humidity.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	±15 %	-0.00006	±	0.00005	3√3	-0.00001	±	0.00001
2 (1A)	±15 %	0.00008	±	0.00005	3√3	0.00002	±	0.00001
3 (2)	±15 %	0.00001	±	0.00005	3√3	<0.00001	±	0.00001
4 (3)	±15 %	-0.00004	±	0.00005	3√3	-0.00001	±	0.00001

2.1.20.4 Composition

The composition of air was obtained from a fact sheet provided by the National Aeronautics and Space Administration (NASA).[a] This fact sheet is a conglomeration of various information sources and do not represent official values as there is no single set of agreed upon values. A summary of the composition of air used in this evaluation is in Table 2.1-170. The composition of air is normalized to 100 % after the water content and air density have been calculated; then the atom densities are calculated. The uncertainty in the composition of air is assumed to have a negligible impact on the total uncertainty of these experiments.

[a] D. R. Williams, "Earth Fact Sheet," NASA Goddard Space Flight Center, Greenbelt, MD, http://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html, last updated November 17, 2010, accessed November 9, 2011.

Table 2.1-170. Composition of Dry Air.[(a)]

Major Gas	Nominal vol.%
N_2	78.08
O_2	20.95
Minor Gas	**ppm (vol.%)**
Ar	9340
CO_2	380
Ne	18.18
He	5.24
CH_4	1.7
Kr	1.14
H_2	0.55
Total	100.004681 %[(b)]

(a) D. R. Williams, "Earth Fact Sheet," NASA Goddard Space Flight Center, Greenbelt, MD, http://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html, last updated November 17, 2010, accessed November 9, 2011.
(b) Numbers do not add up exactly to 100% due to round off and uncertainty. Water is highly variable but typically makes up about 1% of the composition of air.

2.1.21 Isotopic Abundance of Boron

The nominal isotopic abundance of ^{10}B in natural boron is reported as 19.9 % with a range of 19.1 to 20.3 %.[a] A double-sided perturbation was performed in which the isotopic content of all boron in these core configurations (including EBC) was perturbed from the nominal content of 19.9 % to the bounding limits (assuming uniform probability distribution) of 19.1 % and 20.3 % to estimate the uncertainty in k_{eff} due to the uncertainty in the isotopic abundance of ^{10}B. 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 2.1-171.

More recent investigations into the isotopic abundance of boron with unknown origin provides a general approximation of 19.88 ± 0.10 %.[b] This uncertainty is approximately seven times smaller than the bounding perturbation described above. Therefore an additional scaling factor of seven was including in the evaluation of this uncertainty. The calculated uncertainty is negligible (≤0.00010).

[a] E. M. Baum, H. D. Knox, and T. R. Miller, *Nuclides and Isotopes: 16th Edition*, Knolls Atomic Power Laboratory (2002).
[b] G. Žerovnik, M. Škof, and L. Snoj, "Evaluation of Criticality Safety Benchmark Experiments Uncertainty Due to Boron Isotopic Abundance Variations," *Proc. Int. Conf. Nuclear Energy for New Europe 2010*, Portorož, Slovenia, September 6-9, 2010.

Table 2.1-171. Effect of Uncertainty in the Isotopic Abundance of Boron.

Case (Core)	Deviation	Δk_p	±	$\sigma_{\Delta kp}$	Scaling Factor	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1 (1)	19.1 – 20.3 %	-0.00043	±	0.00007	7√3	-0.00004	±	0.00001
2 (1A)	19.1 – 20.3 %	-0.00072	±	0.00007	7√3	-0.00006	±	0.00001
3 (2)	19.1 – 20.3 %	-0.00060	±	0.00007	7√3	-0.00005	±	0.00001
4 (3)	19.1 – 20.3 %	-0.00060	±	0.00006	7√3	-0.00005	±	0.00001

2.1.22 Total Experimental Uncertainty

A compilation of the total evaluated uncertainty in the critical configurations of Cores 1, 1A, 2, and 3 (Cases 1, 2, 3, and 4, respectively) of the HTR-PROTEUS experiments is provided in Tables 2.1-172 though 2.1-175, 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 summary of just the non-negligible uncertainties is provided in Table 2.1-176, with a graphical representation of the primary sources of uncertainty is shown in Figure 2.1-5.

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 location of the upper axial reflector suspended above the core, the fuel enrichment, and the impurity content of the moderator pebbles (Core 2). All uncertainties providing at least 0.05 %Δk_{eff} are highlighted in Tables 2.1-172 through 2.1-176. The uncertainties in the experimental critical configurations for Cores 1, 1A, 2, and 3 were evaluated and determined to be acceptable.

Table 2.1-172. Summary of Evaluated Uncertainties in HTR-PROTEUS Case 1 (Core 1).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Concrete Thickness (mm)	800	100 / √3	neg
Concrete Density (g/cm^3)	3.45683	20 % / √3	neg
Concrete Composition (wt.%)	Table 2.1-3	--	neg
Steel Plate Thickness (mm)	75	1 / √3	neg
Steel Plate Density (g/cm^3)	7.92	0.01	neg
Steel Plate Composition (wt.%)	Table 2.1-6	1 / √3	neg
Radial Reflector Inner Diameter (mm)	~1256	1 / √3	neg
Radial Reflector Outer Diameter (mm)	~3275	1 / √3	neg
Radial Reflector Height (mm)	3304	1 / √3	neg
Radial Reflector Density (g/cm^3)	1.76	0.012	0.00097
Radial Reflector Impurities (ppma EBC)	1.33	0.08	0.00069
C-Driver Hole Positions (mm)	672, 730.5, 789, 847.5, 906	5 / √3	neg
C-Driver Hole Diameter (mm)	27.43	0.01 / √3	neg
Autorod Hole Position (mm)	890	5 / √3	neg
Autorod Hole Diameter (mm)	55	1 / √3	neg
ZEBRA Rod Hole Positions (mm)	896.3	5 / √3	0.00035
ZEBRA Rod Hole Diameter (mm)	45	1 / √3	0.00011
ZEBRA Filler Diameter (mm)	44	1 / √3	NA
ZEBRA Filler Length (mm)	3304	1 / √3	NA
ZEBRA Filler Density (g/cm^3)	1.78	0.012	NA
ZEBRA Filler Impurities (ppma EBC)	1.33	0.08	NA
Safety/Shutdown Rod Hole Positions (mm)	684	5 / √3	neg
Safety/Shutdown Rod Hole Diameter (mm)	45	1 / √3	neg
Thermal Column Width (mm)	~1200	10 / √3	neg
Thermal Column Depth (mm)	~530	10 / √3	neg
Thermal Column Height (mm)	1200	10 / √3	neg
Safety Ring Vertical Thickness (mm)	10	1 / √3	neg
Safety Ring Diametrical Thickness (mm)	96	1 / √3	neg
Safety Ring Density (g/cm^3)	2.70	0.01	neg
Safety Ring Composition (wt.%)	Table 2.1-30	1 / √3	neg
C-Driver Plug Diameter (mm)	26.5	0.1 / √3	neg
C-Driver Plug Length (mm)	3304	1 / √3	neg
C-Driver Plug Density (g/cm^3)	1.765	0.012	neg
C-Driver Plug Impurities (ppma EBC)	1.33	0.08	neg
Upper Axial Cylinder Diameter (mm)	394	1 / √3	neg

Table 2.1-172. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 1 (Core 1).

Perturbed Parameter	**Parameter Value**	**1σ Uncertainty**	**Δk_{eff} (1σ)**
Upper Axial Annulus Inner Diameter (mm)	418.6	1 / √3	neg
Upper Axial Annulus Outer Diameter (mm)	1234	1 / √3	neg
Upper Axial Annulus Geometry	See Section 2.1.4.4		neg
Upper Axial Reflector Height (mm)	780	1 / √3	neg
Location of Upper Axial Reflector (mm)	1893	5 / √3	0.00098
Upper Axial Graphite Mass	~1489.48 kg	0.012 g/cm^3	neg
Upper Axial Graphite Impurities (ppma EBC)	1.33	0.08	neg
Upper Axial Coolant Channel Positions (mm)	300, 355, 410, 462.5, 515	5 / √3	neg
Upper Axial Coolant Channel Diameter (mm)	27.43	0.01 / √3	neg
Upper Axial Plug Diameter (mm)	26.5	0.1 / √3	neg
Upper Axial Plug Length (mm)	780	1 / √3	neg
Upper Axial Plug Density (g/cm^3)	1.76	0.012	neg
Upper Axial Plug Impurities (ppma EBC)	1.33	0.08	neg
Upper Axial Aluminum Dimensions (mm)	Figure 1.1-4	1 / √3	0.00036
Upper Axial Aluminum Density (g/cm^3)	2.70	0.01	neg
Upper Axial Aluminum Composition	Table 2.1-30	1 / √3	0.00019
Lower Axial Cylinder Diameter (mm)	495	1 / √3	neg
Lower Axial Annulus Inner Diameter (mm)	~501	1 / √3	neg
Lower Axial Annulus Outer Diameter (mm)	~1250	1 / √3	neg
Lower Axial Reflector Height (mm)	780	1 / √3	0.00019
Lower Axial Cylinder Density (g/cm^3)	1.76	0.012	neg
Lower Axial Annulus Density (g/cm^3)	1.76	0.012	0.00025
Lower Axial Cylinder Impurities (ppma EBC)	1.33	0.08	neg
Lower Axial Annulus Impurities (ppma EBC)	1.33	0.08	0.00012
Lower Axial Coolant Channel Positions (mm)	300, 355, 410, 462.5, 515	5 / √3	neg
Lower Axial Coolant Channel Diameter (mm)	27.42	0.01 / √3	neg
Lower Axial Plug Diameter (mm)	26.5	0.1 / √3	neg
Lower Axial Plug Length (mm)	780	1 / √3	neg
Lower Axial Plug Density (g/cm^3)	1.76	0.012	neg
Lower Axial Plug Impurities (ppma EBC)	1.33	0.08	neg
Source Position Diameter (mm)	121	1 / √3	neg
Source Position Length (mm)	250	1 / √3	neg
Source Plug Diameter (mm)	120	1 / √3	neg
Source Plug Length (mm)	250	1 / √3	neg
Source Plug Density (g/cm^3)	1.76	0.012	neg

Table 2.1-172. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 1 (Core 1).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Source Plug Impurities (ppma EBC)	1.33	0.08	neg
Aluminum Plugs	--	--	neg
Borated Steel Rod Diameter (mm)	35	1 / √3	neg
Borated Steel Rod Length (mm)	2100	1 / √3	neg
Borated Steel Density (g/cm^3)	6.878	0.029	neg
Boron Content of Borated Steel (wt.%)	~4.75	0.25	neg
Borated Steel Composition (wt.%)	Table 2.1-68	--	neg
Safety/Shutdown Steel Tube Thickness (mm)	2	1 / √3	neg
Safety/Shutdown Steel Tube Length (mm)	2220	10 / √3	neg
Safety/Shutdown Steel Tube Density (g/cm^3)	7.92	0.01	neg
Safety/Shutdown Steel Tube Composition (wt.%)	Table 2.1-71	1 / √3	neg
Aluminum Shock Damper Dimensions (mm)	See Section 2-1.6.10		neg
Aluminum Shock Damper Mass	633.65 g	0.01 g/cm^3 / √3	neg
Aluminum Shock Damper Composition (wt.%)	Table 2.1-74	1 / √3	neg
Autorod Copper Wedge Thickness (mm)	3	1 / √3	neg
Autorod Copper Wedge Length (mm)	2300	10 / √3	neg
Orientation of Autorod Copper Wedge (°)	Unknown	90° / √3	neg
Autorod Copper Wedge Density (g/cm^3)	8.89	0.01	neg
Autorod Copper Wedge Composition (wt.%)	Table 2.1-80	1 / √3	neg
Autorod Aluminum Tube Thickness (mm)	2	1 / √3	neg
Autorod Aluminum Tube Length (mm)	3304	1 / √3	neg
Autorod Aluminum Tube Density (g/cm^3)	2.70	0.01	neg
Autorod Aluminum Tube Composition (wt.%)	Table 2.1-74	1 / √3	neg
Static Measurement Rods	--	--	NA
Quantity of Fuel Pebbles	Table 2.1-85	0	neg
Pebble Packing Fraction	Table 2.1-86	See Section 2.1.19.6	neg
Pebble Random Packing	None	~0	neg
TRISO Random Packing	See Section 2.1.9.4		0.00021
Kernel Radius (cm)	0.02510	0.0006	0.00011
Buffer Thickness (cm)	0.00915	0.00125	neg
IPyC Thickness (cm)	0.00399	0.0005	neg
SiC Thickness (cm)	0.00353	0.0002	neg
OPyC Thickness (cm)	0.00400	0.0004	neg
Fueled Zone Radius (cm)	2.350	0.025	neg
Fuel Pebble Radius (cm)	3.000	0.002	neg

Table 2.1-172. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 1 (Core 1).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
^{234}U Isotopic Content (wt.%)	~0.134	~0.017	0.00016
^{235}U Isotopic Content (wt.%)	~16.762	~0.17	0.00223
^{236}U Isotopic Content (wt.%)	~0.084	~0.017	neg
^{238}U Isotopic Content (wt.%)	~83.020	--	neg
Fuel Pebble Uranium Mass (g)	5.966	0.060	0.00027
Fuel Pebble Carbon Mass (g)	189.4	0.2	neg
Fuel Pebble Total Mass (g)	202.22	0.18	neg
Kernel Density (g/cm^3)	See Section 2.1.9.16		NA
Buffer Density (g/cm^3)	1.05	0.05	neg
IPyC Density (g/cm^3)	1.90	0.05	neg
SiC Density (g/cm^3)	3.20	0.02	neg
OPyC Density (g/cm^3)	1.89	0.05	neg
Kernel Impurities (ppm)	Table 2.1-105	50 %	neg
Buffer Impurities (ppm)	Table 2.1-107	50 %	neg
IPyC Impurities (ppm)	Table 2.1-107	50 %	neg
SiC Impurities (ppm)	Table 2.1-107	50 %	neg
OPyC Impurities (ppm)	Table 2.1-107	50 %	neg
Fueled Zone Impurities (ppm)	Table 2.1-107	50 %	0.00033
Unfueled Zone Impurities (ppm)	Table 2.1-107	50 %	0.00021
Fuel Pebble Water Content (wt.%)	0.01	0.01 / √3	0.00028
Oxygen-to-Uranium Ratio	2.00	0.01	Neg
Quantity of Moderator Pebbles	Table 2.1-116	0	Neg
Moderator Pebble Radius (cm)	3.000	0.0015	Neg
Moderator Pebble Mass (g)	190.54	1.44	0.00014
Moderator Pebble Impurities (ppm)	Table 2.1-119	50 %	0.00100
Moderator Pebble Water Content (wt.%)	0.01	0.01 / √3	0.00018
Start-Up Source	--	--	neg
Detectors	--	--	neg
Temperature Sensors	--	--	neg
Axial Modifier Thickness (mm)	Figure 1.1-17	0.1 / √3	neg
Axial Modifier Height (mm)	1729	1 / √3	neg
Axial Modifier Mass (kg)	211.2	0.1 / √3	neg
Axial Modifier Impurities (ppma EBC)	1.33	0.08	neg
Lattice Support Width (mm)	17.3 and 34.7	0.1 / √3	neg
Lattice Support Length (mm)	310	0.1 / √3	neg

Table 2.1-172. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 1 (Core 1).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Lattice Support Height (mm)	43.6 and 38	0.1 / √3	neg
Lattice Support Mass (kg/layer)	3.36	0.01 / √3	neg
Lattice Support Impurities (ppma EBC)	1.33	0.08	neg
ZEBRA Rod Inner Tube Thickness (mm)	2.5	1 / √3	neg
ZEBRA Rod Outer Tube Thickness (mm)	3.15	0.1 / √3	neg
Vertical Alignment of ZEBRA Tubes (mm)	Figure 1.1-19	10 / √3	0.00012
ZEBRA Rod Cadmium Thickness (mm)	0.25	0.1 / √3	neg
ZEBRA Rod Cadmium Length (mm)	160	1 / √3	neg
ZEBRA Rod Aluminum Density (g/cm^3)	2.65	0.01	neg
ZEBRA Rod Aluminum Composition (wt.%)	Table 2.1-136	1 / √3	neg
ZEBRA Rod Cadmium Density (g/cm^3)	8.65	0.01	neg
ZEBRA Rod Cadmium Composition (wt.%)	Table 2.1-139	1 / √3	neg
Control Rod Inner Tube Thickness (mm)	2	0.1 / √3	NA
Control Rod Outer Tube Thickness (mm)	4	1 / √3	NA
Control Rod Tube Length (mm)	220.0	10 / √3	NA
Control Rod Inner Tube Density (g/cm^3)	7.90	0.01	NA
Control Rod Outer Tube Density (g/cm^3)	7.90	0.01	NA
Control Rod Inner Tube Composition (wt.%)	Table 2.1-145	1 / √3	NA
Control Rod Outer Tube Composition (wt.%)	Table 2.1-147	1 / √3	NA
Polyethylene Rod Diameter (mm)	8.9	0.1 / √3	NA
Polyethylene Rod Length (mm)	860	10 / √3	NA
Polyethylene Rod Linear Density (g/cm)	0.5867	0.0019	NA
Polyethylene Rod H:C Ratio	2.03	0.03	NA
Polyethylene Rod Impurities (ppm EBC)	0.5	0.5	NA
Copper Wire	--	--	NA
Measurement of k_{eff}	See Section 2.1.19.1		neg
Autorod Position (mm)	Table 2.1-154	5 / √3	neg
Safety/Shutdown Rod Positions (mm)	Table 2.1-156	5 / √3	neg
ZEBRA Rod Positions (mm)	Table 2.1-158	5 / √3	neg
Withdrawable Control Rod Positions (mm)	Table 2.1-160	5 / √3	NA
Stacked Pebble Height (mm)	Table 2.1-162	0.06 %	0.00014
Temperature (°)	Table 2.1-164	2	neg
Ambient Air Temperature (°)	Table 2.1-164	2	neg
Ambient Air Pressure (mbarn)	Table 2.1-166	10 / √3	neg
Ambient Air Humidity (%)	Table 2.1-168	5 / √3	neg

Table 2.1-172. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 1 (Core 1).

Perturbed Parameter	**Parameter Value**	**1σ Uncertainty**	**Δk_{eff} (1σ)**
Isotopic Abundance of Boron (%)	19.9	19.1 – 20.3	neg
Total Experimental Uncertainty	--	--	0.00301

Table 2.1-173. Summary of Evaluated Uncertainties in HTR-PROTEUS Case 2 (Core 1A).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Concrete Thickness (mm)	800	100 / √3	neg
Concrete Density (g/cm^3)	3.45683	20 % / √3	neg
Concrete Composition (wt.%)	Table 2.1-3	--	neg
Steel Plate Thickness (mm)	75	1 / √3	neg
Steel Plate Density (g/cm^3)	7.92	0.01	neg
Steel Plate Composition (wt.%)	Table 2.1-6	1 / √3	neg
Radial Reflector Inner Diameter (mm)	~1256	1 / √3	neg
Radial Reflector Outer Diameter (mm)	~3275	1 / √3	neg
Radial Reflector Height (mm)	3304	1 / √3	neg
Radial Reflector Density (g/cm^3)	1.76	0.012	0.00089
Radial Reflector Impurities (ppma EBC)	1.33	0.08	0.00078
C-Driver Hole Positions (mm)	672, 730.5, 789, 847.5, 906	5 / √3	neg
C-Driver Hole Diameter (mm)	27.43	0.01 / √3	neg
Autorod Hole Position (mm)	890	5 / √3	neg
Autorod Hole Diameter (mm)	55	1 / √3	neg
ZEBRA Rod Hole Positions (mm)	896.3	5 / √3	neg
ZEBRA Rod Hole Diameter (mm)	45	1 / √3	neg
ZEBRA Filler Diameter (mm)	44	1 / √3	neg
ZEBRA Filler Length (mm)	3304	1 / √3	neg
ZEBRA Filler Density (g/cm^3)	1.78	0.012	neg
ZEBRA Filler Impurities (ppma EBC)	1.33	0.08	neg
Safety/Shutdown Rod Hole Positions (mm)	684	5 / √3	neg
Safety/Shutdown Rod Hole Diameter (mm)	45	1 / √3	neg
Thermal Column Width (mm)	~1200	10 / √3	neg
Thermal Column Depth (mm)	~530	10 / √3	neg
Thermal Column Height (mm)	1200	10 / √3	neg
Safety Ring Vertical Thickness (mm)	10	1 / √3	neg
Safety Ring Diametrical Thickness (mm)	96	1 / √3	neg
Safety Ring Density (g/cm^3)	2.70	0.01	neg
Safety Ring Composition (wt.%)	Table 2.1-30	1 / √3	neg
C-Driver Plug Diameter (mm)	26.5	0.1 / √3	neg
C-Driver Plug Length (mm)	3304	1 / √3	neg
C-Driver Plug Density (g/cm^3)	1.765	0.012	neg
C-Driver Plug Impurities (ppma EBC)	1.33	0.08	neg
Upper Axial Cylinder Diameter (mm)	394	1 / √3	neg

Table 2.1-173. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 2 (Core 1A).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Upper Axial Annulus Inner Diameter (mm)	418.6	1 / √3	neg
Upper Axial Annulus Outer Diameter (mm)	1234	1 / √3	neg
Upper Axial Annulus Geometry	See Section 2.1.4.4		neg
Upper Axial Reflector Height (mm)	780	1 / √3	neg
Location of Upper Axial Reflector (mm)	1893	5 / √3	0.00110
Upper Axial Graphite Mass	~1489.48 kg	0.012 g/cm^3	neg
Upper Axial Graphite Impurities (ppma EBC)	1.33	0.08	neg
Upper Axial Coolant Channel Positions (mm)	300, 355, 410, 462.5, 515	5 / √3	neg
Upper Axial Coolant Channel Diameter (mm)	27.43	0.01 / √3	neg
Upper Axial Plug Diameter (mm)	26.5	0.1 / √3	neg
Upper Axial Plug Length (mm)	780	1 / √3	neg
Upper Axial Plug Density (g/cm^3)	1.76	0.012	neg
Upper Axial Plug Impurities (ppma EBC)	1.33	0.08	neg
Upper Axial Aluminum Dimensions (mm)	Figure 1.1-4	1 / √3	0.00035
Upper Axial Aluminum Density (g/cm^3)	2.70	0.01	neg
Upper Axial Aluminum Composition	Table 2.1-30	1 / √3	0.00031
Lower Axial Cylinder Diameter (mm)	495	1 / √3	0.00012
Lower Axial Annulus Inner Diameter (mm)	~501	1 / √3	neg
Lower Axial Annulus Outer Diameter (mm)	~1250	1 / √3	neg
Lower Axial Reflector Height (mm)	780	1 / √3	neg
Lower Axial Cylinder Density (g/cm^3)	1.76	0.012	neg
Lower Axial Annulus Density (g/cm^3)	1.76	0.012	0.00021
Lower Axial Cylinder Impurities (ppma EBC)	1.33	0.08	neg
Lower Axial Annulus Impurities (ppma EBC)	1.33	0.08	0.00013
Lower Axial Coolant Channel Positions (mm)	300, 355, 410, 462.5, 515	5 / √3	neg
Lower Axial Coolant Channel Diameter (mm)	27.42	0.01 / √3	neg
Lower Axial Plug Diameter (mm)	26.5	0.1 / √3	neg
Lower Axial Plug Length (mm)	780	1 / √3	neg
Lower Axial Plug Density (g/cm^3)	1.76	0.012	neg
Lower Axial Plug Impurities (ppma EBC)	1.33	0.08	neg
Source Position Diameter (mm)	121	1 / √3	neg
Source Position Length (mm)	250	1 / √3	neg
Source Plug Diameter (mm)	120	1 / √3	neg
Source Plug Length (mm)	250	1 / √3	neg
Source Plug Density (g/cm^3)	1.76	0.012	neg

Table 2.1-173. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 2 (Core 1A).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Source Plug Impurities (ppma EBC)	1.33	0.08	neg
Aluminum Plugs	--	--	NA
Borated Steel Rod Diameter (mm)	35	1 / √3	neg
Borated Steel Rod Length (mm)	2100	1 / √3	neg
Borated Steel Density (g/cm^3)	6.878	0.029	neg
Boron Content of Borated Steel (wt.%)	~4.75	0.25	neg
Borated Steel Composition (wt.%)	Table 2.1-68	--	neg
Safety/Shutdown Steel Tube Thickness (mm)	2	1 / √3	neg
Safety/Shutdown Steel Tube Length (mm)	2220	10 / √3	neg
Safety/Shutdown Steel Tube Density (g/cm^3)	7.92	0.01	neg
Safety/Shutdown Steel Tube Composition (wt.%)	Table 2.1-71	1 / √3	neg
Aluminum Shock Damper Dimensions (mm)	See Section 2-1.6.10		neg
Aluminum Shock Damper Mass	633.65 g	0.01 g/cm^3 / √3	neg
Aluminum Shock Damper Composition (wt.%)	Table 2.1-74	1 / √3	neg
Autorod Copper Wedge Thickness (mm)	3	1 / √3	0.00011
Autorod Copper Wedge Length (mm)	2300	10 / √3	neg
Orientation of Autorod Copper Wedge (°)	Unknown	90° / √3	neg
Autorod Copper Wedge Density (g/cm^3)	8.89	0.01	neg
Autorod Copper Wedge Composition (wt.%)	Table 2.1-80	1 / √3	neg
Autorod Aluminum Tube Thickness (mm)	2	1 / √3	neg
Autorod Aluminum Tube Length (mm)	3304	1 / √3	neg
Autorod Aluminum Tube Density (g/cm^3)	2.70	0.01	neg
Autorod Aluminum Tube Composition (wt.%)	Table 2.1-74	1 / √3	neg
Static Measurement Rods	--	--	NA
Quantity of Fuel Pebbles	Table 2.1-85	0	neg
Pebble Packing Fraction	Table 2.1-86	See Section 2.1.19.6	neg
Pebble Random Packing	None	~0	neg
TRISO Random Packing	See Section 2.1.9.4		neg
Kernel Radius (cm)	0.02510	0.0006	0.00011
Buffer Thickness (cm)	0.00915	0.00125	neg
IPyC Thickness (cm)	0.00399	0.0005	neg
SiC Thickness (cm)	0.00353	0.0002	neg
OPyC Thickness (cm)	0.00400	0.0004	neg
Fueled Zone Radius (cm)	2.350	0.025	neg
Fuel Pebble Radius (cm)	3.000	0.002	neg

Table 2.1-173. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 2 (Core 1A).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
^{234}U Isotopic Content (wt.%)	~0.134	~0.017	0.00020
^{235}U Isotopic Content (wt.%)	~16.762	~0.17	0.00226
^{236}U Isotopic Content (wt.%)	~0.084	~0.017	neg
^{238}U Isotopic Content (wt.%)	~83.020	--	neg
Fuel Pebble Uranium Mass (g)	5.966	0.060	0.00025
Fuel Pebble Carbon Mass (g)	189.4	0.2	neg
Fuel Pebble Total Mass (g)	202.22	0.18	neg
Kernel Density (g/cm^3)	See Section 2.1.9.16		NA
Buffer Density (g/cm^3)	1.05	0.05	neg
IPyC Density (g/cm^3)	1.90	0.05	neg
SiC Density (g/cm^3)	3.20	0.02	neg
OPyC Density (g/cm^3)	1.89	0.05	neg
Kernel Impurities (ppm)	Table 2.1-105	50 %	neg
Buffer Impurities (ppm)	Table 2.1-107	50 %	neg
IPyC Impurities (ppm)	Table 2.1-107	50 %	neg
SiC Impurities (ppm)	Table 2.1-107	50 %	neg
OPyC Impurities (ppm)	Table 2.1-107	50 %	neg
Fueled Zone Impurities (ppm)	Table 2.1-107	50 %	0.00019
Unfueled Zone Impurities (ppm)	Table 2.1-107	50 %	0.00029
Fuel Pebble Water Content (wt.%)	0.01	0.01 / √3	0.00018
Oxygen-to-Uranium Ratio	2.00	0.01	neg
Quantity of Moderator Pebbles	Table 2.1-116	0	neg
Moderator Pebble Radius (cm)	3.000	0.0015	neg
Moderator Pebble Mass (g)	190.54	1.44	0.00014
Moderator Pebble Impurities (ppm)	Table 2.1-119	50 %	0.00108
Moderator Pebble Water Content (wt.%)	0.01	0.01 / √3	neg
Start-Up Source	--	--	neg
Detectors	--	--	neg
Temperature Sensors	--	--	neg
Axial Modifier Thickness (mm)	Figure 1.1-17	0.1 / √3	neg
Axial Modifier Height (mm)	1729	1 / √3	neg
Axial Modifier Mass (kg)	211.2	0.1 / √3	neg
Axial Modifier Impurities (ppma EBC)	1.33	0.08	neg
Lattice Support Width (mm)	17.3 and 34.7	0.1 / √3	neg
Lattice Support Length (mm)	310	0.1 / √3	neg

Table 2.1-173. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 2 (Core 1A).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Lattice Support Height (mm)	43.6 and 38	0.1 / √3	neg
Lattice Support Mass (kg/layer)	3.36	0.01 / √3	neg
Lattice Support Impurities (ppma EBC)	1.33	0.08	neg
ZEBRA Rod Inner Tube Thickness (mm)	2.5	1 / √3	NA
ZEBRA Rod Outer Tube Thickness (mm)	3.15	0.1 / √3	NA
Vertical Alignment of ZEBRA Tubes (mm)	Figure 1.1-19	10 / √3	NA
ZEBRA Rod Cadmium Thickness (mm)	0.25	0.1 / √3	NA
ZEBRA Rod Cadmium Length (mm)	160	1 / √3	NA
ZEBRA Rod Aluminum Density (g/cm^3)	2.65	0.01	NA
ZEBRA Rod Aluminum Composition (wt.%)	Table 2.1-136	1 / √3	NA
ZEBRA Rod Cadmium Density (g/cm^3)	8.65	0.01	NA
ZEBRA Rod Cadmium Composition (wt.%)	Table 2.1-139	1 / √3	NA
Control Rod Inner Tube Thickness (mm)	2	0.1 / √3	neg
Control Rod Outer Tube Thickness (mm)	4	1 / √3	neg
Control Rod Tube Length (mm)	220.0	10 / √3	neg
Control Rod Inner Tube Density (g/cm^3)	7.90	0.01	neg
Control Rod Outer Tube Density (g/cm^3)	7.90	0.01	neg
Control Rod Inner Tube Composition (wt.%)	Table 2.1-145	1 / √3	neg
Control Rod Outer Tube Composition (wt.%)	Table 2.1-147	1 / √3	0.00013
Polyethylene Rod Diameter (mm)	8.9	0.1 / √3	NA
Polyethylene Rod Length (mm)	860	10 / √3	NA
Polyethylene Rod Linear Density (g/cm)	0.5867	0.0019	NA
Polyethylene Rod H:C Ratio	2.03	0.03	NA
Polyethylene Rod Impurities (ppm EBC)	0.5	0.5	NA
Copper Wire	--	--	NA
Measurement of k_{eff}	See Section 2.1.19.1		neg
Autorod Position (mm)	Table 2.1-154	5 / √3	neg
Safety/Shutdown Rod Positions (mm)	Table 2.1-156	5 / √3	neg
ZEBRA Rod Positions (mm)	Table 2.1-158	5 / √3	NA
Withdrawable Control Rod Positions (mm)	Table 2.1-160	5 / √3	neg
Stacked Pebble Height (mm)	Table 2.1-162	0.06 %	0.00014
Temperature (°)	Table 2.1-164	2	neg
Ambient Air Temperature (°)	Table 2.1-164	2	neg
Ambient Air Pressure (mbarn)	Table 2.1-166	10 / √3	neg
Ambient Air Humidity (%)	Table 2.1-168	5 / √3	neg

Table 2.1-173. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 2 (Core 1A).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Isotopic Abundance of Boron (%)	19.9	19.1 – 20.3	neg
Total Experimental Uncertainty	--	--	0.00309

Table 2.1-174. Summary of Evaluated Uncertainties in HTR-PROTEUS Case 3 (Core 2).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Concrete Thickness (mm)	800	100 / √3	neg
Concrete Density (g/cm^3)	3.45683	20 % / √3	neg
Concrete Composition (wt.%)	Table 2.1-3	--	neg
Steel Plate Thickness (mm)	75	1 / √3	neg
Steel Plate Density (g/cm^3)	7.92	0.01	neg
Steel Plate Composition (wt.%)	Table 2.1-6	1 / √3	neg
Radial Reflector Inner Diameter (mm)	~1256	1 / √3	neg
Radial Reflector Outer Diameter (mm)	~3275	1 / √3	neg
Radial Reflector Height (mm)	3304	1 / √3	neg
Radial Reflector Density (g/cm^3)	1.76	0.012	0.00091
Radial Reflector Impurities (ppma EBC)	1.33	0.08	0.00078
C-Driver Hole Positions (mm)	672, 730.5, 789, 847.5, 906	5 / √3	neg
C-Driver Hole Diameter (mm)	27.43	0.01 / √3	neg
Autorod Hole Position (mm)	890	5 / √3	neg
Autorod Hole Diameter (mm)	55	1 / √3	neg
ZEBRA Rod Hole Positions (mm)	896.3	5 / √3	neg
ZEBRA Rod Hole Diameter (mm)	45	1 / √3	neg
ZEBRA Filler Diameter (mm)	44	1 / √3	neg
ZEBRA Filler Length (mm)	3304	1 / √3	neg
ZEBRA Filler Density (g/cm^3)	1.78	0.012	neg
ZEBRA Filler Impurities (ppma EBC)	1.33	0.08	neg
Safety/Shutdown Rod Hole Positions (mm)	684	5 / √3	neg
Safety/Shutdown Rod Hole Diameter (mm)	45	1 / √3	neg
Thermal Column Width (mm)	~1200	10 / √3	neg
Thermal Column Depth (mm)	~530	10 / √3	neg
Thermal Column Height (mm)	1200	10 / √3	neg
Safety Ring Vertical Thickness (mm)	10	1 / √3	neg
Safety Ring Diametrical Thickness (mm)	96	1 / √3	neg
Safety Ring Density (g/cm^3)	2.70	0.01	neg
Safety Ring Composition (wt.%)	Table 2.1-30	1 / √3	neg
C-Driver Plug Diameter (mm)	26.5	0.1 / √3	neg
C-Driver Plug Length (mm)	3304	1 / √3	neg
C-Driver Plug Density (g/cm^3)	1.765	0.012	0.00011
C-Driver Plug Impurities (ppma EBC)	1.33	0.08	neg
Upper Axial Cylinder Diameter (mm)	394	1 / √3	neg

Table 2.1-174. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 3 (Core 2).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Upper Axial Annulus Inner Diameter (mm)	418.6	1 / √3	neg
Upper Axial Annulus Outer Diameter (mm)	1234	1 / √3	neg
Upper Axial Annulus Geometry	See Section 2.1.4.4		neg
Upper Axial Reflector Height (mm)	780	1 / √3	neg
Location of Upper Axial Reflector (mm)	1893	5 / √3	0.00011
Upper Axial Graphite Mass	~1489.48 kg	0.012 g/cm^3	neg
Upper Axial Graphite Impurities (ppma EBC)	1.33	0.08	neg
Upper Axial Coolant Channel Positions (mm)	300, 355, 410, 462.5, 515	5 / √3	neg
Upper Axial Coolant Channel Diameter (mm)	27.43	0.01 / √3	neg
Upper Axial Plug Diameter (mm)	26.5	0.1 / √3	neg
Upper Axial Plug Length (mm)	780	1 / √3	neg
Upper Axial Plug Density (g/cm^3)	1.76	0.012	neg
Upper Axial Plug Impurities (ppma EBC)	1.33	0.08	neg
Upper Axial Aluminum Dimensions (mm)	Figure 1.1-4	1 / √3	neg
Upper Axial Aluminum Density (g/cm^3)	2.70	0.01	neg
Upper Axial Aluminum Composition	Table 2.1-30	1 / √3	neg
Lower Axial Cylinder Diameter (mm)	495	1 / √3	neg
Lower Axial Annulus Inner Diameter (mm)	~501	1 / √3	neg
Lower Axial Annulus Outer Diameter (mm)	~1250	1 / √3	neg
Lower Axial Reflector Height (mm)	780	1 / √3	0.00014
Lower Axial Cylinder Density (g/cm^3)	1.76	0.012	neg
Lower Axial Annulus Density (g/cm^3)	1.76	0.012	0.00030
Lower Axial Cylinder Impurities (ppma EBC)	1.33	0.08	neg
Lower Axial Annulus Impurities (ppma EBC)	1.33	0.08	0.00013
Lower Axial Coolant Channel Positions (mm)	300, 355, 410, 462.5, 515	5 / √3	neg
Lower Axial Coolant Channel Diameter (mm)	27.42	0.01 / √3	neg
Lower Axial Plug Diameter (mm)	26.5	0.1 / √3	neg
Lower Axial Plug Length (mm)	780	1 / √3	neg
Lower Axial Plug Density (g/cm^3)	1.76	0.012	neg
Lower Axial Plug Impurities (ppma EBC)	1.33	0.08	neg
Source Position Diameter (mm)	121	1 / √3	neg
Source Position Length (mm)	250	1 / √3	neg
Source Plug Diameter (mm)	120	1 / √3	neg
Source Plug Length (mm)	250	1 / √3	neg
Source Plug Density (g/cm^3)	1.76	0.012	neg

Table 2.1-174. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 3 (Core 2).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Source Plug Impurities (ppma EBC)	1.33	0.08	neg
Aluminum Plugs	--	--	neg
Borated Steel Rod Diameter (mm)	35	1 / √3	neg
Borated Steel Rod Length (mm)	2100	1 / √3	neg
Borated Steel Density (g/cm^3)	6.878	0.029	neg
Boron Content of Borated Steel (wt.%)	~4.75	0.25	neg
Borated Steel Composition (wt.%)	Table 2.1-68	--	neg
Safety/Shutdown Steel Tube Thickness (mm)	2	1 / √3	neg
Safety/Shutdown Steel Tube Length (mm)	2220	10 / √3	neg
Safety/Shutdown Steel Tube Density (g/cm^3)	7.92	0.01	neg
Safety/Shutdown Steel Tube Composition (wt.%)	Table 2.1-71	1 / √3	neg
Aluminum Shock Damper Dimensions (mm)	See Section 2-1.6.10		neg
Aluminum Shock Damper Mass	633.65 g	0.01 g/cm^3 / √3	neg
Aluminum Shock Damper Composition (wt.%)	Table 2.1-74	1 / √3	neg
Autorod Copper Wedge Thickness (mm)	3	1 / √3	neg
Autorod Copper Wedge Length (mm)	2300	10 / √3	neg
Orientation of Autorod Copper Wedge (°)	Unknown	90° / √3	neg
Autorod Copper Wedge Density (g/cm^3)	8.89	0.01	neg
Autorod Copper Wedge Composition (wt.%)	Table 2.1-80	1 / √3	neg
Autorod Aluminum Tube Thickness (mm)	2	1 / √3	neg
Autorod Aluminum Tube Length (mm)	3304	1 / √3	neg
Autorod Aluminum Tube Density (g/cm^3)	2.70	0.01	neg
Autorod Aluminum Tube Composition (wt.%)	Table 2.1-74	1 / √3	neg
Static Measurement Rods	--	--	NA
Quantity of Fuel Pebbles	Table 2.1-85	0	neg
Pebble Packing Fraction	Table 2.1-86	See Section 2.1.19.6	neg
Pebble Random Packing	None	~0	neg
TRISO Random Packing	See Section 2.1.9.4		neg
Kernel Radius (cm)	0.02510	0.0006	neg
Buffer Thickness (cm)	0.00915	0.00125	neg
IPyC Thickness (cm)	0.00399	0.0005	neg
SiC Thickness (cm)	0.00353	0.0002	neg
OPyC Thickness (cm)	0.00400	0.0004	neg
Fueled Zone Radius (cm)	2.350	0.025	neg
Fuel Pebble Radius (cm)	3.000	0.002	neg

Table 2.1-174. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 3 (Core 2).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
^{234}U Isotopic Content (wt.%)	~0.134	~0.017	0.00022
^{235}U Isotopic Content (wt.%)	~16.762	~0.17	0.00227
^{236}U Isotopic Content (wt.%)	~0.084	~0.017	neg
^{238}U Isotopic Content (wt.%)	~83.020	--	neg
Fuel Pebble Uranium Mass (g)	5.966	0.060	0.00026
Fuel Pebble Carbon Mass (g)	189.4	0.2	neg
Fuel Pebble Total Mass (g)	202.22	0.18	neg
Kernel Density (g/cm^3)	See Section 2.1.9.16		NA
Buffer Density (g/cm^3)	1.05	0.05	neg
IPyC Density (g/cm^3)	1.90	0.05	neg
SiC Density (g/cm^3)	3.20	0.02	neg
OPyC Density (g/cm^3)	1.89	0.05	neg
Kernel Impurities (ppm)	Table 2.1-105	50 %	neg
Buffer Impurities (ppm)	Table 2.1-107	50 %	neg
IPyC Impurities (ppm)	Table 2-107	50 %	neg
SiC Impurities (ppm)	Table 2-107	50 %	neg
OPyC Impurities (ppm)	Table 2-107	50 %	neg
Fueled Zone Impurities (ppm)	Table 2-107	50 %	0.00019
Unfueled Zone Impurities (ppm)	Table 2-107	50 %	0.00029
Fuel Pebble Water Content (wt.%)	0.01	0.01 / √3	0.00030
Oxygen-to-Uranium Ratio	2.00	0.01	neg
Quantity of Moderator Pebbles	Table 2.1-116	0	neg
Moderator Pebble Radius (cm)	3.000	0.0015	neg
Moderator Pebble Mass (g)	190.54	1.44	0.00016
Moderator Pebble Impurities (ppm)	Table 2.1-119	50 %	0.00192
Moderator Pebble Water Content (wt.%)	0.01	0.01 / √3	neg
Start-Up Source	--	--	neg
Detectors	--	--	neg
Temperature Sensors	--	--	neg
Axial Modifier Thickness (mm)	Figure 1.1-17	0.1 / √3	neg
Axial Modifier Height (mm)	1729	1 / √3	neg
Axial Modifier Mass (kg)	211.2	0.1 / √3	neg
Axial Modifier Impurities (ppma EBC)	1.33	0.08	neg
Lattice Support Width (mm)	17.3 and 34.7	0.1 / √3	neg
Lattice Support Length (mm)	310	0.1 / √3	neg

Table 2.1-174. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 3 (Core 2).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Lattice Support Height (mm)	43.6 and 38	0.1 / √3	neg
Lattice Support Mass (kg/layer)	3.36	0.01 / √3	neg
Lattice Support Impurities (ppma EBC)	1.33	0.08	neg
ZEBRA Rod Inner Tube Thickness (mm)	2.5	1 / √3	NA
ZEBRA Rod Outer Tube Thickness (mm)	3.15	0.1 / √3	NA
Vertical Alignment of ZEBRA Tubes (mm)	Figure 1.1-19	10 / √3	NA
ZEBRA Rod Cadmium Thickness (mm)	0.25	0.1 / √3	NA
ZEBRA Rod Cadmium Length (mm)	160	1 / √3	NA
ZEBRA Rod Aluminum Density (g/cm^3)	2.65	0.01	NA
ZEBRA Rod Aluminum Composition (wt.%)	Table 2.1-136	1 / √3	NA
ZEBRA Rod Cadmium Density (g/cm^3)	8.65	0.01	NA
ZEBRA Rod Cadmium Composition (wt.%)	Table 2.1-139	1 / √3	NA
Control Rod Inner Tube Thickness (mm)	2	0.1 / √3	neg
Control Rod Outer Tube Thickness (mm)	4	1 / √3	neg
Control Rod Tube Length (mm)	220.0	10 / √3	neg
Control Rod Inner Tube Density (g/cm^3)	7.90	0.01	neg
Control Rod Outer Tube Density (g/cm^3)	7.90	0.01	neg
Control Rod Inner Tube Composition (wt.%)	Table 2.1-145	1 / √3	neg
Control Rod Outer Tube Composition (wt.%)	Table 2.1-147	1 / √3	neg
Polyethylene Rod Diameter (mm)	8.9	0.1 / √3	NA
Polyethylene Rod Length (mm)	860	10 / √3	NA
Polyethylene Rod Linear Density (g/cm)	0.5867	0.0019	NA
Polyethylene Rod H:C Ratio	2.03	0.03	NA
Polyethylene Rod Impurities (ppm EBC)	0.5	0.5	NA
Copper Wire	--	--	NA
Measurement of k_{eff}	See Section 2.1.19.1		neg
Autorod Position (mm)	Table 2.1-154	5 / √3	neg
Safety/Shutdown Rod Positions (mm)	Table 2.1-156	5 / √3	neg
ZEBRA Rod Positions (mm)	Table 2.1-158	5 / √3	NA
Withdrawable Control Rod Positions (mm)	Table 2.1-160	5 / √3	neg
Stacked Pebble Height (mm)	Table 2.1-162	0.06 %	0.00012
Temperature (°)	Table 2.1-164	2	neg
Ambient Air Temperature (°)	Table 2.1-164	2	neg
Ambient Air Pressure (mbarn)	Table 2.1-166	10 / √3	neg
Ambient Air Humidity (%)	Table 2.1-168	5 / √3	neg

Table 2.1-174. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 3 (Core 2).

Perturbed Parameter	**Parameter Value**	**1σ Uncertainty**	**Δk_{eff} (1σ)**
Isotopic Abundance of Boron (%)	19.9	19.1 – 20.3	neg
Total Experimental Uncertainty	--	--	0.00329

Table 2.1-175. Summary of Evaluated Uncertainties in HTR-PROTEUS Case 4 (Core 3).

Perturbed Parameter	**Parameter Value**	**1σ Uncertainty**	**Δk_{eff} (1σ)**
Concrete Thickness (mm)	800	100 / √3	neg
Concrete Density (g/cm^3)	3.45683	20 % / √3	neg
Concrete Composition (wt.%)	Table 2.1-3	--	neg
Steel Plate Thickness (mm)	75	1 / √3	neg
Steel Plate Density (g/cm^3)	7.92	0.01	neg
Steel Plate Composition (wt.%)	Table 2.1-6	1 / √3	neg
Radial Reflector Inner Diameter (mm)	~1256	1 / √3	neg
Radial Reflector Outer Diameter (mm)	~3275	1 / √3	neg
Radial Reflector Height (mm)	3304	1 / √3	neg
Radial Reflector Density (g/cm^3)	1.76	0.012	0.00076
Radial Reflector Impurities (ppma EBC)	1.33	0.08	0.00062
C-Driver Hole Positions (mm)	672, 730.5, 789, 847.5, 906	5 / √3	neg
C-Driver Hole Diameter (mm)	27.43	0.01 / √3	neg
Autorod Hole Position (mm)	890	5 / √3	neg
Autorod Hole Diameter (mm)	55	1 / √3	neg
ZEBRA Rod Hole Positions (mm)	896.3	5 / √3	neg
ZEBRA Rod Hole Diameter (mm)	45	1 / √3	neg
ZEBRA Filler Diameter (mm)	44	1 / √3	neg
ZEBRA Filler Length (mm)	3304	1 / √3	neg
ZEBRA Filler Density (g/cm^3)	1.78	0.012	neg
ZEBRA Filler Impurities (ppma EBC)	1.33	0.08	neg
Safety/Shutdown Rod Hole Positions (mm)	684	5 / √3	neg
Safety/Shutdown Rod Hole Diameter (mm)	45	1 / √3	neg
Thermal Column Width (mm)	~1200	10 / √3	neg
Thermal Column Depth (mm)	~530	10 / √3	neg
Thermal Column Height (mm)	1200	10 / √3	neg
Safety Ring Vertical Thickness (mm)	10	1 / √3	neg
Safety Ring Diametrical Thickness (mm)	96	1 / √3	neg
Safety Ring Density (g/cm^3)	2.70	0.01	neg
Safety Ring Composition (wt.%)	Table 2.1-30	1 / √3	0.00011
C-Driver Plug Diameter (mm)	26.5	0.1 / √3	neg
C-Driver Plug Length (mm)	3304	1 / √3	neg
C-Driver Plug Density (g/cm^3)	1.765	0.012	neg
C-Driver Plug Impurities (ppma EBC)	1.33	0.08	neg
Upper Axial Cylinder Diameter (mm)	394	1 / √3	neg

Table 2.1-175. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 4 (Core 3).

Perturbed Parameter	**Parameter Value**	**1σ Uncertainty**	**Δk_{eff} (1σ)**
Upper Axial Annulus Inner Diameter (mm)	418.6	1 / √3	neg
Upper Axial Annulus Outer Diameter (mm)	1234	1 / √3	neg
Upper Axial Annulus Geometry	See Section 2.1.4.4		neg
Upper Axial Reflector Height (mm)	780	1 / √3	neg
Location of Upper Axial Reflector (mm)	1893	5 / √3	0.00104
Upper Axial Graphite Mass	~1489.48 kg	0.012 g/cm^3	neg
Upper Axial Graphite Impurities (ppma EBC)	1.33	0.08	neg
Upper Axial Coolant Channel Positions (mm)	300, 355, 410, 462.5, 515	5 / √3	neg
Upper Axial Coolant Channel Diameter (mm)	27.43	0.01 / √3	neg
Upper Axial Plug Diameter (mm)	26.5	0.1 / √3	neg
Upper Axial Plug Length (mm)	780	1 / √3	neg
Upper Axial Plug Density (g/cm^3)	1.76	0.012	neg
Upper Axial Plug Impurities (ppma EBC)	1.33	0.08	neg
Upper Axial Aluminum Dimensions (mm)	Figure 1.1-4	1 / √3	0.00033
Upper Axial Aluminum Density (g/cm^3)	2.70	0.01	Neg
Upper Axial Aluminum Composition	Table 2.1-30	1 / √3	0.00028
Lower Axial Cylinder Diameter (mm)	495	1 / √3	neg
Lower Axial Annulus Inner Diameter (mm)	~501	1 / √3	neg
Lower Axial Annulus Outer Diameter (mm)	~1250	1 / √3	neg
Lower Axial Reflector Height (mm)	780	1 / √3	0.00014
Lower Axial Cylinder Density (g/cm^3)	1.76	0.012	neg
Lower Axial Annulus Density (g/cm^3)	1.76	0.012	0.00021
Lower Axial Cylinder Impurities (ppma EBC)	1.33	0.08	neg
Lower Axial Annulus Impurities (ppma EBC)	1.33	0.08	0.00019
Lower Axial Coolant Channel Positions (mm)	300, 355, 410, 462.5, 515	5 / √3	neg
Lower Axial Coolant Channel Diameter (mm)	27.42	0.01 / √3	neg
Lower Axial Plug Diameter (mm)	26.5	0.1 / √3	neg
Lower Axial Plug Length (mm)	780	1 / √3	neg
Lower Axial Plug Density (g/cm^3)	1.76	0.012	neg
Lower Axial Plug Impurities (ppma EBC)	1.33	0.08	neg
Source Position Diameter (mm)	121	1 / √3	neg
Source Position Length (mm)	250	1 / √3	neg
Source Plug Diameter (mm)	120	1 / √3	neg
Source Plug Length (mm)	250	1 / √3	neg
Source Plug Density (g/cm^3)	1.76	0.012	neg

Table 2.1-175. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 4 (Core 3).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Source Plug Impurities (ppma EBC)	1.33	0.08	neg
Aluminum Plugs	--	--	NA
Borated Steel Rod Diameter (mm)	35	1 / √3	neg
Borated Steel Rod Length (mm)	2100	1 / √3	neg
Borated Steel Density (g/cm^3)	6.878	0.029	neg
Boron Content of Borated Steel (wt.%)	~4.75	0.25	neg
Borated Steel Composition (wt.%)	Table 2.1-68	--	neg
Safety/Shutdown Steel Tube Thickness (mm)	2	1 / √3	neg
Safety/Shutdown Steel Tube Length (mm)	2220	10 / √3	neg
Safety/Shutdown Steel Tube Density (g/cm^3)	7.92	0.01	neg
Safety/Shutdown Steel Tube Composition (wt.%)	Table 2.1-71	1 / √3	neg
Aluminum Shock Damper Dimensions (mm)	See Section 2-1.6.10		neg
Aluminum Shock Damper Mass	633.65 g	0.01 g/cm^3 / √3	neg
Aluminum Shock Damper Composition (wt.%)	Table 2.1-74	/ √3	neg
Autorod Copper Wedge Thickness (mm)	3	1 / √3	neg
Autorod Copper Wedge Length (mm)	2300	10 / √3	neg
Orientation of Autorod Copper Wedge (°)	Unknown	90° / √3	neg
Autorod Copper Wedge Density (g/cm^3)	8.89	0.01	neg
Autorod Copper Wedge Composition (wt.%)	Table 2.1-80	1 / √3	neg
Autorod Aluminum Tube Thickness (mm)	2	1 / √3	neg
Autorod Aluminum Tube Length (mm)	3304	1 / √3	neg
Autorod Aluminum Tube Density (g/cm^3)	2.70	0.01	neg
Autorod Aluminum Tube Composition (wt.%)	Table 2.1-74	1 / √3	neg
Static Measurement Rods	--	--	NA
Quantity of Fuel Pebbles	Table 2.1-85	0	neg
Pebble Packing Fraction	Table 2.1-86	See Section 2.1.19.6	neg
Pebble Random Packing	None	~0	neg
TRISO Random Packing	See Section 2.1.9.4		0.00016
Kernel Radius (cm)	0.02510	0.0006	neg
Buffer Thickness (cm)	0.00915	0.00125	neg
IPyC Thickness (cm)	0.00399	0.0005	neg
SiC Thickness (cm)	0.00353	0.0002	neg
OPyC Thickness (cm)	0.00400	0.0004	neg
Fueled Zone Radius (cm)	2.350	0.025	neg
Fuel Pebble Radius (cm)	3.000	0.002	neg

Table 2.1-175. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 4 (Core 3).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
^{234}U Isotopic Content (wt.%)	~0.134	~0.017	0.00013
^{235}U Isotopic Content (wt.%)	~16.762	~0.17	0.00267
^{236}U Isotopic Content (wt.%)	~0.084	~0.017	neg
^{238}U Isotopic Content (wt.%)	~83.020	--	neg
Fuel Pebble Uranium Mass (g)	5.966	0.060	0.00035
Fuel Pebble Carbon Mass (g)	189.4	0.2	neg
Fuel Pebble Total Mass (g)	202.22	0.18	neg
Kernel Density (g/cm^3)	See Section 2.1.9.16		NA
Buffer Density (g/cm^3)	1.05	0.05	neg
IPyC Density (g/cm^3)	1.90	0.05	neg
SiC Density (g/cm^3)	3.20	0.02	neg
OPyC Density (g/cm^3)	1.89	0.05	neg
Kernel Impurities (ppm)	Table 2.1-105	50 %	neg
Buffer Impurities (ppm)	Table 2.1-107	50 %	neg
IPyC Impurities (ppm)	Table 2.1-107	50 %	neg
SiC Impurities (ppm)	Table 2.1-107	50 %	neg
OPyC Impurities (ppm)	Table 2.1-107	50 %	neg
Fueled Zone Impurities (ppm)	Table 2.1-107	50 %	0.00018
Unfueled Zone Impurities (ppm)	Table 2.1-107	50 %	0.00025
Fuel Pebble Water Content (wt.%)	0.01	0.01 / √3	neg
Oxygen-to-Uranium Ratio	2.00	0.01	0.00013
Quantity of Moderator Pebbles	Table 2.1-116	0	neg
Moderator Pebble Radius (cm)	3.000	0.0015	neg
Moderator Pebble Mass (g)	190.54	1.44	neg
Moderator Pebble Impurities (ppm)	Table 2.1-119	50 %	0.00090
Moderator Pebble Water Content (wt.%)	0.01	0.01 / √3	neg
Start-Up Source	--	--	neg
Detectors	--	--	neg
Temperature Sensors	--	--	neg
Axial Modifier Thickness (mm)	Figure 1.1-17	0.1 / √3	neg
Axial Modifier Height (mm)	1729	1 / √3	neg
Axial Modifier Mass (kg)	211.2	0.1 / √3	neg
Axial Modifier Impurities (ppma EBC)	1.33	0.08	neg
Lattice Support Width (mm)	17.3 and 34.7	0.1 / √3	neg
Lattice Support Length (mm)	310	0.1 / √3	neg

Table 2.1-175. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 4 (Core 3).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Lattice Support Height (mm)	43.6 and 38	0.1 / √3	neg
Lattice Support Mass (kg/layer)	3.36	0.01 / √3	neg
Lattice Support Impurities (ppma EBC)	1.33	0.08	neg
ZEBRA Rod Inner Tube Thickness (mm)	2.5	1 / √3	NA
ZEBRA Rod Outer Tube Thickness (mm)	3.15	0.1 / √3	NA
Vertical Alignment of ZEBRA Tubes (mm)	Figure 1.1-19	10 / √3	NA
ZEBRA Rod Cadmium Thickness (mm)	0.25	0.1 / √3	NA
ZEBRA Rod Cadmium Length (mm)	160	1 / √3	NA
ZEBRA Rod Aluminum Density (g/cm^3)	2.65	0.01	NA
ZEBRA Rod Aluminum Composition (wt.%)	Table 2.1-136	1 / √3	NA
ZEBRA Rod Cadmium Density (g/cm^3)	8.65	0.01	NA
ZEBRA Rod Cadmium Composition (wt.%)	Table 2.1-139	1 / √3	NA
Control Rod Inner Tube Thickness (mm)	2	0.1 / √3	neg
Control Rod Outer Tube Thickness (mm)	4	1 / √3	neg
Control Rod Tube Length (mm)	220.0	10 / √3	neg
Control Rod Inner Tube Density (g/cm^3)	7.90	0.01	neg
Control Rod Outer Tube Density (g/cm^3)	7.90	0.01	neg
Control Rod Inner Tube Composition (wt.%)	Table 2.1-145	1 / √3	neg
Control Rod Outer Tube Composition (wt.%)	Table 2.1-147	1 / √3	neg
Polyethylene Rod Diameter (mm)	8.9	0.1 / √3	neg
Polyethylene Rod Length (mm)	860	10 / √3	neg
Polyethylene Rod Linear Density (g/cm)	0.5867	0.0019	0.00011
Polyethylene Rod H:C Ratio	2.03	0.03	0.00034
Polyethylene Rod Impurities (ppm EBC)	0.5	0.5	neg
Copper Wire	--	--	NA
Measurement of k_{eff}	See Section 2.1.19.1		neg
Autorod Position (mm)	Table 2.1-154	5 / √3	neg
Safety/Shutdown Rod Positions (mm)	Table 2.1-156	5 / √3	neg
ZEBRA Rod Positions (mm)	Table 2.1-158	5 / √3	neg
Withdrawable Control Rod Positions (mm)	Table 2.1-160	5 / √3	neg
Stacked Pebble Height (mm)	Table 2.1-162	0.06 %	0.00011
Temperature (°)	Table 2.1-164	2	neg
Ambient Air Temperature (°)	Table 2.1-164	2	neg
Ambient Air Pressure (mbarn)	Table 2.1-166	10 / √3	neg
Ambient Air Humidity (%)	Table 2.1-168	5 / √3	neg

Table 2.1-175. (cont.). Summary of Evaluated Uncertainties in HTR-PROTEUS Case 4 (Core 3).

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff} (1σ)
Isotopic Abundance of Boron (%)	19.9	19.1 – 20.3	neg
Total Experimental Uncertainty	**--**	**--**	**0.00327**

Table 2.1-176. Summary of Non-Negligible Uncertainties in HTR-PROTEUS [Δk_{eff} (1σ)].

Parameter	Case 1 (Core 1)	Case 2 (Core 1A)	Case 3 (Core 2)	Case 4 (Core 3)
Radial Reflector Density	0.00097	0.00089	0.00091	0.00076
Radial Reflector Impurities	0.00069	0.00078	0.00078	0.00062
ZEBRA Rod Hole Positions	0.00016	neg	neg	neg
Safety Ring Composition	neg	neg	neg	0.00011
C-Driver Plug Density	neg	neg	0.00011	neg
Location of Upper Axial Reflector	0.00098	0.00110	0.00011	0.00104
Upper Axial Aluminum Dimensions	0.00036	0.00035	neg	0.00033
Upper Axial Aluminum Composition	0.00019	0.00031	neg	0.00028
Lower Axial Cylinder Diameter	neg	0.00012	neg	neg
Lower Axial Reflector Height	0.00019	neg	0.00014	0.00014
Lower Axial Annulus Density	0.00025	0.00021	0.00030	0.00021
Lower Axial Annulus Impurities	0.00012	0.00013	0.00013	0.00019
Autorod Copper Wedge Thickness	neg	0.00011	neg	neg
TRISO Random Packing	0.00021	neg	neg	0.00016
Kernel Radius	0.00011	0.00011	neg	neg
^{234}U Isotopic Content	0.00016	0.00020	0.00022	0.00013
^{235}U Isotopic Content	0.00223	0.00226	0.00227	0.00267
Fuel Pebble Uranium Mass	0.00027	0.00025	0.00026	0.00035
Fueled Zone Impurities	0.00023	0.00019	0.00019	0.00018
Unfueled Zone Impurities	0.00021	0.00029	0.00029	0.00025
Fuel Pebble Water Content	0.00028	0.00018	0.00030	neg
Oxygen-to-Uranium Ratio	neg	neg	neg	0.00013
Moderator Pebble Mass	0.00014	0.00014	0.00016	neg
Moderator Pebble Impurities	0.00100	0.00108	0.00192	0.00090
Moderator Pebble Water Content	0.00018	neg	neg	neg
Vertical Alignment of ZEBRA Tubes	0.00012	NA	NA	NA
Control Rod Outer Tube Composition	NA	0.00013	neg	neg
Polyethylene Rod Linear Density	NA	NA	NA	0.00011
Polyethylene Rod H:C Ratio	NA	NA	NA	0.00034
Stacked Pebble Height	0.00014	0.00014	0.00012	0.00011
Total Experimental Uncertainty	**0.00301**	**0.00309**	**0.00329**	**0.00327**

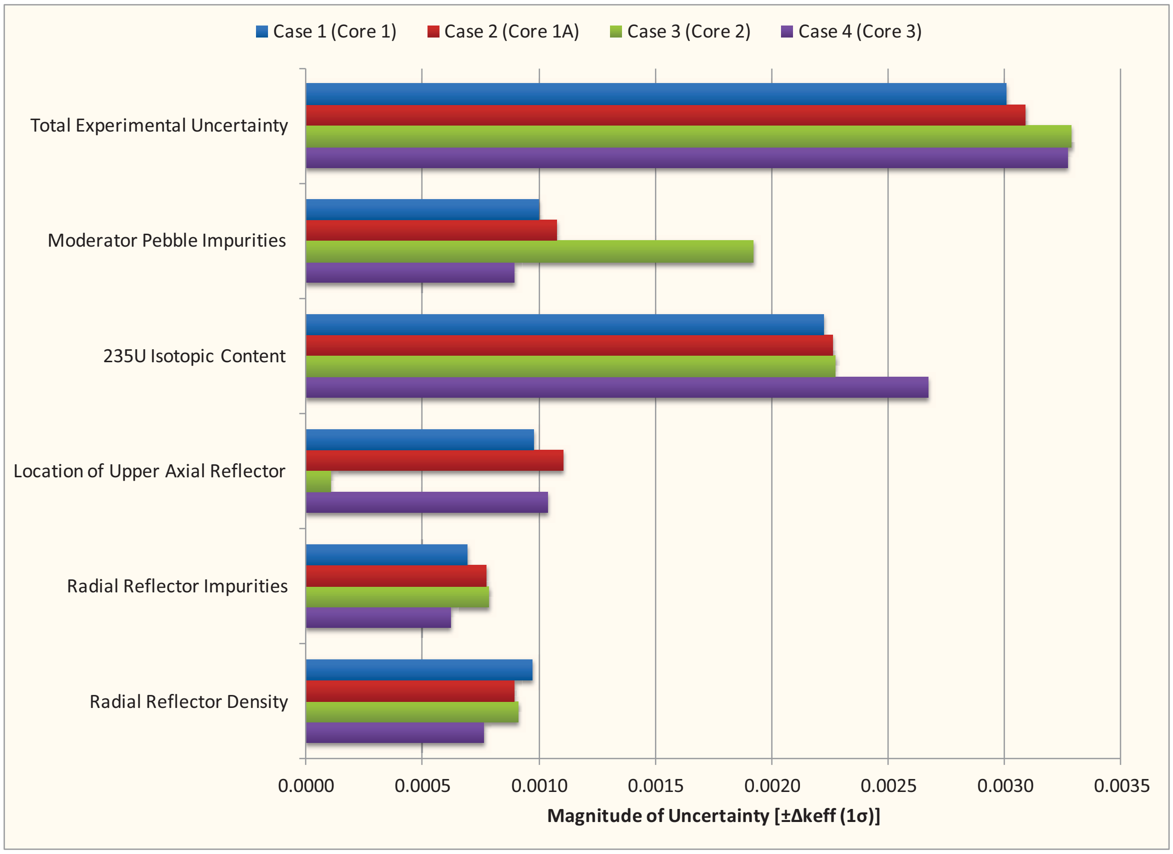

Figure 2.1-5. Graphical Representation of Primary Uncertainties in HTR-PROTEUS.

2.2 Evaluation of Buckling and Extrapolation Length Data

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

2.3 Evaluation of Spectral Characteristics Data

Spectral characteristics measurements were not made.

2.4 Evaluation of Reactivity Effects Data

Reactivity effects measurements were made but have not yet been evaluated.

2.5 Evaluation of Reactivity Coefficient Data

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

2.6 Evaluation of Kinetics Measurements Data

Kinetics measurements were made but have not yet been evaluated.

2.7 Evaluation of Reaction-Rate Distributions

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

2.8 Evaluation of Power Distribution Data

Power distribution measurements were not made.

2.9 Evaluation of Isotopic Measurements

Isotopic measurements were not made.

2.10 Evaluation of Other Miscellaneous Types of Measurements

Other miscellaneous types of measurements were not made.

3.0 BENCHMARK SPECIFICATIONS

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

Four benchmark experiments were evaluated in this report: Cores 1, 1A, 2, and 3. These core configurations represent the hexagonal close packing (HCP) configurations of the HTR-PROTEUS experiment with a moderator-to-fuel pebble ratio of 1:2. Core 1 represents the only configuration utilizing ZEBRA control rods. Cores 1A, 2, and 3 use withdrawable, hollow, stainless steel control rods. Cores 1 and 1A are similar except for the use of different control rods; Core 1A also has one less layer of pebbles (21 layers instead of 22). Core 2 retains the first 16 layers of pebbles from Cores 1 and; however, an additional 17 layers of moderator pebbles were loaded in order to eliminate the void space between the core region and the upper axial reflector. Core 3 retains the first 17 layers of pebbles from Cores 1 and 1A but has polyethylene rods inserted between pebbles to simulate water ingress. The additional partial pebble layer (layer 18) for Core 3 was not included as it was used for core operations and not the reported critical configuration.

The benchmark critical configurations for Cores 1, 1A, 2, and 3 will be referred to as Cases 1, 2, 3, and 4, 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 3.1-17, 3.1-20, 3.1-21, and 3.1-24). Most core configurations in the HTR-PROTEUS experimental series included exact placement of the pebbles, as is the case with Cases 1 through 4 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 1) represented the initial critical experiment, or "base case", against which the modifications in the other core configurations could be compared, and from which reactivity measurements were performed to assess model simplifications. Case 2 (Core 1A) was nearly identical to Case 1 (Core 1); the primary change was to shift the "base case" from a design using ZEBRA rods for gross criticality control to one using withdrawable control rods. The worth of the resting ZEBRA rods was significant. Case 3 (Core 2) represented a modification of the "base case" in which a significant quantity of moderator pebbles was stacked above the fueled portion of the core to investigate the "cavity effect", or void space in the core cavity region between the stack of fuel and moderator pebbles and the upper axial reflector. Case 4 (Core 3) represented the modification of the "base case" to include polyethylene rods placed in channels between the pebbles; this was done to simulate water ingress effects within pebble bed systems.

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 through 3.1-4). 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. Those yielding small (≤0.00100 Δk) or negligible (≤0.00010 Δk) biases were incorporated into the benchmark models (see Table 3.1-5). 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. Therefore, these simplifications were not performed and the features were retained in the benchmark models.

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 Table 3.1-1. The values for Cases 1 through 4 were obtained from Tables 1.1-19, 1.1-21, 1.1-22, and 1.1-23, respectively. The calculated β_{eff} values are 0.00723 (Cases 1 through 3) and 0.00727 (Case 4). 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.

Some of the configurations utilized aluminum plugs in the 12 coolant channels of the lower axial reflector to maintain a level pebble distribution within the core. The effect of removing these plugs was measured.

Start-up sources and a pulsed neutron source 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. To simplify modeling and comparison of the four different cases, all four core configurations were modeled with these open coolant channels. Biases were experimentally measured, and verified using MCNP calculations, for the worth of filling coolant channels in the upper and lower axial reflectors. The measured worths were scaled to calculate the bias for adding empty coolant channels back to the benchmark models of Cases 2 and 4. The worth of four empty channels in the lower axial reflector were added to Case 2; one empty channel in the upper axial reflector and 32 in the lower axial reflector were added to Case 4. The uncertainties were also scaled. Correlation effects, if any, between these biases are assumed to be negligible.

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

Measured Effect	Reactivity Correction ρ¢	±	σ	Reactivity Correction Δk	±	σ
Empty Channels in Ring 2 of Radial Reflector	2.7	±	0.3	0.00020	±	0.00002
Empty Channels in Ring 3 of Radial Reflector	3.8	±	0.6	0.00027	±	0.00005
Aluminum Plugs in Lower Axial Reflector	15.3	±	0.2	0.00111	±	0.00006
Start-Up Sources	3.3	±	0.01	0.00024	±	0.00001
Start-Up Source Penetrations	1	±	0.1	0.00007	±	0.00001
Pulsed Neutron Source and Missing Graphite	4.3	±	0.1	0.00031	±	0.00002
Nuclear Instrumentation (Ionization)	8.4	±	1.8	0.00061	±	0.00013
Nuclear Instrumentation (Fission)	0.8	±	0.6	0.00006	±	0.00004
Temperature Instrumentation in Radial Reflector	10.6	±	0.3	0.00077	±	0.00004
Temperature Instrumentation in Core Cavity	--	±	--	--	±	--
Coolant Channels in Upper Reflector	--	±	--	--	±	--
Coolant Channels in Lower Reflector	--	±	--	--	±	--
Total (Reported β_{eff} = 0.00723)[(a)]	50.20	±	2.05	0.00363	±	0.00017

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

Table 3.1-2. Experimentally Determined Reactivity Corrections for Case 2 (Core 1A).

Measured Effect	Reactivity Correction ρ¢	±	σ	Reactivity Correction Δk	±	σ
Empty Channels in Ring 2 of Radial Reflector	2.7	±	0.3	0.00020	±	0.00002
Empty Channels in Ring 3 of Radial Reflector	--	±	--	--	±	--
Aluminum Plugs in Lower Axial Reflector	--	±	--	--	±	--
Start-Up Sources	3.3	±	0.01	0.00024	±	0.00001
Start-Up Source Penetrations	1	±	0.1	0.00007	±	0.00001
Pulsed Neutron Source and Missing Graphite	--	±	--	--	±	--
Nuclear Instrumentation (Ionization)	9.8	±	2	0.00071	±	0.00015
Nuclear Instrumentation (Fission)	0.8	±	0.6	0.00006	±	0.00004
Temperature Instrumentation in Radial Reflector	15.9	±	0.9	0.00115	±	0.00009
Temperature Instrumentation in Core Cavity	0.5	±	0.3	0.00004	±	0.00002
Coolant Channels in Upper Reflector	--	±	--	--	±	--
Coolant Channels in Lower Reflector	-2.76	±	0.08	-0.00020	±	0.00001
Total (Reported β_{eff} = 0.00723)[(a)]	31.24	±	2.32	0.00226	±	0.00018

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

Table 3.1-3. Experimentally Determined Reactivity Corrections for Case 3 (Core 2).

Measured Effect	Reactivity Correction ρ¢	±	σ	Reactivity Correction Δk	±	σ
Empty Channels in Ring 2 of Radial Reflector	2.3	±	0.3	0.00017	±	0.00002
Empty Channels in Ring 3 of Radial Reflector	--	±	--	--	±	--
Aluminum Plugs in Lower Axial Reflector	15.3	±	0.2	0.00111	±	0.00006
Start-Up Sources	--	±	--	--	±	--
Start-Up Source Penetrations	1	±	0.1	0.00007	±	0.00001
Pulsed Neutron Source and Missing Graphite	--	±	--	--	±	--
Nuclear Instrumentation (Ionization)	7.3	±	1.8	0.00053	±	0.00013
Nuclear Instrumentation (Fission)	0.8	±	0.6	0.00006	±	0.00004
Temperature Instrumentation in Radial Reflector	9.2	±	0.3	0.00067	±	0.00004
Temperature Instrumentation in Core Cavity	--	±	--	--	±	--
Coolant Channels in Upper Reflector	--	±	--	--	±	--
Coolant Channels in Lower Reflector	--	±	--	--	±	--
Total (Reported β_{eff} = 0.00723)[(a)]	35.90	±	1.96	0.00260	±	0.00016

(a) Assumed uncertainty in βeff of 5% (1σ).

Table 3.1-4. Experimentally Determined Reactivity Corrections for Case 4 (Core 3).

Measured Effect	Reactivity Correction ρ¢	±	σ	Reactivity Correction Δk	±	σ
Empty Channels in Ring 2 of Radial Reflector	1.8	±	0.3	0.00013	±	0.00002
Empty Channels in Ring 3 of Radial Reflector	--	±	--	--	±	--
Aluminum Plugs in Lower Axial Reflector	--	±	--	--	±	--
Start-Up Sources	--	±	--	--	±	--
Start-Up Source Penetrations	1	±	0.1	0.00007	±	0.00001
Pulsed Neutron Source and Missing Graphite	--	±	--	--	±	--
Nuclear Instrumentation (Ionization)	5.6	±	1.8	0.00041	±	0.00013
Nuclear Instrumentation (Fission)	0.8	±	0.6	0.00006	±	0.00004
Temperature Instrumentation in Radial Reflector	--	±	--	--	±	--
Temperature Instrumentation in Core Cavity	--	±	--	--	±	--
Coolant Channels in Upper Reflector	-0.11	±	0.06	-0.00001	±	0.00000
Coolant Channels in Lower Reflector	-23.10	±	6.60	-0.00168	±	0.00049
Total (Reported β_{eff} = 0.00727)[(a)]	-14.01	±	6.87	-0.00102	±	0.00051

(a) Assumed uncertainty in βeff of 5% (1σ).

Additional biases were evaluated for the benchmark simplifications listed in Table 3.1-5. The effective bias for most of the individually calculated biases are negligible compared to the statistical uncertainty, except for the bias for homogenizing the radial reflector; therefore, 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: ZEBRA rods, withdrawable control rods, safety/shutdown rods, and autorod. The withdrawable control rods, placed in four of the C-Driver channels in ring 5 of the radial reflector, were not used in Case 1; instead, these channels were filled with graphite rods and are homogenized in the benchmark model of this configuration (Figure 3.1-2). The ZEBRA rod channels were filled with graphite in Cases 2 through 4 and not included in the radial reflector for those configurations (Figure 3.1-3). 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 (see Section 2.1.9.11). The mass of the pebbles was conserved and the resultant bias is negligible.

Impurities in the TRISO particles are removed from the models (Tables 2.1-105 and 2.1-107).

A standard air composition was used for all models with a temperature of 20°C, pressure of 980 mbar, and 50 % humidity (see Section 2.1.20). Neon, helium, and krypton are not included in the benchmark model; the bias for there removal is negligible.

Table 3.1-5. 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 (1)	2 (1A)
Bias (Δk)	0.00118 ± 0.00010	0.00118 ± 0.000010
Case (Core)	3 (2)	4 (3)
Bias (Δk)	0.00034 ± 0.00010	0.00095 ± 0.00010

The total bias for each benchmark configuration (Table 3.1-6) is obtained by summation of the experimentally measured corrections (Tables 3.1-1 through 3.1-4) with the computed simplification bias (Table 3.1-5). The total bias uncertainties are obtained by summing under quadrature the individual bias uncertainties. For example, for Case 1 (Core 1), the measured correction of 0.00363 ± 0.00017 Δk (Table 3.1-1) is added to the calculated simplification bias of 0.00118 ± 0.00010 Δk (Table 3.1-5) to obtain a total simplification bias for the benchmark model of 0.00481 ± 0.00019 Δk (Table 3.1-6).

Table 3.1-6. Total Benchmark Biases (Δk).

Case (Core)	1 (1)			2 (1A)		
Measured Corrections	0.00363	±	0.00017	0.00226	±	0.00018
Calculated Simplifications	0.00118	±	0.00010	0.00118	±	0.00010
Total Bias	**0.00481**	**±**	**0.00019**	**0.00344**	**±**	**0.00021**
Case (Core)	3 (2)			4 (3)		
Measured Corrections	0.00260	±	0.00016	-0.00102	±	0.00051
Calculated Simplifications	0.00034	±	0.00010	0.00095	±	0.00010
Total Bias	**0.00294**	**±**	**0.00019**	**-0.00007**	**±**	**0.00052**

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 and an autorod. Case 1 includes four penetrations for ZEBRA control rods and Cases 2 through 4 include four penetrations for withdrawable control rods. These holes axially penetrate completely through the radial reflector with the x,y positions provided in Table 3.1-7 and shown in Figures 3.1-2 and 3.1-3. While the penetrations for the safety/shutdown rods are preserved in the benchmark model, the rods themselves are not included.

Table 3.1-7. 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
ZEBRA Rod Hole 1 (Case 1/Core 1)	21.84	86.93	4.5
ZEBRA Rod Hole 2 (Case 1/Core 1)	86.93	-21.84	4.5
ZEBRA Rod Hole 3 (Case 1/Core 1)	-21.84	-86.93	4.5
ZEBRA Rod Hole 4 (Case 1/Core 1)	-86.93	21.84	4.5
Withdrawable Control Rod Hole 1 (Cases 2-4/Cores 1A, 2, and 3)	-83.70	34.67	2.743
Withdrawable Control Rod Hole 2 (Cases 2-4/Cores 1A, 2, and 3)	34.67	83.70	2.743
Withdrawable Control Rod Hole 3 (Cases 2-4/Cores 1A, 2, and 3)	83.70	-34.67	2.743
Withdrawable Control Rod Hole 4 (Cases 2-4/Cores 1A, 2, and 3)	-34.67	-83.70	2.743

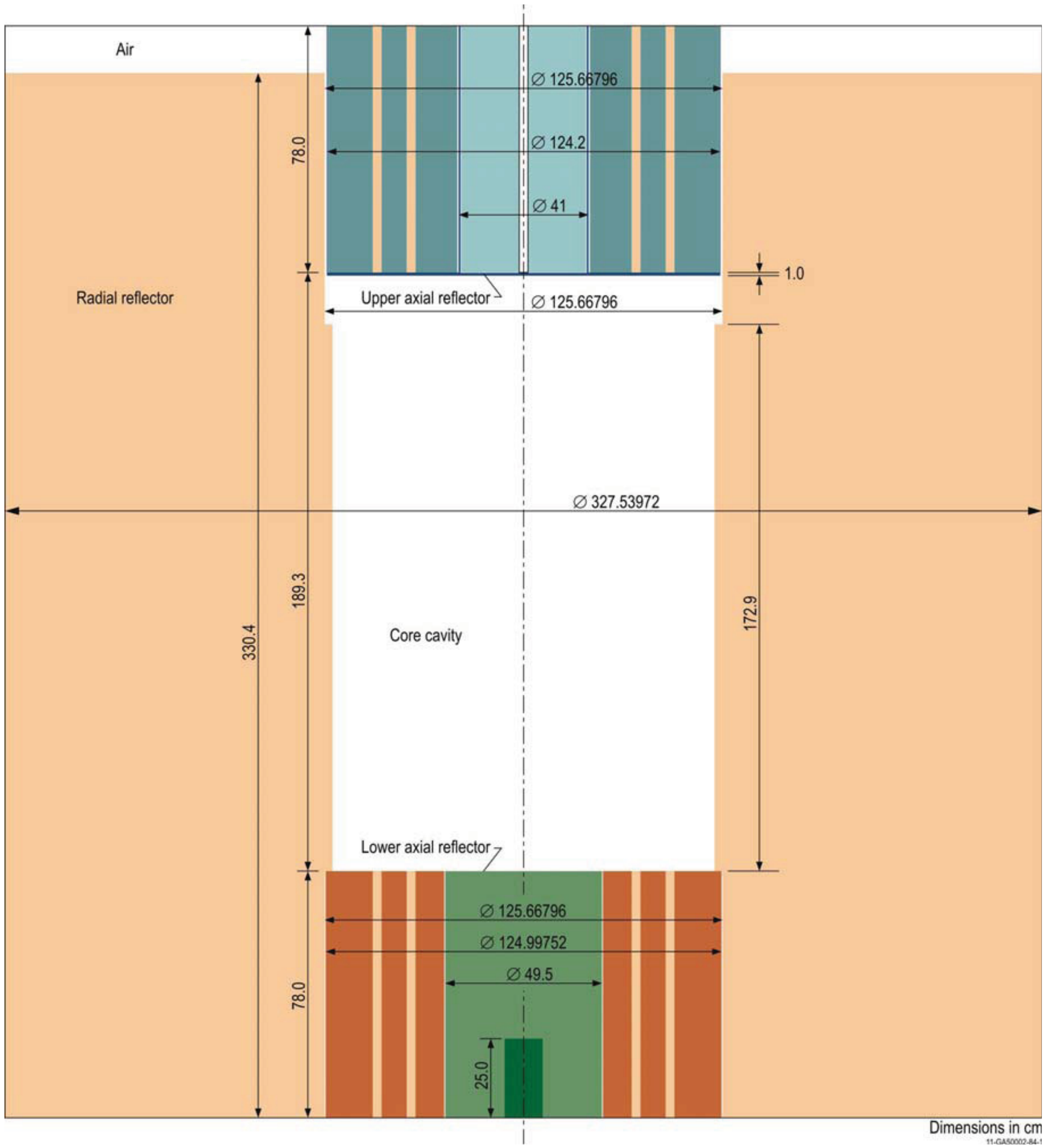

Figure 3.1-1. Radial and Axial Reflectors Surrounding Core Cavity Region.

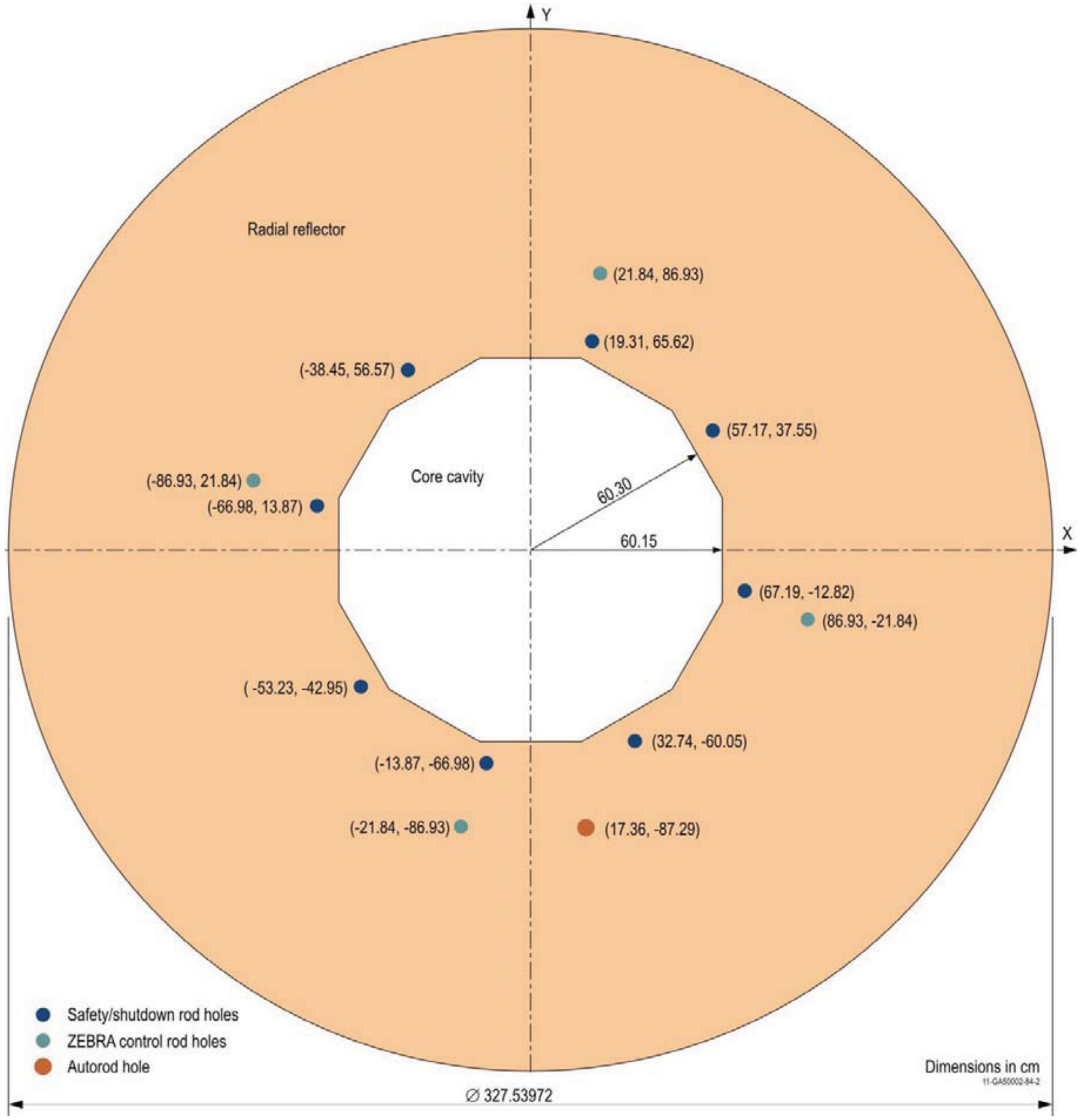

Figure 3.1-2. Radial Reflector Surrounding Core Cavity Region for Case 1 (Core 1).

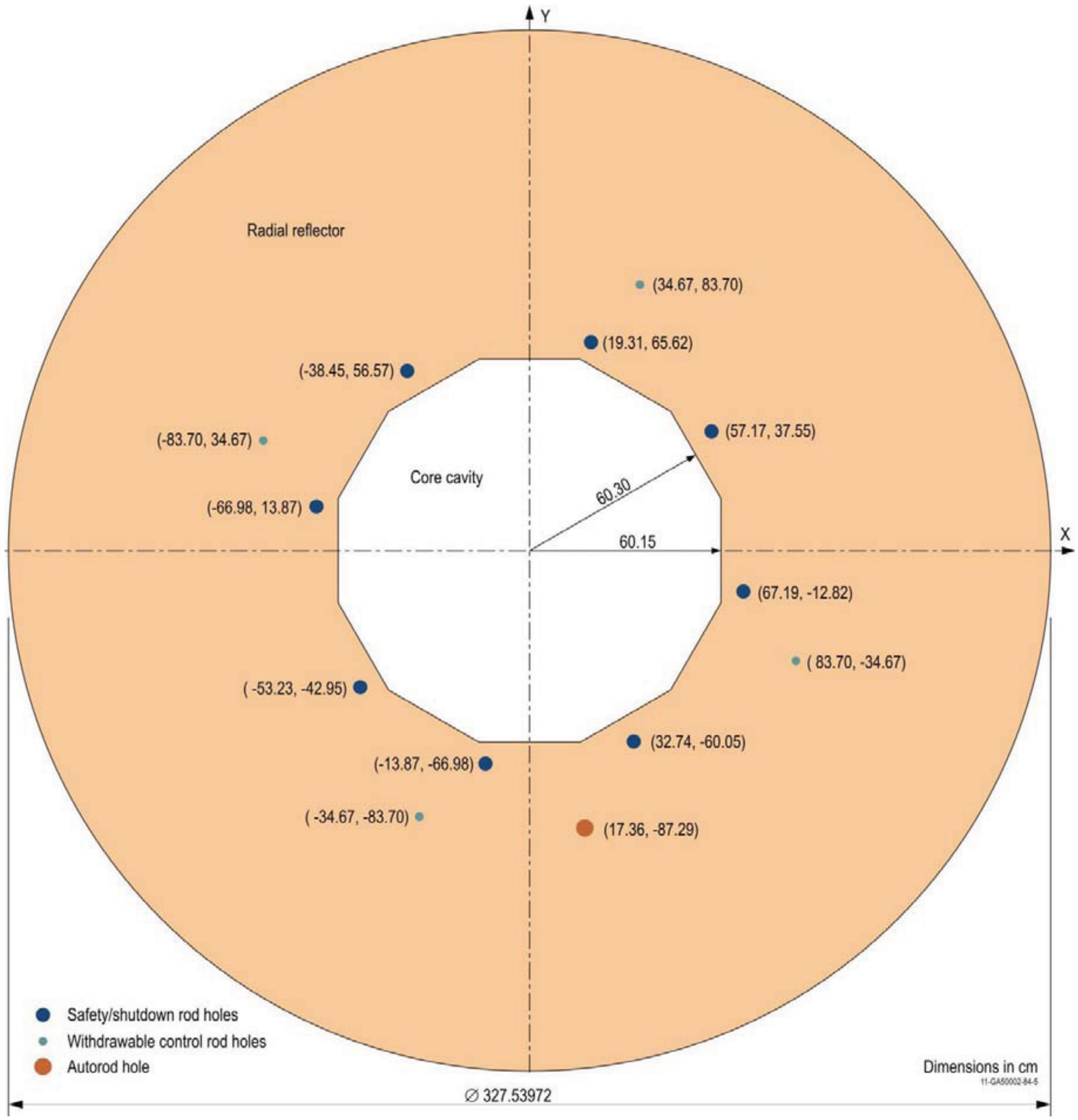

Figure 3.1-3. Radial Reflector Surrounding Core Cavity Region for Cases 2-4 (Cores 1A, 2, and 3).

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 3.1-8). Of the 161 channels, 127 are filled with graphite plugs (diameter of 2.65 cm), as noted in Table 3.1-8 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.

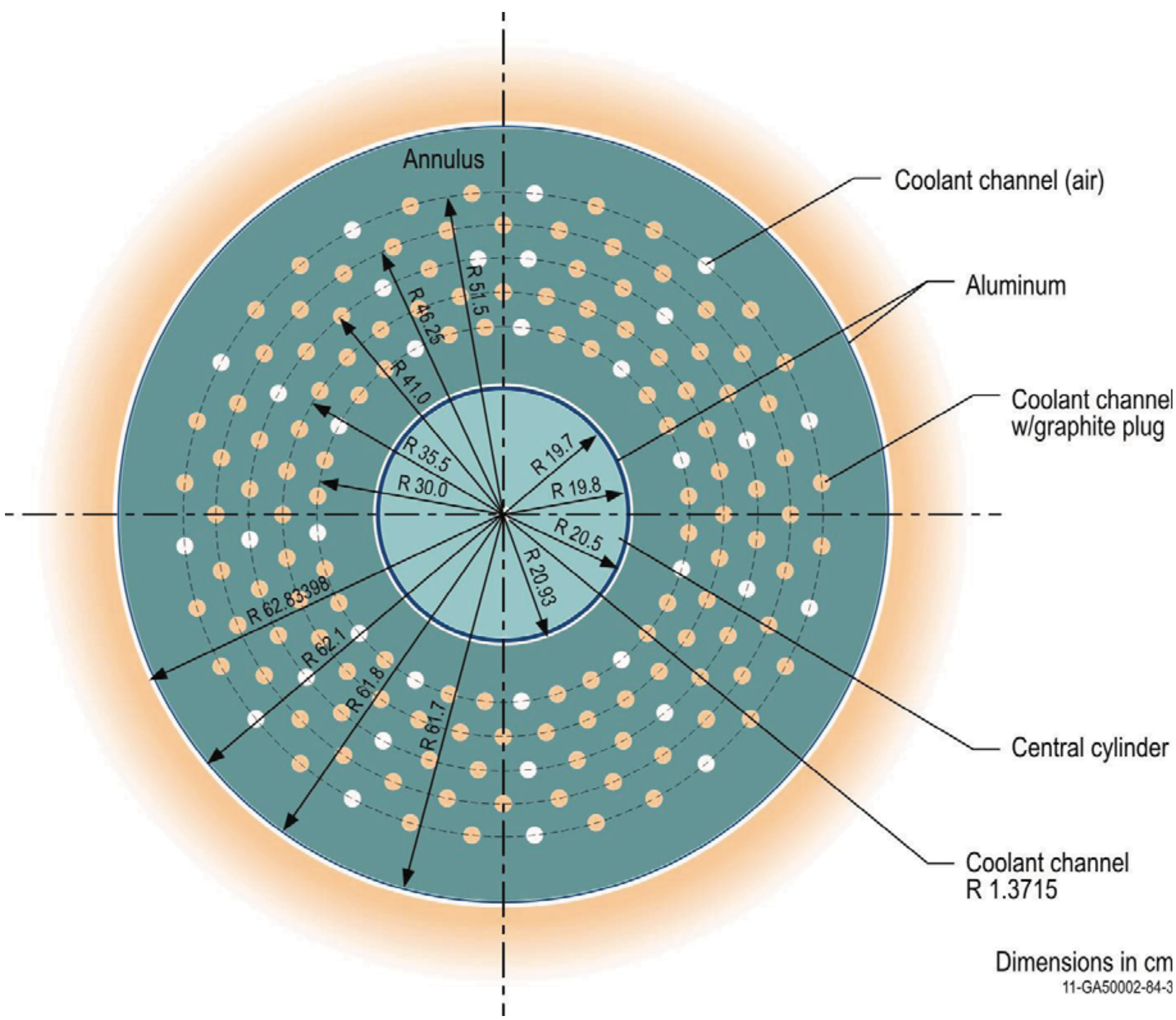

Figure 3.1-4. Upper Axial Reflector.

Table 3.1-8. 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 3.1-8. (cont.). 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 3.1-8). Graphite plugs (diameter of 2.65 cm) fill 127 of the 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.

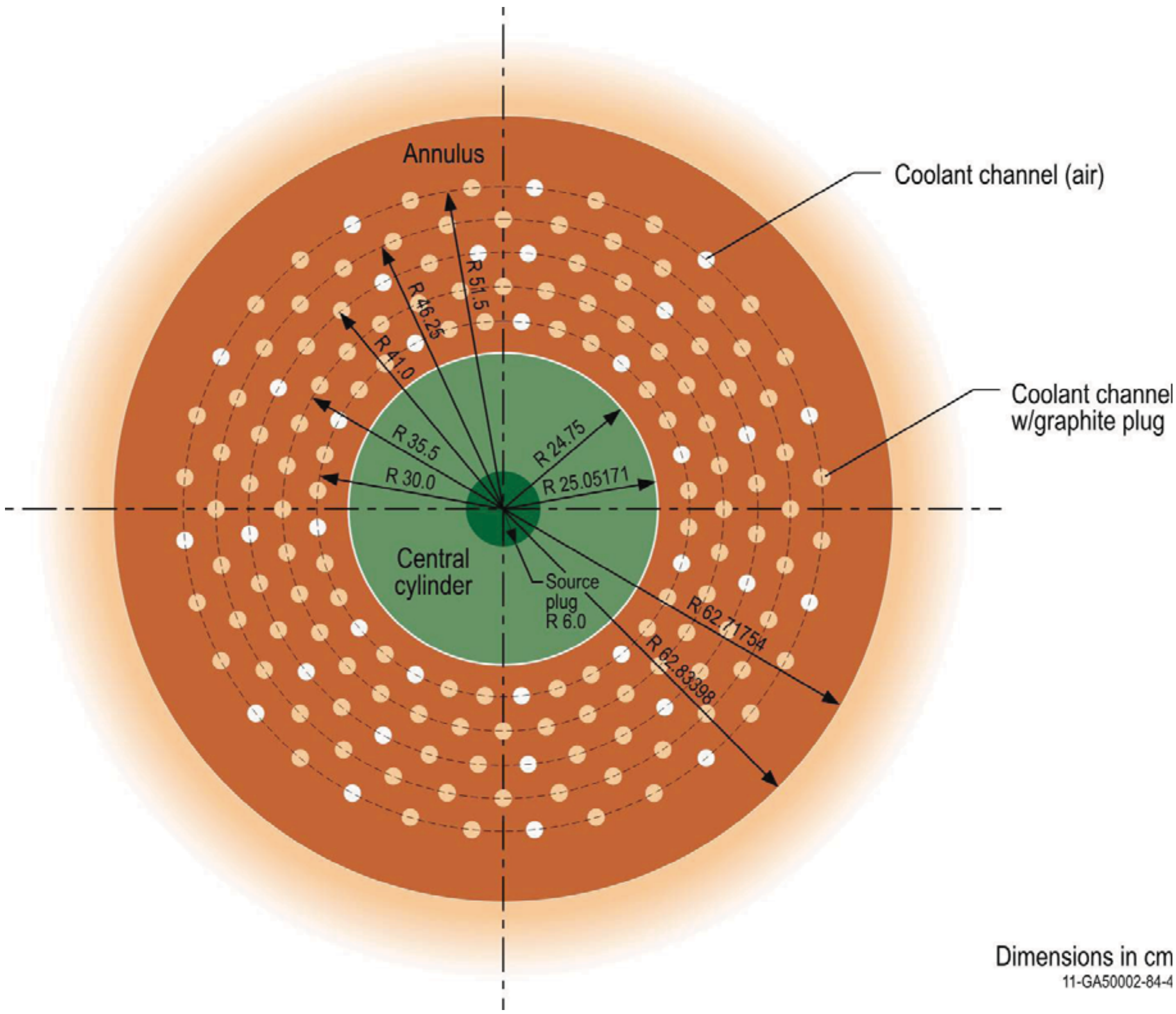

Figure 3.1-5. Lower Axial Reflector.

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 Figures 3.1-2 and 3.1-3 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 3.1-9.

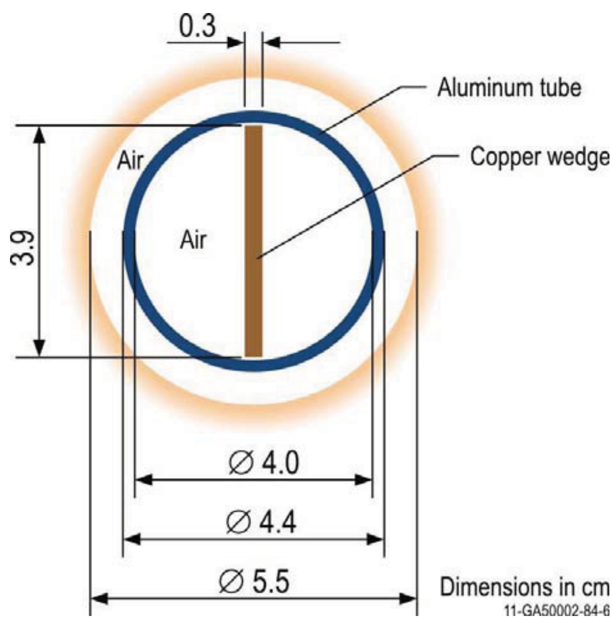

Figure 3.1-6. Top View of Autorod.

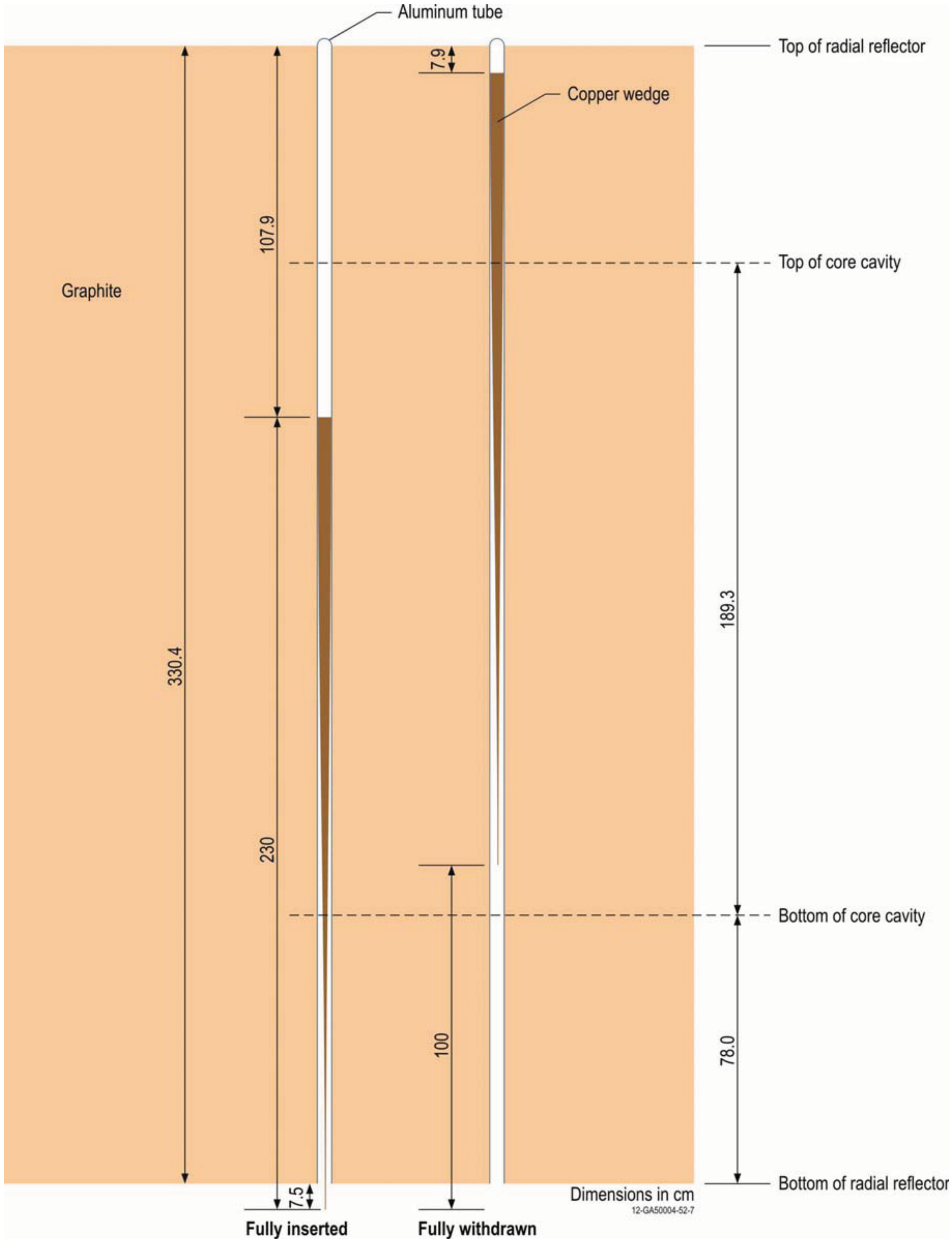

Figure 3.1-7. Autorod Vertical Position within Axial Reflector.

Table 3.1-9. Control Rod Positions (distance in cm).

Case (Core)	**1 (1)**	**2 (1A)**	**3 (2)**	**4 (3)**
Control Rod	**Withdrawn Distance**	**Withdrawn Distance**	**Withdrawn Distance**	**Withdrawn Distance**
Safety/Shutdown Rod 1	NA	NA	NA	NA
Safety/Shutdown Rod 2	NA	NA	NA	NA
Safety/Shutdown Rod 3	NA	NA	NA	NA
Safety/Shutdown Rod 4	NA	NA	NA	NA
Safety/Shutdown Rod 5	NA	NA	NA	NA
Safety/Shutdown Rod 6	NA	NA	NA	NA
Safety/Shutdown Rod 7	NA	NA	NA	NA
Safety/Shutdown Rod 8	NA	NA	NA	NA
Autorod	41.8	13.0	31.6	68.5
ZEBRA Rod 1	14.8	NA	NA	NA
ZEBRA Rod 2	14.8	NA	NA	NA
ZEBRA Rod 3	14.8	NA	NA	NA
ZEBRA Rod 4	14.8	NA	NA	NA
Withdrawable Control Rod 1	NA	15.0	56.4	249.4
Withdrawable Control Rod 2	NA	15.0	56.4	249.4
Withdrawable Control Rod 3	NA	15.0	56.4	249.4
Withdrawable Control Rod 4	NA	15.0	56.4	249.4

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 3.1.2.12. 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.

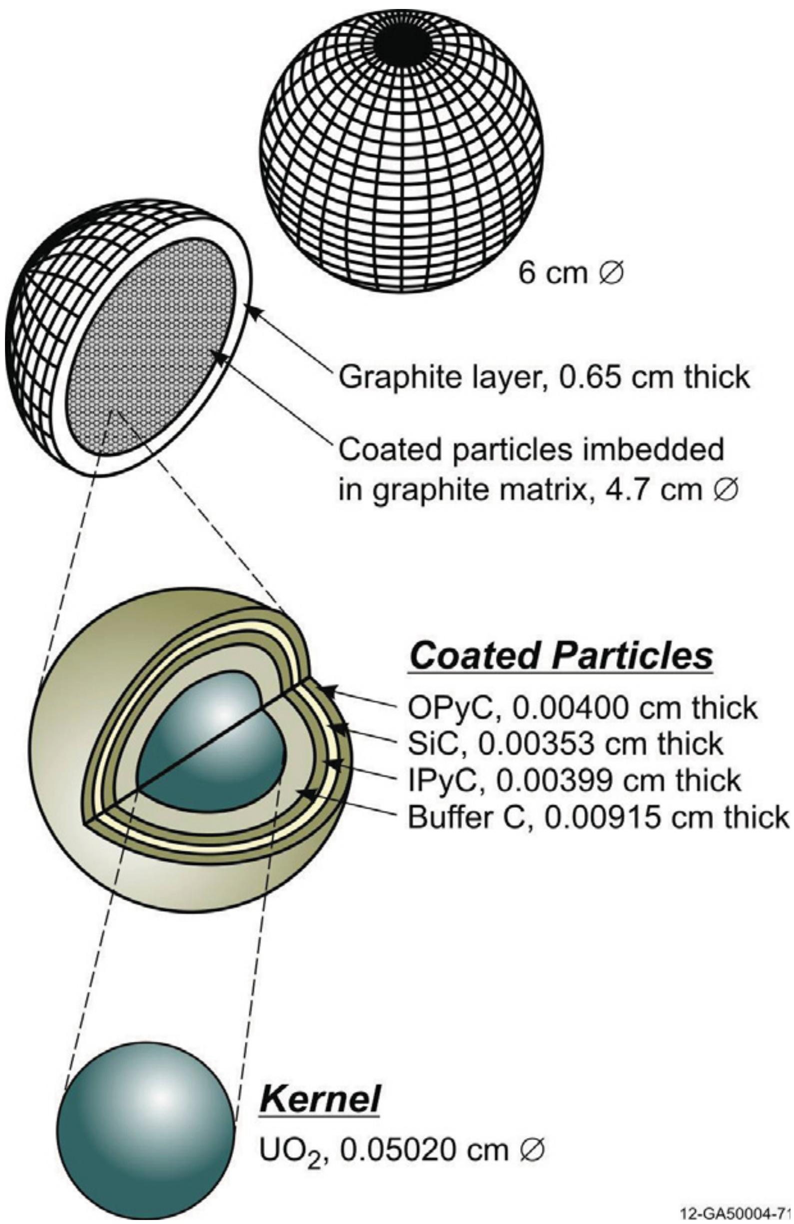

Figure 3.1-8. Fuel Pebble and TRISO Particle.

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 3.1.2.12.

3.1.2.7 Lattice Supports

Graphite filler pieces serving as lattice supports are used to fill vacant positions in the pebble lattice where a complete pebble cannot fit. These fillers are only used within the even layers of each core configuration (see Section 3.1.2.12 for their locations). The dimensions for the two types of lattice fillers are shown in Figure 3.1-9. The position of the bottom surface for both the large (3.47 cm thick) and small (1.73 cm thick) filler pieces for each pebble layer in the core configurations is provided in Table 3.1-10. The filler pieces are placed in the core lattice flush against the inner dodecahedral surface of the radial reflector.

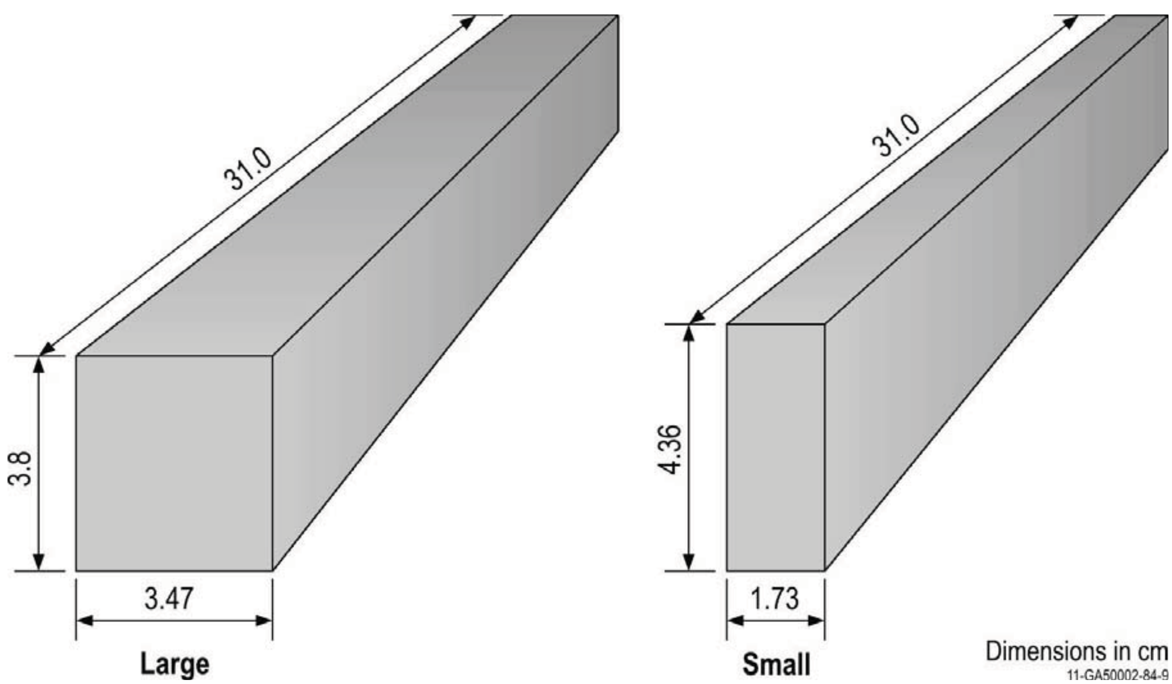

Figure 3.1-9. Lattice Support Spacers.

Table 3.1-10. Location of Bottom Surface of Pebble Lattice Supports.

Lattice Support Type	**Large (3.47 cm thick)**	**Small (1.73 cm thick)**
Pebble Layer	**Distance above Top Surface of Lower Axial Reflector (cm)**	
2	5.998979	5.718979
4	15.796938	15.516938
6	25.594897	25.314897
8	35.392856	35.112856
10	45.190815	44.910815
12	54.988774	54.708774
14	64.786733	64.506733
16	74.584692	74.304692
18	84.382651	84.102651
20	94.180610	93.900610
22	103.978569	103.698569
24	113.776528	113.496528
26	123.574487	123.294487
28	133.372446	133.092446
30	143.170405	142.890405
32	152.968364	152.688364

3.1.2.8 ZEBRA Control Rods

The ZEBRA control rods consisted of a concentric pair of aluminum tubes, each fitted with an outer, axially-segmented, sheath of cadmium (Figures 3.1-10 and 3.1-11). The outer tube is fixed in position with an inner diameter of 3.57 cm, an outer diameter of 4.20 cm, and a height of 368.5 cm extending upward from the bottom of the radial reflector. Each cadmium sheath completely surrounds the tube, is fitted flush to the outer surface, and has a thickness of 0.025 cm. Each sheath segment has a height of 16.0 cm, and a gap of 24.0 cm between the top of one sheath and the bottom of the next sheath. The bottom surface of the bottommost sheath on the outer tube is located 50.2 cm above the bottom of the radial reflector. The moveable inner tube has a total length of 326.35 cm and extends 15.85 below the bottom of the radial reflector when the ZEBRA rod is fully inserted. When fully inserted, the bottom surface of the bottommost cadmium sheath on the inner tube is located 30.2 cm above the bottom of the radial reflector. The sheaths on the inner tube are also 16.0 cm in height, 0.025 cm thick, and spaced 24.0 cm apart. The inner tube has an inner diameter of 3.0 cm and an outer diameter of 3.5 cm. The ZEBRA control rods are considered fully "withdrawn" when the inner tube is raised 20.0 cm and its cadmium sheaths are aligned with the sheaths on the outer tube (see Figure 3.1-11). The withdrawn positions of the ZEBRA rods in Case 1 (Core 1) are provided in Table 3.1-9. The ZEBRA rods were not used in Cases 2 through 4 (Cores 1A, 2, and 3).

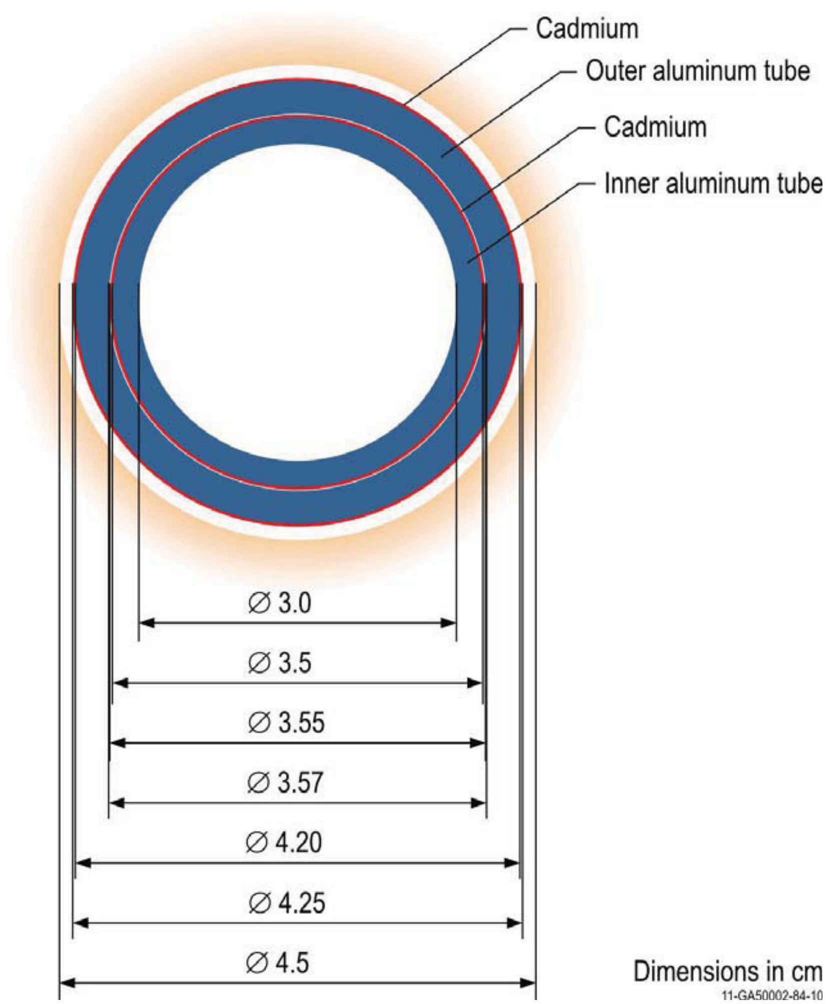

Figure 3.1-10. Top View of ZEBRA Control Rod.

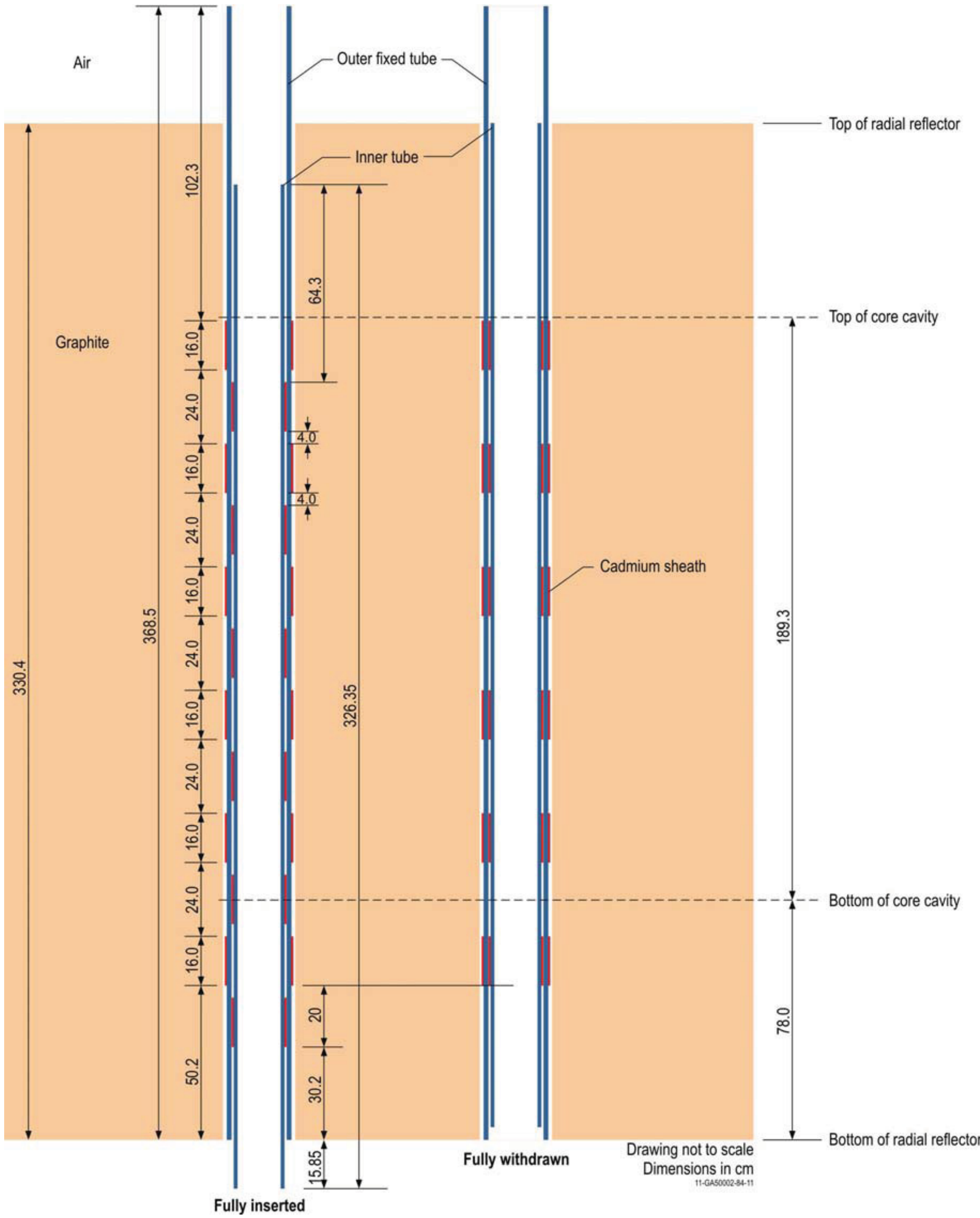

Figure 3.1-11. Axial View of ZEBRA Control Rod.

3.1.2.9 Withdrawable Stainless Steel Control Rods

Withdrawable control rods are used in Cases 2 through 4 (Cores 1A, 2, and 3) instead of the ZEBRA rods. The withdrawable control rods (Figures 3.1-12 through 3.1-14) 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 3.1-13. 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 3.1-14). 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 for Cases 2 through 4 (Cases 1A, 2, and 3) are provided in Table 3.1-9.

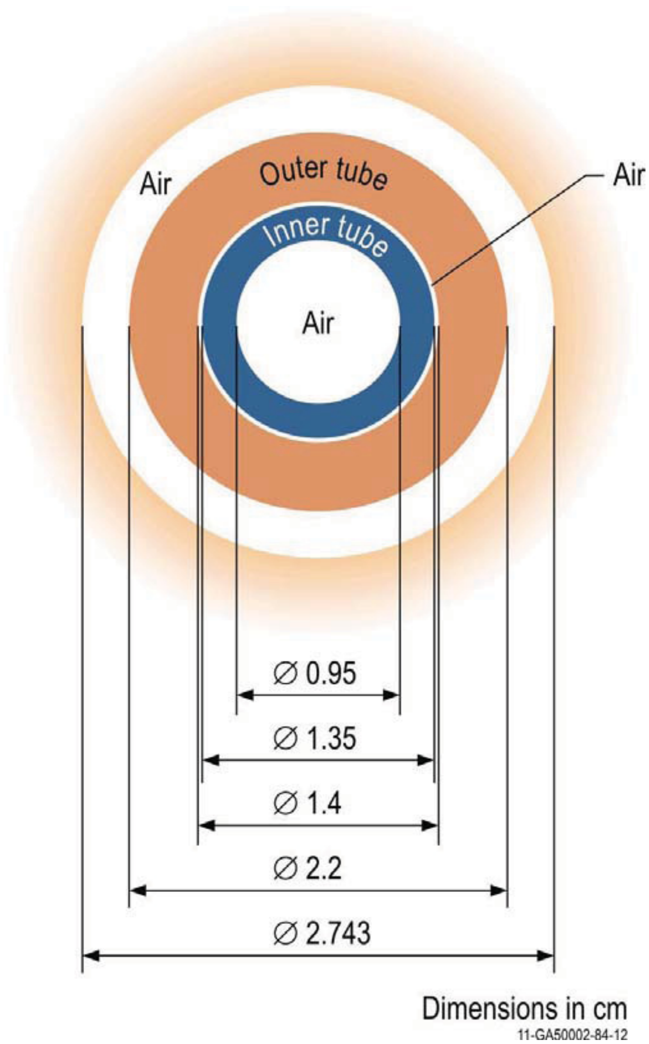

Figure 3.1-12. Top View of Withdrawable Control Rod.

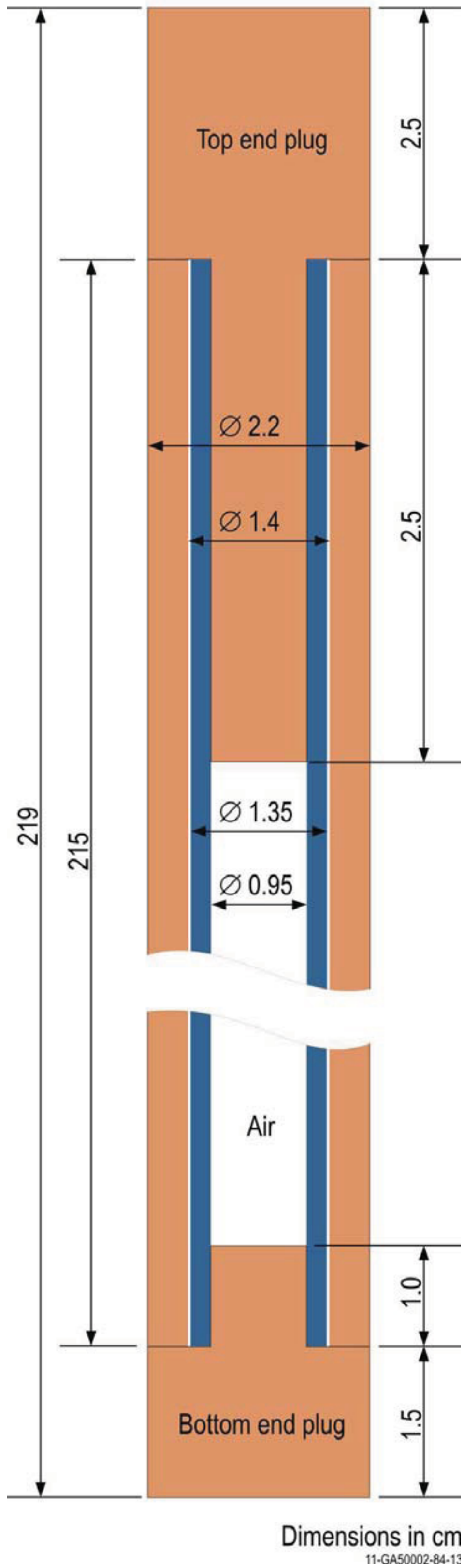

Figure 3.1-13. Axial View of Withdrawable Control Rod.

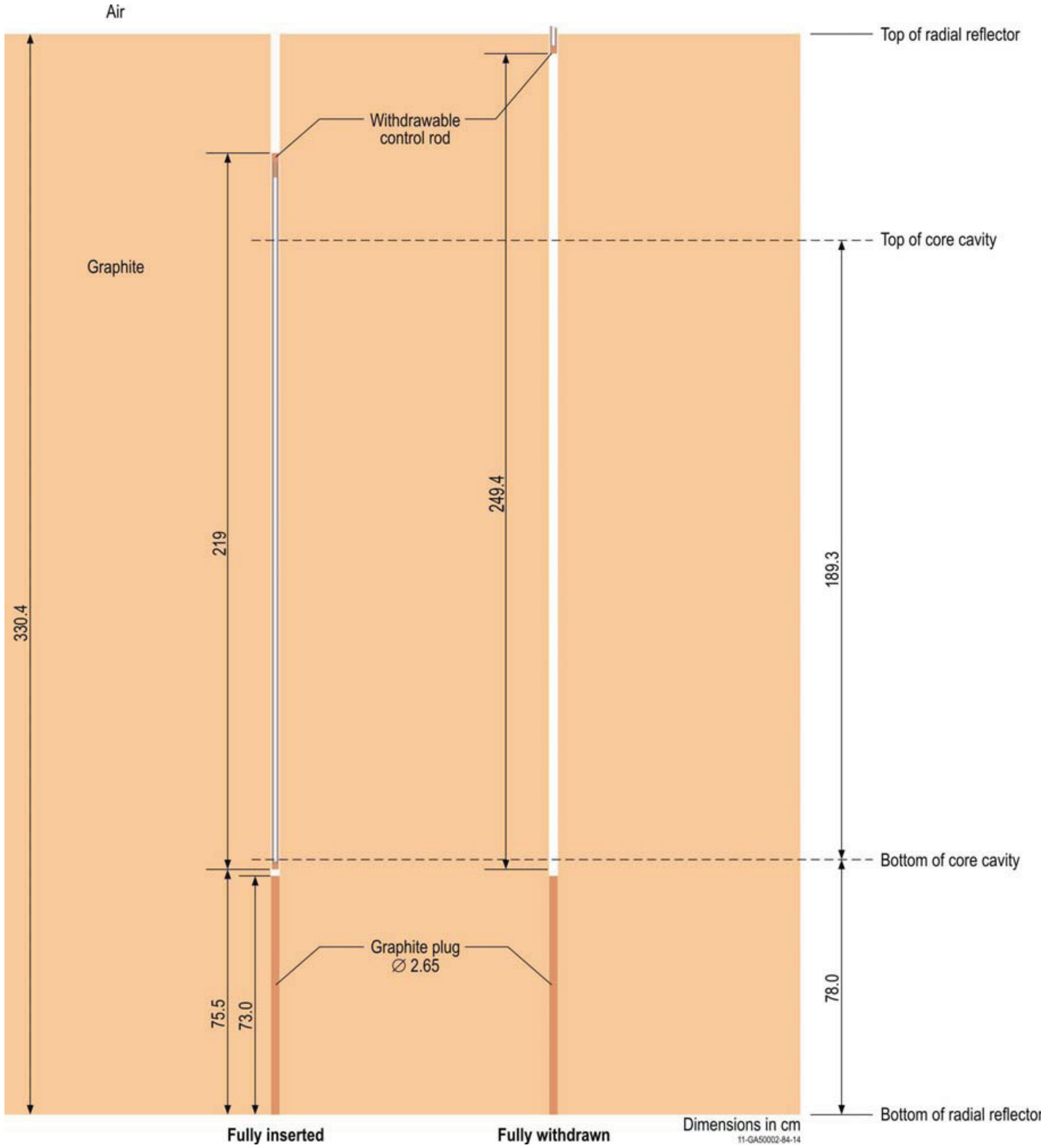

Figure 3.1-14. Withdrawable Control Rod Vertical Position within Axial Reflector.

3.1.2.10 Polyethylene Rods

Polyethylene (sometimes referred to as plastic) rods are used to simulate water ingress in Case 4 (Core 3) only. Each rod has a diameter of 0.89 cm and length of 86.0 cm. There are a total of 327 rods located in the core; they are placed vertically in interstitial pebble channels (see Figures 3.1-24 and 3.1-25).

3.1.2.11 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.

3.1.2.12 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 hexagonal close-packed lattices, as shown in Figure 3.1-15; this arrangement can be visualized as oranges placed in a crate. Information corresponding to the loading of each configuration is provided in Table 3.1-11 with additional visualization of the core descriptions in Figures 3.1-16 through 3.1 25.

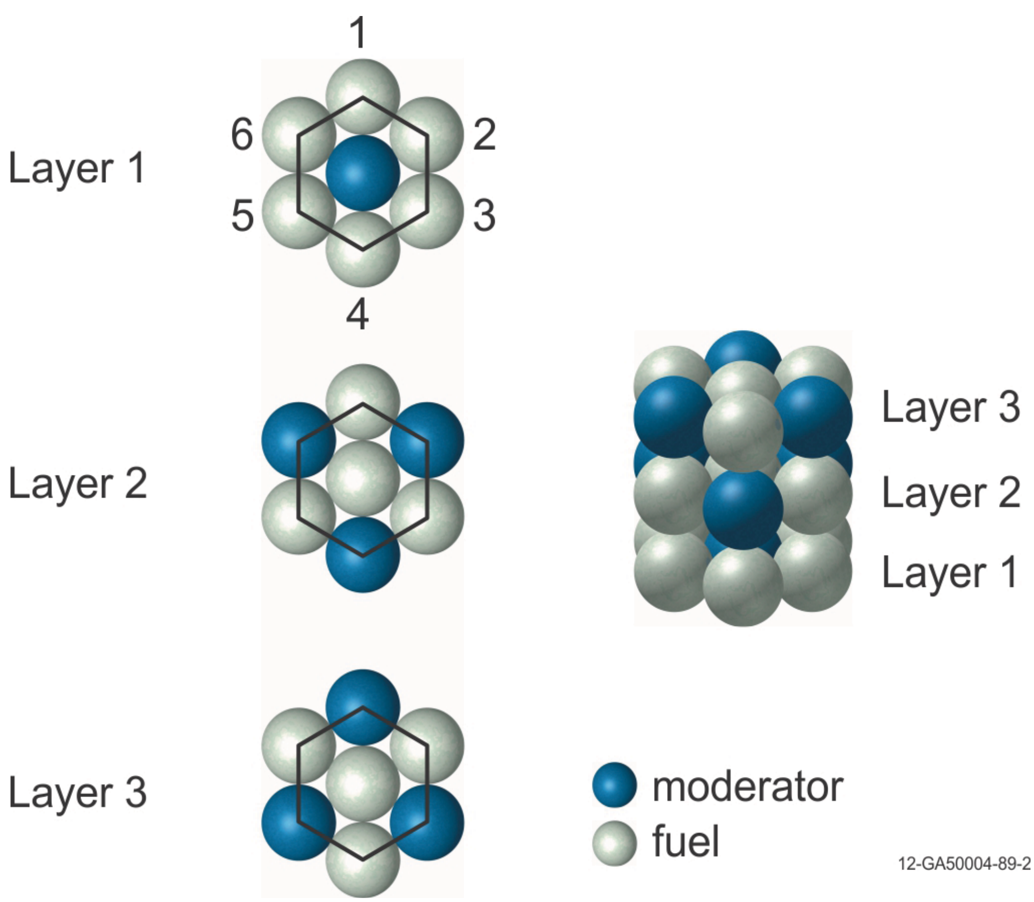

Figure 3.1-15. Subunit for Construction of the Hexagonal Close-Packed (HCP) Cell.

Table 3.1-11. Additional Core Configuration Parameters.

Case	Core	# Fuel Pebbles	# Moderator Pebbles	# Pebble Layers	Core Height (m)	# Polyethylene Rods	Associated Figures
1	1	5181	2585	22	1.0888	0	3.1-16 through 3.1-18
2	1A	4951	2470	21	1.0398	0	3.1-17 through 3.1-19
3	2[(a)]	3768 (FR) 0 (UR)	1880 (FR) 6009 (UR	16 (FR) 17 (UR)	1.6277	0	3.1-17, 3.1-18, 3.1-20 through 3.1-22
4	3	4009	2000	17	0.8438	327	3.1-23 through 3.1-25

(a) FR = Fueled Region, UR = Unfueled Region. Case 3 consists of 16 layers (FR) with fuel and moderator pebbles stacked together with 17 layers (UR) of stacked moderator pebbles on top.

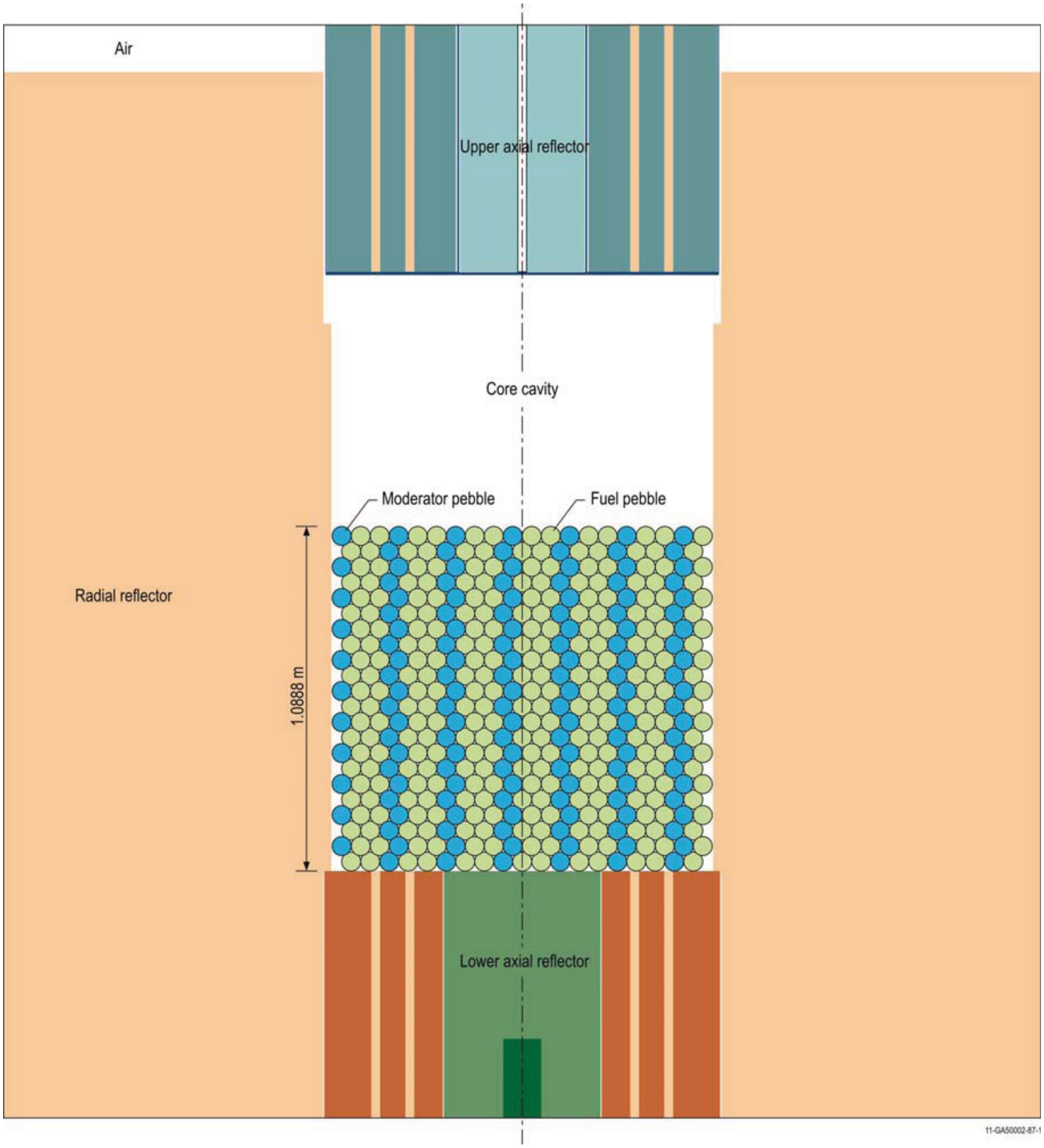

Figure 3.1-16. Vertical Profile of Case 1 (Core 1).

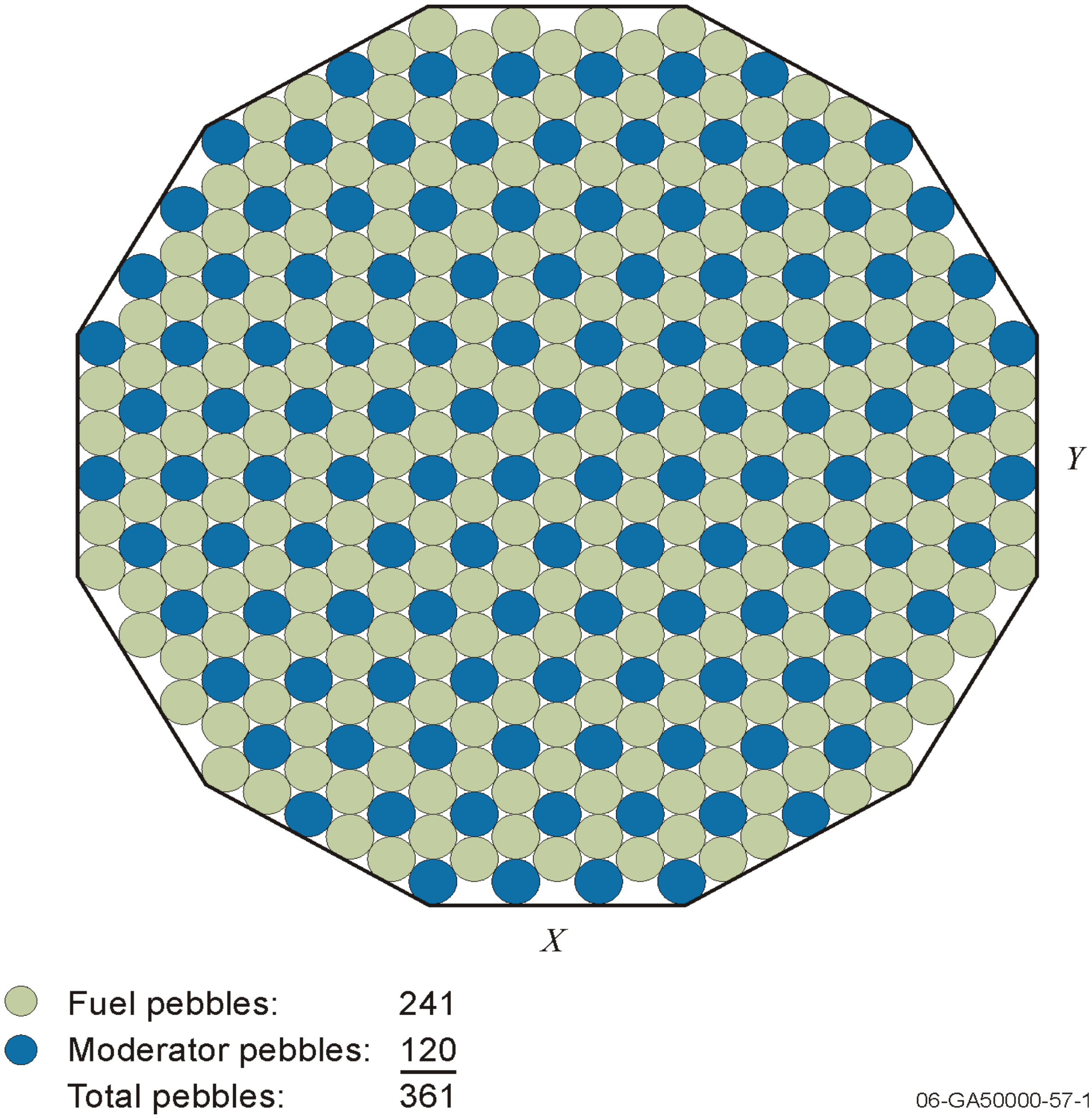

Figure 3.1-17. Odd Fueled Layers (1, 3, 5, 7, etc.) of Cases 1, 2, and 3 (Cores 1, 1A, and 2).

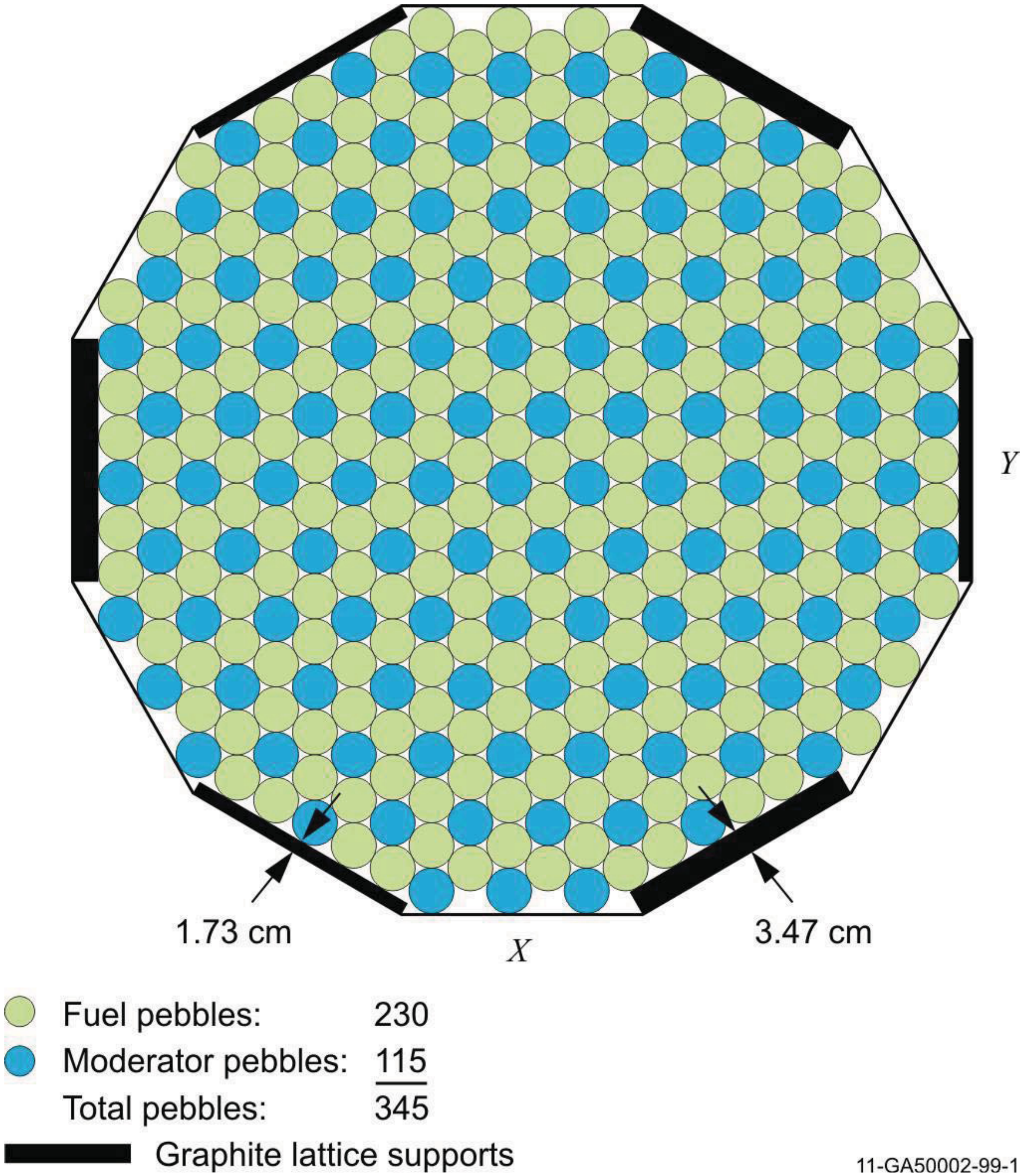

Figure 3.1-18. Even Fueled Layers (2, 4, 6, 8, etc.) of Cases 1, 2, and 3 (Cores 1, 1A, and 2).

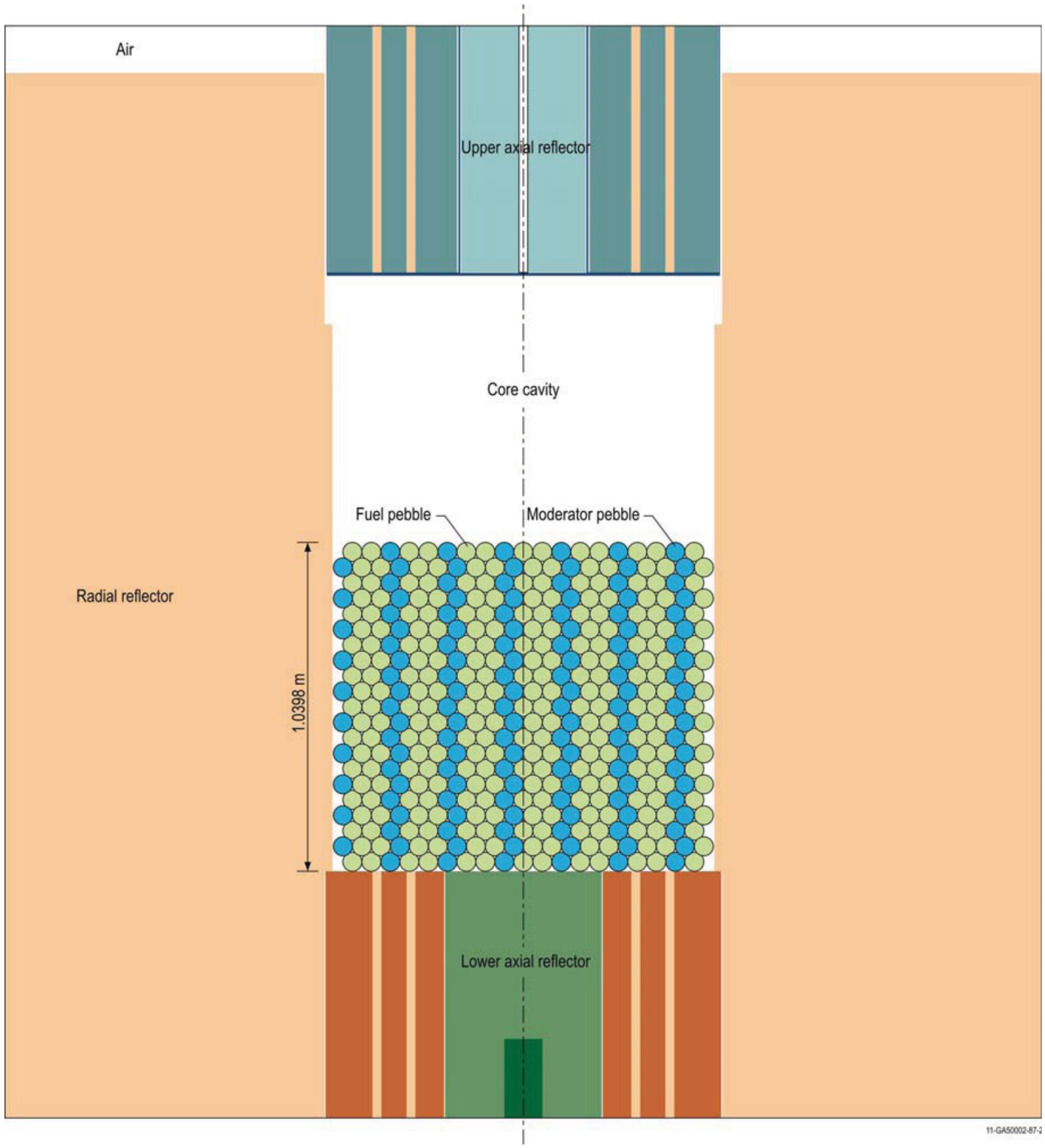

Figure 3.1-19. Vertical Profile of Case 2 (Core 1A).

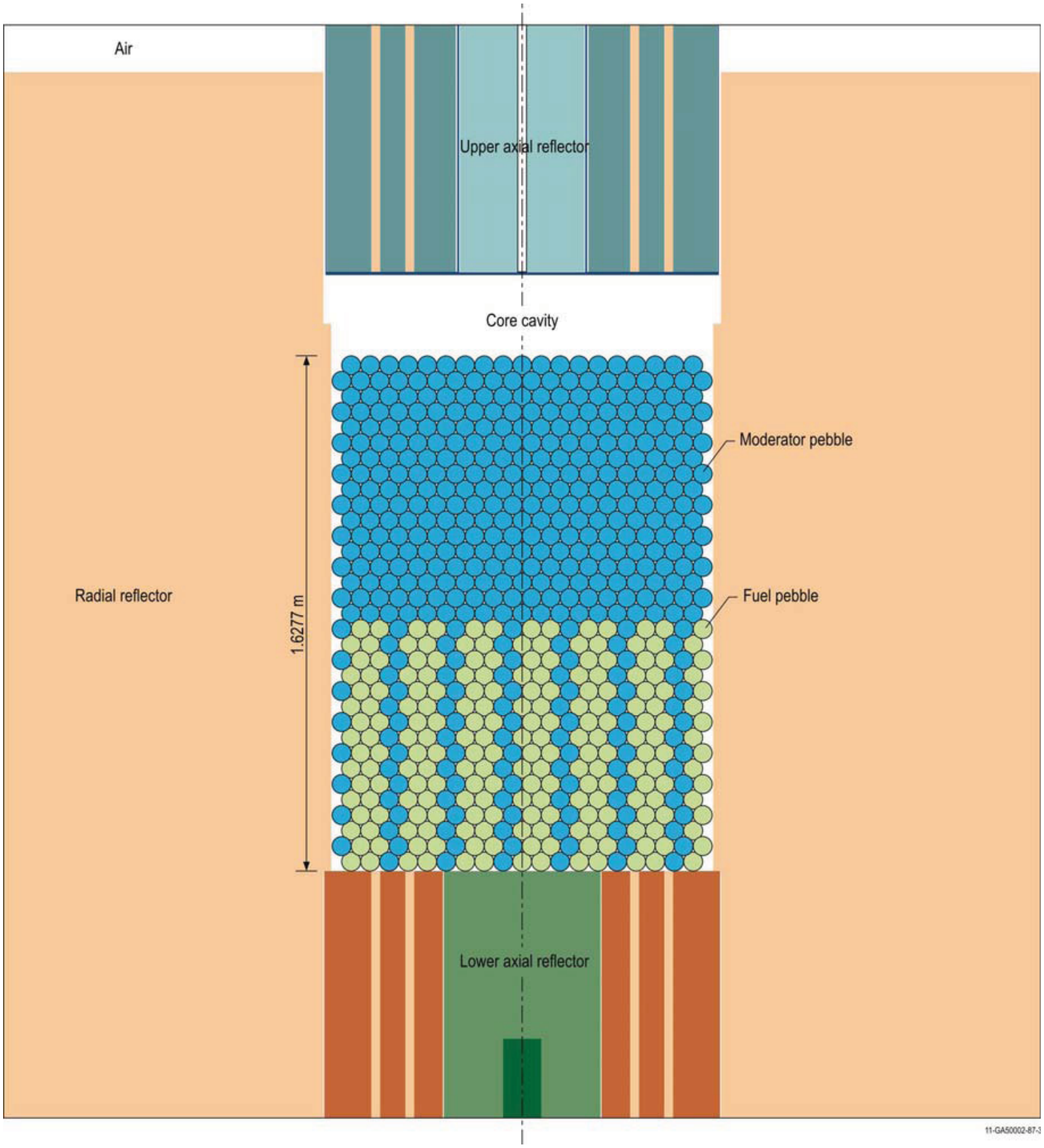

Figure 3.1-20. Vertical Profile of Case 3 (Core 2).

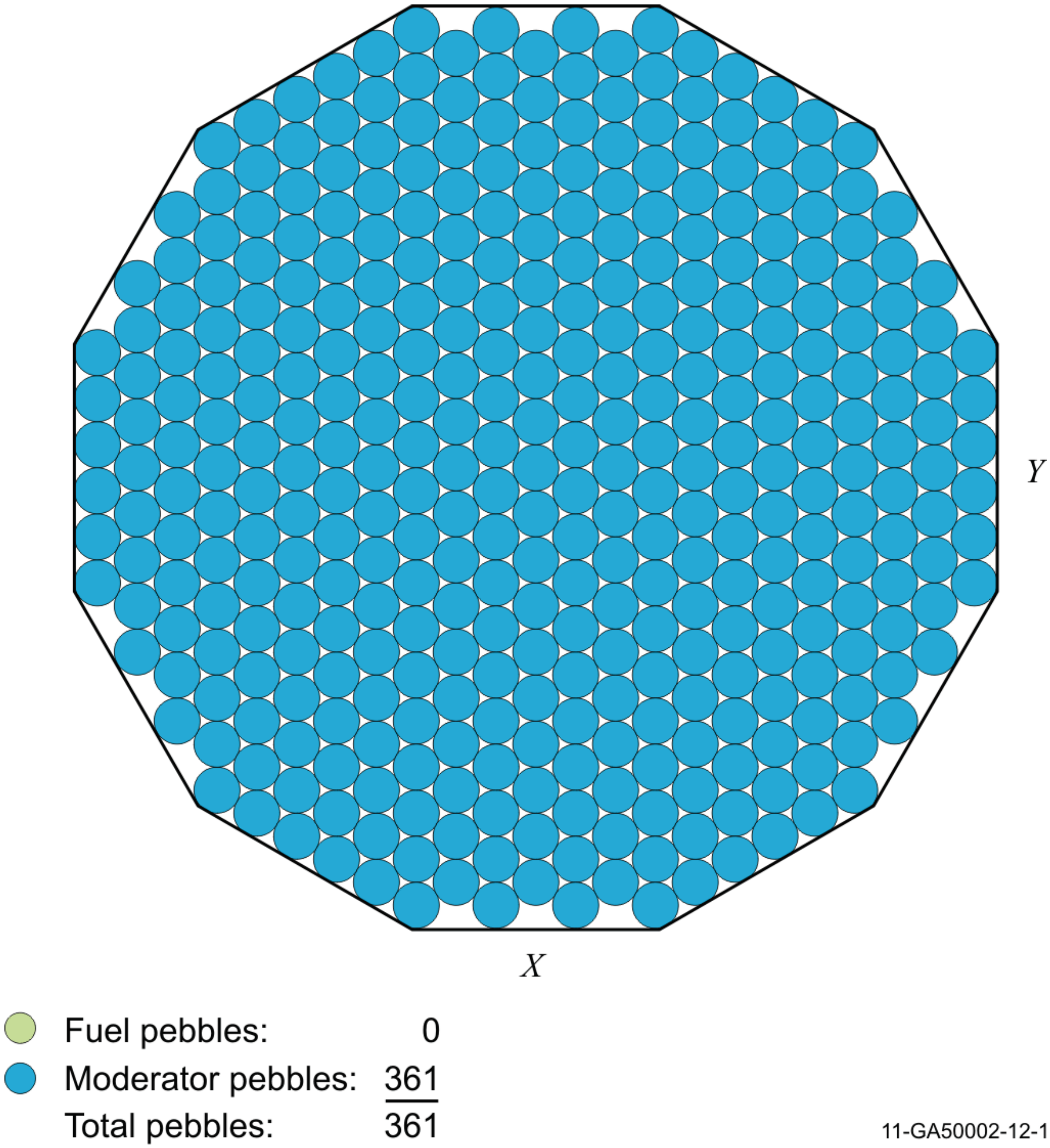

Figure 3.1-21. Odd Moderator Layers (17, 19, 21, etc.) of Case 3 (Core 2).

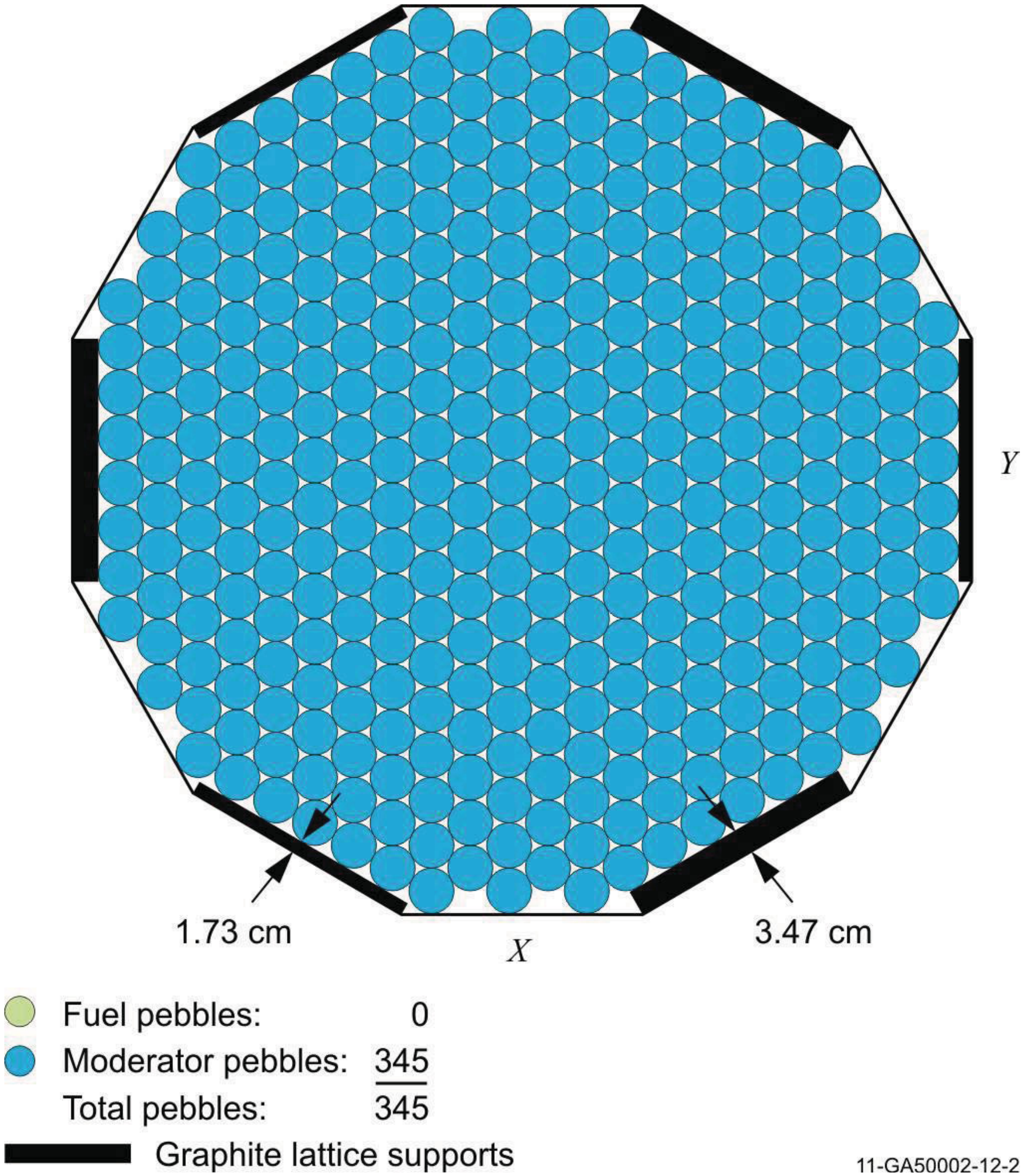

Figure 3.1-22. Even Moderator Layers (18, 20, 22, etc.) of Case 3 (Core 2).

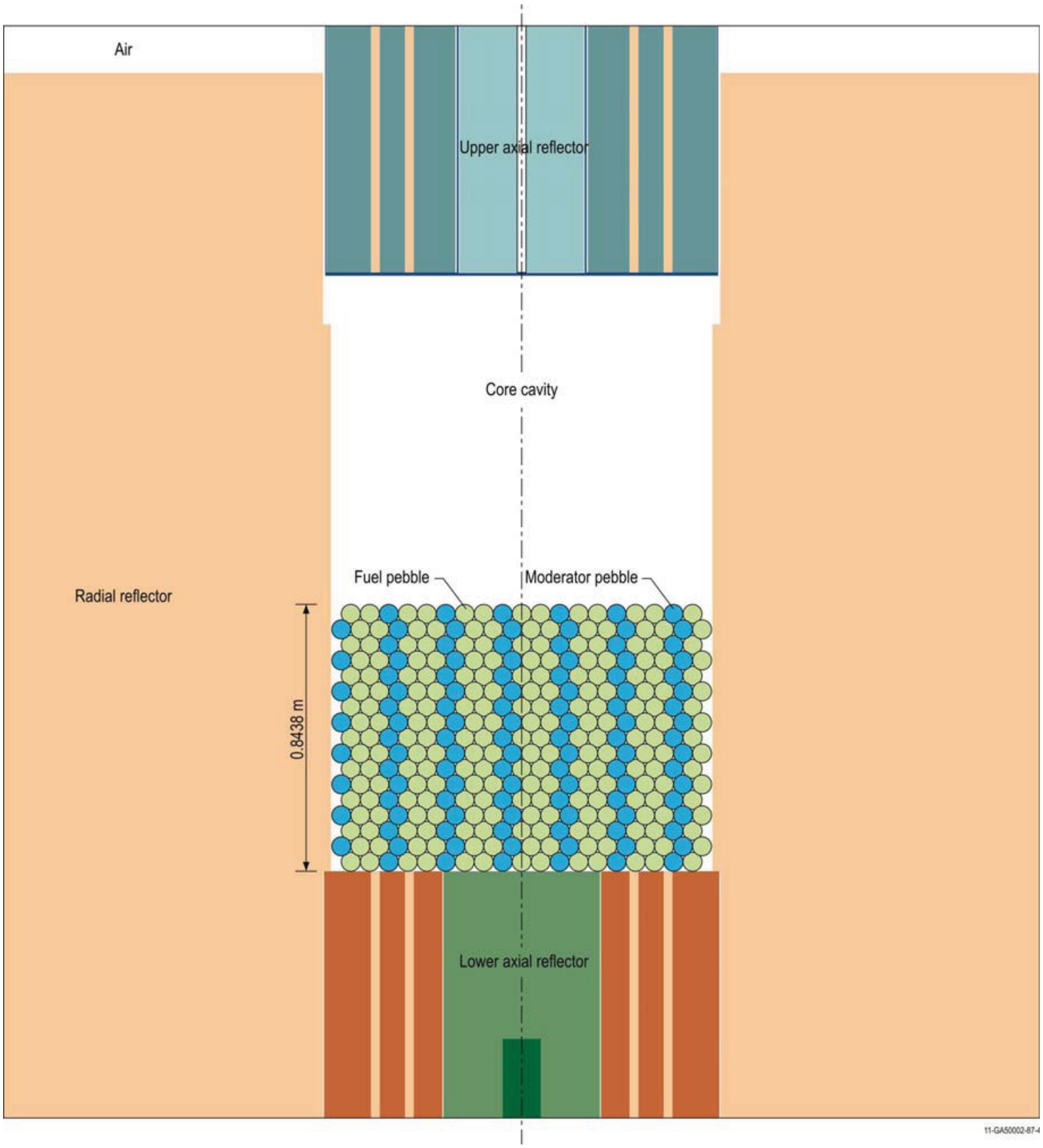

Figure 3.1-23. Vertical Profile of Case 4 (Core 3).

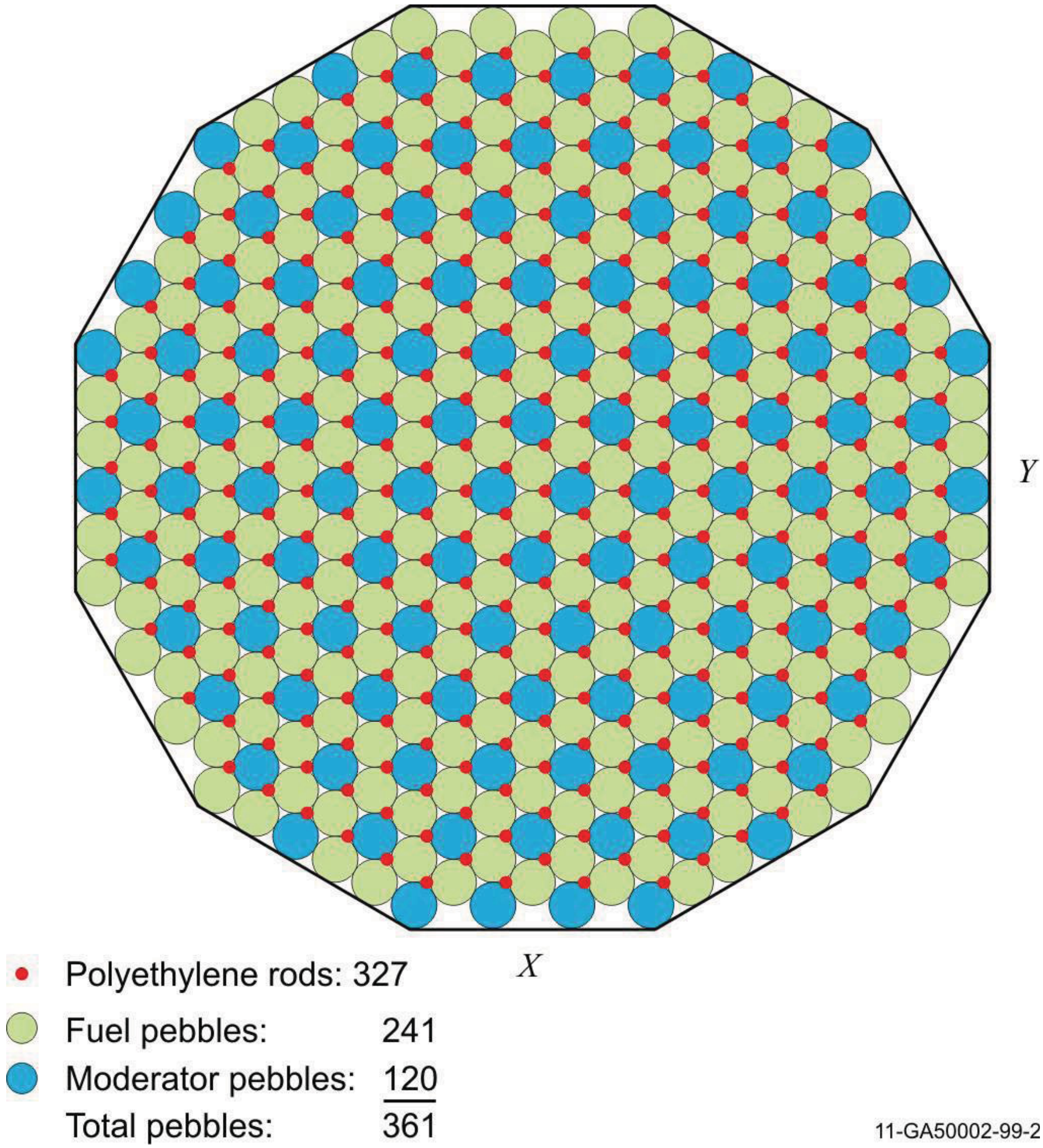

Figure 3.1-24. Odd Fueled Layers (1, 3, 5, 7, etc.) of Case 4 (Core 3).

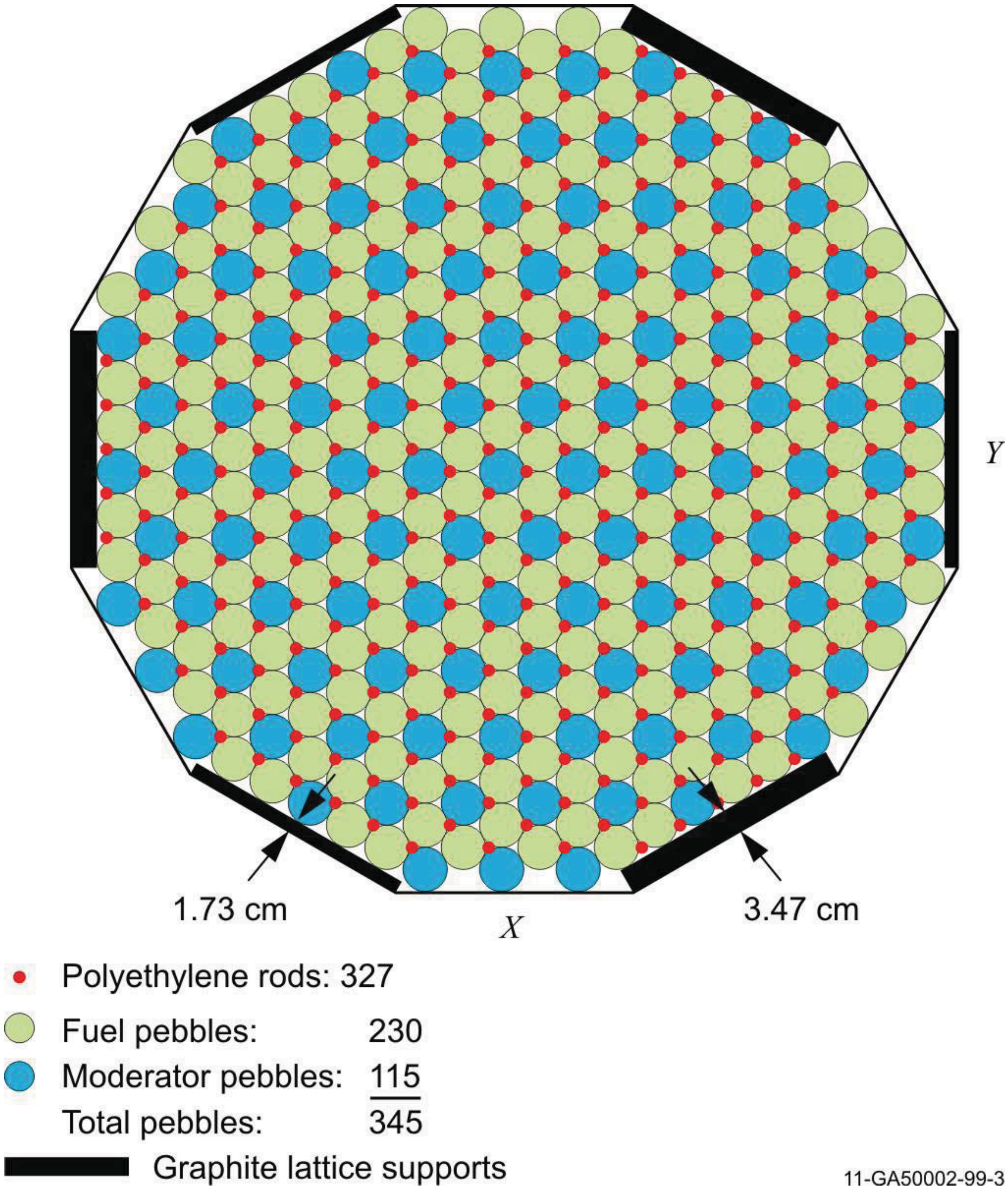

Figure 3.1-25. Even Fueled Layers (2, 4, 6, 8, etc.) of Case 4 (Core 3).

3.1.3 Material Data

3.1.3.1 Radial Reflector

The homogenized (see Section 3.1.1.1) graphite radial reflector has the one of two compositions (Table 3.1-12) depending on whether ZEBRA or withdrawable control rods were used in the assembly. Case 1 (Core 1) used the larger-diameter ZEBRA rod positions with the graphite plugs of the withdrawable control rod positions homogenized into the radial reflector. Cases 2 through 4 (Cores 1A, 2, and 3) used withdrawable control rods with the graphite plugs placed in the ZEBRA rod positions homogenized into the radial reflector (see Section 3.1.1.1). 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 3.1-12. Radial Reflector Graphite Composition.

Case (Core)	1 (1)	2, 3, and 4 (1A, 2, and 3)
Isotope/Element	**Atoms/barn-cm**	**Atoms/barn-cm**
^{10}B	2.3241E-08	2.3253E-08
^{11}B	9.3546E-08	9.3597E-08
C	8.7809E-02	8.7857E-02
Total	8.7809E-02	8.7857E-02
Mass Density (g/cm^3)	1.751304	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 3.1-13). The support structure into which the graphite material is placed is Peraluman-300 (Table 3.1-14).

Table 3.1-13. 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 3.1-14. 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 3.1-15).

Table 3.1-15. 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 3.1-16) within an aluminum guide tube (Table 3.1-17).

Table 3.1-16. 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 3.1-17. 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 3.1-18. The compositions of the additional SiC and graphite layers surrounding the kernel to form the TRISO particle are in Table 3.1-19. 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 3.1-20.

Table 3.1-18. 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 3.1-19. 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 3.1-20. 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 3.1-21.

Table 3.1-21. 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 Lattice Supports

The composition of the graphite lattice supports is in Table 3.1-22.

Table 3.1-22. Lattice Support Graphite Composition.

Isotope/Element	Atoms/barn-cm
^{10}B	2.3130E-08
^{11}B	9.3099E-08
C	8.7390E-02
Total	8.7390E-02
Mass Density (g/cm^3)	1.742939

3.1.3.8 ZEBRA Control Rods

The ZEBRA control rods consist of cadmium sheaths (Table 3.1-23) affixed to aluminum tubes (Table 3.1-24).

Table 3.1-23. ZEBRA Rod Cadmium (Type 5N) Sheath Composition.

Element	Atoms/barn-cm
Cd	4.6340E-02
Cu	4.0987E-09
Fe	9.3278E-09
Pb	5.0281E-08
Mg	6.4297E-07
Al	3.8612E-08
Si	3.7095E-08
Ag	2.4146E-09
Ti	2.1765E-08
Bi	7.4779E-08
Ca	1.2997E-08
Total	4.6340E-02
Mass Density (g/cm^3)	8.65

Table 3.1-24. ZEBRA Rod Peraluman R-257 Tube Composition.

Isotope/Element	Atoms/barn-cm
^{10}B	1.4688E-07
^{11}B	5.9119E-07
Mg	9.1923E-04
Al	5.8004E-02
Si	1.1364E-04
Mn	1.4524E-06
Fe	5.7153E-05
Cu	5.0227E-06
Zn	2.4398E-05
Ga	1.1444E-06
Cd	7.0983E-08
Total	5.9127E-02
Mass Density (g/cm^3)	2.65

3.1.3.9 Withdrawable Control Rods

The withdrawable control rods consist of an inner stainless steel tube (Table 3.1-25) held within an outer stainless steel tube with end plugs (Table 3.1-26).

Table 3.1-25. 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 3.1-26. 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

3.1.3.10 Polyethylene Rods

The composition of the polyethylene (sometimes referred to as plastic) rods is in Table 3.1-27.

Table 3.1-27. Polyethylene Rod Composition.

Isotope/Element	Atoms/barn-cm
^{10}B	5.2270E-09
^{11}B	2.1039E-08
H	8.2017E-02
C	4.0402E-02
Total	1.2242E-01
Mass Density (g/cm^3)	0.94307

3.1.3.11 Ambient Air

The composition of the ambient air is in Table 3.1-28. The air has a temperature of 293 K, pressure of 980 mbar, and 50 % humidity.

Table 3.1-28. 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 2.1.22 for each of the four 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 3.1-29 for each of the four cases. The uncertainty in the benchmark k_{eff} value is obtained by summing under quadrature the total experimental uncertainty (Tables 2.1-172 through 2.1-175) and the total bias uncertainty (Table 3.1-6).

Table 3.1-29. Experimental and Benchmark Eigenvalues, Biases, and Uncertainties.

		Experimental			**Bias**			**Benchmark**		
Case	**Core**	**k_{eff}**	**±**	**σ**	**Δk**	**±**	**σ**	**k_{eff}**	**±**	**σ**
1	1	1.0000	±	0.0030	0.0048	±	0.0002	1.0048	±	0.0030
2	1A	1.0000	±	0.0031	0.0034	±	0.0002	1.0034	±	0.0031
3	2	1.0000	±	0.0033	0.0029	±	0.0002	1.0029	±	0.0033
4	3	1.0000	±	0.0033	-0.0001	±	0.0005	0.9999	±	0.0033

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

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

3.3 Benchmark-Model Specifications for Spectral Characteristics Measurements

Spectral characteristics measurements were not made.

3.4 Benchmark-Model Specifications for Reactivity Effects Measurements

Reactivity effects measurements were made but have not yet been evaluated.

3.5 Benchmark-Model Specifications for Reactivity Coefficient Measurements

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

3.6 Benchmark-Model Specifications for Kinetics Measurements

Kinetics measurements were made but have not yet been evaluated.

3.7 Benchmark-Model Specifications for Reaction-Rate Distribution Measurements

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

3.8 Benchmark-Model Specifications for Power Distribution Measurements

Power distribution measurements were not made.

3.9 Benchmark-Model Specifications for Isotopic Measurements

Isotopic measurements were not made.

3.10 Benchmark-Model Specifications for Other Miscellaneous Types of Measurements

Other miscellaneous types of measurements were not made.

4.0 RESULTS OF SAMPLE CALCULATIONS

4.1 Results of Calculations of the Critical or Subcritical Configurations

The benchmark models described in Section 3 were modeled using 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).[a]

Monte Carlo calculations were performed with 1,650 generations with 50,000 neutrons per generation. The k_{eff} estimates are based on 150 skipped generations and a total of 75,000,000 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 3σ uncertainty. Models developed by Difilippo using MCNP4C with ENDF/B-VI (DLC-189) neutron cross sections produced calculation biases of +110, +280, +560, and +350 pcm for Cases 1 through 4, respectively, with a statistical uncertainty of ~80 pcm.[b] There is no known significant difference between the benchmark models described in Section 3 and the models developed by Difilippo. 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 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 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-002, -003, and -004). 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.[g]

---

[a] Uner, C. and Seker, V., "Monte Carlo Criticality Calculations for a Pebble Bed Reactor with MCNP," *Nucl. Sci. Eng.*, **149**, 131-137 (2005).
[b] Difilippo, F. C., "Monte Carlo Calculations of Pebble Bed Benchmark Configurations of the PROTEUS Facility," *Nucl. Sci. Eng.*, **143**, 240-253 (2003).
[c] Z. Zibi and F. Albornoz, "Validating the MCNP Modelling of the ASTRA Critical Facility," *Proc. HTR 2010*, Prague, Czech Republic, October 18-20, 2010.
[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).
[e] K. Yamashita, et al., "Startup Core Physics Tests of High Temperature Engineering Test Reactor (HTTR), (I)," *J. At. Energy Soc. Jpn.*, **42**, pp. 30-42 (2000) [in Japanese].
[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.

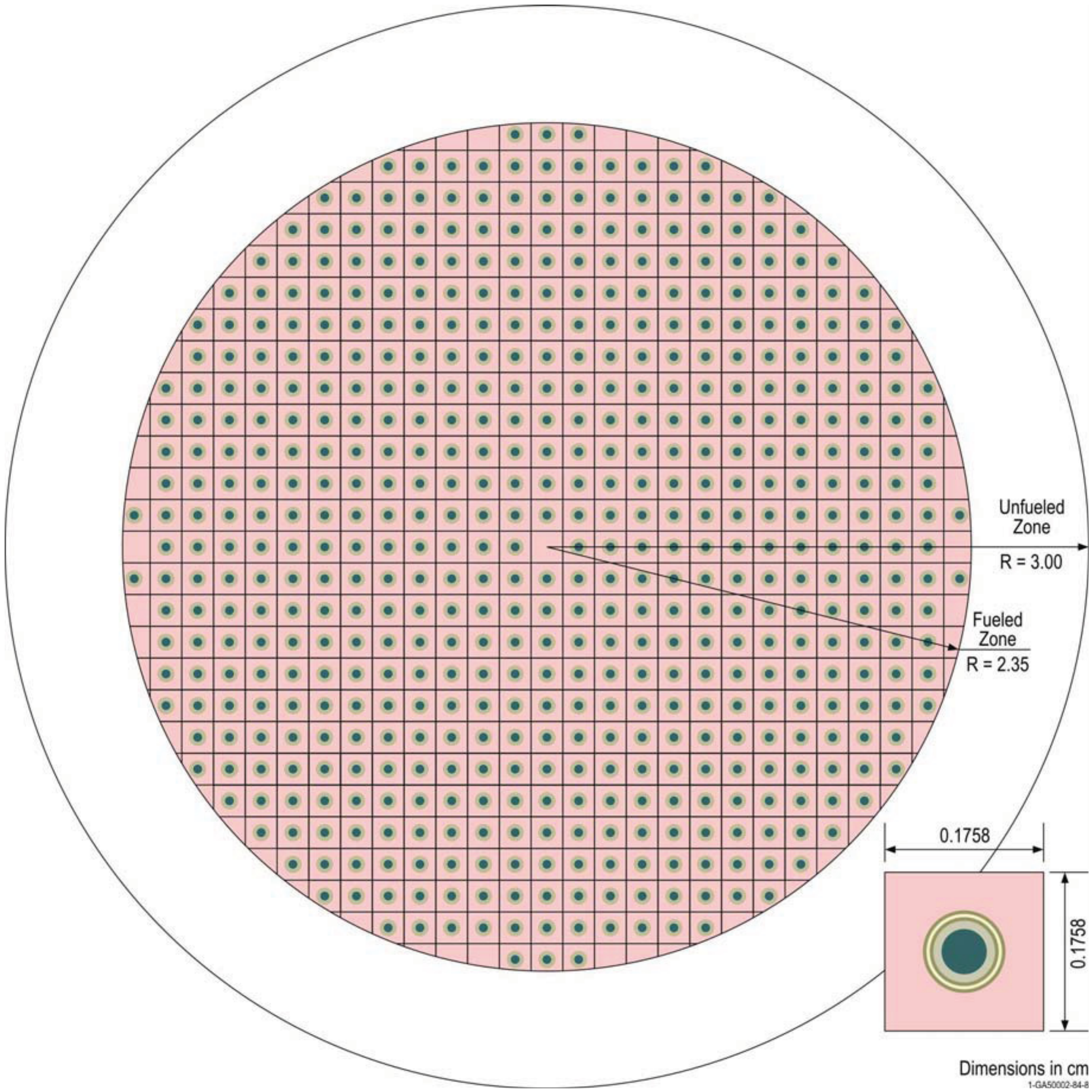

Figure 4.1-1. Regular TRISO Lattice Used in MCNP Calculations of the Benchmark Models.

Table 4.1-1. Comparison of Benchmark Eigenvalues.

Case	Core	Neutron Cross Section Library	Calculated (MCNP5)			Benchmark			$\frac{C-E}{E}(\%)$	Difference (pcm)
			k_{eff}	±	σ	k_{eff}	±	σ		
1	1	ENDF/B-VII.0	1.01061	±	0.00007	1.0048	±	0.0030	0.58	581
2	1A		1.00945	±	0.00007	1.0034	±	0.0031	0.60	605
3	2		1.01044	±	0.00007	1.0029	±	0.0033	0.75	754
4	3		1.00888	±	0.00007	0.9999	±	0.0033	0.90	898

4.2 Results of Buckling and Extrapolation Length Calculations

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

4.3 Results of Spectral-Characteristics Calculations

Spectral characteristics measurements were not made.

4.4 Results of Reactivity-Effects Calculations

Reactivity effects measurements were made but have not yet been evaluated.

4.5 Results of Reactivity Coefficient Calculations

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

4.6 Results of Kinetics Parameter Calculations

Kinetics measurements were made but have not yet been evaluated.

4.7 Results of Reaction-Rate Distribution Calculations

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

4.8 Results of Power Distribution Calculations

Power distribution measurements were not made.

4.9 Results of Isotopic Calculations

Isotopic measurements were not made.

4.10 Results of Calculations for Other Miscellaneous Types of Measurements

Other miscellaneous types of measurements were not made.

5.0 REFERENCES

1. Williams, T., "LEU-HTR PROTEUS: Configuration Descriptions and Critical Balances for the Cores of the HTR-PROTEUS Experimental Programme," TM-41-95-18, v. 1.00, Paul Sherrer Institut, Villigen, November 25, 1996.
2. Mathews, D. and Williams, T., "LEU-HTR PROTEUS System Component Description," TM-41-93-43, v. 2.0, Paul Scherrer Institut, Villigen, November 25, 1996.
3. Williams, T., Rosselet, M., and Scherer, W. (editors), "Critical Experiments and Reactor Physics Calculations for Low-Enriched High Temperature Gas Cooled Reactors," IAEA-TECDOC-1249, International Atomic Energy Agency, Vienna (2001).
4. Williams, T., "HTR PROTEUS CORE 1: Reactivity Corrections for the Critical Balance," TM-41-93-20, Paul Scherrer Institut, Villigen, October 7, 1993.

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.0a 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 = 50,000/1,650/150 continuous-energy cross sections

A.1.7 Other assumptions and characteristics.

Not applicable.

A.1.8 Typical input listings for each code system type.

MCNP5 Input Deck for Case 1 (Core 1):

```
HTR-PROTEUS :: Core 1
c Pebble Bed Experimental Program
c Hexagonal Close Packing with a 1:2 Moderator to Fuel Pebble Ratio
c
c John Darrell Bess - Idaho National Laboratory
c Last Updated: July 23, 2012
c
c Cell Cards *******************************************************************
```

[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).

```
c ------ Air Above Reflector ------
5    10 4.8492E-05  32 -1202 33 -34
          (1101 1102 1103 1104 1105 1106 1107 1108)
          (1109 1110 1111 1112 1113) impend=1
c
c ------ Radial Reflector ------
11   3 8.7809E-02  (33 -34 31 -32
          (1101 1102 1103 1104 1105 1106 1107 1108)
          (1109 1110 1111 1112 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 ------ ZEBRA Control Rod Holes ------
1109 0  -1109 31 -1202 imp:n=1 fill=13 ( 21.84  86.93 0)  $ Rod 1 (Core 1)
1110 0  -1110 31 -1202 imp:n=1 fill=14 ( 86.93 -21.84 0)  $ Rod 2 (Core 1)
1111 0  -1111 31 -1202 imp:n=1 fill=15 (-21.84 -86.93 0)  $ Rod 3 (Core 1)
1112 0  -1112 31 -1202 imp:n=1 fill=16 (-86.93  21.84 0)  $ Rod 4 (Core 1)
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
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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
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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
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
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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 ---------
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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       -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       -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       -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       -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       -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       -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       -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       -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       -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       -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       -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
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       -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
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2105 10 4.8492E-05       -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       -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       -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       -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       -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       -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       -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       -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       -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       -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       -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       -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       -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       -2310 31 -1811 imp:n=1  $ Position 10
2311 10 4.8492E-05  2811 -2311 31 -1811 imp:n=1  $ Position 11
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2312 10 4.8492E-05  2812 -2312 31 -1811 imp:n=1  $ Position 12
2313 10 4.8492E-05       -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       -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       -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       -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       -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       -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       -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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ Position 27
2428 29 8.8245E-02  -2428 31 -1811 imp:n=1  $ Position 28
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
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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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ Position 26
2627 29 8.8245E-02  -2627 31 -1811 imp:n=1  $ Position 27
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
```

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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 ---------
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ Position 25
2826 29 8.8245E-02  -2826 31 -1811 imp:n=1  $ Position 26
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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=41.8 for Core 1            **************************
c ******                     z=13.0 for Core 1A,          **************************
c ******                     z=31.6 for Core 2, &         **************************
c ******                     z=68.5 for Core 3,           **************************
c
3033 0    -3036 imp:n=1 u=11 fill=10 (0 0 41.8)
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 ------ ZEBRA Rods ------
c --------- Inner (Moveable) Sleeve ---------
3041 10 4.8492E-05  -3075:-3061:3074 imp:n=1 u=12  $ Air
3042 16 5.9127E-02  3075 -3076 3061 -3074 imp:n=1 u=12  $ Inner Tube
3043 15 4.6340E-02  3076 -3077 3062 -3063 imp:n=1 u=12  $ Cadmium Sheath 1
3044 15 4.6340E-02  3076 -3077 3064 -3065 imp:n=1 u=12  $ Cadmium Sheath 2
3045 15 4.6340E-02  3076 -3077 3066 -3067 imp:n=1 u=12  $ Cadmium Sheath 3
3046 15 4.6340E-02  3076 -3077 3068 -3069 imp:n=1 u=12  $ Cadmium Sheath 4
3047 15 4.6340E-02  3076 -3077 3070 -3071 imp:n=1 u=12  $ Cadmium Sheath 5
3048 15 4.6340E-02  3076 -3077 3072 -3073 imp:n=1 u=12  $ Cadmium Sheath 6
3049 10 4.8492E-05  3061 -3074 3076
          (-3062:3063:3077) (-3064:3065:3077) (-3066:3067:3077)
          (-3068:3069:3077) (-3070:3071:3077) (-3072:3073:3077)
          imp:n=1 u=12  $ Air
c
c ****** ZEBRA Rods Fully Inserted @ z=0 and Withdrawn @ z=20 ************************
c ****** ZEBRA Rods Withdrawn to z=14.8 for Core 1           ************************
```

```
c ****** ZEBRA Rods Not Utilized in Cores 1A, 2, & 3         ************************
c
c --------- Rod 1 ---------
3051 0    -3054:-31:3053 imp:n=1 u=13 fill=12 (0 0 14.8)
3052 16 5.9127E-02  3054 -3055 31 -3053 imp:n=1 u=13    $ Outer Tube
3053 15 4.6340E-02  3055 -3056 3041 -3042 imp:n=1 u=13  $ Cadmium Sheath 1
3054 15 4.6340E-02  3055 -3056 3043 -3044 imp:n=1 u=13  $ Cadmium Sheath 2
3055 15 4.6340E-02  3055 -3056 3045 -3046 imp:n=1 u=13  $ Cadmium Sheath 3
3056 15 4.6340E-02  3055 -3056 3047 -3048 imp:n=1 u=13  $ Cadmium Sheath 4
3057 15 4.6340E-02  3055 -3056 3049 -3050 imp:n=1 u=13  $ Cadmium Sheath 5
3058 15 4.6340E-02  3055 -3056 3051 -3052 imp:n=1 u=13  $ Cadmium Sheath 6
3059 10 4.8492E-05  31 -3053 3055
          (-3041:3042:3056) (-3043:3044:3056) (-3045:3046:3056)
          (-3047:3048:3056) (-3049:3050:3056) (-3051:3052:3056)
          imp:n=1 u=13  $ Air
c
c --------- Rod 2 ---------
3061 0    -3054:-31:3053 imp:n=1 u=14 fill=12 (0 0 14.8)
3062 16 5.9127E-02  3054 -3055 31 -3053 imp:n=1 u=14    $ Outer Tube
3063 15 4.6340E-02  3055 -3056 3041 -3042 imp:n=1 u=14  $ Cadmium Sheath 1
3064 15 4.6340E-02  3055 -3056 3043 -3044 imp:n=1 u=14  $ Cadmium Sheath 2
3065 15 4.6340E-02  3055 -3056 3045 -3046 imp:n=1 u=14  $ Cadmium Sheath 3
3066 15 4.6340E-02  3055 -3056 3047 -3048 imp:n=1 u=14  $ Cadmium Sheath 4
3067 15 4.6340E-02  3055 -3056 3049 -3050 imp:n=1 u=14  $ Cadmium Sheath 5
3068 15 4.6340E-02  3055 -3056 3051 -3052 imp:n=1 u=14  $ Cadmium Sheath 6
3069 10 4.8492E-05  31 -3053 3055
          (-3041:3042:3056) (-3043:3044:3056) (-3045:3046:3056)
          (-3047:3048:3056) (-3049:3050:3056) (-3051:3052:3056)
          imp:n=1 u=14  $ Air
c
c --------- Rod 3 ---------
3071 0    -3054:-31:3053 imp:n=1 u=15 fill=12 (0 0 14.8)
3072 16 5.9127E-02  3054 -3055 31 -3053 imp:n=1 u=15    $ Outer Tube
3073 15 4.6340E-02  3055 -3056 3041 -3042 imp:n=1 u=15  $ Cadmium Sheath 1
3074 15 4.6340E-02  3055 -3056 3043 -3044 imp:n=1 u=15  $ Cadmium Sheath 2
3075 15 4.6340E-02  3055 -3056 3045 -3046 imp:n=1 u=15  $ Cadmium Sheath 3
3076 15 4.6340E-02  3055 -3056 3047 -3048 imp:n=1 u=15  $ Cadmium Sheath 4
3077 15 4.6340E-02  3055 -3056 3049 -3050 imp:n=1 u=15  $ Cadmium Sheath 5
3078 15 4.6340E-02  3055 -3056 3051 -3052 imp:n=1 u=15  $ Cadmium Sheath 6
3079 10 4.8492E-05  31 -3053 3055
          (-3041:3042:3056) (-3043:3044:3056) (-3045:3046:3056)
          (-3047:3048:3056) (-3049:3050:3056) (-3051:3052:3056)
          imp:n=1 u=15  $ Air
c
c --------- Rod 4 ---------
3081 0    -3054:-31:3053 imp:n=1 u=16 fill=12 (0 0 14.8)
3082 16 5.9127E-02  3054 -3055 31 -3053 imp:n=1 u=16    $ Outer Tube
3083 15 4.6340E-02  3055 -3056 3041 -3042 imp:n=1 u=16  $ Cadmium Sheath 1
3084 15 4.6340E-02  3055 -3056 3043 -3044 imp:n=1 u=16  $ Cadmium Sheath 2
3085 15 4.6340E-02  3055 -3056 3045 -3046 imp:n=1 u=16  $ Cadmium Sheath 3
3086 15 4.6340E-02  3055 -3056 3047 -3048 imp:n=1 u=16  $ Cadmium Sheath 4
3087 15 4.6340E-02  3055 -3056 3049 -3050 imp:n=1 u=16  $ Cadmium Sheath 5
3088 15 4.6340E-02  3055 -3056 3051 -3052 imp:n=1 u=16  $ Cadmium Sheath 6
3089 10 4.8492E-05  31 -3053 3055
          (-3041:3042:3056) (-3043:3044:3056) (-3045:3046:3056)
          (-3047:3048:3056) (-3049:3050:3056) (-3051:3052:3056)
          imp:n=1 u=16  $ Air
c
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
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     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
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     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
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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
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     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 86r
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
     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 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 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
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     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
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     23 10r 22 6r 23 10r
     23 8r 22 10r 23 8r
     23 6r 22 14r 23 6r
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     23 8r 22 10r 23 8r
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     23 144r
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     23 9r 22 8r 23 9r
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     23 8r 22 10r 23 8r
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     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
     23 9r 22 8r 23 9r
     23 8r 22 10r 23 8r
     23 8r 22 10r 23 8r
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     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 ------
c --------- Regular (Full) Lattice ---------
3131 24 8.6859E-02  -3131 imp:n=1 u=24 fill=98 (0 0 4.898979486)  $ Middle Top Fuel Zone
3132 24 8.6859E-02  3131 -3132 imp:n=1 u=24  $ Middle Top Pebble Shell
3133 24 8.6859E-02  -3133 imp:n=1 u=24 fill=98 (-5.196152423 3 4.898979486)  $ NW Top Corner Fuel
Zone
3134 24 8.6859E-02  3133 -3134 imp:n=1 u=24  $ NW Top Corner Pebble Shell
3135 24 8.6859E-02  -3135 imp:n=1 u=24 fill=98 (5.196152423 3 4.898979486)  $ NE Top Corner Fuel
Zone
3136 24 8.6859E-02  3135 -3136 imp:n=1 u=24  $ NE Top Corner Pebble Shell
3137 24 8.6859E-02  -3137 imp:n=1 u=24 fill=98 (0 -6 4.898979486)  $ S Top Corner Fuel Zone
3138 24 8.6859E-02  3137 -3138 imp:n=1 u=24  $ S Top Corner Pebble Shell
3139 24 8.6859E-02  -3139 imp:n=1 u=24 fill=98 (-1.732050808 3 0)  $ NW Middle Edge Fuel Zone
3140 24 8.6859E-02  3139 -3140 imp:n=1 u=24  $ NW Middle Edge Pebble Shell
3141 24 8.6859E-02  -3141 imp:n=1 u=24 fill=98 (3.464101615 0 0)  $ E Middle Edge Fuel Zone
3142 24 8.6859E-02  3141 -3142 imp:n=1 u=24  $ E Middle Edge Pebble Shell
3143 24 8.6859E-02  -3143 imp:n=1 u=24 fill=98 (-6.928203230 0 0)  $ W Middle Edge Fuel Zone
3144 24 8.6859E-02  3143 -3144 imp:n=1 u=24  $ W Middle Edge Pebble Shell
3145 24 8.6859E-02  -3145 imp:n=1 u=24 fill=98 (3.464101615 -6 0)  $ SE Middle Edge Fuel Zone
3146 24 8.6859E-02  3145 -3146 imp:n=1 u=24  $ SE Middle Edge Pebble Shell
3147 24 8.6859E-02  -3147 imp:n=1 u=24 fill=98 (-5.196152423 3 -4.898979486)  $ NW Bottom Corner
Fuel Zone
3148 24 8.6859E-02  3147 -3148 imp:n=1 u=24  $ NW Bottom Corner Pebble Shell
3149 24 8.6859E-02  -3149 imp:n=1 u=24 fill=98 (5.196152423 3 -4.898979486)  $ NE Bottom Corner
Fuel Zone
3150 24 8.6859E-02  3149 -3150 imp:n=1 u=24  $ NE Bottom Corner Pebble Shell
3151 24 8.6859E-02  -3151 imp:n=1 u=24 fill=98 (0 -6 -4.898979486)  $ S Bottom Corner Fuel Zone
3152 24 8.6859E-02  3151 -3152 imp:n=1 u=24  $ S Bottom Corner Pebble Shell
3153 24 8.6859E-02  -3153 imp:n=1 u=24 fill=98 (0 0 -4.898979486)  $ Middle Bottom Fuel Zone
3154 24 8.6859E-02  3153 -3154 imp:n=1 u=24  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 1 ---------
3155 like 3135 but u=25  $ NE Top Corner Fuel Zone
3156 like 3136 but u=25  $ NE Top Corner Pebble Shell
3157 like 3149 but u=25  $ NE Bottom Corner Fuel Zone
3158 like 3150 but u=25  $ NE Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 2 ---------
3159 like 3131 but u=26  $ Middle Top Fuel Zone
3160 like 3132 but u=26  $ Middle Top Pebble Shell
3161 like 3133 but u=26  $ NW Top Corner Fuel Zone
3162 like 3134 but u=26  $ NW Top Corner Pebble Shell
3163 like 3135 but u=26  $ NE Top Corner Fuel Zone
3164 like 3136 but u=26  $ NE Top Corner Pebble Shell
3165 like 3137 but u=26  $ S Top Corner Fuel Zone
3166 like 3138 but u=26  $ S Top Corner Pebble Shell
3167 like 3139 but u=26  $ NW Middle Edge Fuel Zone
3168 like 3140 but u=26  $ NW Middle Edge Pebble Shell
3169 like 3141 but u=26  $ E Middle Edge Fuel Zone
3170 like 3142 but u=26  $ E Middle Edge Pebble Shell
3171 like 3145 but u=26  $ SE Middle Edge Fuel Zone
3172 like 3146 but u=26  $ SE Middle Edge Pebble Shell
3173 like 3147 but u=26  $ NW Bottom Corner Fuel Zone
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3174 like 3148 but u=26  $ NW Bottom Corner Pebble Shell
3175 like 3149 but u=26  $ NE Bottom Corner Fuel Zone
3176 like 3150 but u=26  $ NE Bottom Corner Pebble Shell
3177 like 3151 but u=26  $ S Bottom Corner Fuel Zone
3178 like 3152 but u=26  $ S Bottom Corner Pebble Shell
3179 like 3153 but u=26  $ Middle Bottom Fuel Zone
3180 like 3154 but u=26  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 3 ---------
3181 like 3131 but u=27  $ Middle Top Fuel Zone
3182 like 3132 but u=27  $ Middle Top Pebble Shell
3183 like 3135 but u=27  $ NE Top Corner Fuel Zone
3184 like 3136 but u=27  $ NE Top Corner Pebble Shell
3185 like 3137 but u=27  $ S Top Corner Fuel Zone
3186 like 3138 but u=27  $ S Top Corner Pebble Shell
3189 like 3141 but u=27  $ E Middle Edge Fuel Zone
3190 like 3142 but u=27  $ E Middle Edge Pebble Shell
3191 like 3143 but u=27  $ W Middle Edge Fuel Zone
3192 like 3144 but u=27  $ W Middle Edge Pebble Shell
3193 like 3145 but u=27  $ SE Middle Edge Fuel Zone
3194 like 3146 but u=27  $ SE Middle Edge Pebble Shell
3195 like 3149 but u=27  $ NE Bottom Corner Fuel Zone
3196 like 3150 but u=27  $ NE Bottom Corner Pebble Shell
3197 like 3151 but u=27  $ S Bottom Corner Fuel Zone
3198 like 3152 but u=27  $ S Bottom Corner Pebble Shell
3199 like 3153 but u=27  $ Middle Bottom Fuel Zone
3200 like 3154 but u=27  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 4 ---------
c    *No Fuel Pebbles
c
c --------- Regular (Partial) Lattice 5 ---------
3201 like 3131 but u=29  $ Middle Top Fuel Zone
3202 like 3132 but u=29  $ Middle Top Pebble Shell
3203 like 3135 but u=29  $ NE Top Corner Fuel Zone
3204 like 3136 but u=29  $ NE Top Corner Pebble Shell
3205 like 3137 but u=29  $ S Top Corner Fuel Zone
3206 like 3138 but u=29  $ S Top Corner Pebble Shell
3207 like 3139 but u=29  $ NW Middle Edge Fuel Zone
3208 like 3140 but u=29  $ NW Middle Edge Pebble Shell
3209 like 3141 but u=29  $ E Middle Edge Fuel Zone
3210 like 3142 but u=29  $ E Middle Edge Pebble Shell
3211 like 3145 but u=29  $ SE Middle Edge Fuel Zone
3212 like 3146 but u=29  $ SE Middle Edge Pebble Shell
3213 like 3149 but u=29  $ NE Bottom Corner Fuel Zone
3214 like 3150 but u=29  $ NE Bottom Corner Pebble Shell
3215 like 3151 but u=29  $ S Bottom Corner Fuel Zone
3216 like 3152 but u=29  $ S Bottom Corner Pebble Shell
3217 like 3153 but u=29  $ Middle Bottom Fuel Zone
3218 like 3154 but u=29  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 6 ---------
3219 like 3145 but u=30  $ SE Middle Edge Fuel Zone
3220 like 3146 but u=30  $ SE Middle Edge Pebble Shell
c
c --------- Regular (Partial) Lattice 7 ---------
3221 like 3131 but u=31  $ Middle Top Fuel Zone
3222 like 3132 but u=31  $ Middle Top Pebble Shell
3223 like 3135 but u=31  $ NE Top Corner Fuel Zone
3224 like 3136 but u=31  $ NE Top Corner Pebble Shell
3225 like 3137 but u=31  $ S Top Corner Fuel Zone
3226 like 3138 but u=31  $ S Top Corner Pebble Shell
3227 like 3141 but u=31  $ E Middle Edge Fuel Zone
3228 like 3142 but u=31  $ E Middle Edge Pebble Shell
3229 like 3145 but u=31  $ SE Middle Edge Fuel Zone
3230 like 3146 but u=31  $ SE Middle Edge Pebble Shell
3231 like 3149 but u=31  $ NE Bottom Corner Fuel Zone
3232 like 3150 but u=31  $ NE Bottom Corner Pebble Shell
3233 like 3151 but u=31  $ S Bottom Corner Fuel Zone
3234 like 3152 but u=31  $ S Bottom Corner Pebble Shell
3235 like 3153 but u=31  $ Middle Bottom Fuel Zone
3236 like 3154 but u=31  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 8 ---------
3237 like 3137 but u=32  $ S Top Corner Fuel Zone
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3238 like 3138 but u=32  $ S Top Corner Pebble Shell
3239 like 3145 but u=32  $ SE Middle Edge Fuel Zone
3240 like 3146 but u=32  $ SE Middle Edge Pebble Shell
3241 like 3151 but u=32  $ S Bottom Corner Fuel Zone
3242 like 3152 but u=32  $ S Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 9 ---------
3243 like 3131 but u=33  $ Middle Top Fuel Zone
3244 like 3132 but u=33  $ Middle Top Pebble Shell
3245 like 3133 but u=33  $ NW Top Corner Fuel Zone
3246 like 3134 but u=33  $ NW Top Corner Pebble Shell
3247 like 3135 but u=33  $ NE Top Corner Fuel Zone
3248 like 3136 but u=33  $ NE Top Corner Pebble Shell
3249 like 3137 but u=33  $ S Top Corner Fuel Zone
3250 like 3138 but u=33  $ S Top Corner Pebble Shell
3251 like 3139 but u=33  $ NW Middle Edge Fuel Zone
3252 like 3140 but u=33  $ NW Middle Edge Pebble Shell
3253 like 3141 but u=33  $ E Middle Edge Fuel Zone
3254 like 3142 but u=33  $ E Middle Edge Pebble Shell
3255 like 3143 but u=33  $ W Middle Edge Fuel Zone
3256 like 3144 but u=33  $ W Middle Edge Pebble Shell
3257 like 3145 but u=33  $ SE Middle Edge Fuel Zone
3258 like 3146 but u=33  $ SE Middle Edge Pebble Shell
3259 like 3147 but u=33  $ NW Bottom Corner Fuel Zone
3260 like 3148 but u=33  $ NW Bottom Corner Pebble Shell
3261 like 3149 but u=33  $ NE Bottom Corner Fuel Zone
3262 like 3150 but u=33  $ NE Bottom Corner Pebble Shell
3263 like 3151 but u=33  $ S Bottom Corner Fuel Zone
3264 like 3152 but u=33  $ S Bottom Corner Pebble Shell
3265 like 3153 but u=33  $ Middle Bottom Fuel Zone
3266 like 3154 but u=33  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 10 ---------
3268 like 3137 but u=34  $ S Top Corner Fuel Zone
3269 like 3138 but u=34  $ S Top Corner Pebble Shell
3270 like 3145 but u=34  $ SE Middle Edge Fuel Zone
3271 like 3146 but u=34  $ SE Middle Edge Pebble Shell
3272 like 3151 but u=34  $ S Bottom Corner Fuel Zone
3273 like 3152 but u=34  $ S Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 11 ---------
3274 like 3137 but u=35  $ S Top Corner Fuel Zone
3275 like 3138 but u=35  $ S Top Corner Pebble Shell
3276 like 3151 but u=35  $ S Bottom Corner Fuel Zone
3277 like 3152 but u=35  $ S Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 12 ---------
3278 like 3131 but u=36  $ Middle Top Fuel Zone
3279 like 3132 but u=36  $ Middle Top Pebble Shell
3280 like 3133 but u=36  $ NW Top Corner Fuel Zone
3281 like 3134 but u=36  $ NW Top Corner Pebble Shell
3282 like 3137 but u=36  $ S Top Corner Fuel Zone
3283 like 3138 but u=36  $ S Top Corner Pebble Shell
3284 like 3143 but u=36  $ W Middle Edge Fuel Zone
3285 like 3144 but u=36  $ W Middle Edge Pebble Shell
3286 like 3145 but u=36  $ SE Middle Edge Fuel Zone
3287 like 3146 but u=36  $ SE Middle Edge Pebble Shell
3288 like 3147 but u=36  $ NW Bottom Corner Fuel Zone
3289 like 3148 but u=36  $ NW Bottom Corner Pebble Shell
3290 like 3151 but u=36  $ S Bottom Corner Fuel Zone
3291 like 3152 but u=36  $ S Bottom Corner Pebble Shell
3292 like 3153 but u=36  $ Middle Bottom Fuel Zone
3293 like 3154 but u=36  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 13 ---------
3294 like 3137 but u=37  $ S Top Corner Fuel Zone
3295 like 3138 but u=37  $ S Top Corner Pebble Shell
3296 like 3151 but u=37  $ S Bottom Corner Fuel Zone
3297 like 3152 but u=37  $ S Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 14 ---------
3298 like 3131 but u=38  $ Middle Top Fuel Zone
3299 like 3132 but u=38  $ Middle Top Pebble Shell
3300 like 3133 but u=38  $ NW Top Corner Fuel Zone
3301 like 3134 but u=38  $ NW Top Corner Pebble Shell
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3302 like 3135 but u=38  $ NE Top Corner Fuel Zone
3303 like 3136 but u=38  $ NE Top Corner Pebble Shell
3304 like 3137 but u=38  $ S Top Corner Fuel Zone
3305 like 3138 but u=38  $ S Top Corner Pebble Shell
3306 like 3139 but u=38  $ NW Middle Edge Fuel Zone
3307 like 3140 but u=38  $ NW Middle Edge Pebble Shell
3308 like 3141 but u=38  $ E Middle Edge Fuel Zone
3309 like 3142 but u=38  $ E Middle Edge Pebble Shell
3310 like 3143 but u=38  $ W Middle Edge Fuel Zone
3311 like 3144 but u=38  $ W Middle Edge Pebble Shell
3312 like 3145 but u=38  $ SE Middle Edge Fuel Zone
3313 like 3146 but u=38  $ SE Middle Edge Pebble Shell
3314 like 3147 but u=38  $ NW Bottom Corner Fuel Zone
3315 like 3148 but u=38  $ NW Bottom Corner Pebble Shell
3316 like 3149 but u=38  $ NE Bottom Corner Fuel Zone
3317 like 3150 but u=38  $ NE Bottom Corner Pebble Shell
3318 like 3151 but u=38  $ S Bottom Corner Fuel Zone
3319 like 3152 but u=38  $ S Bottom Corner Pebble Shell
3320 like 3153 but u=38  $ Middle Bottom Fuel Zone
3321 like 3154 but u=38  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 15 ---------
c    *No Fuel Pebbles
c
c --------- Regular (Partial) Lattice 16 ---------
3322 like 3131 but u=40  $ Middle Top Fuel Zone
3323 like 3132 but u=40  $ Middle Top Pebble Shell
3324 like 3133 but u=40  $ NW Top Corner Fuel Zone
3325 like 3134 but u=40  $ NW Top Corner Pebble Shell
3326 like 3137 but u=40  $ S Top Corner Fuel Zone
3327 like 3138 but u=40  $ S Top Corner Pebble Shell
3328 like 3139 but u=40  $ NW Middle Edge Fuel Zone
3329 like 3140 but u=40  $ NW Middle Edge Pebble Shell
3330 like 3141 but u=40  $ E Middle Edge Fuel Zone
3331 like 3142 but u=40  $ E Middle Edge Pebble Shell
3332 like 3143 but u=40  $ W Middle Edge Fuel Zone
3333 like 3144 but u=40  $ W Middle Edge Pebble Shell
3334 like 3145 but u=40  $ SE Middle Edge Fuel Zone
3335 like 3146 but u=40  $ SE Middle Edge Pebble Shell
3336 like 3147 but u=40  $ NW Bottom Corner Fuel Zone
3337 like 3148 but u=40  $ NW Bottom Corner Pebble Shell
3338 like 3151 but u=40  $ S Bottom Corner Fuel Zone
3339 like 3152 but u=40  $ S Bottom Corner Pebble Shell
3340 like 3153 but u=40  $ Middle Bottom Fuel Zone
3341 like 3154 but u=40  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 17 ---------
3342 like 3143 but u=41  $ W Middle Edge Fuel Zone
3343 like 3144 but u=41  $ W Middle Edge Pebble Shell
c
c --------- Regular (Partial) Lattice 18 ---------
3344 like 3131 but u=42  $ Middle Top Fuel Zone
3345 like 3132 but u=42  $ Middle Top Pebble Shell
3346 like 3133 but u=42  $ NW Top Corner Fuel Zone
3347 like 3134 but u=42  $ NW Top Corner Pebble Shell
3348 like 3137 but u=42  $ S Top Corner Fuel Zone
3349 like 3138 but u=42  $ S Top Corner Pebble Shell
3350 like 3139 but u=42  $ NW Middle Edge Fuel Zone
3351 like 3140 but u=42  $ NW Middle Edge Pebble Shell
3352 like 3143 but u=42  $ W Middle Edge Fuel Zone
3353 like 3144 but u=42  $ W Middle Edge Pebble Shell
3354 like 3147 but u=42  $ NW Bottom Corner Fuel Zone
3355 like 3148 but u=42  $ NW Bottom Corner Pebble Shell
3356 like 3151 but u=42  $ S Bottom Corner Fuel Zone
3357 like 3152 but u=42  $ S Bottom Corner Pebble Shell
3358 like 3153 but u=42  $ Middle Bottom Fuel Zone
3359 like 3154 but u=42  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 19 ---------
3360 like 3133 but u=43  $ NW Top Corner Fuel Zone
3361 like 3134 but u=43  $ NW Top Corner Pebble Shell
3362 like 3143 but u=43  $ W Middle Edge Fuel Zone
3363 like 3144 but u=43  $ W Middle Edge Pebble Shell
3364 like 3147 but u=43  $ NW Bottom Corner Fuel Zone
3365 like 3148 but u=43  $ NW Bottom Corner Pebble Shell
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c
c --------- Regular (Partial) Lattice 20 ---------
3366 like 3133 but u=44  $ NW Top Corner Fuel Zone
3367 like 3134 but u=44  $ NW Top Corner Pebble Shell
3368 like 3143 but u=44  $ W Middle Edge Fuel Zone
3369 like 3144 but u=44  $ W Middle Edge Pebble Shell
3370 like 3147 but u=44  $ NW Bottom Corner Fuel Zone
3371 like 3148 but u=44  $ NW Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 21 ---------
3372 like 3131 but u=45  $ Middle Top Fuel Zone
3373 like 3132 but u=45  $ Middle Top Pebble Shell
3374 like 3133 but u=45  $ NW Top Corner Fuel Zone
3375 like 3134 but u=45  $ NW Top Corner Pebble Shell
3376 like 3135 but u=45  $ NE Top Corner Fuel Zone
3377 like 3136 but u=45  $ NE Top Corner Pebble Shell
3378 like 3137 but u=45  $ S Top Corner Fuel Zone
3379 like 3138 but u=45  $ S Top Corner Pebble Shell
3380 like 3139 but u=45  $ NW Middle Edge Fuel Zone
3381 like 3140 but u=45  $ NW Middle Edge Pebble Shell
3382 like 3141 but u=45  $ E Middle Edge Fuel Zone
3383 like 3142 but u=45  $ E Middle Edge Pebble Shell
3384 like 3143 but u=45  $ W Middle Edge Fuel Zone
3385 like 3144 but u=45  $ W Middle Edge Pebble Shell
3386 like 3147 but u=45  $ NW Bottom Corner Fuel Zone
3387 like 3148 but u=45  $ NW Bottom Corner Pebble Shell
3388 like 3149 but u=45  $ NE Bottom Corner Fuel Zone
3389 like 3150 but u=45  $ NE Bottom Corner Pebble Shell
3390 like 3151 but u=45  $ S Bottom Corner Fuel Zone
3391 like 3152 but u=45  $ S Bottom Corner Pebble Shell
3392 like 3153 but u=45  $ Middle Bottom Fuel Zone
3393 like 3154 but u=45  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 22 ---------
3394 like 3133 but u=46  $ NW Top Corner Fuel Zone
3395 like 3134 but u=46  $ NW Top Corner Pebble Shell
3396 like 3147 but u=46  $ NW Bottom Corner Fuel Zone
3397 like 3148 but u=46  $ NW Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 23 ---------
3398 like 3131 but u=47  $ Middle Top Fuel Zone
3399 like 3132 but u=47  $ Middle Top Pebble Shell
3400 like 3133 but u=47  $ NW Top Corner Fuel Zone
3401 like 3134 but u=47  $ NW Top Corner Pebble Shell
3402 like 3135 but u=47  $ NE Top Corner Fuel Zone
3403 like 3136 but u=47  $ NE Top Corner Pebble Shell
3404 like 3139 but u=47  $ NW Middle Edge Fuel Zone
3405 like 3140 but u=47  $ NW Middle Edge Pebble Shell
3406 like 3143 but u=47  $ W Middle Edge Fuel Zone
3407 like 3144 but u=47  $ W Middle Edge Pebble Shell
3408 like 3147 but u=47  $ NW Bottom Corner Fuel Zone
3409 like 3148 but u=47  $ NW Bottom Corner Pebble Shell
3410 like 3149 but u=47  $ NE Bottom Corner Fuel Zone
3411 like 3150 but u=47  $ NE Bottom Corner Pebble Shell
3412 like 3153 but u=47  $ Middle Bottom Fuel Zone
3413 like 3154 but u=47  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 24 ---------
3414 like 3131 but u=48  $ Middle Top Fuel Zone
3415 like 3132 but u=48  $ Middle Top Pebble Shell
3416 like 3133 but u=48  $ NW Top Corner Fuel Zone
3417 like 3134 but u=48  $ NW Top Corner Pebble Shell
3418 like 3135 but u=48  $ NE Top Corner Fuel Zone
3419 like 3136 but u=48  $ NE Top Corner Pebble Shell
3420 like 3137 but u=48  $ S Top Corner Fuel Zone
3421 like 3138 but u=48  $ S Top Corner Pebble Shell
3422 like 3139 but u=48  $ NW Middle Edge Fuel Zone
3423 like 3140 but u=48  $ NW Middle Edge Pebble Shell
3424 like 3141 but u=48  $ E Middle Edge Fuel Zone
3425 like 3142 but u=48  $ E Middle Edge Pebble Shell
3426 like 3143 but u=48  $ W Middle Edge Fuel Zone
3427 like 3144 but u=48  $ W Middle Edge Pebble Shell
3428 like 3147 but u=48  $ NW Bottom Corner Fuel Zone
3429 like 3148 but u=48  $ NW Bottom Corner Pebble Shell
3430 like 3149 but u=48  $ NE Bottom Corner Fuel Zone
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3431 like 3150 but u=48  $ NE Bottom Corner Pebble Shell
3432 like 3151 but u=48  $ S Bottom Corner Fuel Zone
3433 like 3152 but u=48  $ S Bottom Corner Pebble Shell
3434 like 3153 but u=48  $ Middle Bottom Fuel Zone
3435 like 3154 but u=48  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 25 ---------
3436 like 3133 but u=49  $ NW Top Corner Fuel Zone
3437 like 3134 but u=49  $ NW Top Corner Pebble Shell
3438 like 3147 but u=49  $ NW Bottom Corner Fuel Zone
3439 like 3148 but u=49  $ NW Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 26 ---------
c    *No Fuel Pebbles
c
c --------- Regular (Partial) Lattice 27 ---------
c    *No Fuel Pebbles
c
c --------- Regular (Partial) Lattice 28 ---------
3440 like 3131 but u=52  $ Middle Top Fuel Zone
3441 like 3132 but u=52  $ Middle Top Pebble Shell
3442 like 3133 but u=52  $ NW Top Corner Fuel Zone
3443 like 3134 but u=52  $ NW Top Corner Pebble Shell
3444 like 3135 but u=52  $ NE Top Corner Fuel Zone
3445 like 3136 but u=52  $ NE Top Corner Pebble Shell
3446 like 3139 but u=52  $ NW Middle Edge Fuel Zone
3447 like 3140 but u=52  $ NW Middle Edge Pebble Shell
3448 like 3141 but u=52  $ E Middle Edge Fuel Zone
3449 like 3142 but u=52  $ E Middle Edge Pebble Shell
3450 like 3143 but u=52  $ W Middle Edge Fuel Zone
3451 like 3144 but u=52  $ W Middle Edge Pebble Shell
3452 like 3147 but u=52  $ NW Bottom Corner Fuel Zone
3453 like 3148 but u=52  $ NW Bottom Corner Pebble Shell
3454 like 3149 but u=52  $ NE Bottom Corner Fuel Zone
3455 like 3150 but u=52  $ NE Bottom Corner Pebble Shell
3456 like 3153 but u=52  $ Middle Bottom Fuel Zone
3457 like 3154 but u=52  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 29 ---------
3458 like 3131 but u=53  $ Middle Top Fuel Zone
3459 like 3132 but u=53  $ Middle Top Pebble Shell
3460 like 3133 but u=53  $ NW Top Corner Fuel Zone
3461 like 3134 but u=53  $ NW Top Corner Pebble Shell
3462 like 3135 but u=53  $ NE Top Corner Fuel Zone
3463 like 3136 but u=53  $ NE Top Corner Pebble Shell
3464 like 3139 but u=53  $ NW Middle Edge Fuel Zone
3465 like 3140 but u=53  $ NW Middle Edge Pebble Shell
3466 like 3141 but u=53  $ E Middle Edge Fuel Zone
3467 like 3142 but u=53  $ E Middle Edge Pebble Shell
3468 like 3147 but u=53  $ NW Bottom Corner Fuel Zone
3469 like 3148 but u=53  $ NW Bottom Corner Pebble Shell
3470 like 3149 but u=53  $ NE Bottom Corner Fuel Zone
3471 like 3150 but u=53  $ NE Bottom Corner Pebble Shell
3472 like 3153 but u=53  $ Middle Bottom Fuel Zone
3473 like 3154 but u=53  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 30 ---------
3474 like 3135 but u=54  $ NE Top Corner Fuel Zone
3475 like 3136 but u=54  $ NE Top Corner Pebble Shell
3476 like 3149 but u=54  $ NE Bottom Corner Fuel Zone
3477 like 3150 but u=54  $ NE Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 31 ---------
3478 like 3135 but u=55  $ NE Top Corner Fuel Zone
3479 like 3136 but u=55  $ NE Top Corner Pebble Shell
3480 like 3149 but u=55  $ NE Bottom Corner Fuel Zone
3481 like 3150 but u=55  $ NE Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 32 ---------
3482 like 3131 but u=56  $ Middle Top Fuel Zone
3483 like 3132 but u=56  $ Middle Top Pebble Shell
3484 like 3133 but u=56  $ NW Top Corner Fuel Zone
3485 like 3134 but u=56  $ NW Top Corner Pebble Shell
3486 like 3135 but u=56  $ NE Top Corner Fuel Zone
3487 like 3136 but u=56  $ NE Top Corner Pebble Shell
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3488 like 3137 but u=56  $ S Top Corner Fuel Zone
3489 like 3138 but u=56  $ S Top Corner Pebble Shell
3490 like 3139 but u=56  $ NW Middle Edge Fuel Zone
3491 like 3140 but u=56  $ NW Middle Edge Pebble Shell
3492 like 3141 but u=56  $ E Middle Edge Fuel Zone
3493 like 3142 but u=56  $ E Middle Edge Pebble Shell
3494 like 3145 but u=56  $ SE Middle Edge Fuel Zone
3495 like 3146 but u=56  $ SE Middle Edge Pebble Shell
3496 like 3147 but u=56  $ NW Bottom Corner Fuel Zone
3497 like 3148 but u=56  $ NW Bottom Corner Pebble Shell
3498 like 3149 but u=56  $ NE Bottom Corner Fuel Zone
3499 like 3150 but u=56  $ NE Bottom Corner Pebble Shell
3500 like 3151 but u=56  $ S Bottom Corner Fuel Zone
3501 like 3152 but u=56  $ S Bottom Corner Pebble Shell
3502 like 3153 but u=56  $ Middle Bottom Fuel Zone
3503 like 3154 but u=56  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 33 ---------
3504 like 3135 but u=57  $ NE Top Corner Fuel Zone
3505 like 3136 but u=57  $ NE Top Corner Pebble Shell
3506 like 3149 but u=57  $ NE Bottom Corner Fuel Zone
3507 like 3150 but u=57  $ NE Bottom Corner Pebble Shell
c
c --------- Bottom and Middle Layers Only Lattices ---------
3650 like 3139 but u=224  $ NW Middle Edge Fuel Zone
3651 like 3140 but u=224  $ NW Middle Edge Pebble Shell
3652 like 3141 but u=224  $ E Middle Edge Fuel Zone
3653 like 3142 but u=224  $ E Middle Edge Pebble Shell
3654 like 3143 but u=224  $ W Middle Edge Fuel Zone
3655 like 3144 but u=224  $ W Middle Edge Pebble Shell
3656 like 3145 but u=224  $ SE Middle Edge Fuel Zone
3657 like 3146 but u=224  $ SE Middle Edge Pebble Shell
3658 like 3147 but u=224  $ NW Bottom Corner Fuel Zone
3659 like 3148 but u=224  $ NW Bottom Corner Pebble Shell
3660 like 3149 but u=224  $ NE Bottom Corner Fuel Zone
3661 like 3150 but u=224  $ NE Bottom Corner Pebble Shell
3662 like 3151 but u=224  $ S Bottom Corner Fuel Zone
3663 like 3152 but u=224  $ S Bottom Corner Pebble Shell
3664 like 3153 but u=224  $ Middle Bottom Fuel Zone
3665 like 3154 but u=224  $ Middle Bottom Pebble Shell
3666 like 3149 but u=225  $ NE Bottom Corner Fuel Zone
3667 like 3150 but u=225  $ NE Bottom Corner Pebble Shell
3668 like 3139 but u=226  $ NW Middle Edge Fuel Zone
3669 like 3140 but u=226  $ NW Middle Edge Pebble Shell
3670 like 3141 but u=226  $ E Middle Edge Fuel Zone
3671 like 3142 but u=226  $ E Middle Edge Pebble Shell
3672 like 3145 but u=226  $ SE Middle Edge Fuel Zone
3673 like 3146 but u=226  $ SE Middle Edge Pebble Shell
3674 like 3147 but u=226  $ NW Bottom Corner Fuel Zone
3675 like 3148 but u=226  $ NW Bottom Corner Pebble Shell
3676 like 3149 but u=226  $ NE Bottom Corner Fuel Zone
3677 like 3150 but u=226  $ NE Bottom Corner Pebble Shell
3678 like 3151 but u=226  $ S Bottom Corner Fuel Zone
3679 like 3152 but u=226  $ S Bottom Corner Pebble Shell
3680 like 3153 but u=226  $ Middle Bottom Fuel Zone
3681 like 3154 but u=226  $ Middle Bottom Pebble Shell
3682 like 3141 but u=227  $ E Middle Edge Fuel Zone
3683 like 3142 but u=227  $ E Middle Edge Pebble Shell
3684 like 3143 but u=227  $ W Middle Edge Fuel Zone
3685 like 3144 but u=227  $ W Middle Edge Pebble Shell
3686 like 3145 but u=227  $ SE Middle Edge Fuel Zone
3687 like 3146 but u=227  $ SE Middle Edge Pebble Shell
3688 like 3149 but u=227  $ NE Bottom Corner Fuel Zone
3689 like 3150 but u=227  $ NE Bottom Corner Pebble Shell
3690 like 3151 but u=227  $ S Bottom Corner Fuel Zone
3691 like 3152 but u=227  $ S Bottom Corner Pebble Shell
3692 like 3153 but u=227  $ Middle Bottom Fuel Zone
3693 like 3154 but u=227  $ Middle Bottom Pebble Shell
3694 like 3139 but u=229  $ NW Middle Edge Fuel Zone
3695 like 3140 but u=229  $ NW Middle Edge Pebble Shell
3696 like 3141 but u=229  $ E Middle Edge Fuel Zone
3697 like 3142 but u=229  $ E Middle Edge Pebble Shell
3698 like 3145 but u=229  $ SE Middle Edge Fuel Zone
3699 like 3146 but u=229  $ SE Middle Edge Pebble Shell
3700 like 3149 but u=229  $ NE Bottom Corner Fuel Zone
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3701 like 3150 but u=229  $ NE Bottom Corner Pebble Shell
3702 like 3151 but u=229  $ S Bottom Corner Fuel Zone
3703 like 3152 but u=229  $ S Bottom Corner Pebble Shell
3704 like 3153 but u=229  $ Middle Bottom Fuel Zone
3705 like 3154 but u=229  $ Middle Bottom Pebble Shell
3706 like 3145 but u=230  $ SE Middle Edge Fuel Zone
3707 like 3146 but u=230  $ SE Middle Edge Pebble Shell
3708 like 3141 but u=231  $ E Middle Edge Fuel Zone
3709 like 3142 but u=231  $ E Middle Edge Pebble Shell
3710 like 3145 but u=231  $ SE Middle Edge Fuel Zone
3711 like 3146 but u=231  $ SE Middle Edge Pebble Shell
3712 like 3149 but u=231  $ NE Bottom Corner Fuel Zone
3713 like 3150 but u=231  $ NE Bottom Corner Pebble Shell
3714 like 3151 but u=231  $ S Bottom Corner Fuel Zone
3715 like 3152 but u=231  $ S Bottom Corner Pebble Shell
3716 like 3153 but u=231  $ Middle Bottom Fuel Zone
3717 like 3154 but u=231  $ Middle Bottom Pebble Shell
3718 like 3145 but u=232  $ SE Middle Edge Fuel Zone
3719 like 3146 but u=232  $ SE Middle Edge Pebble Shell
3720 like 3151 but u=232  $ S Bottom Corner Fuel Zone
3721 like 3152 but u=232  $ S Bottom Corner Pebble Shell
3722 like 3139 but u=233  $ NW Middle Edge Fuel Zone
3723 like 3140 but u=233  $ NW Middle Edge Pebble Shell
3724 like 3141 but u=233  $ E Middle Edge Fuel Zone
3725 like 3142 but u=233  $ E Middle Edge Pebble Shell
3726 like 3143 but u=233  $ W Middle Edge Fuel Zone
3727 like 3144 but u=233  $ W Middle Edge Pebble Shell
3728 like 3145 but u=233  $ SE Middle Edge Fuel Zone
3729 like 3146 but u=233  $ SE Middle Edge Pebble Shell
3730 like 3147 but u=233  $ NW Bottom Corner Fuel Zone
3731 like 3148 but u=233  $ NW Bottom Corner Pebble Shell
3732 like 3149 but u=233  $ NE Bottom Corner Fuel Zone
3733 like 3150 but u=233  $ NE Bottom Corner Pebble Shell
3734 like 3151 but u=233  $ S Bottom Corner Fuel Zone
3735 like 3152 but u=233  $ S Bottom Corner Pebble Shell
3736 like 3153 but u=233  $ Middle Bottom Fuel Zone
3737 like 3154 but u=233  $ Middle Bottom Pebble Shell
3738 like 3145 but u=234  $ SE Middle Edge Fuel Zone
3739 like 3146 but u=234  $ SE Middle Edge Pebble Shell
3740 like 3151 but u=234  $ S Bottom Corner Fuel Zone
3741 like 3152 but u=234  $ S Bottom Corner Pebble Shell
3742 like 3151 but u=235  $ S Bottom Corner Fuel Zone
3743 like 3152 but u=235  $ S Bottom Corner Pebble Shell
3744 like 3143 but u=236  $ W Middle Edge Fuel Zone
3745 like 3144 but u=236  $ W Middle Edge Pebble Shell
3746 like 3145 but u=236  $ SE Middle Edge Fuel Zone
3747 like 3146 but u=236  $ SE Middle Edge Pebble Shell
3748 like 3147 but u=236  $ NW Bottom Corner Fuel Zone
3749 like 3148 but u=236  $ NW Bottom Corner Pebble Shell
3750 like 3151 but u=236  $ S Bottom Corner Fuel Zone
3751 like 3152 but u=236  $ S Bottom Corner Pebble Shell
3752 like 3153 but u=236  $ Middle Bottom Fuel Zone
3753 like 3154 but u=236  $ Middle Bottom Pebble Shell
3754 like 3151 but u=237  $ S Bottom Corner Fuel Zone
3755 like 3152 but u=237  $ S Bottom Corner Pebble Shell
3756 like 3139 but u=238  $ NW Middle Edge Fuel Zone
3757 like 3140 but u=238  $ NW Middle Edge Pebble Shell
3758 like 3141 but u=238  $ E Middle Edge Fuel Zone
3759 like 3142 but u=238  $ E Middle Edge Pebble Shell
3760 like 3143 but u=238  $ W Middle Edge Fuel Zone
3761 like 3144 but u=238  $ W Middle Edge Pebble Shell
3762 like 3145 but u=238  $ SE Middle Edge Fuel Zone
3763 like 3146 but u=238  $ SE Middle Edge Pebble Shell
3764 like 3147 but u=238  $ NW Bottom Corner Fuel Zone
3765 like 3148 but u=238  $ NW Bottom Corner Pebble Shell
3766 like 3149 but u=238  $ NE Bottom Corner Fuel Zone
3767 like 3150 but u=238  $ NE Bottom Corner Pebble Shell
3768 like 3151 but u=238  $ S Bottom Corner Fuel Zone
3769 like 3152 but u=238  $ S Bottom Corner Pebble Shell
3770 like 3153 but u=238  $ Middle Bottom Fuel Zone
3771 like 3154 but u=238  $ Middle Bottom Pebble Shell
3772 like 3139 but u=240  $ NW Middle Edge Fuel Zone
3773 like 3140 but u=240  $ NW Middle Edge Pebble Shell
3774 like 3141 but u=240  $ E Middle Edge Fuel Zone
3775 like 3142 but u=240  $ E Middle Edge Pebble Shell
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3776 like 3143 but u=240  $ W Middle Edge Fuel Zone
3777 like 3144 but u=240  $ W Middle Edge Pebble Shell
3778 like 3145 but u=240  $ SE Middle Edge Fuel Zone
3779 like 3146 but u=240  $ SE Middle Edge Pebble Shell
3780 like 3147 but u=240  $ NW Bottom Corner Fuel Zone
3781 like 3148 but u=240  $ NW Bottom Corner Pebble Shell
3782 like 3151 but u=240  $ S Bottom Corner Fuel Zone
3783 like 3152 but u=240  $ S Bottom Corner Pebble Shell
3784 like 3153 but u=240  $ Middle Bottom Fuel Zone
3785 like 3154 but u=240  $ Middle Bottom Pebble Shell
3786 like 3143 but u=241  $ W Middle Edge Fuel Zone
3787 like 3144 but u=241  $ W Middle Edge Pebble Shell
3788 like 3139 but u=242  $ NW Middle Edge Fuel Zone
3789 like 3140 but u=242  $ NW Middle Edge Pebble Shell
3790 like 3143 but u=242  $ W Middle Edge Fuel Zone
3791 like 3144 but u=242  $ W Middle Edge Pebble Shell
3792 like 3147 but u=242  $ NW Bottom Corner Fuel Zone
3793 like 3148 but u=242  $ NW Bottom Corner Pebble Shell
3794 like 3151 but u=242  $ S Bottom Corner Fuel Zone
3795 like 3152 but u=242  $ S Bottom Corner Pebble Shell
3796 like 3153 but u=242  $ Middle Bottom Fuel Zone
3797 like 3154 but u=242  $ Middle Bottom Pebble Shell
3798 like 3143 but u=243  $ W Middle Edge Fuel Zone
3799 like 3144 but u=243  $ W Middle Edge Pebble Shell
3800 like 3147 but u=243  $ NW Bottom Corner Fuel Zone
3801 like 3148 but u=243  $ NW Bottom Corner Pebble Shell
3802 like 3143 but u=244  $ W Middle Edge Fuel Zone
3803 like 3144 but u=244  $ W Middle Edge Pebble Shell
3804 like 3147 but u=244  $ NW Bottom Corner Fuel Zone
3805 like 3148 but u=244  $ NW Bottom Corner Pebble Shell
3806 like 3139 but u=245  $ NW Middle Edge Fuel Zone
3807 like 3140 but u=245  $ NW Middle Edge Pebble Shell
3808 like 3141 but u=245  $ E Middle Edge Fuel Zone
3809 like 3142 but u=245  $ E Middle Edge Pebble Shell
3810 like 3143 but u=245  $ W Middle Edge Fuel Zone
3811 like 3144 but u=245  $ W Middle Edge Pebble Shell
3812 like 3147 but u=245  $ NW Bottom Corner Fuel Zone
3813 like 3148 but u=245  $ NW Bottom Corner Pebble Shell
3814 like 3149 but u=245  $ NE Bottom Corner Fuel Zone
3815 like 3150 but u=245  $ NE Bottom Corner Pebble Shell
3816 like 3151 but u=245  $ S Bottom Corner Fuel Zone
3817 like 3152 but u=245  $ S Bottom Corner Pebble Shell
3818 like 3153 but u=245  $ Middle Bottom Fuel Zone
3819 like 3154 but u=245  $ Middle Bottom Pebble Shell
3820 like 3147 but u=246  $ NW Bottom Corner Fuel Zone
3821 like 3148 but u=246  $ NW Bottom Corner Pebble Shell
3822 like 3139 but u=247  $ NW Middle Edge Fuel Zone
3823 like 3140 but u=247  $ NW Middle Edge Pebble Shell
3824 like 3143 but u=247  $ W Middle Edge Fuel Zone
3825 like 3144 but u=247  $ W Middle Edge Pebble Shell
3826 like 3147 but u=247  $ NW Bottom Corner Fuel Zone
3827 like 3148 but u=247  $ NW Bottom Corner Pebble Shell
3828 like 3149 but u=247  $ NE Bottom Corner Fuel Zone
3829 like 3150 but u=247  $ NE Bottom Corner Pebble Shell
3830 like 3153 but u=247  $ Middle Bottom Fuel Zone
3831 like 3154 but u=247  $ Middle Bottom Pebble Shell
3832 like 3139 but u=248  $ NW Middle Edge Fuel Zone
3833 like 3140 but u=248  $ NW Middle Edge Pebble Shell
3834 like 3141 but u=248  $ E Middle Edge Fuel Zone
3835 like 3142 but u=248  $ E Middle Edge Pebble Shell
3836 like 3143 but u=248  $ W Middle Edge Fuel Zone
3837 like 3144 but u=248  $ W Middle Edge Pebble Shell
3838 like 3147 but u=248  $ NW Bottom Corner Fuel Zone
3839 like 3148 but u=248  $ NW Bottom Corner Pebble Shell
3840 like 3149 but u=248  $ NE Bottom Corner Fuel Zone
3841 like 3150 but u=248  $ NE Bottom Corner Pebble Shell
3842 like 3151 but u=248  $ S Bottom Corner Fuel Zone
3843 like 3152 but u=248  $ S Bottom Corner Pebble Shell
3844 like 3153 but u=248  $ Middle Bottom Fuel Zone
3845 like 3154 but u=248  $ Middle Bottom Pebble Shell
3846 like 3147 but u=249  $ NW Bottom Corner Fuel Zone
3847 like 3148 but u=249  $ NW Bottom Corner Pebble Shell
3848 like 3139 but u=252  $ NW Middle Edge Fuel Zone
3849 like 3140 but u=252  $ NW Middle Edge Pebble Shell
3850 like 3141 but u=252  $ E Middle Edge Fuel Zone
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3851 like 3142 but u=252  $ E Middle Edge Pebble Shell
3852 like 3143 but u=252  $ W Middle Edge Fuel Zone
3853 like 3144 but u=252  $ W Middle Edge Pebble Shell
3854 like 3147 but u=252  $ NW Bottom Corner Fuel Zone
3855 like 3148 but u=252  $ NW Bottom Corner Pebble Shell
3856 like 3149 but u=252  $ NE Bottom Corner Fuel Zone
3857 like 3150 but u=252  $ NE Bottom Corner Pebble Shell
3858 like 3153 but u=252  $ Middle Bottom Fuel Zone
3859 like 3154 but u=252  $ Middle Bottom Pebble Shell
3860 like 3139 but u=253  $ NW Middle Edge Fuel Zone
3861 like 3140 but u=253  $ NW Middle Edge Pebble Shell
3862 like 3141 but u=253  $ E Middle Edge Fuel Zone
3863 like 3142 but u=253  $ E Middle Edge Pebble Shell
3864 like 3147 but u=253  $ NW Bottom Corner Fuel Zone
3865 like 3148 but u=253  $ NW Bottom Corner Pebble Shell
3866 like 3149 but u=253  $ NE Bottom Corner Fuel Zone
3867 like 3150 but u=253  $ NE Bottom Corner Pebble Shell
3868 like 3153 but u=253  $ Middle Bottom Fuel Zone
3869 like 3154 but u=253  $ Middle Bottom Pebble Shell
3870 like 3149 but u=254  $ NE Bottom Corner Fuel Zone
3871 like 3150 but u=254  $ NE Bottom Corner Pebble Shell
3872 like 3149 but u=255  $ NE Bottom Corner Fuel Zone
3873 like 3150 but u=255  $ NE Bottom Corner Pebble Shell
3874 like 3139 but u=256  $ NW Middle Edge Fuel Zone
3875 like 3140 but u=256  $ NW Middle Edge Pebble Shell
3876 like 3141 but u=256  $ E Middle Edge Fuel Zone
3877 like 3142 but u=256  $ E Middle Edge Pebble Shell
3878 like 3145 but u=256  $ SE Middle Edge Fuel Zone
3879 like 3146 but u=256  $ SE Middle Edge Pebble Shell
3880 like 3147 but u=256  $ NW Bottom Corner Fuel Zone
3881 like 3148 but u=256  $ NW Bottom Corner Pebble Shell
3882 like 3149 but u=256  $ NE Bottom Corner Fuel Zone
3883 like 3150 but u=256  $ NE Bottom Corner Pebble Shell
3884 like 3151 but u=256  $ S Bottom Corner Fuel Zone
3885 like 3152 but u=256  $ S Bottom Corner Pebble Shell
3886 like 3153 but u=256  $ Middle Bottom Fuel Zone
3887 like 3154 but u=256  $ Middle Bottom Pebble Shell
3888 like 3149 but u=257  $ NE Bottom Corner Fuel Zone
3889 like 3150 but u=257  $ NE Bottom Corner Pebble Shell
c
c --------- Top Layer Only Lattices ---------
3890 like 3131 but u=324  $ Middle Top Fuel Zone
3891 like 3132 but u=324  $ Middle Top Pebble Shell
3892 like 3133 but u=324  $ NW Top Corner Fuel Zone
3893 like 3134 but u=324  $ NW Top Corner Pebble Shell
3894 like 3135 but u=324  $ NE Top Corner Fuel Zone
3895 like 3136 but u=324  $ NE Top Corner Pebble Shell
3896 like 3137 but u=324  $ S Top Corner Fuel Zone
3897 like 3138 but u=324  $ S Top Corner Pebble Shell
3898 like 3135 but u=325  $ NE Top Corner Fuel Zone
3899 like 3136 but u=325  $ NE Top Corner Pebble Shell
3900 like 3131 but u=326  $ Middle Top Fuel Zone
3901 like 3132 but u=326  $ Middle Top Pebble Shell
3902 like 3133 but u=326  $ NW Top Corner Fuel Zone
3903 like 3134 but u=326  $ NW Top Corner Pebble Shell
3904 like 3135 but u=326  $ NE Top Corner Fuel Zone
3905 like 3136 but u=326  $ NE Top Corner Pebble Shell
3906 like 3137 but u=326  $ S Top Corner Fuel Zone
3907 like 3138 but u=326  $ S Top Corner Pebble Shell
3908 like 3131 but u=327  $ Middle Top Fuel Zone
3909 like 3132 but u=327  $ Middle Top Pebble Shell
3910 like 3135 but u=327  $ NE Top Corner Fuel Zone
3911 like 3136 but u=327  $ NE Top Corner Pebble Shell
3912 like 3137 but u=327  $ S Top Corner Fuel Zone
3913 like 3138 but u=327  $ S Top Corner Pebble Shell
3914 like 3131 but u=329  $ Middle Top Fuel Zone
3915 like 3132 but u=329  $ Middle Top Pebble Shell
3916 like 3135 but u=329  $ NE Top Corner Fuel Zone
3917 like 3136 but u=329  $ NE Top Corner Pebble Shell
3918 like 3137 but u=329  $ S Top Corner Fuel Zone
3919 like 3138 but u=329  $ S Top Corner Pebble Shell
3920 like 3131 but u=331  $ Middle Top Fuel Zone
3921 like 3132 but u=331  $ Middle Top Pebble Shell
3922 like 3135 but u=331  $ NE Top Corner Fuel Zone
3923 like 3136 but u=331  $ NE Top Corner Pebble Shell
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3924 like 3137 but u=331  $ S Top Corner Fuel Zone
3925 like 3138 but u=331  $ S Top Corner Pebble Shell
3926 like 3137 but u=332  $ S Top Corner Fuel Zone
3927 like 3138 but u=332  $ S Top Corner Pebble Shell
3928 like 3131 but u=333  $ Middle Top Fuel Zone
3929 like 3132 but u=333  $ Middle Top Pebble Shell
3930 like 3133 but u=333  $ NW Top Corner Fuel Zone
3931 like 3134 but u=333  $ NW Top Corner Pebble Shell
3932 like 3135 but u=333  $ NE Top Corner Fuel Zone
3933 like 3136 but u=333  $ NE Top Corner Pebble Shell
3934 like 3137 but u=333  $ S Top Corner Fuel Zone
3935 like 3138 but u=333  $ S Top Corner Pebble Shell
3936 like 3137 but u=334  $ S Top Corner Fuel Zone
3937 like 3138 but u=334  $ S Top Corner Pebble Shell
3938 like 3137 but u=335  $ S Top Corner Fuel Zone
3939 like 3138 but u=335  $ S Top Corner Pebble Shell
3940 like 3131 but u=336  $ Middle Top Fuel Zone
3941 like 3132 but u=336  $ Middle Top Pebble Shell
3942 like 3133 but u=336  $ NW Top Corner Fuel Zone
3943 like 3134 but u=336  $ NW Top Corner Pebble Shell
3944 like 3137 but u=336  $ S Top Corner Fuel Zone
3945 like 3138 but u=336  $ S Top Corner Pebble Shell
3946 like 3137 but u=337  $ S Top Corner Fuel Zone
3947 like 3138 but u=337  $ S Top Corner Pebble Shell
3948 like 3131 but u=338  $ Middle Top Fuel Zone
3949 like 3132 but u=338  $ Middle Top Pebble Shell
3950 like 3133 but u=338  $ NW Top Corner Fuel Zone
3951 like 3134 but u=338  $ NW Top Corner Pebble Shell
3952 like 3135 but u=338  $ NE Top Corner Fuel Zone
3953 like 3136 but u=338  $ NE Top Corner Pebble Shell
3954 like 3137 but u=338  $ S Top Corner Fuel Zone
3955 like 3138 but u=338  $ S Top Corner Pebble Shell
3956 like 3131 but u=340  $ Middle Top Fuel Zone
3957 like 3132 but u=340  $ Middle Top Pebble Shell
3958 like 3133 but u=340  $ NW Top Corner Fuel Zone
3959 like 3134 but u=340  $ NW Top Corner Pebble Shell
3960 like 3137 but u=340  $ S Top Corner Fuel Zone
3961 like 3138 but u=340  $ S Top Corner Pebble Shell
3962 like 3131 but u=342  $ Middle Top Fuel Zone
3963 like 3132 but u=342  $ Middle Top Pebble Shell
3964 like 3133 but u=342  $ NW Top Corner Fuel Zone
3965 like 3134 but u=342  $ NW Top Corner Pebble Shell
3966 like 3137 but u=342  $ S Top Corner Fuel Zone
3967 like 3138 but u=342  $ S Top Corner Pebble Shell
3968 like 3133 but u=343  $ NW Top Corner Fuel Zone
3969 like 3134 but u=343  $ NW Top Corner Pebble Shell
3970 like 3133 but u=344  $ NW Top Corner Fuel Zone
3971 like 3134 but u=344  $ NW Top Corner Pebble Shell
3972 like 3131 but u=345  $ Middle Top Fuel Zone
3973 like 3132 but u=345  $ Middle Top Pebble Shell
3974 like 3133 but u=345  $ NW Top Corner Fuel Zone
3975 like 3134 but u=345  $ NW Top Corner Pebble Shell
3976 like 3135 but u=345  $ NE Top Corner Fuel Zone
3977 like 3136 but u=345  $ NE Top Corner Pebble Shell
3978 like 3137 but u=345  $ S Top Corner Fuel Zone
3979 like 3138 but u=345  $ S Top Corner Pebble Shell
3980 like 3133 but u=346  $ NW Top Corner Fuel Zone
3981 like 3134 but u=346  $ NW Top Corner Pebble Shell
3982 like 3131 but u=347  $ Middle Top Fuel Zone
3983 like 3132 but u=347  $ Middle Top Pebble Shell
3984 like 3133 but u=347  $ NW Top Corner Fuel Zone
3985 like 3134 but u=347  $ NW Top Corner Pebble Shell
3986 like 3135 but u=347  $ NE Top Corner Fuel Zone
3987 like 3136 but u=347  $ NE Top Corner Pebble Shell
3988 like 3131 but u=348  $ Middle Top Fuel Zone
3989 like 3132 but u=348  $ Middle Top Pebble Shell
3990 like 3133 but u=348  $ NW Top Corner Fuel Zone
3991 like 3134 but u=348  $ NW Top Corner Pebble Shell
3992 like 3135 but u=348  $ NE Top Corner Fuel Zone
3993 like 3136 but u=348  $ NE Top Corner Pebble Shell
3994 like 3137 but u=348  $ S Top Corner Fuel Zone
3995 like 3138 but u=348  $ S Top Corner Pebble Shell
3996 like 3133 but u=349  $ NW Top Corner Fuel Zone
3997 like 3134 but u=349  $ NW Top Corner Pebble Shell
3998 like 3131 but u=352  $ Middle Top Fuel Zone
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3999 like 3132 but u=352  $ Middle Top Pebble Shell
4000 like 3133 but u=352  $ NW Top Corner Fuel Zone
4001 like 3134 but u=352  $ NW Top Corner Pebble Shell
4002 like 3135 but u=352  $ NE Top Corner Fuel Zone
4003 like 3136 but u=352  $ NE Top Corner Pebble Shell
4004 like 3131 but u=353  $ Middle Top Fuel Zone
4005 like 3132 but u=353  $ Middle Top Pebble Shell
4006 like 3133 but u=353  $ NW Top Corner Fuel Zone
4007 like 3134 but u=353  $ NW Top Corner Pebble Shell
4008 like 3135 but u=353  $ NE Top Corner Fuel Zone
4009 like 3136 but u=353  $ NE Top Corner Pebble Shell
4010 like 3135 but u=354  $ NE Top Corner Fuel Zone
4011 like 3136 but u=354  $ NE Top Corner Pebble Shell
4012 like 3135 but u=355  $ NE Top Corner Fuel Zone
4013 like 3136 but u=355  $ NE Top Corner Pebble Shell
4014 like 3131 but u=356  $ Middle Top Fuel Zone
4015 like 3132 but u=356  $ Middle Top Pebble Shell
4016 like 3133 but u=356  $ NW Top Corner Fuel Zone
4017 like 3134 but u=356  $ NW Top Corner Pebble Shell
4018 like 3135 but u=356  $ NE Top Corner Fuel Zone
4019 like 3136 but u=356  $ NE Top Corner Pebble Shell
4020 like 3137 but u=356  $ S Top Corner Fuel Zone
4021 like 3138 but u=356  $ S Top Corner Pebble Shell
4022 like 3135 but u=357  $ NE Top Corner Fuel Zone
4023 like 3136 but u=357  $ NE Top Corner Pebble Shell
c
c ------ Moderator Pebbles ------
c --------- Regular (Full) Lattice ---------
4131 26 8.4461E-02  -4131 imp:n=1 u=24  $ N Top Corner Pebble
4132 26 8.4461E-02  -4132 imp:n=1 u=24  $ SE Top Corner Pebble
4133 26 8.4461E-02  -4133 imp:n=1 u=24  $ SW Top Corner Pebble
4134 26 8.4461E-02  -4134 imp:n=1 u=24  $ NE Middle Edge Pebble
4135 26 8.4461E-02  -4135 imp:n=1 u=24  $ SW Middle Edge Pebble
4136 26 8.4461E-02  -4136 imp:n=1 u=24  $ N Bottom Corner Pebble
4137 26 8.4461E-02  -4137 imp:n=1 u=24  $ SE Bottom Corner Pebble
4138 26 8.4461E-02  -4138 imp:n=1 u=24  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 1 ---------
4139 like 4132 but u=25  $ SE Top Corner Pebble
4140 like 4137 but u=25  $ SE Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 2 ---------
4141 like 4131 but u=26  $ N Top Corner Pebble
4142 like 4132 but u=26  $ SE Top Corner Pebble
4143 like 4133 but u=26  $ SW Top Corner Pebble
4144 like 4134 but u=26  $ NE Middle Edge Pebble
4145 like 4135 but u=26  $ SW Middle Edge Pebble
4146 like 4136 but u=26  $ N Bottom Corner Pebble
4147 like 4137 but u=26  $ SE Bottom Corner Pebble
4148 like 4138 but u=26  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 3 ---------
4149 like 4131 but u=27  $ N Top Corner Pebble
4150 like 4132 but u=27  $ SE Top Corner Pebble
4151 like 4134 but u=27  $ NE Middle Edge Pebble
4152 like 4136 but u=27  $ N Bottom Corner Pebble
4153 like 4137 but u=27  $ SE Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 4 ---------
4154 like 4132 but u=28  $ SE Top Corner Pebble
4155 like 4137 but u=28  $ SE Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 5 ---------
4156 like 4131 but u=29  $ N Top Corner Pebble
4157 like 4132 but u=29  $ SE Top Corner Pebble
4158 like 4133 but u=29  $ SW Top Corner Pebble
4159 like 4134 but u=29  $ NE Middle Edge Pebble
4160 like 4135 but u=29  $ SW Middle Edge Pebble
4161 like 4136 but u=29  $ N Bottom Corner Pebble
4162 like 4137 but u=29  $ SE Bottom Corner Pebble
4163 like 4138 but u=29  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 6 ---------
4164 like 4132 but u=30  $ SE Top Corner Pebble
4165 like 4137 but u=30  $ SE Bottom Corner Pebble
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c
c --------- Regular (Partial) Lattice 7 ---------
4166 like 4132 but u=31  $ SE Top Corner Pebble
4167 like 4133 but u=31  $ SW Top Corner Pebble
4168 like 4135 but u=31  $ SW Middle Edge Pebble
4169 like 4137 but u=31  $ SE Bottom Corner Pebble
4170 like 4138 but u=31  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 8 ---------
4171 like 4132 but u=32  $ SE Top Corner Pebble
4172 like 4137 but u=32  $ SE Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 9 ---------
4173 like 4132 but u=33  $ SE Top Corner Pebble
4174 like 4133 but u=33  $ SW Top Corner Pebble
4175 like 4135 but u=33  $ SW Middle Edge Pebble
4176 like 4137 but u=33  $ SE Bottom Corner Pebble
4177 like 4138 but u=33  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 10 ---------
c    *No Moderator Pebbles
c
c --------- Regular (Partial) Lattice 11 ---------
c    *No Moderator Pebbles
c
c --------- Regular (Partial) Lattice 12 ---------
4178 like 4132 but u=36  $ SE Top Corner Pebble
4179 like 4133 but u=36  $ SW Top Corner Pebble
4180 like 4135 but u=36  $ SW Middle Edge Pebble
4181 like 4137 but u=36  $ SE Bottom Corner Pebble
4182 like 4138 but u=36  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 13 ---------
4183 like 4133 but u=37  $ SW Top Corner Pebble
4184 like 4138 but u=37  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 14 ---------
4185 like 4131 but u=38  $ N Top Corner Pebble
4186 like 4132 but u=38  $ SE Top Corner Pebble
4187 like 4133 but u=38  $ SW Top Corner Pebble
4188 like 4135 but u=38  $ SW Middle Edge Pebble
4189 like 4136 but u=38  $ N Bottom Corner Pebble
4190 like 4137 but u=38  $ SE Bottom Corner Pebble
4191 like 4138 but u=38  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 15 ---------
4192 like 4133 but u=39  $ SW Top Corner Pebble
4193 like 4138 but u=39  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 16 ---------
4194 like 4131 but u=40  $ N Top Corner Pebble
4195 like 4132 but u=40  $ SE Top Corner Pebble
4196 like 4133 but u=40  $ SW Top Corner Pebble
4197 like 4135 but u=40  $ SW Middle Edge Pebble
4198 like 4136 but u=40  $ N Bottom Corner Pebble
4199 like 4137 but u=40  $ SE Bottom Corner Pebble
4200 like 4138 but u=40  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 17 ---------
4201 like 4133 but u=41  $ SW Top Corner Pebble
4202 like 4138 but u=41  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 18 ---------
4203 like 4131 but u=42  $ N Top Corner Pebble
4204 like 4133 but u=42  $ SW Top Corner Pebble
4205 like 4135 but u=42  $ SW Middle Edge Pebble
4206 like 4136 but u=42  $ N Bottom Corner Pebble
4207 like 4138 but u=42  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 19 ---------
4208 like 4133 but u=43  $ SW Top Corner Pebble
4209 like 4138 but u=43  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 20 ---------
c    *No Moderator Pebbles
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c
c --------- Regular (Partial) Lattice 21 ---------
4210 like 4131 but u=45  $ N Top Corner Pebble
4211 like 4133 but u=45  $ SW Top Corner Pebble
4212 like 4134 but u=45  $ NE Middle Edge Pebble
4213 like 4135 but u=45  $ SW Middle Edge Pebble
4214 like 4136 but u=45  $ N Bottom Corner Pebble
4215 like 4138 but u=45  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 22 ---------
c    *No Moderator Pebbles
c
c --------- Regular (Partial) Lattice 23 ---------
4216 like 4131 but u=47  $ N Top Corner Pebble
4217 like 4133 but u=47  $ SW Top Corner Pebble
4218 like 4134 but u=47  $ NE Middle Edge Pebble
4219 like 4136 but u=47  $ N Bottom Corner Pebble
4220 like 4138 but u=47  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 24 ---------
4221 like 4131 but u=48  $ N Top Corner Pebble
4222 like 4132 but u=48  $ SE Top Corner Pebble
4223 like 4133 but u=48  $ SW Top Corner Pebble
4224 like 4134 but u=48  $ NE Middle Edge Pebble
4225 like 4135 but u=48  $ SW Middle Edge Pebble
4226 like 4136 but u=48  $ N Bottom Corner Pebble
4227 like 4137 but u=48  $ SE Bottom Corner Pebble
4228 like 4138 but u=48  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 25 ---------
4229 like 4131 but u=49  $ N Top Corner Pebble
4230 like 4136 but u=49  $ N Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 26 ---------
4231 like 4131 but u=50  $ N Top Corner Pebble
4232 like 4136 but u=50  $ N Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 27 ---------
4233 like 4131 but u=51  $ N Top Corner Pebble
4234 like 4134 but u=51  $ NE Middle Edge Pebble
4235 like 4136 but u=51  $ N Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 28 ---------
4236 like 4131 but u=52  $ N Top Corner Pebble
4237 like 4132 but u=52  $ SE Top Corner Pebble
4238 like 4133 but u=52  $ SW Top Corner Pebble
4239 like 4134 but u=52  $ NE Middle Edge Pebble
4240 like 4135 but u=52  $ SW Middle Edge Pebble
4241 like 4136 but u=52  $ N Bottom Corner Pebble
4242 like 4137 but u=52  $ SE Bottom Corner Pebble
4243 like 4138 but u=52  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 29 ---------
4244 like 4131 but u=53  $ N Top Corner Pebble
4245 like 4132 but u=53  $ SE Top Corner Pebble
4246 like 4134 but u=53  $ NE Middle Edge Pebble
4247 like 4136 but u=53  $ N Bottom Corner Pebble
4248 like 4137 but u=53  $ SE Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 30 ---------
4249 like 4131 but u=54  $ N Top Corner Pebble
4250 like 4134 but u=54  $ NE Middle Edge Pebble
4251 like 4136 but u=54  $ N Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 31 ---------
4252 like 4134 but u=55  $ NE Middle Edge Pebble
c
c --------- Regular (Partial) Lattice 32 ---------
4253 like 4131 but u=56  $ N Top Corner Pebble
4254 like 4132 but u=56  $ SE Top Corner Pebble
4255 like 4134 but u=56  $ NE Middle Edge Pebble
4256 like 4135 but u=56  $ SW Middle Edge Pebble
4257 like 4136 but u=56  $ N Bottom Corner Pebble
4258 like 4137 but u=56  $ SE Bottom Corner Pebble
c
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c --------- Regular (Partial) Lattice 33 ---------
c    *No Moderator Pebbles
c
c --------- Bottom and Middle Layers Only Lattices ---------
4310 like 4134 but u=224  $ NE Middle Edge Pebble
4311 like 4135 but u=224  $ SW Middle Edge Pebble
4312 like 4136 but u=224  $ N Bottom Corner Pebble
4313 like 4137 but u=224  $ SE Bottom Corner Pebble
4314 like 4138 but u=224  $ SW Bottom Corner Pebble
4315 like 4137 but u=225  $ SE Bottom Corner Pebble
4316 like 4134 but u=226  $ NE Middle Edge Pebble
4317 like 4135 but u=226  $ SW Middle Edge Pebble
4318 like 4136 but u=226  $ N Bottom Corner Pebble
4319 like 4137 but u=226  $ SE Bottom Corner Pebble
4320 like 4138 but u=226  $ SW Bottom Corner Pebble
4321 like 4134 but u=227  $ NE Middle Edge Pebble
4322 like 4136 but u=227  $ N Bottom Corner Pebble
4323 like 4137 but u=227  $ SE Bottom Corner Pebble
4324 like 4137 but u=228  $ SE Bottom Corner Pebble
4325 like 4134 but u=229  $ NE Middle Edge Pebble
4326 like 4135 but u=229  $ SW Middle Edge Pebble
4327 like 4136 but u=229  $ N Bottom Corner Pebble
4328 like 4137 but u=229  $ SE Bottom Corner Pebble
4329 like 4138 but u=229  $ SW Bottom Corner Pebble
4330 like 4137 but u=230  $ SE Bottom Corner Pebble
4331 like 4135 but u=231  $ SW Middle Edge Pebble
4332 like 4137 but u=231  $ SE Bottom Corner Pebble
4333 like 4138 but u=231  $ SW Bottom Corner Pebble
4334 like 4137 but u=232  $ SE Bottom Corner Pebble
4335 like 4135 but u=233  $ SW Middle Edge Pebble
4336 like 4137 but u=233  $ SE Bottom Corner Pebble
4337 like 4138 but u=233  $ SW Bottom Corner Pebble
4338 like 4135 but u=236  $ SW Middle Edge Pebble
4339 like 4137 but u=236  $ SE Bottom Corner Pebble
4340 like 4138 but u=236  $ SW Bottom Corner Pebble
4341 like 4138 but u=237  $ SW Bottom Corner Pebble
4342 like 4135 but u=238  $ SW Middle Edge Pebble
4343 like 4136 but u=238  $ N Bottom Corner Pebble
4344 like 4137 but u=238  $ SE Bottom Corner Pebble
4345 like 4138 but u=238  $ SW Bottom Corner Pebble
4346 like 4138 but u=239  $ SW Bottom Corner Pebble
4347 like 4135 but u=240  $ SW Middle Edge Pebble
4348 like 4136 but u=240  $ N Bottom Corner Pebble
4349 like 4137 but u=240  $ SE Bottom Corner Pebble
4350 like 4138 but u=240  $ SW Bottom Corner Pebble
4351 like 4138 but u=241  $ SW Bottom Corner Pebble
4352 like 4135 but u=242  $ SW Middle Edge Pebble
4353 like 4136 but u=242  $ N Bottom Corner Pebble
4354 like 4138 but u=242  $ SW Bottom Corner Pebble
4355 like 4138 but u=243  $ SW Bottom Corner Pebble
4356 like 4134 but u=245  $ NE Middle Edge Pebble
4357 like 4135 but u=245  $ SW Middle Edge Pebble
4358 like 4136 but u=245  $ N Bottom Corner Pebble
4359 like 4138 but u=245  $ SW Bottom Corner Pebble
4360 like 4134 but u=247  $ NE Middle Edge Pebble
4361 like 4136 but u=247  $ N Bottom Corner Pebble
4362 like 4138 but u=247  $ SW Bottom Corner Pebble
4363 like 4134 but u=248  $ NE Middle Edge Pebble
4364 like 4135 but u=248  $ SW Middle Edge Pebble
4365 like 4136 but u=248  $ N Bottom Corner Pebble
4366 like 4137 but u=248  $ SE Bottom Corner Pebble
4367 like 4138 but u=248  $ SW Bottom Corner Pebble
4368 like 4136 but u=249  $ N Bottom Corner Pebble
4369 like 4136 but u=250  $ N Bottom Corner Pebble
4370 like 4134 but u=251  $ NE Middle Edge Pebble
4371 like 4136 but u=251  $ N Bottom Corner Pebble
4372 like 4134 but u=252  $ NE Middle Edge Pebble
4373 like 4135 but u=252  $ SW Middle Edge Pebble
4374 like 4136 but u=252  $ N Bottom Corner Pebble
4375 like 4137 but u=252  $ SE Bottom Corner Pebble
4376 like 4138 but u=252  $ SW Bottom Corner Pebble
4377 like 4134 but u=253  $ NE Middle Edge Pebble
4378 like 4136 but u=253  $ N Bottom Corner Pebble
4379 like 4137 but u=253  $ SE Bottom Corner Pebble
4380 like 4134 but u=254  $ NE Middle Edge Pebble
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4381 like 4136 but u=254  $ N Bottom Corner Pebble
4382 like 4134 but u=255  $ NE Middle Edge Pebble
4383 like 4134 but u=256  $ NE Middle Edge Pebble
4384 like 4135 but u=256  $ SW Middle Edge Pebble
4385 like 4136 but u=256  $ N Bottom Corner Pebble
4386 like 4137 but u=256  $ SE Bottom Corner Pebble
c
c --------- Top Layer Only Lattices ---------
4387 like 4131 but u=324  $ N Top Corner Pebble
4388 like 4132 but u=324  $ SE Top Corner Pebble
4389 like 4133 but u=324  $ SW Top Corner Pebble
4390 like 4132 but u=325  $ SE Top Corner Pebble
4391 like 4131 but u=326  $ N Top Corner Pebble
4392 like 4132 but u=326  $ SE Top Corner Pebble
4393 like 4133 but u=326  $ SW Top Corner Pebble
4394 like 4131 but u=327  $ N Top Corner Pebble
4395 like 4132 but u=327  $ SE Top Corner Pebble
4396 like 4132 but u=328  $ SE Top Corner Pebble
4397 like 4131 but u=329  $ N Top Corner Pebble
4398 like 4132 but u=329  $ SE Top Corner Pebble
4399 like 4133 but u=329  $ SW Top Corner Pebble
4401 like 4132 but u=330  $ SE Top Corner Pebble
4402 like 4132 but u=331  $ SE Top Corner Pebble
4403 like 4133 but u=331  $ SW Top Corner Pebble
4404 like 4132 but u=332  $ SE Top Corner Pebble
4405 like 4132 but u=333  $ SE Top Corner Pebble
4406 like 4133 but u=333  $ SW Top Corner Pebble
4407 like 4132 but u=336  $ SE Top Corner Pebble
4408 like 4133 but u=336  $ SW Top Corner Pebble
4409 like 4133 but u=337  $ SW Top Corner Pebble
4410 like 4131 but u=338  $ N Top Corner Pebble
4411 like 4132 but u=338  $ SE Top Corner Pebble
4412 like 4133 but u=338  $ SW Top Corner Pebble
4413 like 4133 but u=339  $ SW Top Corner Pebble
4414 like 4131 but u=340  $ N Top Corner Pebble
4415 like 4132 but u=340  $ SE Top Corner Pebble
4416 like 4133 but u=340  $ SW Top Corner Pebble
4417 like 4133 but u=341  $ SW Top Corner Pebble
4418 like 4131 but u=342  $ N Top Corner Pebble
4419 like 4133 but u=342  $ SW Top Corner Pebble
4420 like 4133 but u=343  $ SW Top Corner Pebble
4421 like 4131 but u=345  $ N Top Corner Pebble
4422 like 4133 but u=345  $ SW Top Corner Pebble
4423 like 4131 but u=347  $ N Top Corner Pebble
4424 like 4133 but u=347  $ SW Top Corner Pebble
4425 like 4131 but u=348  $ N Top Corner Pebble
4426 like 4132 but u=348  $ SE Top Corner Pebble
4427 like 4133 but u=348  $ SW Top Corner Pebble
4428 like 4131 but u=349  $ N Top Corner Pebble
4429 like 4131 but u=350  $ N Top Corner Pebble
4430 like 4131 but u=351  $ N Top Corner Pebble
4431 like 4131 but u=352  $ N Top Corner Pebble
4432 like 4132 but u=352  $ SE Top Corner Pebble
4433 like 4133 but u=352  $ SW Top Corner Pebble
4434 like 4131 but u=353  $ N Top Corner Pebble
4435 like 4132 but u=353  $ SE Top Corner Pebble
4436 like 4131 but u=354  $ N Top Corner Pebble
4437 like 4131 but u=356  $ N Top Corner Pebble
4438 like 4132 but u=356  $ SE Top Corner Pebble
c
c ------ Air ------
c --------- Regular (Full) Lattice ---------
5131 10 4.8492E-05  3132 3134 3136 3138 3140 3142 3144 3146 3148 3150 3152 3154
          4131 4132 4133 4134 4135 4136 4137 4138 imp:n=1 u=24
c
c --------- Regular (Partial) Lattices ---------
5132 10 4.8492E-05  3136 3150 4132 4137 imp:n=1 u=25  $ 1
5133 10 4.8492E-05  3132 3134 3136 3138 3140 3142 3146 3148 3150 3152 3154
          4131 4132 4133 4134 4135 4136 4137 4138 imp:n=1 u=26  $ 2
5134 10 4.8492E-05  3132 3136 3138 3142 3144 3146 3150 3152 3154
          4131 4132 4134 4136 4137 imp:n=1 u=27  $ 3
5135 10 4.8492E-05  4132 4137 imp:n=1 u=28  $ 4
5136 10 4.8492E-05  3132 3136 3138 3140 3142 3146 3150 3152 3154
          4131 4132 4133 4134 4135 4136 4137 4138 imp:n=1 u=29  $ 5
5137 10 4.8492E-05  3146 4132 4137 imp:n=1 u=30  $ 6
```

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5138 10 4.8492E-05  3132 3136 3138 3142 3146 3150 3152 3154
          4132 4133 4135 4137 4138 imp:n=1 u=31  $ 7
5139 10 4.8492E-05  3138 3146 3152 4132 4137 imp:n=1 u=32  $ 8
5140 10 4.8492E-05  3132 3134 3136 3138 3140 3142 3144 3146 3148 3150 3152 3154
          4132 4133 4135 4137 4138 imp:n=1 u=33  $ 9
5141 10 4.8492E-05  3138 3146 3152 imp:n=1 u=34  $ 10
5142 10 4.8492E-05  3138 3152 imp:n=1 u=35  $ 11
5143 10 4.8492E-05  3132 3134 3138 3144 3146 3148 3152 3154
          4132 4133 4135 4137 4138 imp:n=1 u=36  $ 12
5144 10 4.8492E-05  3138 3152 4133 4138 imp:n=1 u=37  $ 13
5145 10 4.8492E-05  3132 3134 3136 3138 3140 3142 3144 3146 3148 3150 3152 3154
          4131 4132 4133 4135 4136 4137 4138 imp:n=1 u=38  $ 14
5146 10 4.8492E-05  4133 4138 imp:n=1 u=39  $ 15
5147 10 4.8492E-05  3132 3134 3138 3140 3142 3144 3146 3148 3152 3154
          4131 4132 4133 4135 4136 4137 4138 imp:n=1 u=40  $ 16
5148 10 4.8492E-05  3144 4133 4138 imp:n=1 u=41  $ 17
5149 10 4.8492E-05  3132 3134 3138 3140 3144 3148 3152 3154
          4131 4133 4135 4136 4138 imp:n=1 u=42  $ 18
5150 10 4.8492E-05  3134 3144 3148 4133 4138 imp:n=1 u=43  $ 19
5151 10 4.8492E-05  3134 3144 3148 imp:n=1 u=44  $ 20
5152 10 4.8492E-05  3132 3134 3136 3138 3140 3142 3144 3148 3150 3152 3154
          4131 4133 4134 4135 4136 4138 imp:n=1 u=45  $ 21
5153 10 4.8492E-05  3134 3148 imp:n=1 u=46  $ 22
5154 10 4.8492E-05  3132 3134 3136 3140 3144 3148 3150 3154
          4131 4133 4134 4136 4138 imp:n=1 u=47  $ 23
5155 10 4.8492E-05  3132 3134 3136 3138 3140 3142 3144 3148 3150 3152 3154
          4131 4132 4133 4134 4135 4136 4137 4138 imp:n=1 u=48  $ 24
5156 10 4.8492E-05  3134 3148 4131 4136 imp:n=1 u=49  $ 25
5157 10 4.8492E-05  4131 4136 imp:n=1 u=50  $ 26
5158 10 4.8492E-05  4131 4134 4136 imp:n=1 u=51  $ 27
5159 10 4.8492E-05  3132 3134 3136 3140 3142 3144 3148 3150 3154
          4131 4132 4133 4134 4135 4136 4137 4138 imp:n=1 u=52  $ 28
5160 10 4.8492E-05  3132 3134 3136 3140 3142 3148 3150 3154
          4131 4132 4134 4136 4137 imp:n=1 u=53  $ 29
5161 10 4.8492E-05  3136 3150 4131 4134 4136 imp:n=1 u=54  $ 30
5162 10 4.8492E-05  3136 3150 4134 imp:n=1 u=55  $ 31
5163 10 4.8492E-05  3132 3134 3136 3138 3140 3142 3146 3148 3150 3152 3154
          4131 4132 4134 4135 4136 4137 imp:n=1 u=56  $ 32
5164 10 4.8492E-05  3136 3150 imp:n=1 u=57  $ 33
c
c --------- Bottom and Middle Layers Only Lattices ---------
5199 10 4.8492E-05  3140 3142 3144 3146 3148 3150 3152 3154
          4134 4135 4136 4137 4138 imp:n=1 u=224  $ regular
5200 10 4.8492E-05  3150 4137 imp:n=1 u=225  $ 1
5201 10 4.8492E-05  3140 3142 3146 3148 3150 3152 3154
          4134 4135 4136 4137 4138 imp:n=1 u=226  $ 2
5202 10 4.8492E-05  3142 3144 3146 3150 3152 3154 4134 4136 4137 imp:n=1 u=227  $ 3
5203 10 4.8492E-05  4137 imp:n=1 u=228  $ 4
5204 10 4.8492E-05  3140 3142 3146 3150 3152 3154 4134 4135 4136 4137 4138
           imp:n=1 u=229  $ 5
5205 10 4.8492E-05  3146 4137 imp:n=1 u=230  $ 6
5206 10 4.8492E-05  3142 3146 3150 3152 3154 4135 4137 4138 imp:n=1 u=231  $ 7
5207 10 4.8492E-05  3146 3152 4137 imp:n=1 u=232  $ 8
5208 10 4.8492E-05  3140 3142 3144 3146 3148 3150 3152 3154
          4135 4137 4138 imp:n=1 u=233  $ 9
5209 10 4.8492E-05  3146 3152 imp:n=1 u=234  $ 10
5210 10 4.8492E-05  3152 imp:n=1 u=235  $ 11
5211 10 4.8492E-05  3144 3146 3148 3152 3154 4135 4137 4138 imp:n=1 u=236  $ 12
5212 10 4.8492E-05  3152 4138 imp:n=1 u=237  $ 13
5213 10 4.8492E-05  3140 3142 3144 3146 3148 3150 3152 3154
          4135 4136 4137 4138 imp:n=1 u=238  $ 14
5214 10 4.8492E-05  4138 imp:n=1 u=239  $ 15
5215 10 4.8492E-05  3140 3142 3144 3146 3148 3152 3154
          4135 4136 4137 4138 imp:n=1 u=240  $ 16
5216 10 4.8492E-05  3144 4138 imp:n=1 u=241  $ 17
5217 10 4.8492E-05  3140 3144 3148 3152 3154 4135 4136 4138 imp:n=1 u=242  $ 18
5218 10 4.8492E-05  3144 3148 4138 imp:n=1 u=243  $ 19
5219 10 4.8492E-05  3144 3148 imp:n=1 u=244  $ 20
5220 10 4.8492E-05  3140 3142 3144 3148 3150 3152 3154
          4134 4135 4136 4138 imp:n=1 u=245  $ 21
5221 10 4.8492E-05  3148 imp:n=1 u=246  $ 22
5222 10 4.8492E-05  3140 3144 3148 3150 3154 4134 4136 4138 imp:n=1 u=247  $ 23
5223 10 4.8492E-05  3140 3142 3144 3148 3150 3152 3154
          4134 4135 4136 4137 4138 imp:n=1 u=248  $ 24
5224 10 4.8492E-05  3148 4136 imp:n=1 u=249  $ 25
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5225 10 4.8492E-05  4136 imp:n=1 u=250  $ 26
5226 10 4.8492E-05  4134 4136 imp:n=1 u=251  $ 27
5227 10 4.8492E-05  3140 3142 3144 3148 3150 3154
          4134 4135 4136 4137 4138 imp:n=1 u=252  $ 28
5228 10 4.8492E-05  3140 3142 3148 3150 3154 4134 4136 4137 imp:n=1 u=253  $ 29
5229 10 4.8492E-05  3150 4134 4136 imp:n=1 u=254  $ 30
5230 10 4.8492E-05  3150 4134 imp:n=1 u=255  $ 3`
5231 10 4.8492E-05  3140 3142 3146 3148 3150 3152 3154
          4134 4135 4136 4137 imp:n=1 u=256  $ 31
5232 10 4.8492E-05  3150 imp:n=1 u=257  $ 32
c
c --------- Top Layer Only Lattices ---------
5233 10 4.8492E-05  3132 3134 3136 3138 4131 4132 4133 imp:n=1 u=324  $ regular
5234 10 4.8492E-05  3136 4132 imp:n=1 u=325  $ 1
5235 10 4.8492E-05  3132 3134 3136 3138 4131 4132 4133 imp:n=1 u=326  $ 2
5236 10 4.8492E-05  3132 3136 3138 4131 4132 imp:n=1 u=327  $ 3
5237 10 4.8492E-05  4132 imp:n=1 u=328  $ 4
5238 10 4.8492E-05  3132 3136 3138 4131 4132 4133 imp:n=1 u=329  $ 5
5239 10 4.8492E-05  4132 imp:n=1 u=330  $ 6
5240 10 4.8492E-05  3132 3136 3138 4132 4133 imp:n=1 u=331  $ 7
5241 10 4.8492E-05  3138 4132 imp:n=1 u=332  $ 8
5242 10 4.8492E-05  3132 3134 3136 3138 4132 4133 imp:n=1 u=333  $ 9
5243 10 4.8492E-05  3138 imp:n=1 u=334  $ 10
5244 10 4.8492E-05  3138 imp:n=1 u=335  $ 11
5245 10 4.8492E-05  3132 3134 3138 4132 4133 imp:n=1 u=336  $ 12
5246 10 4.8492E-05  3138 4133 imp:n=1 u=337  $ 13
5247 10 4.8492E-05  3132 3134 3136 3138 4131 4132 4133 imp:n=1 u=338  $ 14
5248 10 4.8492E-05  4133 imp:n=1 u=339  $ 15
5249 10 4.8492E-05  3132 3134 3138 4131 4132 4133 imp:n=1 u=340  $ 16
5250 10 4.8492E-05  4133 imp:n=1 u=341  $ 17
5251 10 4.8492E-05  3132 3134 3138 4131 4133 imp:n=1 u=342  $ 18
5252 10 4.8492E-05  3134 4133 imp:n=1 u=343  $ 19
5253 10 4.8492E-05  3134 imp:n=1 u=344  $ 20
5254 10 4.8492E-05  3132 3134 3136 3138 4131 4133 imp:n=1 u=345  $ 21
5255 10 4.8492E-05  3134 imp:n=1 u=346  $ 22
5256 10 4.8492E-05  3132 3134 3136 4131 4133 imp:n=1 u=347  $ 23
5257 10 4.8492E-05  3132 3134 3136 3138 4131 4132 4133 imp:n=1 u=348  $ 24
5258 10 4.8492E-05  3134 4131 imp:n=1 u=349  $ 25
5259 10 4.8492E-05  4131 imp:n=1 u=350  $ 26
5260 10 4.8492E-05  4131 imp:n=1 u=351  $ 27
5261 10 4.8492E-05  3132 3134 3136 4131 4132 4133 imp:n=1 u=352  $ 28
5262 10 4.8492E-05  3132 3134 3136 4131 4132 imp:n=1 u=353  $ 29
5263 10 4.8492E-05  3136 4131 imp:n=1 u=354  $ 30
5264 10 4.8492E-05  3136 imp:n=1 u=355  $ 31
5265 10 4.8492E-05  3132 3134 3136 3138 4131 4132 imp:n=1 u=356  $ 32
5266 10 4.8492E-05  3136 imp:n=1 u=357  $ 33
c
c ------ Pebble Layers ------------------------------------------------------
6000 10 4.8492E-05  -9999 imp:n=1 u=99  $ Air
c
c --------- Regular Lattice Description ---------
6001 10 4.8492E-05  -6001 imp:n=1 u=100 lat=2 fill=-8:8 -8:8 0:0
     99  16r
     99   9r                    51  51  51  50                        99  2r
     99   7r              54  53  52  52  52  47  49                  99  1r
     99   5r           55  53  24  24  24  24  24  48  47  46             99
     99   4r         55  56  24  24  24  24  24  24  24  45  44          99
     99   3r       55  56  24  24  24  24  24  24  24  24  45  44        99
     99   2r     57  56  24  24  24  24  24  24  24  24  24  45  44      99
     99   2r       27  24  24  24  24  24  24  24  24  24  24  42      99  1r
     99   1r     25  26  24  24  24  24  24  24  24  24  24  24  43    99  1r
     99   1r       27  24  24  24  24  24  24  24  24  24  24  42      99  2r
     99          28  29  24  24  24  24  24  24  24  24  24  40  41    99  2r
     99            30  29  24  24  24  24  24  24  24  24  40  41      99  3r
     99              30  29  24  24  24  24  24  24  24  40  41       99  4r
     99                30  31  24  24  24  24  38  36  39             99  5r
     99   1r                32  31  33  33  33  36  37                99  7r
     99   2r                      34  34  34  35                      99  9r
     99  16r
c
c --------- Bottom and Middle Layers Only Lattice Description ---------
6003 10 4.8492E-05  -6001 imp:n=1 u=104 lat=2 fill=-8:8 -8:8 0:0
     99  16r
     99   9r                   251 251 251 250                        99  2r
     99   7r             254 253 252 252 252 247 249                  99  1r
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     99   5r          255 253 224 224 224 224 224 248 247 246              99
     99   4r        255 256 224 224 224 224 224 224 224 245 244            99
     99   3r      255 256 224 224 224 224 224 224 224 224 245 244          99
     99   2r    257 256 224 224 224 224 224 224 224 224 224 245 244        99
     99   2r      227 224 224 224 224 224 224 224 224 224 224 242        99  1r
     99   1r    225 226 224 224 224 224 224 224 224 224 224 224 243      99  1r
     99   1r      227 224 224 224 224 224 224 224 224 224 224 242        99  2r
     99         228 229 224 224 224 224 224 224 224 224 224 240 241      99  2r
     99           230 229 224 224 224 224 224 224 224 224 240 241        99  3r
     99             230 229 224 224 224 224 224 224 224 240 241          99  4r
     99               230 231 224 224 224 224 224 238 236 239            99  5r
     99   1r                232 231 233 233 233 236 237                  99  7r
     99   2r                      234 234 234 235                        99  9r
     99  16r
c
c --------- Top Layer Only Lattice Description ---------
6004 10 4.8492E-05  -6001 imp:n=1 u=106 lat=2 fill=-8:8 -8:8 0:0
     99  16r
     99   9r                      351 351 351 350                        99  2r
     99   7r                354 353 352 352 352 347 349                  99  1r
     99   5r          355 353 324 324 324 324 324 348 347 346              99
     99   4r        355 356 324 324 324 324 324 324 324 345 344            99
     99   3r      355 356 324 324 324 324 324 324 324 324 345 344          99
     99   2r    357 356 324 324 324 324 324 324 324 324 324 345 344        99
     99   2r      327 324 324 324 324 324 324 324 324 324 324 342        99  1r
     99   1r    325 326 324 324 324 324 324 324 324 324 324 324 343      99  1r
     99   1r      327 324 324 324 324 324 324 324 324 324 324 342        99  2r
     99         328 329 324 324 324 324 324 324 324 324 324 340 341      99  2r
     99           330 329 324 324 324 324 324 324 324 324 340 341        99  3r
     99             330 329 324 324 324 324 324 324 324 340 341          99  4r
     99               330 331 324 324 324 324 324 338 336 339            99  5r
     99   1r                332 331 333 333 333 336 337                  99  7r
     99   2r                      334 334 334 335                        99  9r
     99  16r
c
c
c --------- Regular Lattice Layer ---------
6011 10 4.8492E-05  -6002 imp:n=1 u=101 fill=100
c
c --------- Bottom and Middle Only Lattice Layer ---------
6013 10 4.8492E-05  -6002 imp:n=1 u=105 fill=104
c
c --------- Top Only Lattice Layer ---------
6014 10 4.8492E-05  -6002 imp:n=1 u=107 fill=106
c
c --------- Air Layer ---------
6021 10 4.8492E-05  -6002 imp:n=1 u=120
c
c --------- Pebbled Core Layers ---------
6101 10 4.8492E-05  -6003 imp:n=1 u=121 lat=2 fill=0:0 0:0 -1:21  $ Core 1
            120 1r 107 101 9r 105 120 8r
c
c --------- Pebble-Filled Core Cavity ---------
6102 10 4.8492E-05  -7001 -7002 -9001 #9011 #9012 #9013 #9014 #9015 #9016 #9017
         #9018 #9019 #9020 #9021 #9022 #9023 #9024 #9025 #9026 #9027 #9028 #9029
          #9030 #9031 #9032 #9033 #9034
          imp:n=1 *fill=121 (0 0 66.30306154 30 120 90  60 30 90  90 90 0)
6103 10 4.8492E-05  -7001 -7002 9001 -9002  #9035 #9036 #9037 #9038 #9039 #9040
         #9041 #9042 #9043 #9044 #9045 #9046 #9047 #9048 #9049 #9050 #9051 #9052
          #9053 #9054 #9055 #9056 #9057 #9058
          imp:n=1 *fill=121 (0 0 66.30306154 30 120 90  60 30 90  90 90 0)
6104 10 4.8492E-05  -7001 -7002 9002 -9003  #9059 #9060 #9061 #9062 #9063 #9064
         #9065 #9066 #9067 #9068 #9069 #9070 #9071 #9072 #9073 #9074 #9075 #9076
          #9077 #9078 #9079 #9080 #9081 #9082
          imp:n=1 *fill=121 (0 0 66.30306154 30 120 90  60 30 90  90 90 0)
6105 10 4.8492E-05  -7001 -7002 9003 #9083 #9084 #9085 #9086 #9087
         #9088 #9089 #9090 #9091 #9092 #9093 #9094 #9095 #9096 #9097 #9098
          #9099 #9100 #9101 #9102 #9103 #9104 #9105 #9106
          imp:n=1 *fill=121 (0 0 66.30306154 30 120 90  60 30 90  90 90 0)
c
c ------ Lattice Spacers ------
9011 32 8.7390E-02  7031 -7032 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 2
9012 32 8.7390E-02  7131 -7132 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 2
9013 32 8.7390E-02  7031 -7032 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 2
9014 32 8.7390E-02  7131 -7132 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 2
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9015 32 8.7390E-02  7031 -7032 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 2
9016 32 8.7390E-02  7131 -7132 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 2
9017 32 8.7390E-02  7033 -7034 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 4
9018 32 8.7390E-02  7133 -7134 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 4
9019 32 8.7390E-02  7033 -7034 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 4
9020 32 8.7390E-02  7133 -7134 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 4
9021 32 8.7390E-02  7033 -7034 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 4
9022 32 8.7390E-02  7133 -7134 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 4
9023 32 8.7390E-02  7035 -7036 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 6
9024 32 8.7390E-02  7135 -7136 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 6
9025 32 8.7390E-02  7035 -7036 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 6
9026 32 8.7390E-02  7135 -7136 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 6
9027 32 8.7390E-02  7035 -7036 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 6
9028 32 8.7390E-02  7135 -7136 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 6
9029 32 8.7390E-02  7037 -7038 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 8
9030 32 8.7390E-02  7137 -7138 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 8
9031 32 8.7390E-02  7037 -7038 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 8
9032 32 8.7390E-02  7137 -7138 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 8
9033 32 8.7390E-02  7037 -7038 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 8
9034 32 8.7390E-02  7137 -7138 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 8
9035 32 8.7390E-02  7039 -7040 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 10
9036 32 8.7390E-02  7139 -7140 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 10
9037 32 8.7390E-02  7039 -7040 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 10
9038 32 8.7390E-02  7139 -7140 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 10
9039 32 8.7390E-02  7039 -7040 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 10
9040 32 8.7390E-02  7139 -7140 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 10
9041 32 8.7390E-02  7041 -7042 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 12
9042 32 8.7390E-02  7141 -7142 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 12
9043 32 8.7390E-02  7041 -7042 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 12
9044 32 8.7390E-02  7141 -7142 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 12
9045 32 8.7390E-02  7041 -7042 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 12
9046 32 8.7390E-02  7141 -7142 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 12
9047 32 8.7390E-02  7043 -7044 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 14
9048 32 8.7390E-02  7143 -7144 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 14
9049 32 8.7390E-02  7043 -7044 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 14
9050 32 8.7390E-02  7143 -7144 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 14
9051 32 8.7390E-02  7043 -7044 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 14
9052 32 8.7390E-02  7143 -7144 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 14
9053 32 8.7390E-02  7045 -7046 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 16
9054 32 8.7390E-02  7145 -7146 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 16
9055 32 8.7390E-02  7045 -7046 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 16
9056 32 8.7390E-02  7145 -7146 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 16
9057 32 8.7390E-02  7045 -7046 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 16
9058 32 8.7390E-02  7145 -7146 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 16
9059 32 8.7390E-02  7047 -7048 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 18
9060 32 8.7390E-02  7147 -7148 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 18
9061 32 8.7390E-02  7047 -7048 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 18
9062 32 8.7390E-02  7147 -7148 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 18
9063 32 8.7390E-02  7047 -7048 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 18
9064 32 8.7390E-02  7147 -7148 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 18
9065 32 8.7390E-02  7049 -7050 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 20
9066 32 8.7390E-02  7149 -7150 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 20
9067 32 8.7390E-02  7049 -7050 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 20
9068 32 8.7390E-02  7149 -7150 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 20
9069 32 8.7390E-02  7049 -7050 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 20
9070 32 8.7390E-02  7149 -7150 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 20
9071 32 8.7390E-02  7051 -7052 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 22
9072 32 8.7390E-02  7151 -7152 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 22
9073 32 8.7390E-02  7051 -7052 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 22
9074 32 8.7390E-02  7151 -7152 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 22
9075 32 8.7390E-02  7051 -7052 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 22
9076 32 8.7390E-02  7151 -7152 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 22
9077 10 4.8492E-05  7053 -7054 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 24
9078 10 4.8492E-05  7153 -7154 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 24
9079 10 4.8492E-05  7053 -7054 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 24
9080 10 4.8492E-05  7153 -7154 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 24
9081 10 4.8492E-05  7053 -7054 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 24
9082 10 4.8492E-05  7153 -7154 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 24
9083 10 4.8492E-05  7055 -7056 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 26
9084 10 4.8492E-05  7155 -7156 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 26
9085 10 4.8492E-05  7055 -7056 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 26
9086 10 4.8492E-05  7155 -7156 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 26
9087 10 4.8492E-05  7055 -7056 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 26
9088 10 4.8492E-05  7155 -7156 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 26
9089 10 4.8492E-05  7057 -7058 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 28
```

```
9090 10 4.8492E-05  7157 -7158 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 28
9091 10 4.8492E-05  7057 -7058 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 28
9092 10 4.8492E-05  7157 -7158 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 28
9093 10 4.8492E-05  7057 -7058 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 28
9094 10 4.8492E-05  7157 -7158 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 28
9095 10 4.8492E-05  7059 -7060 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 30
9096 10 4.8492E-05  7159 -7160 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 30
9097 10 4.8492E-05  7059 -7060 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 30
9098 10 4.8492E-05  7159 -7160 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 30
9099 10 4.8492E-05  7059 -7060 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 30
9100 10 4.8492E-05  7159 -7160 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 30
9101 10 4.8492E-05  7061 -7062 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 32
9102 10 4.8492E-05  7161 -7162 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 32
9103 10 4.8492E-05  7061 -7062 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 32
9104 10 4.8492E-05  7161 -7162 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 32
9105 10 4.8492E-05  7061 -7062 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 32
9106 10 4.8492E-05  7161 -7162 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 32
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 ------ 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 ------ 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
```

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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
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
```

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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
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
```

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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
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
```

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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
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
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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
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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
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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 ------ ZEBRA Rods ------
c --------- Outer (Fixed) Sleeve ---------
c    *Same as Bottom of Radial Reflector  $ Bottom of Tube
3041  pz   50.2    $ Bottom of Cadmium Sheath 1
3042  pz   66.2    $ Top of Cadmium Sheath 1
3043  pz   90.2    $ Bottom of Cadmium Sheath 2
3044  pz  106.2    $ Top of Cadmium Sheath 2
3045  pz  130.2    $ Bottom of Cadmium Sheath 3
3046  pz  146.2    $ Top of Cadmium Sheath 3
3047  pz  170.2    $ Bottom of Cadmium Sheath 4
3048  pz  186.2    $ Top of Cadmium Sheath 4
3049  pz  210.2    $ Bottom of Cadmium Sheath 5
3050  pz  226.2    $ Top of Cadmium Sheath 5
3051  pz  250.2    $ Bottom of Cadmium Sheath 6
3052  pz  266.2    $ Top of Cadmium Sheath 6
3053  pz  368.5    $ Top of Tube
3054  cz    1.785  $ Tube Inner Radius
3055  cz    2.1    $ Tube Outer Radius
3056  cz    2.125  $ Cadmium Sheath Radius
c
c --------- Inner (Moveable) Sleeve ---------
3061  pz  -15.85  $ Bottom of Tube
3062  pz   30.2   $ Bottom of Cadmium Sheath 1
3063  pz   46.2   $ Top of Cadmium Sheath 1
3064  pz   70.2   $ Bottom of Cadmium Sheath 2
3065  pz   86.2   $ Top of Cadmium Sheath 2
3066  pz  110.2   $ Bottom of Cadmium Sheath 3
3067  pz  126.2   $ Top of Cadmium Sheath 3
3068  pz  150.2   $ Bottom of Cadmium Sheath 4
3069  pz  166.2   $ Top of Cadmium Sheath 4
3070  pz  190.2   $ Bottom of Cadmium Sheath 5
3071  pz  206.2   $ Top of Cadmium Sheath 5
3072  pz  230.2   $ Bottom of Cadmium Sheath 6
3073  pz  246.2   $ Top of Cadmium Sheath 6
3074  pz  310.5   $ Top of Tube
3075  cz    1.5   $ Tube Inner Radius
3076  cz    1.75  $ Tube Outer Radius
3077  cz    1.775 $ Cadmium Sheath Radius
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  4.898979486 2.35  $ Middle Top Fuel Zone
3132  s   0            0  4.898979486 3.00  $ Middle Top Pebble Shell
3133  s  -5.196152423  3  4.898979486 2.35  $ NW Top Corner Fuel Zone
3134  s  -5.196152423  3  4.898979486 3.00  $ NW Top Corner Pebble Shell
3135  s   5.196152423  3  4.898979486 2.35  $ NE Top Corner Fuel Zone
3136  s   5.196152423  3  4.898979486 3.00  $ NE Top Corner Pebble Shell
3137  s   0           -6  4.898979486 2.35  $ S Top Corner Fuel Zone
3138  s   0           -6  4.898979486 3.00  $ S Top Corner Pebble Shell
3139  s  -1.732050808  3  0           2.35  $ NW Middle Edge Fuel Zone
3140  s  -1.732050808  3  0           3.00  $ NW Middle Edge Pebble Shell
3141  s   3.464101615  0  0           2.35  $ E Middle Edge Fuel Zone
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3142  s   3.464101615  0  0           3.00  $ E Middle Edge Pebble Shell
3143  s  -6.928203230  0  0           2.35  $ W Middle Edge Fuel Zone
3144  s  -6.928203230  0  0           3.00  $ W Middle Edge Pebble Shell
3145  s   3.464101615 -6  0           2.35  $ SE Middle Edge Fuel Zone
3146  s   3.464101615 -6  0           3.00  $ SE Middle Edge Pebble Shell
3147  s  -5.196152423  3 -4.898979486 2.35  $ NW Bottom Corner Fuel Zone
3148  s  -5.196152423  3 -4.898979486 3.00  $ NW Bottom Corner Pebble Shell
3149  s   5.196152423  3 -4.898979486 2.35  $ NE Bottom Corner Fuel Zone
3150  s   5.196152423  3 -4.898979486 3.00  $ NE Bottom Corner Pebble Shell
3151  s   0           -6 -4.898979486 2.35  $ S Bottom Corner Fuel Zone
3152  s   0           -6 -4.898979486 3.00  $ S Bottom Corner Pebble Shell
3153  s   0            0 -4.898979486 2.35  $ Middle Bottom Fuel Zone
3154  s   0            0 -4.898979486 3.00  $ Middle Bottom Pebble Shell
c
c ------ Moderator Pebble ------
4131  s   0            6  4.898979486 3.00  $ N Top Corner Pebble
4132  s   5.196152423 -3  4.898979486 3.00  $ SE Top Corner Pebble
4133  s  -5.196152423 -3  4.898979486 3.00  $ SW Top Corner Pebble
4134  s   3.464101615  6  0           3.00  $ NE Middle Edge Pebble
4135  s  -1.732050808 -3  0           3.00  $ SW Middle Edge Pebble
4136  s   0            6 -4.898979486 3.00  $ N Bottom Corner Pebble
4137  s   5.196152423 -3 -4.898979486 3.00  $ SE Bottom Corner Pebble
4138  s  -5.196152423 -3 -4.898979486 3.00  $ SW Bottom Corner Pebble
c
c ------ HCP Pebble Lattice ------
6001  hex  0 0 -5.1  0 0 10.2  5.196152423 0 0
c
c ------ HCP Pebble Layer Lattice ------
6002  hex  0 0 -5  0 0 10  63 0 0
6003  hex  0 0 -4.898979486  0 0 9.797958971  61 0 0
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 ------ Lattice Spacers ------
9001  pz 120
9002  pz 160
9003  pz 200
7028  hex  0 0 78  0 0 172.9  0 56.83 0  $ Inside Surface of Larger Spacers
7029  hex  0 0 78  0 0 172.9  0 58.57 0  $ Inside Surface of Small Spacers
7030  py   0
c
7031  pz   83.99897948  $ Bottom Large Spacer Layer 2
7032  pz   87.79897948  $ Top Large Spacer Layer 2
7033  pz   93.79693845  $ Bottom Large Spacer Layer 4
7034  pz   97.59693845  $ Top Large Spacer Layer 4
7035  pz  103.5948974   $ Bottom Large Spacer Layer 6
7036  pz  107.3948974   $ Top Large Spacer Layer 6
7037  pz  113.3928564   $ Bottom Large Spacer Layer 8
7038  pz  117.1928564   $ Top Large Spacer Layer 8
7039  pz  123.1908154   $ Bottom Large Spacer Layer 10
7040  pz  126.9908154   $ Top Large Spacer Layer 10
7041  pz  132.9887743   $ Bottom Large Spacer Layer 12
7042  pz  136.7887743   $ Top Large Spacer Layer 12
7043  pz  142.7867333   $ Bottom Large Spacer Layer 14
7044  pz  146.5867333   $ Top Large Spacer Layer 14
7045  pz  152.5846923   $ Bottom Large Spacer Layer 16
7046  pz  156.3846923   $ Top Large Spacer Layer 16
7047  pz  162.3826513   $ Bottom Large Spacer Layer 18
7048  pz  166.1826513   $ Top Large Spacer Layer 18
7049  pz  172.1806102   $ Bottom Large Spacer Layer 20
7050  pz  175.9806102   $ Top Large Spacer Layer 20
7051  pz  181.9785692   $ Bottom Large Spacer Layer 22
7052  pz  185.7785692   $ Top Large Spacer Layer 22
7053  pz  191.7765282   $ Bottom Large Spacer Layer 24
7054  pz  195.5765282   $ Top Large Spacer Layer 24
7055  pz  201.5744871   $ Bottom Large Spacer Layer 26
7056  pz  205.3744871   $ Top Large Spacer Layer 26
7057  pz  211.3724461   $ Bottom Large Spacer Layer 28
7058  pz  215.1724461   $ Top Large Spacer Layer 28
7059  pz  221.1704051   $ Bottom Large Spacer Layer 30
7060  pz  224.9704051   $ Top Large Spacer Layer 30
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7061  pz  230.968364    $ Bottom Large Spacer Layer 32
7062  pz  234.768364    $ Top Large Spacer Layer 32
c
7131  pz   83.71897948  $ Bottom Small Spacer Layer 2
7132  pz   88.07897948  $ Top Small Spacer Layer 2
7133  pz   93.51693845  $ Bottom Small Spacer Layer 4
7134  pz   97.87693845  $ Top Small Spacer Layer 4
7135  pz  103.3148974   $ Bottom Small Spacer Layer 6
7136  pz  107.6748974   $ Top Small Spacer Layer 6
7137  pz  113.1128564   $ Bottom Small Spacer Layer 8
7138  pz  117.4728564   $ Top Small Spacer Layer 8
7139  pz  122.9108154   $ Bottom Small Spacer Layer 10
7140  pz  127.2708154   $ Top Small Spacer Layer 10
7141  pz  132.7087743   $ Bottom Small Spacer Layer 12
7142  pz  137.0687743   $ Top Small Spacer Layer 12
7143  pz  142.5067333   $ Bottom Small Spacer Layer 14
7144  pz  146.8667333   $ Top Small Spacer Layer 14
7145  pz  152.3046923   $ Bottom Small Spacer Layer 16
7146  pz  156.6646923   $ Top Small Spacer Layer 16
7147  pz  162.1026513   $ Bottom Small Spacer Layer 18
7148  pz  166.4626513   $ Top Small Spacer Layer 18
7149  pz  171.9006102   $ Bottom Small Spacer Layer 20
7150  pz  176.2606102   $ Top Small Spacer Layer 20
7151  pz  181.6985692   $ Bottom Small Spacer Layer 22
7152  pz  186.0585692   $ Top Small Spacer Layer 22
7153  pz  191.4965282   $ Bottom Small Spacer Layer 24
7154  pz  195.8565282   $ Top Small Spacer Layer 24
7155  pz  201.2944871   $ Bottom Small Spacer Layer 26
7156  pz  205.6544871   $ Top Small Spacer Layer 26
7157  pz  211.0924461   $ Bottom Small Spacer Layer 28
7158  pz  215.4524461   $ Top Small Spacer Layer 28
7159  pz  220.8904051   $ Bottom Small Spacer Layer 30
7160  pz  225.2504051   $ Top Small Spacer Layer 30
7161  pz  230.688364    $ Bottom Small Spacer Layer 32
7162  pz  235.048364    $ Top Small Spacer Layer 32
c
7201  px -15.5  $ West Surface N/S Spacers
7202  px  15.5  $ East Surface N/S Spacers
7203  p  -44.471332 43.573394 0 -41.466224 41.838394 0 -41.463224 41.838394 1  $ North Surface of
NW/SE Spacers
7204  p  -59.971332 16.726606 0 -56.966224 14.991606 0 -56.966224 14.991606 1  $ South Surface of
NW/SE Spacers
7205  p   44.471332 43.573394 0  41.466224 41.838394 0  41.466224 41.838394 1  $ North Surface of
NE/SW Spacers
7206  p   59.971332 16.726606 0  56.966224 14.991606 0  56.966224 14.991606 1  $ South Surface of
NE/SW Spacers
c
c --- Water Ingress Simulation -------------------------------------------------
c ------ Polyethylene Rods ------
c    *Polyethylene Rods Not Used in Configurations 1, 1A, & 2
7021  c/z  -3.464101615  0.0 0.445  $ W Rod
7022  c/z   1.732050808  3.0 0.445  $ NE Rod
7023  c/z   1.732050808 -3.0 0.445  $ SE Rod
7024  pz   -0.28265126              $ 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 2.3241E-08   5011.70c 9.3546E-08   6000.70c 8.7809E-02
c         Total 8.7809E-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
```

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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 ------ Cadmium (i.e. 5N) ------
m15   48106.70c 5.7924E-04  48108.70c 4.1242E-04  48110.70c 5.7878E-03
      48111.70c 5.9315E-03  48112.70c 1.1182E-02  48113.70c 5.6627E-03
      48114.70c 1.3313E-02  48116.70c 3.4708E-03  29063.70c 2.8351E-09
      29065.70c 1.2636E-09  26054.70c 5.4521E-10  26056.70c 8.5586E-09
      26057.70c 1.9766E-10  26058.70c 2.6304E-11  82204.70c 7.0393E-10
      82206.70c 1.2118E-08  82207.70c 1.1112E-08  82208.70c 2.6347E-08
      12024.70c 5.0788E-07  12025.70c 6.4297E-08  12026.70c 7.0791E-08
      13027.70c 3.8612E-08  14028.70c 3.4212E-08  14029.70c 1.7372E-09
      14030.70c 1.1452E-09  47107.70c 1.2517E-09  47109.70c 1.1629E-09
      22046.70c 1.7956E-09  22047.70c 1.6193E-09  22048.70c 1.6045E-08
      22049.70c 1.1775E-09  22050.70c 1.1274E-09  83209.70c 7.4779E-08
      20040.70c 1.2600E-08  20042.70c 8.4093E-11  20043.70c 1.7547E-11
      20044.70c 2.7113E-10  20046.70c 5.1990E-13  20048.70c 2.4305E-11
c         Total 4.6340E-02
mt15  al27.12t fe56.12t
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c
c ------ Peraluman R-257 (ZEBRA Rods) ------
m16    5010.70c 1.4688E-07   5011.70c 5.9119E-07  12024.70c 7.2610E-04
      12025.70c 9.1923E-05  12026.70c 1.0121E-04  13027.70c 5.8004E-02
      14028.70c 1.0481E-04  14029.70c 5.3221E-06  14030.70c 3.5084E-06
      25055.70c 1.4524E-06  26054.70c 3.3406E-06  26056.70c 5.2440E-05
      26057.70c 1.2111E-06  26058.70c 1.6117E-07  29063.70c 3.4742E-06
      29065.70c 1.5485E-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 5.9127E-02
mt16  al27.12t 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 *** 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 made but have not yet been evaluated.

A.3 Spectral-Characteristics Configurations

Spectral characteristics measurements were not made.

A.4 Reactivity-Effects Configurations

Reactivity effects measurements were made but have not yet been evaluated.

A.5 Reactivity Coefficient Configurations

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

A.6 Kinetics Parameter Configurations

Kinetics measurements were made but have not yet been evaluated.

A.7 Reaction-Rate Configurations

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

A.8 Power Distribution Configurations

Power distribution measurements were not made.

A.9 Isotopic Configurations

Isotopic measurements were not made.

A.10 Configurations of Other Miscellaneous Types of Measurements

Other miscellaneous types of measurements were not made.

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 through B.1-1 for Cases 1 through 4 (Cores 1, 1A, 2, and 3), respectively.

Table B.1-1. Neutron Spectral Data for Benchmark Model for Case 1 (Core 1).

Neutron Cross Section Library		ENDF/B-VII.0
k_{eff}		1.01061
$\pm\sigma_k$		0.00007
Neutron Leakage (%)[a]		14.05
Fission Fraction, by Energy (%)	**Thermal (<0.625 eV)**	93.32
	Intermediate	6.26
	Fast (>100 keV)	0.41
Average Number of Neutrons Produced per Fission		2.437
Energy of Average Neutron Lethargy Causing Fission (eV)		0.067043
Neutron Generation Time, Λ (msec)		1.49479
Rossi-α ($msec^{-1}$)		-4.72150E-03
β_{eff}		0.00706

(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 1A).

Neutron Cross Section Library		ENDF/B-VII.0
k_{eff} **$\pm\sigma_k$**		1.00945 0.00007
Neutron Leakage (%)[(a)]		15.43
Fission Fraction, by Energy (%)	**Thermal (<0.625 eV)**	93.44
	Intermediate	6.15
	Fast (>100 keV)	0.41
Average Number of Neutrons Produced per Fission		2.437
Energy of Average Neutron Lethargy Causing Fission (eV)		0.066066
Neutron Generation Time, Λ (msec)		1.62019
Rossi-α ($msec^{-1}$)		-4.32111E-03
β_{eff}		0.00700

(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.1-3. Neutron Spectral Data for Benchmark Model for Case 3 (Core 2).

Neutron Cross Section Library		ENDF/B-VII.0
k_{eff}		1.01044
$\pm\sigma_k$		0.00007
Neutron Leakage (%)[(a)]		14.83
Fission Fraction, by Energy (%)	**Thermal (<0.625 eV)**	93.74
	Intermediate	5.86
	Fast (>100 keV)	0.40
Average Number of Neutrons Produced per Fission		2.437
Energy of Average Neutron Lethargy Causing Fission (eV)		0.063000
Neutron Generation Time, Λ (msec)		1.67731
Rossi-α ($msec^{-1}$)		-4.17634E-03
β_{eff}		0.00701

(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.1-4. Neutron Spectral Data for Benchmark Model for Case 4 (Core 3).

Neutron Cross Section Library		ENDF/B-VII.0
k_{eff}		1.00888
$\pm\sigma_k$		0.00007
Neutron Leakage (%)[(a)]		15.29
Fission Fraction, by Energy (%)	**Thermal (<0.625 eV)**	95.30
	Intermediate	4.33
	Fast (>100 keV)	0.37
Average Number of Neutrons Produced per Fission		2.437
Energy of Average Neutron Lethargy Causing Fission (eV)		0.051992
Neutron Generation Time, Λ (msec)		1.45964
Rossi-α ($msec^{-1}$)		-4.85717E-03
β_{eff}		0.00709

(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 1, 1A, 2, and 3 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 50,000 neutrons per generation. The k_{eff} estimates (with the first 150 generations skipped) are the result of 75,000,000 neutron histories. Calculated results obtained with this input deck are provided in Tables C.1-1 through C.1-4 for each core, respectively.

The input deck provided below is for core configuration 1. The following portions of the code need reconfigured for core configurations 1A, 2, and 3:

- ZEBRA rods replaced by graphite fillers
- C-Driver channels in ring 5 of radial reflector replaced with withdrawable control rods
- Autorod position
- Withdrawable control rod positions
- Core cavity filled with correct pebble configuration
- Lattice supports provided for proper amount of pebble layers
- Change air composition and atom density.

Table C.1-1. Neutron Spectral Data for Detailed Model (Core 1).

Neutron Cross Section Library		ENDF/B-VII.0
k_{eff}		1.00943
$\pm\sigma_k$		0.00007
Neutron Leakage (%)[(a)]		1.42
Fission Fraction, by Energy (%)	Thermal (<0.625 eV)	93.32
	Intermediate	6.27
	Fast (>100 keV)	0.41
Average Number of Neutrons Produced per Fission		2.437
Energy of Average Neutron Lethargy Causing Fission (eV)		0.067084
Neutron Generation Time, Λ (msec)		1.49956
Rossi-α (msec^{-1})		-4.7249E-03
β_{eff}		0.00709

(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 1A).

Neutron Cross Section Library		ENDF/B-VII.0
k_{eff}		1.00827
$\pm\sigma_k$		0.00007
Neutron Leakage (%)[(a)]		1.51
Fission Fraction, by Energy (%)	**Thermal (<0.625 eV)**	93.43
	Intermediate	6.16
	Fast (>100 keV)	0.41
Average Number of Neutrons Produced per Fission		2.438
Energy of Average Neutron Lethargy Causing Fission (eV)		0.066103
Neutron Generation Time, Λ (msec)		1.63030
Rossi-α ($msec^{-1}$)		-4.29972E-03
β_{eff}		0.00701

(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.1-3. Neutron Spectral Data for Detailed Model (Core 2).

Neutron Cross Section Library		ENDF/B-VII.0
k_{eff} $\pm\sigma_k$		1.01010 0.00007
Neutron Leakage (%)[(a)]		0.84
Fission Fraction, by Energy (%)	Thermal (<0.625 eV)	93.75
	Intermediate	5.86
	Fast (>100 keV)	0.40
Average Number of Neutrons Produced per Fission		2.437
Energy of Average Neutron Lethargy Causing Fission (eV)		0.063750
Neutron Generation Time, Λ (msec)		1.69638
Rossi-α ($msec^{-1}$)		-4.11990E-03
β_{eff}		0.00699

(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.1-4. Neutron Spectral Data for Detailed Model (Core 3).

Neutron Cross Section Library		ENDF/B-VII.0
k_{eff}		1.00793
$\pm\sigma_k$		0.00007
Neutron Leakage (%)[(a)]		1.47
Fission Fraction, by Energy (%)	**Thermal (<0.625 eV)**	95.30
	Intermediate	4.33
	Fast (>100 keV)	0.37
Average Number of Neutrons Produced per Fission		2.438
Energy of Average Neutron Lethargy Causing Fission (eV)		0.052019
Neutron Generation Time, Λ (msec)		1.46375
Rossi-α ($msec^{-1}$)		-4.86896E-03
β_{eff}		0.00713

(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 1 (can be modified for Cores 1A, 2, and 3):

```
HTR-PROTEUS :: Cores 1, 1A, 2, & 3
c Pebble Bed Experimental Program
c Hexagonal Close Packing with a 1:2 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 4.8129E-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 4.8129E-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 4.8129E-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 4.8129E-05  -101 601 31 -32 imp:n=1  $ Position 1
102  10 4.8129E-05  -102 602 31 -32 imp:n=1  $ Position 2
c    *Replaced by Safety/Shutdown Rod  $ Position 3
104  10 4.8129E-05  -104 604 31 -32 imp:n=1  $ Position 4
105  10 4.8129E-05  -105 605 31 -32 imp:n=1  $ Position 5
106  10 4.8129E-05  -106 606 31 -32 imp:n=1  $ Position 6
107  10 4.8129E-05  -107 607 31 -32 imp:n=1  $ Position 7
108  10 4.8129E-05  -108 608 31 -32 imp:n=1  $ Position 8
109  10 4.8129E-05  -109 609 31 -32 imp:n=1  $ Position 9
110  10 4.8129E-05  -110 610 31 -32 imp:n=1  $ Position 10
c    *Replaced by Safety/Shutdown Rod  $ Position 11
112  10 4.8129E-05  -112 612 31 -32 imp:n=1  $ Position 12
113  10 4.8129E-05  -113 613 31 -32 imp:n=1  $ Position 13
114  10 4.8129E-05  -114 614 31 -32 imp:n=1  $ Position 14
115  10 4.8129E-05  -115 615 31 -32 imp:n=1  $ Position 15
116  10 4.8129E-05  -116 616 31 -32 imp:n=1  $ Position 16
117  10 4.8129E-05  -117 617 31 -32 imp:n=1  $ Position 17
118  10 4.8129E-05  -118 618 31 -32 imp:n=1  $ Position 18
119  10 4.8129E-05  -119 619 31 -32 imp:n=1  $ Position 19
c    *Replaced by Safety/Shutdown Rod  $ Position 20
121  10 4.8129E-05  -121 621 31 -32 imp:n=1  $ Position 21
122  10 4.8129E-05  -122 622 31 -32 imp:n=1  $ Position 22
123  10 4.8129E-05  -123 623 31 -32 imp:n=1  $ Position 23
124  10 4.8129E-05  -124 624 31 -32 imp:n=1  $ Position 24
125  10 4.8129E-05  -125 625 31 -32 imp:n=1  $ Position 25
126  10 4.8129E-05  -126 626 31 -32 imp:n=1  $ Position 26
c    *Replaced by Safety/Shutdown Rod  $ Position 27
128  10 4.8129E-05  -128 628 31 -32 imp:n=1  $ Position 28
129  10 4.8129E-05  -129 629 31 -32 imp:n=1  $ Position 29
130  10 4.8129E-05  -130 630 31 -32 imp:n=1  $ Position 30
131  10 4.8129E-05  -131 631 31 -32 imp:n=1  $ Position 31
132  10 4.8129E-05  -132 632 31 -32 imp:n=1  $ Position 32
133  10 4.8129E-05  -133 633 31 -32 imp:n=1  $ Position 33
134  10 4.8129E-05  -134 634 31 -32 imp:n=1  $ Position 34
c    *Replaced by Safety/Shutdown Rod  $ Position 35
136  10 4.8129E-05   -136 636 31 -32 imp:n=1  $ Position 36
137  10 4.8129E-05   -137 637 31 -32 imp:n=1  $ Position 37
138  10 4.8129E-05   -138 638 31 -32 imp:n=1  $ Position 38
139  10 4.8129E-05   -139 639 31 -32 imp:n=1  $ Position 39
140  10 4.8129E-05   -140 640 31 -32 imp:n=1  $ Position 40
141  10 4.8129E-05   -141 641 31 -32 imp:n=1  $ Position 41
142  10 4.8129E-05   -142 642 31 -32 imp:n=1  $ Position 42
143  10 4.8129E-05   -143 643 31 -32 imp:n=1  $ Position 43
c    *Replaced by Safety/Shutdown Rod  $ Position 44
145  10 4.8129E-05   -145 645 31 -32 imp:n=1  $ Position 45
146  10 4.8129E-05   -146 646 31 -32 imp:n=1  $ Position 46
147  10 4.8129E-05   -147 647 31 -32 imp:n=1  $ Position 47
148  10 4.8129E-05   -148 648 31 -32 imp:n=1  $ Position 48
149  10 4.8129E-05   -149 649 31 -32 imp:n=1  $ Position 49
150  10 4.8129E-05   -150 650 31 -32 imp:n=1  $ Position 50
c    *Replaced by Safety/Shutdown Rod  $ Position 51
152  10 4.8129E-05   -152 652 31 -32 imp:n=1  $ Position 52
```

```
153  10 4.8129E-05   -153 653 31 -32 imp:n=1  $ Position 53
154  10 4.8129E-05   -154 654 31 -32 imp:n=1  $ Position 54
155  10 4.8129E-05   -155 655 31 -32 imp:n=1  $ Position 55
156  10 4.8129E-05   -156 656 31 -32 imp:n=1  $ Position 56
157  10 4.8129E-05   -157 657 31 -32 imp:n=1  $ Position 57
c    *Replaced by Safety/Shutdown Rod  $ Position 58
159  10 4.8129E-05   -159 659 31 -32 imp:n=1  $ Position 59
160  10 4.8129E-05   -160 660 31 -32 imp:n=1  $ Position 60
161  10 4.8129E-05   -161 661 31 -32 imp:n=1  $ Position 61
162  10 4.8129E-05   -162 662 31 -32 imp:n=1  $ Position 62
163  10 4.8129E-05   -163 663 31 -32 imp:n=1  $ Position 63
164  10 4.8129E-05   -164 664 31 -32 imp:n=1  $ Position 64
c
c --------- Ring 2 ---------
201  10 4.8129E-05   -201 701 31 -32 imp:n=1  $ Position 1
202  10 4.8129E-05   -202 702 31 -32 imp:n=1  $ Position 2
203  10 4.8129E-05   -203 703 31 -32 imp:n=1  $ Position 3
204  10 4.8129E-05   -204 704 31 -32 imp:n=1  $ Position 4
205  10 4.8129E-05   -205 705 31 -32 imp:n=1  $ Position 5
206  10 4.8129E-05   -206 706 31 -32 imp:n=1  $ Position 6
207  10 4.8129E-05   -207 707 31 -32 imp:n=1  $ Position 7
208  10 4.8129E-05   -208 708 31 -32 imp:n=1  $ Position 8
209  10 4.8129E-05   -209 709 31 -32 imp:n=1  $ Position 9
210  10 4.8129E-05   -210 710 31 -32 imp:n=1  $ Position 10
211  10 4.8129E-05   -211 711 31 -32 imp:n=1  $ Position 11
212  10 4.8129E-05   -212 712 31 -32 imp:n=1  $ Position 12
213  10 4.8129E-05   -213 713 31 -32 imp:n=1  $ Position 13
214  10 4.8129E-05   -214 714 31 -32 imp:n=1  $ Position 14
215  10 4.8129E-05   -215 715 31 -32 imp:n=1  $ Position 15
216  10 4.8129E-05   -216 716 31 -32 imp:n=1  $ Position 16
217  10 4.8129E-05   -217 717 31 -32 imp:n=1  $ Position 17
218  10 4.8129E-05   -218 718 31 -32 imp:n=1  $ Position 18
219  10 4.8129E-05   -219 719 31 -32 imp:n=1  $ Position 19
220  10 4.8129E-05   -220 720 31 -32 imp:n=1  $ Position 20
221  10 4.8129E-05   -221 721 31 -32 imp:n=1  $ Position 21
222  10 4.8129E-05   -222 722 31 -32 imp:n=1  $ Position 22
223  10 4.8129E-05   -223 723 31 -32 imp:n=1  $ Position 23
224  10 4.8129E-05   -224 724 31 -32 imp:n=1  $ Position 24
225  10 4.8129E-05   -225 725 31 -32 imp:n=1  $ Position 25
226  10 4.8129E-05   -226 726 31 -32 imp:n=1  $ Position 26
227  10 4.8129E-05   -227 727 31 -32 imp:n=1  $ Position 27
228  10 4.8129E-05   -228 728 31 -32 imp:n=1  $ Position 28
229  10 4.8129E-05   -229 729 31 -32 imp:n=1  $ Position 29
230  10 4.8129E-05   -230 730 31 -32 imp:n=1  $ Position 30
231  10 4.8129E-05   -231 731 31 -32 imp:n=1  $ Position 31
232  10 4.8129E-05   -232 732 31 -32 imp:n=1  $ Position 32
233  10 4.8129E-05   -233 733 31 -32 imp:n=1  $ Position 33
234  10 4.8129E-05   -234 734 31 -32 imp:n=1  $ Position 34
235  10 4.8129E-05   -235 735 31 -32 imp:n=1  $ Position 35
236  10 4.8129E-05   -236 736 31 -32 imp:n=1  $ Position 36
237  10 4.8129E-05   -237 737 31 -32 imp:n=1  $ Position 37
238  10 4.8129E-05   -238 738 31 -32 imp:n=1  $ Position 38
239  10 4.8129E-05   -239 739 31 -32 imp:n=1  $ Position 39
240  10 4.8129E-05   -240 740 31 -32 imp:n=1  $ Position 40
241  10 4.8129E-05   -241 741 31 -32 imp:n=1  $ Position 41
242  10 4.8129E-05   -242 742 31 -32 imp:n=1  $ Position 42
243  10 4.8129E-05   -243 743 31 -32 imp:n=1  $ Position 43
244  10 4.8129E-05   -244 744 31 -32 imp:n=1  $ Position 44
245  10 4.8129E-05   -245 745 31 -32 imp:n=1  $ Position 45
246  10 4.8129E-05   -246 746 31 -32 imp:n=1  $ Position 46
247  10 4.8129E-05   -247 747 31 -32 imp:n=1  $ Position 47
248  10 4.8129E-05   -248 748 31 -32 imp:n=1  $ Position 48
249  10 4.8129E-05   -249 749 31 -32 imp:n=1  $ Position 49
250  10 4.8129E-05   -250 750 31 -32 imp:n=1  $ Position 50
251  10 4.8129E-05   -251 751 31 -32 imp:n=1  $ Position 51
252  10 4.8129E-05   -252 752 31 -32 imp:n=1  $ Position 52
253  10 4.8129E-05   -253 753 31 -32 imp:n=1  $ Position 53
254  10 4.8129E-05   -254 754 31 -32 imp:n=1  $ Position 54
255  10 4.8129E-05   -255 755 31 -32 imp:n=1  $ Position 55
256  10 4.8129E-05   -256 756 31 -32 imp:n=1  $ Position 56
257  10 4.8129E-05   -257 757 31 -32 imp:n=1  $ Position 57
258  10 4.8129E-05   -258 758 31 -32 imp:n=1  $ Position 58
259  10 4.8129E-05   -259 759 31 -32 imp:n=1  $ Position 59
260  10 4.8129E-05   -260 760 31 -32 imp:n=1  $ Position 60
261  10 4.8129E-05   -261 761 31 -32 imp:n=1  $ Position 61
```

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262  10 4.8129E-05   -262 762 31 -32 imp:n=1  $ Position 62
263  10 4.8129E-05   -263 763 31 -32 imp:n=1  $ Position 63
264  10 4.8129E-05   -264 764 31 -32 imp:n=1  $ Position 64
c
c --------- Ring 3 ---------
301  10 4.8129E-05   -301 801 31 -32 imp:n=1  $ Position 1
302  10 4.8129E-05   -302 802 31 -32 imp:n=1  $ Position 2
303  10 4.8129E-05   -303 803 31 -32 imp:n=1  $ Position 3
304  10 4.8129E-05   -304 804 31 -32 imp:n=1  $ Position 4
305  10 4.8129E-05   -305 805 31 -32 imp:n=1  $ Position 5
306  10 4.8129E-05   -306 806 31 -32 imp:n=1  $ Position 6
307  10 4.8129E-05   -307 807 31 -32 imp:n=1  $ Position 7
308  10 4.8129E-05   -308 808 31 -32 imp:n=1  $ Position 8
309  10 4.8129E-05   -309 809 31 -32 imp:n=1  $ Position 9
310  10 4.8129E-05   -310 810 31 -32 imp:n=1  $ Position 10
311  10 4.8129E-05   -311 811 31 -32 imp:n=1  $ Position 11
312  10 4.8129E-05   -312 812 31 -32 imp:n=1  $ Position 12
313  10 4.8129E-05   -313 813 31 -32 imp:n=1  $ Position 13
314  10 4.8129E-05   -314 814 31 -32 imp:n=1  $ Position 14
315  10 4.8129E-05   -315 815 31 -32 imp:n=1  $ Position 15
316  10 4.8129E-05   -316 816 31 -32 imp:n=1  $ Position 16
317  10 4.8129E-05   -317 817 31 -32 imp:n=1  $ Position 17
318  10 4.8129E-05   -318 818 31 -32 imp:n=1  $ Position 18
319  10 4.8129E-05   -319 819 31 -32 imp:n=1  $ Position 19
320  10 4.8129E-05   -320 820 31 -32 imp:n=1  $ Position 20
321  10 4.8129E-05   -321 821 31 -32 imp:n=1  $ Position 21
322  10 4.8129E-05   -322 822 31 -32 imp:n=1  $ Position 22
323  10 4.8129E-05   -323 823 31 -32 imp:n=1  $ Position 23
324  10 4.8129E-05   -324 824 31 -32 imp:n=1  $ Position 24
325  10 4.8129E-05   -325 825 31 -32 imp:n=1  $ Position 25
326  10 4.8129E-05   -326 826 31 -32 imp:n=1  $ Position 26
327  10 4.8129E-05   -327 827 31 -32 imp:n=1  $ Position 27
328  10 4.8129E-05   -328 828 31 -32 imp:n=1  $ Position 28
329  10 4.8129E-05   -329 829 31 -32 imp:n=1  $ Position 29
330  10 4.8129E-05   -330 830 31 -32 imp:n=1  $ Position 30
331  10 4.8129E-05   -331 831 31 -32 imp:n=1  $ Position 31
332  10 4.8129E-05   -332 832 31 -32 imp:n=1  $ Position 32
333  10 4.8129E-05   -333 833 31 -32 imp:n=1  $ Position 33
334  10 4.8129E-05   -334 834 31 -32 imp:n=1  $ Position 34
335  10 4.8129E-05   -335 835 31 -32 imp:n=1  $ Position 35
336  10 4.8129E-05   -336 836 31 -32 imp:n=1  $ Position 36
337  10 4.8129E-05   -337 837 31 -32 imp:n=1  $ Position 37
338  10 4.8129E-05   -338 838 31 -32 imp:n=1  $ Position 38
339  10 4.8129E-05   -339 839 31 -32 imp:n=1  $ Position 39
340  10 4.8129E-05   -340 840 31 -32 imp:n=1  $ Position 40
341  10 4.8129E-05   -341 841 31 -32 imp:n=1  $ Position 41
342  10 4.8129E-05   -342 842 31 -32 imp:n=1  $ Position 42
343  10 4.8129E-05   -343 843 31 -32 imp:n=1  $ Position 43
344  10 4.8129E-05   -344 844 31 -32 imp:n=1  $ Position 44
345  10 4.8129E-05   -345 845 31 -32 imp:n=1  $ Position 45
346  10 4.8129E-05   -346 846 31 -32 imp:n=1  $ Position 46
347  10 4.8129E-05   -347 847 31 -32 imp:n=1  $ Position 47
348  10 4.8129E-05   -348 848 31 -32 imp:n=1  $ Position 48
349  10 4.8129E-05   -349 849 31 -32 imp:n=1  $ Position 49
350  10 4.8129E-05   -350 850 31 -32 imp:n=1  $ Position 50
351  10 4.8129E-05   -351 851 31 -32 imp:n=1  $ Position 51
352  10 4.8129E-05   -352 852 31 -32 imp:n=1  $ Position 52
353  10 4.8129E-05   -353 853 31 -32 imp:n=1  $ Position 53
354  10 4.8129E-05   -354 854 31 -32 imp:n=1  $ Position 54
355  10 4.8129E-05   -355 855 31 -32 imp:n=1  $ Position 55
356  10 4.8129E-05   -356 856 31 -32 imp:n=1  $ Position 56
357  10 4.8129E-05   -357 857 31 -32 imp:n=1  $ Position 57
358  10 4.8129E-05   -358 858 31 -32 imp:n=1  $ Position 58
359  10 4.8129E-05   -359 859 31 -32 imp:n=1  $ Position 59
360  10 4.8129E-05   -360 860 31 -32 imp:n=1  $ Position 60
361  10 4.8129E-05   -361 861 31 -32 imp:n=1  $ Position 61
362  10 4.8129E-05   -362 862 31 -32 imp:n=1  $ Position 62
363  10 4.8129E-05   -363 863 31 -32 imp:n=1  $ Position 63
364  10 4.8129E-05   -364 864 31 -32 imp:n=1  $ Position 64
c
c --------- Ring 4 ---------
401  10 4.8129E-05   -401 901 31 -32 imp:n=1  $ Position 1
402  10 4.8129E-05   -402 902 31 -32 imp:n=1  $ Position 2
403  10 4.8129E-05   -403 903 31 -32 imp:n=1  $ Position 3
404  10 4.8129E-05   -404 904 31 -32 imp:n=1  $ Position 4
```

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405  10 4.8129E-05   -405 905 31 -32 imp:n=1  $ Position 5
406  10 4.8129E-05   -406 906 31 -32 imp:n=1  $ Position 6
407  10 4.8129E-05   -407 907 31 -32 imp:n=1  $ Position 7
408  10 4.8129E-05   -408 908 31 -32 imp:n=1  $ Position 8
409  10 4.8129E-05   -409 909 31 -32 imp:n=1  $ Position 9
410  10 4.8129E-05   -410 910 31 -32 imp:n=1  $ Position 10
411  10 4.8129E-05   -411 911 31 -32 imp:n=1  $ Position 11
412  10 4.8129E-05   -412 912 31 -32 imp:n=1  $ Position 12
413  10 4.8129E-05   -413 913 31 -32 imp:n=1  $ Position 13
414  10 4.8129E-05   -414 914 31 -32 imp:n=1  $ Position 14
415  10 4.8129E-05   -415 915 31 -32 imp:n=1  $ Position 15
416  10 4.8129E-05   -416 916 31 -32 imp:n=1  $ Position 16
417  10 4.8129E-05   -417 917 31 -32 imp:n=1  $ Position 17
418  10 4.8129E-05   -418 918 31 -32 imp:n=1  $ Position 18
419  10 4.8129E-05   -419 919 31 -32 imp:n=1  $ Position 19
420  10 4.8129E-05   -420 920 31 -32 imp:n=1  $ Position 20
421  10 4.8129E-05   -421 921 31 -32 imp:n=1  $ Position 21
422  10 4.8129E-05   -422 922 31 -32 imp:n=1  $ Position 22
423  10 4.8129E-05   -423 923 31 -32 imp:n=1  $ Position 23
424  10 4.8129E-05   -424 924 31 -32 imp:n=1  $ Position 24
425  10 4.8129E-05   -425 925 31 -32 imp:n=1  $ Position 25
426  10 4.8129E-05   -426 926 31 -32 imp:n=1  $ Position 26
427  10 4.8129E-05   -427 927 31 -32 imp:n=1  $ Position 27
428  10 4.8129E-05   -428 928 31 -32 imp:n=1  $ Position 28
429  10 4.8129E-05   -429 929 31 -32 imp:n=1  $ Position 29
430  10 4.8129E-05   -430 930 31 -32 imp:n=1  $ Position 30
431  10 4.8129E-05   -431 931 31 -32 imp:n=1  $ Position 31
432  10 4.8129E-05   -432 932 31 -32 imp:n=1  $ Position 32
433  10 4.8129E-05   -433 933 31 -32 imp:n=1  $ Position 33
434  10 4.8129E-05   -434 934 31 -32 imp:n=1  $ Position 34
435  10 4.8129E-05   -435 935 31 -32 imp:n=1  $ Position 35
436  10 4.8129E-05   -436 936 31 -32 imp:n=1  $ Position 36
437  10 4.8129E-05   -437 937 31 -32 imp:n=1  $ Position 37
438  10 4.8129E-05   -438 938 31 -32 imp:n=1  $ Position 38
439  10 4.8129E-05   -439 939 31 -32 imp:n=1  $ Position 39
440  10 4.8129E-05   -440 940 31 -32 imp:n=1  $ Position 40
441  10 4.8129E-05   -441 941 31 -32 imp:n=1  $ Position 41
442  10 4.8129E-05   -442 942 31 -32 imp:n=1  $ Position 42
443  10 4.8129E-05   -443 943 31 -32 imp:n=1  $ Position 43
444  10 4.8129E-05   -444 944 31 -32 imp:n=1  $ Position 44
445  10 4.8129E-05   -445 945 31 -32 imp:n=1  $ Position 45
446  10 4.8129E-05   -446 946 31 -32 imp:n=1  $ Position 46
447  10 4.8129E-05   -447 947 31 -32 imp:n=1  $ Position 47
448  10 4.8129E-05   -448 948 31 -32 imp:n=1  $ Position 48
449  10 4.8129E-05   -449 949 31 -32 imp:n=1  $ Position 49
450  10 4.8129E-05   -450 950 31 -32 imp:n=1  $ Position 50
451  10 4.8129E-05   -451 951 31 -32 imp:n=1  $ Position 51
452  10 4.8129E-05   -452 952 31 -32 imp:n=1  $ Position 52
453  10 4.8129E-05   -453 953 31 -32 imp:n=1  $ Position 53
454  10 4.8129E-05   -454 954 31 -32 imp:n=1  $ Position 54
455  10 4.8129E-05   -455 955 31 -32 imp:n=1  $ Position 55
456  10 4.8129E-05   -456 956 31 -32 imp:n=1  $ Position 56
457  10 4.8129E-05   -457 957 31 -32 imp:n=1  $ Position 57
458  10 4.8129E-05   -458 958 31 -32 imp:n=1  $ Position 58
459  10 4.8129E-05   -459 959 31 -32 imp:n=1  $ Position 59
460  10 4.8129E-05   -460 960 31 -32 imp:n=1  $ Position 60
461  10 4.8129E-05   -461 961 31 -32 imp:n=1  $ Position 61
462  10 4.8129E-05   -462 962 31 -32 imp:n=1  $ Position 62
463  10 4.8129E-05   -463 963 31 -32 imp:n=1  $ Position 63
464  10 4.8129E-05   -464 964 31 -32 imp:n=1  $ Position 64
c
c --------- Ring 5 ---------
501  10 4.8129E-05   -501 1001 31 -32 imp:n=1  $ Position 1
502  10 4.8129E-05   -502 1002 31 -32 imp:n=1  $ Position 2
503  10 4.8129E-05   -503 1003 31 -32 imp:n=1  $ Position 3 (Core 1)
3105 10 4.8129E-05   -503 32 -9       imp:n=1  $ Air (Core 1)
c 503  10 4.8129E-05   -503 1003 31 -3091 imp:n=1  $ Position 3 (Cores 1A, 2, & 3)
c 3105 0    -503 3091 -9 imp:n=1 fill=21 (-83.70  34.67 0)  $ Control Rod 4 (Cores 1A, 2, & 3)
504  10 4.8129E-05   -504 1004 31 -32 imp:n=1  $ Position 4
505  10 4.8129E-05   -505 1005 31 -32 imp:n=1  $ Position 5
506  10 4.8129E-05   -506 1006 31 -32 imp:n=1  $ Position 6
507  10 4.8129E-05   -507 1007 31 -32 imp:n=1  $ Position 7
508  10 4.8129E-05   -508 1008 31 -32 imp:n=1  $ Position 8
509  10 4.8129E-05   -509 1009 31 -32 imp:n=1  $ Position 9
510  10 4.8129E-05   -510 1010 31 -32 imp:n=1  $ Position 10
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511  10 4.8129E-05   -511 1011 31 -32 imp:n=1  $ Position 11
512  10 4.8129E-05   -512 1012 31 -32 imp:n=1  $ Position 12
513  10 4.8129E-05   -513 1013 31 -32 imp:n=1  $ Position 13
514  10 4.8129E-05   -514 1014 31 -32 imp:n=1  $ Position 14
515  10 4.8129E-05   -515 1015 31 -32 imp:n=1  $ Position 15
516  10 4.8129E-05   -516 1016 31 -32 imp:n=1  $ Position 16
517  10 4.8129E-05   -517 1017 31 -32 imp:n=1  $ Position 17
518  10 4.8129E-05   -518 1018 31 -32 imp:n=1  $ Position 18
519  10 4.8129E-05   -519 1019 31 -32 imp:n=1  $ Position 19 (Core 1)
3102 10 4.8129E-05   -519 32 -9       imp:n=1  $ Air (Core 1)
c 519  10 4.8129E-05   -519 1019 31 -3091 imp:n=1  $ Position 19 (Cores 1A, 2, & 3)
c 3102 0    -519 3091 -9 imp:n=1 fill=18 ( 34.67  83.70 0)  $ Control Rod 1 (Cores 1A, 2, & 3)
520  10 4.8129E-05   -520 1020 31 -32 imp:n=1  $ Position 20
521  10 4.8129E-05   -521 1021 31 -32 imp:n=1  $ Position 21
522  10 4.8129E-05   -522 1022 31 -32 imp:n=1  $ Position 22
523  10 4.8129E-05   -523 1023 31 -32 imp:n=1  $ Position 23
524  10 4.8129E-05   -524 1024 31 -32 imp:n=1  $ Position 24
525  10 4.8129E-05   -525 1025 31 -32 imp:n=1  $ Position 25
526  10 4.8129E-05   -526 1026 31 -32 imp:n=1  $ Position 26
527  10 4.8129E-05   -527 1027 31 -32 imp:n=1  $ Position 27
528  10 4.8129E-05   -528 1028 31 -32 imp:n=1  $ Position 28
529  10 4.8129E-05   -529 1029 31 -32 imp:n=1  $ Position 29
530  10 4.8129E-05   -530 1030 31 -32 imp:n=1  $ Position 30
531  10 4.8129E-05   -531 1031 31 -32 imp:n=1  $ Position 31
532  10 4.8129E-05   -532 1032 31 -32 imp:n=1  $ Position 32
533  10 4.8129E-05   -533 1033 31 -32 imp:n=1  $ Position 33
534  10 4.8129E-05   -534 1034 31 -32 imp:n=1  $ Position 34
535  10 4.8129E-05   -535 1035 31 -32 imp:n=1  $ Position 35 (Core 1)
3103 10 4.8129E-05   -535 32 -9       imp:n=1  $ Air (Core 1)
c 535  10 4.8129E-05   -535 1035 31 -3091 imp:n=1  $ Position 35 (Cores 1A, 2, & 3)
c 3103 0    -535 3091 -9 imp:n=1 fill=19 ( 83.70 -34.67 0)  $ Control Rod 2 (Cores 1A, 2, & 3)
536  10 4.8129E-05   -536 1036 31 -32 imp:n=1  $ Position 36
537  10 4.8129E-05   -537 1037 31 -32 imp:n=1  $ Position 37
538  10 4.8129E-05   -538 1038 31 -32 imp:n=1  $ Position 38
539  10 4.8129E-05   -539 1039 31 -32 imp:n=1  $ Position 39
540  10 4.8129E-05   -540 1040 31 -32 imp:n=1  $ Position 40
541  10 4.8129E-05   -541 1041 31 -32 imp:n=1  $ Position 41
542  10 4.8129E-05   -542 1042 31 -32 imp:n=1  $ Position 42
543  10 4.8129E-05   -543 1043 31 -32 imp:n=1  $ Position 43
544  10 4.8129E-05   -544 1044 31 -32 imp:n=1  $ Position 44
c    *Replaced by Autorod  $ Position 45
546  10 4.8129E-05   -546 1046 31 -32 imp:n=1  $ Position 46
547  10 4.8129E-05   -547 1047 31 -32 imp:n=1  $ Position 47
548  10 4.8129E-05   -548 1048 31 -32 imp:n=1  $ Position 48
549  10 4.8129E-05   -549 1049 31 -32 imp:n=1  $ Position 49
550  10 4.8129E-05   -550 1050 31 -32 imp:n=1  $ Position 50
551  10 4.8129E-05   -551 1051 31 -32 imp:n=1  $ Position 51 (Core 1)
3104 10 4.8129E-05   -551 32 -9       imp:n=1  $ Air (Core 1)
c 551  10 4.8129E-05   -551 1051 31 -3091 imp:n=1  $ Position 51 (Cores 1A, 2, & 3)
c 3104 0    -551 3091 -9 imp:n=1 fill=20 (-34.67 -83.70 0)  $ Control Rod 3 (Cores 1A, 2, & 3)
552  10 4.8129E-05   -552 1052 31 -32 imp:n=1  $ Position 52
553  10 4.8129E-05   -553 1053 31 -32 imp:n=1  $ Position 53
554  10 4.8129E-05   -554 1054 31 -32 imp:n=1  $ Position 54
555  10 4.8129E-05   -555 1055 31 -32 imp:n=1  $ Position 55
556  10 4.8129E-05   -556 1056 31 -32 imp:n=1  $ Position 56
557  10 4.8129E-05   -557 1057 31 -32 imp:n=1  $ Position 57
558  10 4.8129E-05   -558 1058 31 -32 imp:n=1  $ Position 58
559  10 4.8129E-05   -559 1059 31 -32 imp:n=1  $ Position 59
560  10 4.8129E-05   -560 1060 31 -32 imp:n=1  $ Position 60
561  10 4.8129E-05   -561 1061 31 -32 imp:n=1  $ Position 61
562  10 4.8129E-05   -562 1062 31 -32 imp:n=1  $ Position 62
563  10 4.8129E-05   -563 1063 31 -32 imp:n=1  $ Position 63
564  10 4.8129E-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
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
```

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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 -32 imp:n=1  $ Position 3 (Core 1)
c 1003 27 8.8496E-02  -1003 31 -3091 imp:n=1  $ Position 3 (Cores 1A, 2, & 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 -32 imp:n=1  $ Position 19 (Core 1)
c 1019 27 8.8496E-02  -1019 31 -3091 imp:n=1  $ Position 19 (Cores 1A, 2, & 3)
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 -32 imp:n=1  $ Position 35 (Core 1)
c 1035 27 8.8496E-02  -1035 31 -3091 imp:n=1  $ Position 35 (Cores 1A, 2, & 3)
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
```

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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 -32 imp:n=1  $ Position 51 (Core 1)
c 1051 27 8.8496E-02  -1051 31 -3091 imp:n=1  $ Position 51 (Cores 1A, 2, & 3)
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
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 ------
1109 0  -1109 15 -9 imp:n=1 fill=13 ( 21.84  86.93 0)  $ Rod 1 (Core 1)
c 1109 10 4.8129E-05  (11109 -1109 15 -9):(-11109 32 -9) imp:n=1  $ Air (Cores 1A, 2, & 3)
c 11109 28 8.9248E-02 -11109 15 -32 imp:n=1  $ Graphite Filler (Cores 1A, 2, & 3)
1110 0  -1110 15 -9 imp:n=1 fill=14 ( 86.93 -21.84 0)  $ Rod 2 (Core 1)
c 1110 10 4.8129E-05  (11110 -1110 15 -9):(-11110 32 -9) imp:n=1  $ Air (Cores 1A, 2, & 3)
c 11110 28 8.9248E-02 -11110 15 -32 imp:n=1  $ Graphite Filler (Cores 1A, 2, & 3)
1111 0  -1111 15 -9 imp:n=1 fill=15 (-21.84 -86.93 0)  $ Rod 3 (Core 1)
c 1111 10 4.8129E-05  (11111 -1111 15 -9):(-11111 32 -9) imp:n=1  $ Air (Cores 1A, 2, & 3)
c 11111 28 8.9248E-02 -11111 15 -32 imp:n=1  $ Graphite Filler (Cores 1A, 2, & 3)
1112 0  -1112 15 -9 imp:n=1 fill=16 (-86.93  21.84 0)  $ Rod 4 (Core 1)
c 1112 10 4.8129E-05  (11112 -1112 15 -9):(-11112 32 -9) imp:n=1  $ Air (Cores 1A, 2, & 3)
c 11112 28 8.9248E-02 -11112 15 -32 imp:n=1  $ Graphite Filler (Cores 1A, 2, & 3)
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 4.8129E-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
```

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           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 4.8129E-05  2401 -1301 1201 -1202 imp:n=1  $ Position 1
1302 10 4.8129E-05  2402 -1302 1201 -1202 imp:n=1  $ Position 2
1303 10 4.8129E-05       -1303 1201 -1202 imp:n=1  $ Position 3
1304 10 4.8129E-05  2404 -1304 1201 -1202 imp:n=1  $ Position 4
1305 10 4.8129E-05  2405 -1305 1201 -1202 imp:n=1  $ Position 5
1306 10 4.8129E-05       -1306 1201 -1202 imp:n=1  $ Position 6
1307 10 4.8129E-05  2407 -1307 1201 -1202 imp:n=1  $ Position 7
1308 10 4.8129E-05  2408 -1308 1201 -1202 imp:n=1  $ Position 8
1309 10 4.8129E-05       -1309 1201 -1202 imp:n=1  $ Position 9
1310 10 4.8129E-05  2410 -1310 1201 -1202 imp:n=1  $ Position 10
1311 10 4.8129E-05  2411 -1311 1201 -1202 imp:n=1  $ Position 11
1312 10 4.8129E-05       -1312 1201 -1202 imp:n=1  $ Position 12
1313 10 4.8129E-05  2413 -1313 1201 -1202 imp:n=1  $ Position 13
1314 10 4.8129E-05  2414 -1314 1201 -1202 imp:n=1  $ Position 14
1315 10 4.8129E-05       -1315 1201 -1202 imp:n=1  $ Position 15
1316 10 4.8129E-05  2416 -1316 1201 -1202 imp:n=1  $ Position 16
1317 10 4.8129E-05  2417 -1317 1201 -1202 imp:n=1  $ Position 17
1318 10 4.8129E-05       -1318 1201 -1202 imp:n=1  $ Position 18
1319 10 4.8129E-05  2419 -1319 1201 -1202 imp:n=1  $ Position 19
1320 10 4.8129E-05  2420 -1320 1201 -1202 imp:n=1  $ Position 20
1321 10 4.8129E-05       -1321 1201 -1202 imp:n=1  $ Position 21
1322 10 4.8129E-05  2422 -1322 1201 -1202 imp:n=1  $ Position 22
1323 10 4.8129E-05  2423 -1323 1201 -1202 imp:n=1  $ Position 23
1324 10 4.8129E-05       -1324 1201 -1202 imp:n=1  $ Position 24
1325 10 4.8129E-05  2425 -1325 1201 -1202 imp:n=1  $ Position 25
1326 10 4.8129E-05  2426 -1326 1201 -1202 imp:n=1  $ Position 26
1327 10 4.8129E-05       -1327 1201 -1202 imp:n=1  $ Position 27
1328 10 4.8129E-05  2428 -1328 1201 -1202 imp:n=1  $ Position 28
1329 10 4.8129E-05       -1329 1201 -1202 imp:n=1  $ Position 29
1330 10 4.8129E-05  2430 -1330 1201 -1202 imp:n=1  $ Position 30
1331 10 4.8129E-05  2431 -1331 1201 -1202 imp:n=1  $ Position 31
1332 10 4.8129E-05       -1332 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 2 ---------
1401 10 4.8129E-05  2501 -1401 1201 -1202 imp:n=1  $ Position 1
1402 10 4.8129E-05  2502 -1402 1201 -1202 imp:n=1  $ Position 2
1403 10 4.8129E-05  2503 -1403 1201 -1202 imp:n=1  $ Position 3
1404 10 4.8129E-05  2504 -1404 1201 -1202 imp:n=1  $ Position 4
1405 10 4.8129E-05  2505 -1405 1201 -1202 imp:n=1  $ Position 5
1406 10 4.8129E-05  2506 -1406 1201 -1202 imp:n=1  $ Position 6
1407 10 4.8129E-05  2507 -1407 1201 -1202 imp:n=1  $ Position 7
1408 10 4.8129E-05  2508 -1408 1201 -1202 imp:n=1  $ Position 8
1409 10 4.8129E-05  2509 -1409 1201 -1202 imp:n=1  $ Position 9
1410 10 4.8129E-05  2510 -1410 1201 -1202 imp:n=1  $ Position 10
1411 10 4.8129E-05  2511 -1411 1201 -1202 imp:n=1  $ Position 11
1412 10 4.8129E-05  2512 -1412 1201 -1202 imp:n=1  $ Position 12
1413 10 4.8129E-05  2513 -1413 1201 -1202 imp:n=1  $ Position 13
1414 10 4.8129E-05  2514 -1414 1201 -1202 imp:n=1  $ Position 14
1415 10 4.8129E-05  2515 -1415 1201 -1202 imp:n=1  $ Position 15
1416 10 4.8129E-05  2516 -1416 1201 -1202 imp:n=1  $ Position 16
1417 10 4.8129E-05  2517 -1417 1201 -1202 imp:n=1  $ Position 17
1418 10 4.8129E-05  2518 -1418 1201 -1202 imp:n=1  $ Position 18
1419 10 4.8129E-05  2519 -1419 1201 -1202 imp:n=1  $ Position 19
1420 10 4.8129E-05  2520 -1420 1201 -1202 imp:n=1  $ Position 20
1421 10 4.8129E-05  2521 -1421 1201 -1202 imp:n=1  $ Position 21
1422 10 4.8129E-05  2522 -1422 1201 -1202 imp:n=1  $ Position 22
1423 10 4.8129E-05  2523 -1423 1201 -1202 imp:n=1  $ Position 23
1424 10 4.8129E-05  2524 -1424 1201 -1202 imp:n=1  $ Position 24
1425 10 4.8129E-05  2525 -1425 1201 -1202 imp:n=1  $ Position 25
```

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1426 10 4.8129E-05  2526 -1426 1201 -1202 imp:n=1  $ Position 26
1427 10 4.8129E-05  2527 -1427 1201 -1202 imp:n=1  $ Position 27
1428 10 4.8129E-05  2528 -1428 1201 -1202 imp:n=1  $ Position 28
1429 10 4.8129E-05  2529 -1429 1201 -1202 imp:n=1  $ Position 29
1430 10 4.8129E-05  2530 -1430 1201 -1202 imp:n=1  $ Position 30
1431 10 4.8129E-05  2531 -1431 1201 -1202 imp:n=1  $ Position 31
1432 10 4.8129E-05  2532 -1432 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 3 ---------
1501 10 4.8129E-05  2601 -1501 1201 -1202 imp:n=1  $ Position 1
1502 10 4.8129E-05       -1502 1201 -1202 imp:n=1  $ Position 2
1503 10 4.8129E-05  2603 -1503 1201 -1202 imp:n=1  $ Position 3
1504 10 4.8129E-05  2604 -1504 1201 -1202 imp:n=1  $ Position 4
1505 10 4.8129E-05       -1505 1201 -1202 imp:n=1  $ Position 5
1506 10 4.8129E-05  2606 -1506 1201 -1202 imp:n=1  $ Position 6
1507 10 4.8129E-05  2607 -1507 1201 -1202 imp:n=1  $ Position 7
1508 10 4.8129E-05       -1508 1201 -1202 imp:n=1  $ Position 8
1509 10 4.8129E-05  2609 -1509 1201 -1202 imp:n=1  $ Position 9
1510 10 4.8129E-05  2610 -1510 1201 -1202 imp:n=1  $ Position 10
1511 10 4.8129E-05       -1511 1201 -1202 imp:n=1  $ Position 11
1512 10 4.8129E-05  2612 -1512 1201 -1202 imp:n=1  $ Position 12
1513 10 4.8129E-05  2613 -1513 1201 -1202 imp:n=1  $ Position 13
1514 10 4.8129E-05       -1514 1201 -1202 imp:n=1  $ Position 14
1515 10 4.8129E-05  2615 -1515 1201 -1202 imp:n=1  $ Position 15
1516 10 4.8129E-05  2616 -1516 1201 -1202 imp:n=1  $ Position 16
1517 10 4.8129E-05       -1517 1201 -1202 imp:n=1  $ Position 17
1518 10 4.8129E-05  2618 -1518 1201 -1202 imp:n=1  $ Position 18
1519 10 4.8129E-05  2619 -1519 1201 -1202 imp:n=1  $ Position 19
1520 10 4.8129E-05       -1520 1201 -1202 imp:n=1  $ Position 20
1521 10 4.8129E-05  2621 -1521 1201 -1202 imp:n=1  $ Position 21
1522 10 4.8129E-05  2622 -1522 1201 -1202 imp:n=1  $ Position 22
1523 10 4.8129E-05       -1523 1201 -1202 imp:n=1  $ Position 23
1524 10 4.8129E-05  2624 -1524 1201 -1202 imp:n=1  $ Position 24
1525 10 4.8129E-05  2625 -1525 1201 -1202 imp:n=1  $ Position 25
1526 10 4.8129E-05       -1526 1201 -1202 imp:n=1  $ Position 26
1527 10 4.8129E-05  2627 -1527 1201 -1202 imp:n=1  $ Position 27
1528 10 4.8129E-05       -1528 1201 -1202 imp:n=1  $ Position 28
1529 10 4.8129E-05  2629 -1529 1201 -1202 imp:n=1  $ Position 29
1530 10 4.8129E-05  2630 -1530 1201 -1202 imp:n=1  $ Position 30
1531 10 4.8129E-05       -1531 1201 -1202 imp:n=1  $ Position 31
1532 10 4.8129E-05  2632 -1532 1201 -1202 imp:n=1  $ Position 32
c
c --------- Ring 4 ---------
1601 10 4.8129E-05  2701 -1601 1201 -1202 imp:n=1  $ Position 1
1602 10 4.8129E-05  2702 -1602 1201 -1202 imp:n=1  $ Position 2
1603 10 4.8129E-05  2703 -1603 1201 -1202 imp:n=1  $ Position 3
1604 10 4.8129E-05  2704 -1604 1201 -1202 imp:n=1  $ Position 4
1605 10 4.8129E-05  2705 -1605 1201 -1202 imp:n=1  $ Position 5
1606 10 4.8129E-05  2706 -1606 1201 -1202 imp:n=1  $ Position 6
1607 10 4.8129E-05  2707 -1607 1201 -1202 imp:n=1  $ Position 7
1608 10 4.8129E-05  2708 -1608 1201 -1202 imp:n=1  $ Position 8
1609 10 4.8129E-05  2709 -1609 1201 -1202 imp:n=1  $ Position 9
1610 10 4.8129E-05  2710 -1610 1201 -1202 imp:n=1  $ Position 10
1611 10 4.8129E-05  2711 -1611 1201 -1202 imp:n=1  $ Position 11
1612 10 4.8129E-05  2712 -1612 1201 -1202 imp:n=1  $ Position 12
1613 10 4.8129E-05  2713 -1613 1201 -1202 imp:n=1  $ Position 13
1614 10 4.8129E-05  2714 -1614 1201 -1202 imp:n=1  $ Position 14
1615 10 4.8129E-05  2715 -1615 1201 -1202 imp:n=1  $ Position 15
1616 10 4.8129E-05  2716 -1616 1201 -1202 imp:n=1  $ Position 16
1617 10 4.8129E-05  2717 -1617 1201 -1202 imp:n=1  $ Position 17
1618 10 4.8129E-05  2718 -1618 1201 -1202 imp:n=1  $ Position 18
1619 10 4.8129E-05  2719 -1619 1201 -1202 imp:n=1  $ Position 19
1620 10 4.8129E-05  2720 -1620 1201 -1202 imp:n=1  $ Position 20
1621 10 4.8129E-05  2721 -1621 1201 -1202 imp:n=1  $ Position 21
1622 10 4.8129E-05  2722 -1622 1201 -1202 imp:n=1  $ Position 22
1623 10 4.8129E-05  2723 -1623 1201 -1202 imp:n=1  $ Position 23
1624 10 4.8129E-05  2724 -1624 1201 -1202 imp:n=1  $ Position 24
1625 10 4.8129E-05  2725 -1625 1201 -1202 imp:n=1  $ Position 25
1626 10 4.8129E-05  2726 -1626 1201 -1202 imp:n=1  $ Position 26
1627 10 4.8129E-05  2727 -1627 1201 -1202 imp:n=1  $ Position 27
1628 10 4.8129E-05  2728 -1628 1201 -1202 imp:n=1  $ Position 28
1629 10 4.8129E-05  2729 -1629 1201 -1202 imp:n=1  $ Position 29
1630 10 4.8129E-05  2730 -1630 1201 -1202 imp:n=1  $ Position 30
1631 10 4.8129E-05  2731 -1631 1201 -1202 imp:n=1  $ Position 31
1632 10 4.8129E-05  2732 -1632 1201 -1202 imp:n=1  $ Position 32
```

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c
c --------- Ring 5 ---------
1701 10 4.8129E-05       -1701 1201 -1202 imp:n=1  $ Position 1
1702 10 4.8129E-05  2802 -1702 1201 -1202 imp:n=1  $ Position 2
1703 10 4.8129E-05  2803 -1703 1201 -1202 imp:n=1  $ Position 3
1704 10 4.8129E-05       -1704 1201 -1202 imp:n=1  $ Position 4
1705 10 4.8129E-05  2805 -1705 1201 -1202 imp:n=1  $ Position 5
1706 10 4.8129E-05  2806 -1706 1201 -1202 imp:n=1  $ Position 6
1707 10 4.8129E-05       -1707 1201 -1202 imp:n=1  $ Position 7
1708 10 4.8129E-05  2808 -1708 1201 -1202 imp:n=1  $ Position 8
1709 10 4.8129E-05  2809 -1709 1201 -1202 imp:n=1  $ Position 9
1710 10 4.8129E-05       -1710 1201 -1202 imp:n=1  $ Position 10
1711 10 4.8129E-05  2811 -1711 1201 -1202 imp:n=1  $ Position 11
1712 10 4.8129E-05  2812 -1712 1201 -1202 imp:n=1  $ Position 12
1713 10 4.8129E-05       -1713 1201 -1202 imp:n=1  $ Position 13
1714 10 4.8129E-05  2814 -1714 1201 -1202 imp:n=1  $ Position 14
1715 10 4.8129E-05  2815 -1715 1201 -1202 imp:n=1  $ Position 15
1716 10 4.8129E-05       -1716 1201 -1202 imp:n=1  $ Position 16
1717 10 4.8129E-05  2817 -1717 1201 -1202 imp:n=1  $ Position 17
1718 10 4.8129E-05  2818 -1718 1201 -1202 imp:n=1  $ Position 18
1719 10 4.8129E-05       -1719 1201 -1202 imp:n=1  $ Position 19
1720 10 4.8129E-05  2820 -1720 1201 -1202 imp:n=1  $ Position 20
1721 10 4.8129E-05  2821 -1721 1201 -1202 imp:n=1  $ Position 21
1722 10 4.8129E-05       -1722 1201 -1202 imp:n=1  $ Position 22
1723 10 4.8129E-05  2823 -1723 1201 -1202 imp:n=1  $ Position 23
1724 10 4.8129E-05  2824 -1724 1201 -1202 imp:n=1  $ Position 24
1725 10 4.8129E-05       -1725 1201 -1202 imp:n=1  $ Position 25
1726 10 4.8129E-05  2826 -1726 1201 -1202 imp:n=1  $ Position 26
1727 10 4.8129E-05       -1727 1201 -1202 imp:n=1  $ Position 27
1728 10 4.8129E-05  2828 -1728 1201 -1202 imp:n=1  $ Position 28
1729 10 4.8129E-05  2829 -1729 1201 -1202 imp:n=1  $ Position 29
1730 10 4.8129E-05       -1730 1201 -1202 imp:n=1  $ Position 30
1731 10 4.8129E-05  2831 -1731 1201 -1202 imp:n=1  $ Position 31
1732 10 4.8129E-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
```

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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
```

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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
1801  10 4.8129E-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 4.8129E-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 4.8129E-05  1201 -1202  1222 -1211 imp:n=1  $ Air Gap
1807  10 4.8129E-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 4.8129E-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 4.8129E-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 4.8129E-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
```

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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 4.8129E-05  31 -1821 1823 -1822 imp:n=1  $ Neutron Source Channel
c
c ------ Graphite Annulus ------
1831  10 4.8129E-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 4.8129E-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 4.8129E-05  2401 -1901 31 -1811 imp:n=1  $ Position 1
1902 10 4.8129E-05  2402 -1902 31 -1811 imp:n=1  $ Position 2
1903 10 4.8129E-05       -1903 31 -1811 imp:n=1  $ Position 3
1904 10 4.8129E-05  2404 -1904 31 -1811 imp:n=1  $ Position 4
1905 10 4.8129E-05  2405 -1905 31 -1811 imp:n=1  $ Position 5
1906 10 4.8129E-05       -1906 31 -1811 imp:n=1  $ Position 6
1907 10 4.8129E-05  2407 -1907 31 -1811 imp:n=1  $ Position 7
1908 10 4.8129E-05  2408 -1908 31 -1811 imp:n=1  $ Position 8
1909 10 4.8129E-05       -1909 31 -1811 imp:n=1  $ Position 9
1910 10 4.8129E-05  2410 -1910 31 -1811 imp:n=1  $ Position 10
1911 10 4.8129E-05  2411 -1911 31 -1811 imp:n=1  $ Position 11
1912 10 4.8129E-05       -1912 31 -1811 imp:n=1  $ Position 12
1913 10 4.8129E-05  2413 -1913 31 -1811 imp:n=1  $ Position 13
1914 10 4.8129E-05  2414 -1914 31 -1811 imp:n=1  $ Position 14
1915 10 4.8129E-05       -1915 31 -1811 imp:n=1  $ Position 15
1916 10 4.8129E-05  2416 -1916 31 -1811 imp:n=1  $ Position 16
1917 10 4.8129E-05  2417 -1917 31 -1811 imp:n=1  $ Position 17
1918 10 4.8129E-05       -1918 31 -1811 imp:n=1  $ Position 18
1919 10 4.8129E-05  2419 -1919 31 -1811 imp:n=1  $ Position 19
1920 10 4.8129E-05  2420 -1920 31 -1811 imp:n=1  $ Position 20
1921 10 4.8129E-05       -1921 31 -1811 imp:n=1  $ Position 21
1922 10 4.8129E-05  2422 -1922 31 -1811 imp:n=1  $ Position 22
1923 10 4.8129E-05  2423 -1923 31 -1811 imp:n=1  $ Position 23
1924 10 4.8129E-05       -1924 31 -1811 imp:n=1  $ Position 24
1925 10 4.8129E-05  2425 -1925 31 -1811 imp:n=1  $ Position 25
```

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1926 10 4.8129E-05  2426 -1926 31 -1811 imp:n=1  $ Position 26
1927 10 4.8129E-05       -1927 31 -1811 imp:n=1  $ Position 27
1928 10 4.8129E-05  2428 -1928 31 -1811 imp:n=1  $ Position 28
1929 10 4.8129E-05       -1929 31 -1811 imp:n=1  $ Position 29
1930 10 4.8129E-05  2430 -1930 31 -1811 imp:n=1  $ Position 30
1931 10 4.8129E-05  2431 -1931 31 -1811 imp:n=1  $ Position 31
1932 10 4.8129E-05       -1932 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 2 ---------
2001 10 4.8129E-05  2501 -2001 31 -1811 imp:n=1  $ Position 1
2002 10 4.8129E-05  2502 -2002 31 -1811 imp:n=1  $ Position 2
2003 10 4.8129E-05  2503 -2003 31 -1811 imp:n=1  $ Position 3
2004 10 4.8129E-05  2504 -2004 31 -1811 imp:n=1  $ Position 4
2005 10 4.8129E-05  2505 -2005 31 -1811 imp:n=1  $ Position 5
2006 10 4.8129E-05  2506 -2006 31 -1811 imp:n=1  $ Position 6
2007 10 4.8129E-05  2507 -2007 31 -1811 imp:n=1  $ Position 7
2008 10 4.8129E-05  2508 -2008 31 -1811 imp:n=1  $ Position 8
2009 10 4.8129E-05  2509 -2009 31 -1811 imp:n=1  $ Position 9
2010 10 4.8129E-05  2510 -2010 31 -1811 imp:n=1  $ Position 10
2011 10 4.8129E-05  2511 -2011 31 -1811 imp:n=1  $ Position 11
2012 10 4.8129E-05  2512 -2012 31 -1811 imp:n=1  $ Position 12
2013 10 4.8129E-05  2513 -2013 31 -1811 imp:n=1  $ Position 13
2014 10 4.8129E-05  2514 -2014 31 -1811 imp:n=1  $ Position 14
2015 10 4.8129E-05  2515 -2015 31 -1811 imp:n=1  $ Position 15
2016 10 4.8129E-05  2516 -2016 31 -1811 imp:n=1  $ Position 16
2017 10 4.8129E-05  2517 -2017 31 -1811 imp:n=1  $ Position 17
2018 10 4.8129E-05  2518 -2018 31 -1811 imp:n=1  $ Position 18
2019 10 4.8129E-05  2519 -2019 31 -1811 imp:n=1  $ Position 19
2020 10 4.8129E-05  2520 -2020 31 -1811 imp:n=1  $ Position 20
2021 10 4.8129E-05  2521 -2021 31 -1811 imp:n=1  $ Position 21
2022 10 4.8129E-05  2522 -2022 31 -1811 imp:n=1  $ Position 22
2023 10 4.8129E-05  2523 -2023 31 -1811 imp:n=1  $ Position 23
2024 10 4.8129E-05  2524 -2024 31 -1811 imp:n=1  $ Position 24
2025 10 4.8129E-05  2525 -2025 31 -1811 imp:n=1  $ Position 25
2026 10 4.8129E-05  2526 -2026 31 -1811 imp:n=1  $ Position 26
2027 10 4.8129E-05  2527 -2027 31 -1811 imp:n=1  $ Position 27
2028 10 4.8129E-05  2528 -2028 31 -1811 imp:n=1  $ Position 28
2029 10 4.8129E-05  2529 -2029 31 -1811 imp:n=1  $ Position 29
2030 10 4.8129E-05  2530 -2030 31 -1811 imp:n=1  $ Position 30
2031 10 4.8129E-05  2531 -2031 31 -1811 imp:n=1  $ Position 31
2032 10 4.8129E-05  2532 -2032 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 3 ---------
2101 10 4.8129E-05  2601 -2101 31 -1811 imp:n=1  $ Position 1
2102 10 4.8129E-05       -2102 31 -1811 imp:n=1  $ Position 2
2103 10 4.8129E-05  2603 -2103 31 -1811 imp:n=1  $ Position 3
2104 10 4.8129E-05  2604 -2104 31 -1811 imp:n=1  $ Position 4
2105 10 4.8129E-05       -2105 31 -1811 imp:n=1  $ Position 5
2106 10 4.8129E-05  2606 -2106 31 -1811 imp:n=1  $ Position 6
2107 10 4.8129E-05  2607 -2107 31 -1811 imp:n=1  $ Position 7
2108 10 4.8129E-05       -2108 31 -1811 imp:n=1  $ Position 8
2109 10 4.8129E-05  2609 -2109 31 -1811 imp:n=1  $ Position 9
2110 10 4.8129E-05  2610 -2110 31 -1811 imp:n=1  $ Position 10
2111 10 4.8129E-05       -2111 31 -1811 imp:n=1  $ Position 11
2112 10 4.8129E-05  2612 -2112 31 -1811 imp:n=1  $ Position 12
2113 10 4.8129E-05  2613 -2113 31 -1811 imp:n=1  $ Position 13
2114 10 4.8129E-05       -2114 31 -1811 imp:n=1  $ Position 14
2115 10 4.8129E-05  2615 -2115 31 -1811 imp:n=1  $ Position 15
2116 10 4.8129E-05  2616 -2116 31 -1811 imp:n=1  $ Position 16
2117 10 4.8129E-05       -2117 31 -1811 imp:n=1  $ Position 17
2118 10 4.8129E-05  2618 -2118 31 -1811 imp:n=1  $ Position 18
2119 10 4.8129E-05  2619 -2119 31 -1811 imp:n=1  $ Position 19
2120 10 4.8129E-05       -2120 31 -1811 imp:n=1  $ Position 20
2121 10 4.8129E-05  2621 -2121 31 -1811 imp:n=1  $ Position 21
2122 10 4.8129E-05  2622 -2122 31 -1811 imp:n=1  $ Position 22
2123 10 4.8129E-05       -2123 31 -1811 imp:n=1  $ Position 23
2124 10 4.8129E-05  2624 -2124 31 -1811 imp:n=1  $ Position 24
2125 10 4.8129E-05  2625 -2125 31 -1811 imp:n=1  $ Position 25
2126 10 4.8129E-05       -2126 31 -1811 imp:n=1  $ Position 26
2127 10 4.8129E-05  2627 -2127 31 -1811 imp:n=1  $ Position 27
2128 10 4.8129E-05       -2128 31 -1811 imp:n=1  $ Position 28
2129 10 4.8129E-05  2629 -2129 31 -1811 imp:n=1  $ Position 29
2130 10 4.8129E-05  2630 -2130 31 -1811 imp:n=1  $ Position 30
2131 10 4.8129E-05       -2131 31 -1811 imp:n=1  $ Position 31
2132 10 4.8129E-05  2632 -2132 31 -1811 imp:n=1  $ Position 32
```

```
c
c --------- Ring 4 ---------
2201 10 4.8129E-05  2701 -2201 31 -1811 imp:n=1  $ Position 1
2202 10 4.8129E-05  2702 -2202 31 -1811 imp:n=1  $ Position 2
2203 10 4.8129E-05  2703 -2203 31 -1811 imp:n=1  $ Position 3
2204 10 4.8129E-05  2704 -2204 31 -1811 imp:n=1  $ Position 4
2205 10 4.8129E-05  2705 -2205 31 -1811 imp:n=1  $ Position 5
2206 10 4.8129E-05  2706 -2206 31 -1811 imp:n=1  $ Position 6
2207 10 4.8129E-05  2707 -2207 31 -1811 imp:n=1  $ Position 7
2208 10 4.8129E-05  2708 -2208 31 -1811 imp:n=1  $ Position 8
2209 10 4.8129E-05  2709 -2209 31 -1811 imp:n=1  $ Position 9
2210 10 4.8129E-05  2710 -2210 31 -1811 imp:n=1  $ Position 10
2211 10 4.8129E-05  2711 -2211 31 -1811 imp:n=1  $ Position 11
2212 10 4.8129E-05  2712 -2212 31 -1811 imp:n=1  $ Position 12
2213 10 4.8129E-05  2713 -2213 31 -1811 imp:n=1  $ Position 13
2214 10 4.8129E-05  2714 -2214 31 -1811 imp:n=1  $ Position 14
2215 10 4.8129E-05  2715 -2215 31 -1811 imp:n=1  $ Position 15
2216 10 4.8129E-05  2716 -2216 31 -1811 imp:n=1  $ Position 16
2217 10 4.8129E-05  2717 -2217 31 -1811 imp:n=1  $ Position 17
2218 10 4.8129E-05  2718 -2218 31 -1811 imp:n=1  $ Position 18
2219 10 4.8129E-05  2719 -2219 31 -1811 imp:n=1  $ Position 19
2220 10 4.8129E-05  2720 -2220 31 -1811 imp:n=1  $ Position 20
2221 10 4.8129E-05  2721 -2221 31 -1811 imp:n=1  $ Position 21
2222 10 4.8129E-05  2722 -2222 31 -1811 imp:n=1  $ Position 22
2223 10 4.8129E-05  2723 -2223 31 -1811 imp:n=1  $ Position 23
2224 10 4.8129E-05  2724 -2224 31 -1811 imp:n=1  $ Position 24
2225 10 4.8129E-05  2725 -2225 31 -1811 imp:n=1  $ Position 25
2226 10 4.8129E-05  2726 -2226 31 -1811 imp:n=1  $ Position 26
2227 10 4.8129E-05  2727 -2227 31 -1811 imp:n=1  $ Position 27
2228 10 4.8129E-05  2728 -2228 31 -1811 imp:n=1  $ Position 28
2229 10 4.8129E-05  2729 -2229 31 -1811 imp:n=1  $ Position 29
2230 10 4.8129E-05  2730 -2230 31 -1811 imp:n=1  $ Position 30
2231 10 4.8129E-05  2731 -2231 31 -1811 imp:n=1  $ Position 31
2232 10 4.8129E-05  2732 -2232 31 -1811 imp:n=1  $ Position 32
c
c --------- Ring 5 ---------
2301 10 4.8129E-05       -2301 31 -1811 imp:n=1  $ Position 1
2302 10 4.8129E-05  2802 -2302 31 -1811 imp:n=1  $ Position 2
2303 10 4.8129E-05  2803 -2303 31 -1811 imp:n=1  $ Position 3
2304 10 4.8129E-05       -2304 31 -1811 imp:n=1  $ Position 4
2305 10 4.8129E-05  2805 -2305 31 -1811 imp:n=1  $ Position 5
2306 10 4.8129E-05  2806 -2306 31 -1811 imp:n=1  $ Position 6
2307 10 4.8129E-05       -2307 31 -1811 imp:n=1  $ Position 7
2308 10 4.8129E-05  2808 -2308 31 -1811 imp:n=1  $ Position 8
2309 10 4.8129E-05  2809 -2309 31 -1811 imp:n=1  $ Position 9
2310 10 4.8129E-05       -2310 31 -1811 imp:n=1  $ Position 10
2311 10 4.8129E-05  2811 -2311 31 -1811 imp:n=1  $ Position 11
2312 10 4.8129E-05  2812 -2312 31 -1811 imp:n=1  $ Position 12
2313 10 4.8129E-05       -2313 31 -1811 imp:n=1  $ Position 13
2314 10 4.8129E-05  2814 -2314 31 -1811 imp:n=1  $ Position 14
2315 10 4.8129E-05  2815 -2315 31 -1811 imp:n=1  $ Position 15
2316 10 4.8129E-05       -2316 31 -1811 imp:n=1  $ Position 16
2317 10 4.8129E-05  2817 -2317 31 -1811 imp:n=1  $ Position 17
2318 10 4.8129E-05  2818 -2318 31 -1811 imp:n=1  $ Position 18
2319 10 4.8129E-05       -2319 31 -1811 imp:n=1  $ Position 19
2320 10 4.8129E-05  2820 -2320 31 -1811 imp:n=1  $ Position 20
2321 10 4.8129E-05  2821 -2321 31 -1811 imp:n=1  $ Position 21
2322 10 4.8129E-05       -2322 31 -1811 imp:n=1  $ Position 22
2323 10 4.8129E-05  2823 -2323 31 -1811 imp:n=1  $ Position 23
2324 10 4.8129E-05  2824 -2324 31 -1811 imp:n=1  $ Position 24
2325 10 4.8129E-05       -2325 31 -1811 imp:n=1  $ Position 25
2326 10 4.8129E-05  2826 -2326 31 -1811 imp:n=1  $ Position 26
2327 10 4.8129E-05       -2327 31 -1811 imp:n=1  $ Position 27
2328 10 4.8129E-05  2828 -2328 31 -1811 imp:n=1  $ Position 28
2329 10 4.8129E-05  2829 -2329 31 -1811 imp:n=1  $ Position 29
2330 10 4.8129E-05       -2330 31 -1811 imp:n=1  $ Position 30
2331 10 4.8129E-05  2831 -2331 31 -1811 imp:n=1  $ Position 31
2332 10 4.8129E-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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ Position 27
2428 29 8.8245E-02  -2428 31 -1811 imp:n=1  $ Position 28
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ Position 11
```

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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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ Position 26
2627 29 8.8245E-02  -2627 31 -1811 imp:n=1  $ Position 27
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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 ---------
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
```

```
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ Position 25
2826 29 8.8245E-02  -2826 31 -1811 imp:n=1  $ Position 26
c    *Coolant Channel (No Plug)   $ 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
c    *Coolant Channel (No Plug)   $ 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    *Exact Placement of 12 Aluminum Plugs Unknown
c    *Plugs Not Present in Some Configurations
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 4.8129E-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=41.8 for Core 1            *************************
```

```
c ******                     z=13.0 for Core 1A,          *************************
c ******                     z=31.6 for Core 2, &         *************************
c ******                     z=68.5 for Core 3,           *************************
c
3033 0    -3036 imp:n=1 u=11 fill=10 (0 0 41.8)
3034 113 5.9746E-02  3036 -3037 15 -32 imp:n=1 u=11  $ Aluminum Tube
3035 10 4.8129E-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 --------- Inner (Moveable) Sleeve ---------
3041 10 4.8129E-05  -3075:-3061:3074 imp:n=1 u=12  $ Air
3042 16 5.9127E-02  3075 -3076 3061 -3074 imp:n=1 u=12  $ Inner Tube
3043 15 4.6340E-02  3076 -3077 3062 -3063 imp:n=1 u=12  $ Cadmium Sheath 1
3044 15 4.6340E-02  3076 -3077 3064 -3065 imp:n=1 u=12  $ Cadmium Sheath 2
3045 15 4.6340E-02  3076 -3077 3066 -3067 imp:n=1 u=12  $ Cadmium Sheath 3
3046 15 4.6340E-02  3076 -3077 3068 -3069 imp:n=1 u=12  $ Cadmium Sheath 4
3047 15 4.6340E-02  3076 -3077 3070 -3071 imp:n=1 u=12  $ Cadmium Sheath 5
3048 15 4.6340E-02  3076 -3077 3072 -3073 imp:n=1 u=12  $ Cadmium Sheath 6
3049 10 4.8129E-05  3061 -3074 3076
          (-3062:3063:3077) (-3064:3065:3077) (-3066:3067:3077)
          (-3068:3069:3077) (-3070:3071:3077) (-3072:3073:3077)
          imp:n=1 u=12  $ Air
c
c ****** ZEBRA Rods Fully Inserted @ z=0 and Withdrawn @ z=20 ***********************
c ****** ZEBRA Rods Withdrawn to z=14.8 for Core 1            ***********************
c ****** ZEBRA Rods Not Utilized in Cores 1A, 2, & 3          ***********************
c
c --------- Rod 1 ---------
3051 0    -3054:-15:3053 imp:n=1 u=13 fill=12 (0 0 14.8)
3052 16 5.9127E-02  3054 -3055 15 -3053 imp:n=1 u=13    $ Outer Tube
3053 15 4.6340E-02  3055 -3056 3041 -3042 imp:n=1 u=13  $ Cadmium Sheath 1
3054 15 4.6340E-02  3055 -3056 3043 -3044 imp:n=1 u=13  $ Cadmium Sheath 2
3055 15 4.6340E-02  3055 -3056 3045 -3046 imp:n=1 u=13  $ Cadmium Sheath 3
3056 15 4.6340E-02  3055 -3056 3047 -3048 imp:n=1 u=13  $ Cadmium Sheath 4
3057 15 4.6340E-02  3055 -3056 3049 -3050 imp:n=1 u=13  $ Cadmium Sheath 5
3058 15 4.6340E-02  3055 -3056 3051 -3052 imp:n=1 u=13  $ Cadmium Sheath 6
3059 10 4.8129E-05  15 -3053 3055
          (-3041:3042:3056) (-3043:3044:3056) (-3045:3046:3056)
          (-3047:3048:3056) (-3049:3050:3056) (-3051:3052:3056)
          imp:n=1 u=13  $ Air
c
c --------- Rod 2 ---------
3061 0    -3054:-15:3053 imp:n=1 u=14 fill=12 (0 0 14.8)
3062 16 5.9127E-02  3054 -3055 15 -3053 imp:n=1 u=14    $ Outer Tube
3063 15 4.6340E-02  3055 -3056 3041 -3042 imp:n=1 u=14  $ Cadmium Sheath 1
3064 15 4.6340E-02  3055 -3056 3043 -3044 imp:n=1 u=14  $ Cadmium Sheath 2
3065 15 4.6340E-02  3055 -3056 3045 -3046 imp:n=1 u=14  $ Cadmium Sheath 3
3066 15 4.6340E-02  3055 -3056 3047 -3048 imp:n=1 u=14  $ Cadmium Sheath 4
3067 15 4.6340E-02  3055 -3056 3049 -3050 imp:n=1 u=14  $ Cadmium Sheath 5
3068 15 4.6340E-02  3055 -3056 3051 -3052 imp:n=1 u=14  $ Cadmium Sheath 6
3069 10 4.8129E-05  15 -3053 3055
          (-3041:3042:3056) (-3043:3044:3056) (-3045:3046:3056)
          (-3047:3048:3056) (-3049:3050:3056) (-3051:3052:3056)
          imp:n=1 u=14  $ Air
c
c --------- Rod 3 ---------
3071 0    -3054:-15:3053 imp:n=1 u=15 fill=12 (0 0 14.8)
3072 16 5.9127E-02  3054 -3055 15 -3053 imp:n=1 u=15    $ Outer Tube
3073 15 4.6340E-02  3055 -3056 3041 -3042 imp:n=1 u=15  $ Cadmium Sheath 1
3074 15 4.6340E-02  3055 -3056 3043 -3044 imp:n=1 u=15  $ Cadmium Sheath 2
3075 15 4.6340E-02  3055 -3056 3045 -3046 imp:n=1 u=15  $ Cadmium Sheath 3
3076 15 4.6340E-02  3055 -3056 3047 -3048 imp:n=1 u=15  $ Cadmium Sheath 4
3077 15 4.6340E-02  3055 -3056 3049 -3050 imp:n=1 u=15  $ Cadmium Sheath 5
3078 15 4.6340E-02  3055 -3056 3051 -3052 imp:n=1 u=15  $ Cadmium Sheath 6
3079 10 4.8129E-05  15 -3053 3055
          (-3041:3042:3056) (-3043:3044:3056) (-3045:3046:3056)
          (-3047:3048:3056) (-3049:3050:3056) (-3051:3052:3056)
          imp:n=1 u=15  $ Air
c
c --------- Rod 4 ---------
3081 0    -3054:-15:3053 imp:n=1 u=16 fill=12 (0 0 14.8)
3082 16 5.9127E-02  3054 -3055 15 -3053 imp:n=1 u=16    $ Outer Tube
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3083 15 4.6340E-02  3055 -3056 3041 -3042 imp:n=1 u=16  $ Cadmium Sheath 1
3084 15 4.6340E-02  3055 -3056 3043 -3044 imp:n=1 u=16  $ Cadmium Sheath 2
3085 15 4.6340E-02  3055 -3056 3045 -3046 imp:n=1 u=16  $ Cadmium Sheath 3
3086 15 4.6340E-02  3055 -3056 3047 -3048 imp:n=1 u=16  $ Cadmium Sheath 4
3087 15 4.6340E-02  3055 -3056 3049 -3050 imp:n=1 u=16  $ Cadmium Sheath 5
3088 15 4.6340E-02  3055 -3056 3051 -3052 imp:n=1 u=16  $ Cadmium Sheath 6
3089 10 4.8129E-05  15 -3053 3055
          (-3041:3042:3056) (-3043:3044:3056) (-3045:3046:3056)
          (-3047:3048:3056) (-3049:3050:3056) (-3051:3052:3056)
          imp:n=1 u=16  $ Air
c
c ------ Withdrawable Control Rods ------
3091 10 4.8129E-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 4.8129E-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 4.8129E-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 Not Utilized in Core 1                                **********
c ****** Control Rods Withdrawn to z=15.0 for Core 1A                       **********
c ****** Control Rods Withdrawn to z=56.4 for Core 2                        **********
c ****** Control Rods Fully Withdrawn to z=249.4 for Core 3                 **********
c
3098 0  -3095 imp:n=1 u=18 fill=17 (0 0 0)  $ Rod 1
3099 0  -3095 imp:n=1 u=19 fill=17 (0 0 0)  $ Rod 2
3100 0  -3095 imp:n=1 u=20 fill=17 (0 0 0)  $ Rod 3
3101 0  -3095 imp:n=1 u=21 fill=17 (0 0 0)  $ Rod 4
c
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
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
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     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
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     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
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     23 3r 22 20r 23 3r
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     23 3r 22 20r 23 3r
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     23 4r 22 18r 23 4r
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     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
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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
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     23 7r 22 12r 23 7r
     23 9r 22 8r 23 9r
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     23 86r
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     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
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     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
     23 86r
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     23 7r 22 12r 23 7r
     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 7r 22 12r 23 7r
     23 8r 22 10r 23 8r
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     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
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     23 3r 22 20r 23 3r
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     23 5r 22 16r 23 5r
     23 6r 22 14r 23 6r
     23 8r 22 10r 23 8r
     23 10r 22 6r 23 10r
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     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
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     23 3r 22 20r 23 3r
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     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
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     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
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     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 4r 22 18r 23 4r
     23 4r 22 18r 23 4r
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     23 5r 22 16r 23 5r
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     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
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     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
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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 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
     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
     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 ------
c --------- Regular (Full) Lattice ---------
3131 24 8.6859E-02  -3131 imp:n=1 u=24 fill=98 (0 0 4.898979486)  $ Middle Top Fuel Zone
3132 25 8.6859E-02  3131 -3132 imp:n=1 u=24  $ Middle Top Pebble Shell
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3133 24 8.6859E-02  -3133 imp:n=1 u=24 fill=98 (-5.196152423 3 4.898979486)  $ NW Top Corner Fuel
Zone
3134 25 8.6859E-02  3133 -3134 imp:n=1 u=24  $ NW Top Corner Pebble Shell
3135 24 8.6859E-02  -3135 imp:n=1 u=24 fill=98 (5.196152423 3 4.898979486)  $ NE Top Corner Fuel
Zone
3136 25 8.6859E-02  3135 -3136 imp:n=1 u=24  $ NE Top Corner Pebble Shell
3137 24 8.6859E-02  -3137 imp:n=1 u=24 fill=98 (0 -6 4.898979486)  $ S Top Corner Fuel Zone
3138 25 8.6859E-02  3137 -3138 imp:n=1 u=24  $ S Top Corner Pebble Shell
3139 24 8.6859E-02  -3139 imp:n=1 u=24 fill=98 (-1.732050808 3 0)  $ NW Middle Edge Fuel Zone
3140 25 8.6859E-02  3139 -3140 imp:n=1 u=24  $ NW Middle Edge Pebble Shell
3141 24 8.6859E-02  -3141 imp:n=1 u=24 fill=98 (3.464101615 0 0)  $ E Middle Edge Fuel Zone
3142 25 8.6859E-02  3141 -3142 imp:n=1 u=24  $ E Middle Edge Pebble Shell
3143 24 8.6859E-02  -3143 imp:n=1 u=24 fill=98 (-6.928203230 0 0)  $ W Middle Edge Fuel Zone
3144 25 8.6859E-02  3143 -3144 imp:n=1 u=24  $ W Middle Edge Pebble Shell
3145 24 8.6859E-02  -3145 imp:n=1 u=24 fill=98 (3.464101615 -6 0)  $ SE Middle Edge Fuel Zone
3146 25 8.6859E-02  3145 -3146 imp:n=1 u=24  $ SE Middle Edge Pebble Shell
3147 24 8.6859E-02  -3147 imp:n=1 u=24 fill=98 (-5.196152423 3 -4.898979486)  $ NW Bottom Corner
Fuel Zone
3148 25 8.6859E-02  3147 -3148 imp:n=1 u=24  $ NW Bottom Corner Pebble Shell
3149 24 8.6859E-02  -3149 imp:n=1 u=24 fill=98 (5.196152423 3 -4.898979486)  $ NE Bottom Corner
Fuel Zone
3150 25 8.6859E-02  3149 -3150 imp:n=1 u=24  $ NE Bottom Corner Pebble Shell
3151 24 8.6859E-02  -3151 imp:n=1 u=24 fill=98 (0 -6 -4.898979486)  $ S Bottom Corner Fuel Zone
3152 25 8.6859E-02  3151 -3152 imp:n=1 u=24  $ S Bottom Corner Pebble Shell
3153 24 8.6859E-02  -3153 imp:n=1 u=24 fill=98 (0 0 -4.898979486)  $ Middle Bottom Fuel Zone
3154 25 8.6859E-02  3153 -3154 imp:n=1 u=24  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 1 ---------
3155 like 3135 but u=25  $ NE Top Corner Fuel Zone
3156 like 3136 but u=25  $ NE Top Corner Pebble Shell
3157 like 3149 but u=25  $ NE Bottom Corner Fuel Zone
3158 like 3150 but u=25  $ NE Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 2 ---------
3159 like 3131 but u=26  $ Middle Top Fuel Zone
3160 like 3132 but u=26  $ Middle Top Pebble Shell
3161 like 3133 but u=26  $ NW Top Corner Fuel Zone
3162 like 3134 but u=26  $ NW Top Corner Pebble Shell
3163 like 3135 but u=26  $ NE Top Corner Fuel Zone
3164 like 3136 but u=26  $ NE Top Corner Pebble Shell
3165 like 3137 but u=26  $ S Top Corner Fuel Zone
3166 like 3138 but u=26  $ S Top Corner Pebble Shell
3167 like 3139 but u=26  $ NW Middle Edge Fuel Zone
3168 like 3140 but u=26  $ NW Middle Edge Pebble Shell
3169 like 3141 but u=26  $ E Middle Edge Fuel Zone
3170 like 3142 but u=26  $ E Middle Edge Pebble Shell
3171 like 3145 but u=26  $ SE Middle Edge Fuel Zone
3172 like 3146 but u=26  $ SE Middle Edge Pebble Shell
3173 like 3147 but u=26  $ NW Bottom Corner Fuel Zone
3174 like 3148 but u=26  $ NW Bottom Corner Pebble Shell
3175 like 3149 but u=26  $ NE Bottom Corner Fuel Zone
3176 like 3150 but u=26  $ NE Bottom Corner Pebble Shell
3177 like 3151 but u=26  $ S Bottom Corner Fuel Zone
3178 like 3152 but u=26  $ S Bottom Corner Pebble Shell
3179 like 3153 but u=26  $ Middle Bottom Fuel Zone
3180 like 3154 but u=26  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 3 ---------
3181 like 3131 but u=27  $ Middle Top Fuel Zone
3182 like 3132 but u=27  $ Middle Top Pebble Shell
3183 like 3135 but u=27  $ NE Top Corner Fuel Zone
3184 like 3136 but u=27  $ NE Top Corner Pebble Shell
3185 like 3137 but u=27  $ S Top Corner Fuel Zone
3186 like 3138 but u=27  $ S Top Corner Pebble Shell
3189 like 3141 but u=27  $ E Middle Edge Fuel Zone
3190 like 3142 but u=27  $ E Middle Edge Pebble Shell
3191 like 3143 but u=27  $ W Middle Edge Fuel Zone
3192 like 3144 but u=27  $ W Middle Edge Pebble Shell
3193 like 3145 but u=27  $ SE Middle Edge Fuel Zone
3194 like 3146 but u=27  $ SE Middle Edge Pebble Shell
3195 like 3149 but u=27  $ NE Bottom Corner Fuel Zone
3196 like 3150 but u=27  $ NE Bottom Corner Pebble Shell
3197 like 3151 but u=27  $ S Bottom Corner Fuel Zone
3198 like 3152 but u=27  $ S Bottom Corner Pebble Shell
3199 like 3153 but u=27  $ Middle Bottom Fuel Zone
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3200 like 3154 but u=27  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 4 ---------
c    *No Fuel Pebbles
c
c --------- Regular (Partial) Lattice 5 ---------
3201 like 3131 but u=29  $ Middle Top Fuel Zone
3202 like 3132 but u=29  $ Middle Top Pebble Shell
3203 like 3135 but u=29  $ NE Top Corner Fuel Zone
3204 like 3136 but u=29  $ NE Top Corner Pebble Shell
3205 like 3137 but u=29  $ S Top Corner Fuel Zone
3206 like 3138 but u=29  $ S Top Corner Pebble Shell
3207 like 3139 but u=29  $ NW Middle Edge Fuel Zone
3208 like 3140 but u=29  $ NW Middle Edge Pebble Shell
3209 like 3141 but u=29  $ E Middle Edge Fuel Zone
3210 like 3142 but u=29  $ E Middle Edge Pebble Shell
3211 like 3145 but u=29  $ SE Middle Edge Fuel Zone
3212 like 3146 but u=29  $ SE Middle Edge Pebble Shell
3213 like 3149 but u=29  $ NE Bottom Corner Fuel Zone
3214 like 3150 but u=29  $ NE Bottom Corner Pebble Shell
3215 like 3151 but u=29  $ S Bottom Corner Fuel Zone
3216 like 3152 but u=29  $ S Bottom Corner Pebble Shell
3217 like 3153 but u=29  $ Middle Bottom Fuel Zone
3218 like 3154 but u=29  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 6 ---------
3219 like 3145 but u=30  $ SE Middle Edge Fuel Zone
3220 like 3146 but u=30  $ SE Middle Edge Pebble Shell
c
c --------- Regular (Partial) Lattice 7 ---------
3221 like 3131 but u=31  $ Middle Top Fuel Zone
3222 like 3132 but u=31  $ Middle Top Pebble Shell
3223 like 3135 but u=31  $ NE Top Corner Fuel Zone
3224 like 3136 but u=31  $ NE Top Corner Pebble Shell
3225 like 3137 but u=31  $ S Top Corner Fuel Zone
3226 like 3138 but u=31  $ S Top Corner Pebble Shell
3227 like 3141 but u=31  $ E Middle Edge Fuel Zone
3228 like 3142 but u=31  $ E Middle Edge Pebble Shell
3229 like 3145 but u=31  $ SE Middle Edge Fuel Zone
3230 like 3146 but u=31  $ SE Middle Edge Pebble Shell
3231 like 3149 but u=31  $ NE Bottom Corner Fuel Zone
3232 like 3150 but u=31  $ NE Bottom Corner Pebble Shell
3233 like 3151 but u=31  $ S Bottom Corner Fuel Zone
3234 like 3152 but u=31  $ S Bottom Corner Pebble Shell
3235 like 3153 but u=31  $ Middle Bottom Fuel Zone
3236 like 3154 but u=31  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 8 ---------
3237 like 3137 but u=32  $ S Top Corner Fuel Zone
3238 like 3138 but u=32  $ S Top Corner Pebble Shell
3239 like 3145 but u=32  $ SE Middle Edge Fuel Zone
3240 like 3146 but u=32  $ SE Middle Edge Pebble Shell
3241 like 3151 but u=32  $ S Bottom Corner Fuel Zone
3242 like 3152 but u=32  $ S Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 9 ---------
3243 like 3131 but u=33  $ Middle Top Fuel Zone
3244 like 3132 but u=33  $ Middle Top Pebble Shell
3245 like 3133 but u=33  $ NW Top Corner Fuel Zone
3246 like 3134 but u=33  $ NW Top Corner Pebble Shell
3247 like 3135 but u=33  $ NE Top Corner Fuel Zone
3248 like 3136 but u=33  $ NE Top Corner Pebble Shell
3249 like 3137 but u=33  $ S Top Corner Fuel Zone
3250 like 3138 but u=33  $ S Top Corner Pebble Shell
3251 like 3139 but u=33  $ NW Middle Edge Fuel Zone
3252 like 3140 but u=33  $ NW Middle Edge Pebble Shell
3253 like 3141 but u=33  $ E Middle Edge Fuel Zone
3254 like 3142 but u=33  $ E Middle Edge Pebble Shell
3255 like 3143 but u=33  $ W Middle Edge Fuel Zone
3256 like 3144 but u=33  $ W Middle Edge Pebble Shell
3257 like 3145 but u=33  $ SE Middle Edge Fuel Zone
3258 like 3146 but u=33  $ SE Middle Edge Pebble Shell
3259 like 3147 but u=33  $ NW Bottom Corner Fuel Zone
3260 like 3148 but u=33  $ NW Bottom Corner Pebble Shell
3261 like 3149 but u=33  $ NE Bottom Corner Fuel Zone
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3262 like 3150 but u=33  $ NE Bottom Corner Pebble Shell
3263 like 3151 but u=33  $ S Bottom Corner Fuel Zone
3264 like 3152 but u=33  $ S Bottom Corner Pebble Shell
3265 like 3153 but u=33  $ Middle Bottom Fuel Zone
3266 like 3154 but u=33  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 10 ---------
3268 like 3137 but u=34  $ S Top Corner Fuel Zone
3269 like 3138 but u=34  $ S Top Corner Pebble Shell
3270 like 3145 but u=34  $ SE Middle Edge Fuel Zone
3271 like 3146 but u=34  $ SE Middle Edge Pebble Shell
3272 like 3151 but u=34  $ S Bottom Corner Fuel Zone
3273 like 3152 but u=34  $ S Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 11 ---------
3274 like 3137 but u=35  $ S Top Corner Fuel Zone
3275 like 3138 but u=35  $ S Top Corner Pebble Shell
3276 like 3151 but u=35  $ S Bottom Corner Fuel Zone
3277 like 3152 but u=35  $ S Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 12 ---------
3278 like 3131 but u=36  $ Middle Top Fuel Zone
3279 like 3132 but u=36  $ Middle Top Pebble Shell
3280 like 3133 but u=36  $ NW Top Corner Fuel Zone
3281 like 3134 but u=36  $ NW Top Corner Pebble Shell
3282 like 3137 but u=36  $ S Top Corner Fuel Zone
3283 like 3138 but u=36  $ S Top Corner Pebble Shell
3284 like 3143 but u=36  $ W Middle Edge Fuel Zone
3285 like 3144 but u=36  $ W Middle Edge Pebble Shell
3286 like 3145 but u=36  $ SE Middle Edge Fuel Zone
3287 like 3146 but u=36  $ SE Middle Edge Pebble Shell
3288 like 3147 but u=36  $ NW Bottom Corner Fuel Zone
3289 like 3148 but u=36  $ NW Bottom Corner Pebble Shell
3290 like 3151 but u=36  $ S Bottom Corner Fuel Zone
3291 like 3152 but u=36  $ S Bottom Corner Pebble Shell
3292 like 3153 but u=36  $ Middle Bottom Fuel Zone
3293 like 3154 but u=36  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 13 ---------
3294 like 3137 but u=37  $ S Top Corner Fuel Zone
3295 like 3138 but u=37  $ S Top Corner Pebble Shell
3296 like 3151 but u=37  $ S Bottom Corner Fuel Zone
3297 like 3152 but u=37  $ S Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 14 ---------
3298 like 3131 but u=38  $ Middle Top Fuel Zone
3299 like 3132 but u=38  $ Middle Top Pebble Shell
3300 like 3133 but u=38  $ NW Top Corner Fuel Zone
3301 like 3134 but u=38  $ NW Top Corner Pebble Shell
3302 like 3135 but u=38  $ NE Top Corner Fuel Zone
3303 like 3136 but u=38  $ NE Top Corner Pebble Shell
3304 like 3137 but u=38  $ S Top Corner Fuel Zone
3305 like 3138 but u=38  $ S Top Corner Pebble Shell
3306 like 3139 but u=38  $ NW Middle Edge Fuel Zone
3307 like 3140 but u=38  $ NW Middle Edge Pebble Shell
3308 like 3141 but u=38  $ E Middle Edge Fuel Zone
3309 like 3142 but u=38  $ E Middle Edge Pebble Shell
3310 like 3143 but u=38  $ W Middle Edge Fuel Zone
3311 like 3144 but u=38  $ W Middle Edge Pebble Shell
3312 like 3145 but u=38  $ SE Middle Edge Fuel Zone
3313 like 3146 but u=38  $ SE Middle Edge Pebble Shell
3314 like 3147 but u=38  $ NW Bottom Corner Fuel Zone
3315 like 3148 but u=38  $ NW Bottom Corner Pebble Shell
3316 like 3149 but u=38  $ NE Bottom Corner Fuel Zone
3317 like 3150 but u=38  $ NE Bottom Corner Pebble Shell
3318 like 3151 but u=38  $ S Bottom Corner Fuel Zone
3319 like 3152 but u=38  $ S Bottom Corner Pebble Shell
3320 like 3153 but u=38  $ Middle Bottom Fuel Zone
3321 like 3154 but u=38  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 15 ---------
c    *No Fuel Pebbles
c
c --------- Regular (Partial) Lattice 16 ---------
3322 like 3131 but u=40  $ Middle Top Fuel Zone
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3323 like 3132 but u=40  $ Middle Top Pebble Shell
3324 like 3133 but u=40  $ NW Top Corner Fuel Zone
3325 like 3134 but u=40  $ NW Top Corner Pebble Shell
3326 like 3137 but u=40  $ S Top Corner Fuel Zone
3327 like 3138 but u=40  $ S Top Corner Pebble Shell
3328 like 3139 but u=40  $ NW Middle Edge Fuel Zone
3329 like 3140 but u=40  $ NW Middle Edge Pebble Shell
3330 like 3141 but u=40  $ E Middle Edge Fuel Zone
3331 like 3142 but u=40  $ E Middle Edge Pebble Shell
3332 like 3143 but u=40  $ W Middle Edge Fuel Zone
3333 like 3144 but u=40  $ W Middle Edge Pebble Shell
3334 like 3145 but u=40  $ SE Middle Edge Fuel Zone
3335 like 3146 but u=40  $ SE Middle Edge Pebble Shell
3336 like 3147 but u=40  $ NW Bottom Corner Fuel Zone
3337 like 3148 but u=40  $ NW Bottom Corner Pebble Shell
3338 like 3151 but u=40  $ S Bottom Corner Fuel Zone
3339 like 3152 but u=40  $ S Bottom Corner Pebble Shell
3340 like 3153 but u=40  $ Middle Bottom Fuel Zone
3341 like 3154 but u=40  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 17 ---------
3342 like 3143 but u=41  $ W Middle Edge Fuel Zone
3343 like 3144 but u=41  $ W Middle Edge Pebble Shell
c
c --------- Regular (Partial) Lattice 18 ---------
3344 like 3131 but u=42  $ Middle Top Fuel Zone
3345 like 3132 but u=42  $ Middle Top Pebble Shell
3346 like 3133 but u=42  $ NW Top Corner Fuel Zone
3347 like 3134 but u=42  $ NW Top Corner Pebble Shell
3348 like 3137 but u=42  $ S Top Corner Fuel Zone
3349 like 3138 but u=42  $ S Top Corner Pebble Shell
3350 like 3139 but u=42  $ NW Middle Edge Fuel Zone
3351 like 3140 but u=42  $ NW Middle Edge Pebble Shell
3352 like 3143 but u=42  $ W Middle Edge Fuel Zone
3353 like 3144 but u=42  $ W Middle Edge Pebble Shell
3354 like 3147 but u=42  $ NW Bottom Corner Fuel Zone
3355 like 3148 but u=42  $ NW Bottom Corner Pebble Shell
3356 like 3151 but u=42  $ S Bottom Corner Fuel Zone
3357 like 3152 but u=42  $ S Bottom Corner Pebble Shell
3358 like 3153 but u=42  $ Middle Bottom Fuel Zone
3359 like 3154 but u=42  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 19 ---------
3360 like 3133 but u=43  $ NW Top Corner Fuel Zone
3361 like 3134 but u=43  $ NW Top Corner Pebble Shell
3362 like 3143 but u=43  $ W Middle Edge Fuel Zone
3363 like 3144 but u=43  $ W Middle Edge Pebble Shell
3364 like 3147 but u=43  $ NW Bottom Corner Fuel Zone
3365 like 3148 but u=43  $ NW Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 20 ---------
3366 like 3133 but u=44  $ NW Top Corner Fuel Zone
3367 like 3134 but u=44  $ NW Top Corner Pebble Shell
3368 like 3143 but u=44  $ W Middle Edge Fuel Zone
3369 like 3144 but u=44  $ W Middle Edge Pebble Shell
3370 like 3147 but u=44  $ NW Bottom Corner Fuel Zone
3371 like 3148 but u=44  $ NW Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 21 ---------
3372 like 3131 but u=45  $ Middle Top Fuel Zone
3373 like 3132 but u=45  $ Middle Top Pebble Shell
3374 like 3133 but u=45  $ NW Top Corner Fuel Zone
3375 like 3134 but u=45  $ NW Top Corner Pebble Shell
3376 like 3135 but u=45  $ NE Top Corner Fuel Zone
3377 like 3136 but u=45  $ NE Top Corner Pebble Shell
3378 like 3137 but u=45  $ S Top Corner Fuel Zone
3379 like 3138 but u=45  $ S Top Corner Pebble Shell
3380 like 3139 but u=45  $ NW Middle Edge Fuel Zone
3381 like 3140 but u=45  $ NW Middle Edge Pebble Shell
3382 like 3141 but u=45  $ E Middle Edge Fuel Zone
3383 like 3142 but u=45  $ E Middle Edge Pebble Shell
3384 like 3143 but u=45  $ W Middle Edge Fuel Zone
3385 like 3144 but u=45  $ W Middle Edge Pebble Shell
3386 like 3147 but u=45  $ NW Bottom Corner Fuel Zone
3387 like 3148 but u=45  $ NW Bottom Corner Pebble Shell
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3388 like 3149 but u=45  $ NE Bottom Corner Fuel Zone
3389 like 3150 but u=45  $ NE Bottom Corner Pebble Shell
3390 like 3151 but u=45  $ S Bottom Corner Fuel Zone
3391 like 3152 but u=45  $ S Bottom Corner Pebble Shell
3392 like 3153 but u=45  $ Middle Bottom Fuel Zone
3393 like 3154 but u=45  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 22 ---------
3394 like 3133 but u=46  $ NW Top Corner Fuel Zone
3395 like 3134 but u=46  $ NW Top Corner Pebble Shell
3396 like 3147 but u=46  $ NW Bottom Corner Fuel Zone
3397 like 3148 but u=46  $ NW Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 23 ---------
3398 like 3131 but u=47  $ Middle Top Fuel Zone
3399 like 3132 but u=47  $ Middle Top Pebble Shell
3400 like 3133 but u=47  $ NW Top Corner Fuel Zone
3401 like 3134 but u=47  $ NW Top Corner Pebble Shell
3402 like 3135 but u=47  $ NE Top Corner Fuel Zone
3403 like 3136 but u=47  $ NE Top Corner Pebble Shell
3404 like 3139 but u=47  $ NW Middle Edge Fuel Zone
3405 like 3140 but u=47  $ NW Middle Edge Pebble Shell
3406 like 3143 but u=47  $ W Middle Edge Fuel Zone
3407 like 3144 but u=47  $ W Middle Edge Pebble Shell
3408 like 3147 but u=47  $ NW Bottom Corner Fuel Zone
3409 like 3148 but u=47  $ NW Bottom Corner Pebble Shell
3410 like 3149 but u=47  $ NE Bottom Corner Fuel Zone
3411 like 3150 but u=47  $ NE Bottom Corner Pebble Shell
3412 like 3153 but u=47  $ Middle Bottom Fuel Zone
3413 like 3154 but u=47  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 24 ---------
3414 like 3131 but u=48  $ Middle Top Fuel Zone
3415 like 3132 but u=48  $ Middle Top Pebble Shell
3416 like 3133 but u=48  $ NW Top Corner Fuel Zone
3417 like 3134 but u=48  $ NW Top Corner Pebble Shell
3418 like 3135 but u=48  $ NE Top Corner Fuel Zone
3419 like 3136 but u=48  $ NE Top Corner Pebble Shell
3420 like 3137 but u=48  $ S Top Corner Fuel Zone
3421 like 3138 but u=48  $ S Top Corner Pebble Shell
3422 like 3139 but u=48  $ NW Middle Edge Fuel Zone
3423 like 3140 but u=48  $ NW Middle Edge Pebble Shell
3424 like 3141 but u=48  $ E Middle Edge Fuel Zone
3425 like 3142 but u=48  $ E Middle Edge Pebble Shell
3426 like 3143 but u=48  $ W Middle Edge Fuel Zone
3427 like 3144 but u=48  $ W Middle Edge Pebble Shell
3428 like 3147 but u=48  $ NW Bottom Corner Fuel Zone
3429 like 3148 but u=48  $ NW Bottom Corner Pebble Shell
3430 like 3149 but u=48  $ NE Bottom Corner Fuel Zone
3431 like 3150 but u=48  $ NE Bottom Corner Pebble Shell
3432 like 3151 but u=48  $ S Bottom Corner Fuel Zone
3433 like 3152 but u=48  $ S Bottom Corner Pebble Shell
3434 like 3153 but u=48  $ Middle Bottom Fuel Zone
3435 like 3154 but u=48  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 25 ---------
3436 like 3133 but u=49  $ NW Top Corner Fuel Zone
3437 like 3134 but u=49  $ NW Top Corner Pebble Shell
3438 like 3147 but u=49  $ NW Bottom Corner Fuel Zone
3439 like 3148 but u=49  $ NW Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 26 ---------
c    *No Fuel Pebbles
c
c --------- Regular (Partial) Lattice 27 ---------
c    *No Fuel Pebbles
c
c --------- Regular (Partial) Lattice 28 ---------
3440 like 3131 but u=52  $ Middle Top Fuel Zone
3441 like 3132 but u=52  $ Middle Top Pebble Shell
3442 like 3133 but u=52  $ NW Top Corner Fuel Zone
3443 like 3134 but u=52  $ NW Top Corner Pebble Shell
3444 like 3135 but u=52  $ NE Top Corner Fuel Zone
3445 like 3136 but u=52  $ NE Top Corner Pebble Shell
3446 like 3139 but u=52  $ NW Middle Edge Fuel Zone
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3447 like 3140 but u=52  $ NW Middle Edge Pebble Shell
3448 like 3141 but u=52  $ E Middle Edge Fuel Zone
3449 like 3142 but u=52  $ E Middle Edge Pebble Shell
3450 like 3143 but u=52  $ W Middle Edge Fuel Zone
3451 like 3144 but u=52  $ W Middle Edge Pebble Shell
3452 like 3147 but u=52  $ NW Bottom Corner Fuel Zone
3453 like 3148 but u=52  $ NW Bottom Corner Pebble Shell
3454 like 3149 but u=52  $ NE Bottom Corner Fuel Zone
3455 like 3150 but u=52  $ NE Bottom Corner Pebble Shell
3456 like 3153 but u=52  $ Middle Bottom Fuel Zone
3457 like 3154 but u=52  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 29 ---------
3458 like 3131 but u=53  $ Middle Top Fuel Zone
3459 like 3132 but u=53  $ Middle Top Pebble Shell
3460 like 3133 but u=53  $ NW Top Corner Fuel Zone
3461 like 3134 but u=53  $ NW Top Corner Pebble Shell
3462 like 3135 but u=53  $ NE Top Corner Fuel Zone
3463 like 3136 but u=53  $ NE Top Corner Pebble Shell
3464 like 3139 but u=53  $ NW Middle Edge Fuel Zone
3465 like 3140 but u=53  $ NW Middle Edge Pebble Shell
3466 like 3141 but u=53  $ E Middle Edge Fuel Zone
3467 like 3142 but u=53  $ E Middle Edge Pebble Shell
3468 like 3147 but u=53  $ NW Bottom Corner Fuel Zone
3469 like 3148 but u=53  $ NW Bottom Corner Pebble Shell
3470 like 3149 but u=53  $ NE Bottom Corner Fuel Zone
3471 like 3150 but u=53  $ NE Bottom Corner Pebble Shell
3472 like 3153 but u=53  $ Middle Bottom Fuel Zone
3473 like 3154 but u=53  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 30 ---------
3474 like 3135 but u=54  $ NE Top Corner Fuel Zone
3475 like 3136 but u=54  $ NE Top Corner Pebble Shell
3476 like 3149 but u=54  $ NE Bottom Corner Fuel Zone
3477 like 3150 but u=54  $ NE Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 31 ---------
3478 like 3135 but u=55  $ NE Top Corner Fuel Zone
3479 like 3136 but u=55  $ NE Top Corner Pebble Shell
3480 like 3149 but u=55  $ NE Bottom Corner Fuel Zone
3481 like 3150 but u=55  $ NE Bottom Corner Pebble Shell
c
c --------- Regular (Partial) Lattice 32 ---------
3482 like 3131 but u=56  $ Middle Top Fuel Zone
3483 like 3132 but u=56  $ Middle Top Pebble Shell
3484 like 3133 but u=56  $ NW Top Corner Fuel Zone
3485 like 3134 but u=56  $ NW Top Corner Pebble Shell
3486 like 3135 but u=56  $ NE Top Corner Fuel Zone
3487 like 3136 but u=56  $ NE Top Corner Pebble Shell
3488 like 3137 but u=56  $ S Top Corner Fuel Zone
3489 like 3138 but u=56  $ S Top Corner Pebble Shell
3490 like 3139 but u=56  $ NW Middle Edge Fuel Zone
3491 like 3140 but u=56  $ NW Middle Edge Pebble Shell
3492 like 3141 but u=56  $ E Middle Edge Fuel Zone
3493 like 3142 but u=56  $ E Middle Edge Pebble Shell
3494 like 3145 but u=56  $ SE Middle Edge Fuel Zone
3495 like 3146 but u=56  $ SE Middle Edge Pebble Shell
3496 like 3147 but u=56  $ NW Bottom Corner Fuel Zone
3497 like 3148 but u=56  $ NW Bottom Corner Pebble Shell
3498 like 3149 but u=56  $ NE Bottom Corner Fuel Zone
3499 like 3150 but u=56  $ NE Bottom Corner Pebble Shell
3500 like 3151 but u=56  $ S Bottom Corner Fuel Zone
3501 like 3152 but u=56  $ S Bottom Corner Pebble Shell
3502 like 3153 but u=56  $ Middle Bottom Fuel Zone
3503 like 3154 but u=56  $ Middle Bottom Pebble Shell
c
c --------- Regular (Partial) Lattice 33 ---------
3504 like 3135 but u=57  $ NE Top Corner Fuel Zone
3505 like 3136 but u=57  $ NE Top Corner Pebble Shell
3506 like 3149 but u=57  $ NE Bottom Corner Fuel Zone
3507 like 3150 but u=57  $ NE Bottom Corner Pebble Shell
c
c --------- Bottom Layer Only Lattices ---------
3508 like 3147 but u=124  $ NW Bottom Corner Fuel Zone
3509 like 3148 but u=124  $ NW Bottom Corner Pebble Shell
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3510 like 3149 but u=124  $ NE Bottom Corner Fuel Zone
3511 like 3150 but u=124  $ NE Bottom Corner Pebble Shell
3512 like 3151 but u=124  $ S Bottom Corner Fuel Zone
3513 like 3152 but u=124  $ S Bottom Corner Pebble Shell
3514 like 3153 but u=124  $ Middle Bottom Fuel Zone
3515 like 3154 but u=124  $ Middle Bottom Pebble Shell
3516 like 3149 but u=125  $ NE Bottom Corner Fuel Zone
3517 like 3150 but u=125  $ NE Bottom Corner Pebble Shell
3518 like 3147 but u=126  $ NW Bottom Corner Fuel Zone
3519 like 3148 but u=126  $ NW Bottom Corner Pebble Shell
3520 like 3149 but u=126  $ NE Bottom Corner Fuel Zone
3521 like 3150 but u=126  $ NE Bottom Corner Pebble Shell
3522 like 3151 but u=126  $ S Bottom Corner Fuel Zone
3523 like 3152 but u=126  $ S Bottom Corner Pebble Shell
3524 like 3153 but u=126  $ Middle Bottom Fuel Zone
3525 like 3154 but u=126  $ Middle Bottom Pebble Shell
3526 like 3149 but u=127  $ NE Bottom Corner Fuel Zone
3527 like 3150 but u=127  $ NE Bottom Corner Pebble Shell
3528 like 3151 but u=127  $ S Bottom Corner Fuel Zone
3529 like 3152 but u=127  $ S Bottom Corner Pebble Shell
3530 like 3153 but u=127  $ Middle Bottom Fuel Zone
3531 like 3154 but u=127  $ Middle Bottom Pebble Shell
3532 like 3149 but u=129  $ NE Bottom Corner Fuel Zone
3533 like 3150 but u=129  $ NE Bottom Corner Pebble Shell
3534 like 3151 but u=129  $ S Bottom Corner Fuel Zone
3535 like 3152 but u=129  $ S Bottom Corner Pebble Shell
3536 like 3153 but u=129  $ Middle Bottom Fuel Zone
3537 like 3154 but u=129  $ Middle Bottom Pebble Shell
3538 like 3149 but u=131  $ NE Bottom Corner Fuel Zone
3539 like 3150 but u=131  $ NE Bottom Corner Pebble Shell
3540 like 3151 but u=131  $ S Bottom Corner Fuel Zone
3541 like 3152 but u=131  $ S Bottom Corner Pebble Shell
3542 like 3153 but u=131  $ Middle Bottom Fuel Zone
3543 like 3154 but u=131  $ Middle Bottom Pebble Shell
3544 like 3151 but u=132  $ S Bottom Corner Fuel Zone
3545 like 3152 but u=132  $ S Bottom Corner Pebble Shell
3546 like 3147 but u=133  $ NW Bottom Corner Fuel Zone
3547 like 3148 but u=133  $ NW Bottom Corner Pebble Shell
3548 like 3149 but u=133  $ NE Bottom Corner Fuel Zone
3549 like 3150 but u=133  $ NE Bottom Corner Pebble Shell
3550 like 3151 but u=133  $ S Bottom Corner Fuel Zone
3551 like 3152 but u=133  $ S Bottom Corner Pebble Shell
3552 like 3153 but u=133  $ Middle Bottom Fuel Zone
3553 like 3154 but u=133  $ Middle Bottom Pebble Shell
3554 like 3151 but u=134  $ S Bottom Corner Fuel Zone
3555 like 3152 but u=134  $ S Bottom Corner Pebble Shell
3556 like 3151 but u=135  $ S Bottom Corner Fuel Zone
3557 like 3152 but u=135  $ S Bottom Corner Pebble Shell
3558 like 3147 but u=136  $ NW Bottom Corner Fuel Zone
3559 like 3148 but u=136  $ NW Bottom Corner Pebble Shell
3560 like 3151 but u=136  $ S Bottom Corner Fuel Zone
3561 like 3152 but u=136  $ S Bottom Corner Pebble Shell
3562 like 3153 but u=136  $ Middle Bottom Fuel Zone
3563 like 3154 but u=136  $ Middle Bottom Pebble Shell
3564 like 3151 but u=137  $ S Bottom Corner Fuel Zone
3565 like 3152 but u=137  $ S Bottom Corner Pebble Shell
3566 like 3147 but u=138  $ NW Bottom Corner Fuel Zone
3567 like 3148 but u=138  $ NW Bottom Corner Pebble Shell
3568 like 3149 but u=138  $ NE Bottom Corner Fuel Zone
3569 like 3150 but u=138  $ NE Bottom Corner Pebble Shell
3570 like 3151 but u=138  $ S Bottom Corner Fuel Zone
3571 like 3152 but u=138  $ S Bottom Corner Pebble Shell
3572 like 3153 but u=138  $ Middle Bottom Fuel Zone
3573 like 3154 but u=138  $ Middle Bottom Pebble Shell
3574 like 3147 but u=140  $ NW Bottom Corner Fuel Zone
3575 like 3148 but u=140  $ NW Bottom Corner Pebble Shell
3576 like 3151 but u=140  $ S Bottom Corner Fuel Zone
3577 like 3152 but u=140  $ S Bottom Corner Pebble Shell
3578 like 3153 but u=140  $ Middle Bottom Fuel Zone
3579 like 3154 but u=140  $ Middle Bottom Pebble Shell
3580 like 3147 but u=142  $ NW Bottom Corner Fuel Zone
3581 like 3148 but u=142  $ NW Bottom Corner Pebble Shell
3582 like 3151 but u=142  $ S Bottom Corner Fuel Zone
3583 like 3152 but u=142  $ S Bottom Corner Pebble Shell
3584 like 3153 but u=142  $ Middle Bottom Fuel Zone
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3585 like 3154 but u=142  $ Middle Bottom Pebble Shell
3586 like 3147 but u=143  $ NW Bottom Corner Fuel Zone
3587 like 3148 but u=143  $ NW Bottom Corner Pebble Shell
3588 like 3147 but u=144  $ NW Bottom Corner Fuel Zone
3589 like 3148 but u=144  $ NW Bottom Corner Pebble Shell
3590 like 3147 but u=145  $ NW Bottom Corner Fuel Zone
3591 like 3148 but u=145  $ NW Bottom Corner Pebble Shell
3592 like 3149 but u=145  $ NE Bottom Corner Fuel Zone
3593 like 3150 but u=145  $ NE Bottom Corner Pebble Shell
3594 like 3151 but u=145  $ S Bottom Corner Fuel Zone
3595 like 3152 but u=145  $ S Bottom Corner Pebble Shell
3596 like 3153 but u=145  $ Middle Bottom Fuel Zone
3597 like 3154 but u=145  $ Middle Bottom Pebble Shell
3598 like 3147 but u=146  $ NW Bottom Corner Fuel Zone
3599 like 3148 but u=146  $ NW Bottom Corner Pebble Shell
3600 like 3147 but u=147  $ NW Bottom Corner Fuel Zone
3609 like 3148 but u=147  $ NW Bottom Corner Pebble Shell
3610 like 3149 but u=147  $ NE Bottom Corner Fuel Zone
3611 like 3150 but u=147  $ NE Bottom Corner Pebble Shell
3612 like 3153 but u=147  $ Middle Bottom Fuel Zone
3613 like 3154 but u=147  $ Middle Bottom Pebble Shell
3614 like 3147 but u=148  $ NW Bottom Corner Fuel Zone
3615 like 3148 but u=148  $ NW Bottom Corner Pebble Shell
3616 like 3149 but u=148  $ NE Bottom Corner Fuel Zone
3617 like 3150 but u=148  $ NE Bottom Corner Pebble Shell
3618 like 3151 but u=148  $ S Bottom Corner Fuel Zone
3619 like 3152 but u=148  $ S Bottom Corner Pebble Shell
3620 like 3153 but u=148  $ Middle Bottom Fuel Zone
3621 like 3154 but u=148  $ Middle Bottom Pebble Shell
3622 like 3147 but u=149  $ NW Bottom Corner Fuel Zone
3623 like 3148 but u=149  $ NW Bottom Corner Pebble Shell
3624 like 3147 but u=152  $ NW Bottom Corner Fuel Zone
3625 like 3148 but u=152  $ NW Bottom Corner Pebble Shell
3626 like 3149 but u=152  $ NE Bottom Corner Fuel Zone
3627 like 3150 but u=152  $ NE Bottom Corner Pebble Shell
3628 like 3153 but u=152  $ Middle Bottom Fuel Zone
3629 like 3154 but u=152  $ Middle Bottom Pebble Shell
3630 like 3147 but u=153  $ NW Bottom Corner Fuel Zone
3631 like 3148 but u=153  $ NW Bottom Corner Pebble Shell
3632 like 3149 but u=153  $ NE Bottom Corner Fuel Zone
3633 like 3150 but u=153  $ NE Bottom Corner Pebble Shell
3634 like 3153 but u=153  $ Middle Bottom Fuel Zone
3635 like 3154 but u=153  $ Middle Bottom Pebble Shell
3636 like 3149 but u=154  $ NE Bottom Corner Fuel Zone
3637 like 3150 but u=154  $ NE Bottom Corner Pebble Shell
3638 like 3149 but u=155  $ NE Bottom Corner Fuel Zone
3639 like 3150 but u=155  $ NE Bottom Corner Pebble Shell
3640 like 3147 but u=156  $ NW Bottom Corner Fuel Zone
3641 like 3148 but u=156  $ NW Bottom Corner Pebble Shell
3642 like 3149 but u=156  $ NE Bottom Corner Fuel Zone
3643 like 3150 but u=156  $ NE Bottom Corner Pebble Shell
3644 like 3151 but u=156  $ S Bottom Corner Fuel Zone
3645 like 3152 but u=156  $ S Bottom Corner Pebble Shell
3646 like 3153 but u=156  $ Middle Bottom Fuel Zone
3647 like 3154 but u=156  $ Middle Bottom Pebble Shell
3648 like 3149 but u=157  $ NE Bottom Corner Fuel Zone
3649 like 3150 but u=157  $ NE Bottom Corner Pebble Shell
c
c --------- Bottom and Middle Layers Only Lattices ---------
3650 like 3139 but u=224  $ NW Middle Edge Fuel Zone
3651 like 3140 but u=224  $ NW Middle Edge Pebble Shell
3652 like 3141 but u=224  $ E Middle Edge Fuel Zone
3653 like 3142 but u=224  $ E Middle Edge Pebble Shell
3654 like 3143 but u=224  $ W Middle Edge Fuel Zone
3655 like 3144 but u=224  $ W Middle Edge Pebble Shell
3656 like 3145 but u=224  $ SE Middle Edge Fuel Zone
3657 like 3146 but u=224  $ SE Middle Edge Pebble Shell
3658 like 3147 but u=224  $ NW Bottom Corner Fuel Zone
3659 like 3148 but u=224  $ NW Bottom Corner Pebble Shell
3660 like 3149 but u=224  $ NE Bottom Corner Fuel Zone
3661 like 3150 but u=224  $ NE Bottom Corner Pebble Shell
3662 like 3151 but u=224  $ S Bottom Corner Fuel Zone
3663 like 3152 but u=224  $ S Bottom Corner Pebble Shell
3664 like 3153 but u=224  $ Middle Bottom Fuel Zone
3665 like 3154 but u=224  $ Middle Bottom Pebble Shell
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3666 like 3149 but u=225  $ NE Bottom Corner Fuel Zone
3667 like 3150 but u=225  $ NE Bottom Corner Pebble Shell
3668 like 3139 but u=226  $ NW Middle Edge Fuel Zone
3669 like 3140 but u=226  $ NW Middle Edge Pebble Shell
3670 like 3141 but u=226  $ E Middle Edge Fuel Zone
3671 like 3142 but u=226  $ E Middle Edge Pebble Shell
3672 like 3145 but u=226  $ SE Middle Edge Fuel Zone
3673 like 3146 but u=226  $ SE Middle Edge Pebble Shell
3674 like 3147 but u=226  $ NW Bottom Corner Fuel Zone
3675 like 3148 but u=226  $ NW Bottom Corner Pebble Shell
3676 like 3149 but u=226  $ NE Bottom Corner Fuel Zone
3677 like 3150 but u=226  $ NE Bottom Corner Pebble Shell
3678 like 3151 but u=226  $ S Bottom Corner Fuel Zone
3679 like 3152 but u=226  $ S Bottom Corner Pebble Shell
3680 like 3153 but u=226  $ Middle Bottom Fuel Zone
3681 like 3154 but u=226  $ Middle Bottom Pebble Shell
3682 like 3141 but u=227  $ E Middle Edge Fuel Zone
3683 like 3142 but u=227  $ E Middle Edge Pebble Shell
3684 like 3143 but u=227  $ W Middle Edge Fuel Zone
3685 like 3144 but u=227  $ W Middle Edge Pebble Shell
3686 like 3145 but u=227  $ SE Middle Edge Fuel Zone
3687 like 3146 but u=227  $ SE Middle Edge Pebble Shell
3688 like 3149 but u=227  $ NE Bottom Corner Fuel Zone
3689 like 3150 but u=227  $ NE Bottom Corner Pebble Shell
3690 like 3151 but u=227  $ S Bottom Corner Fuel Zone
3691 like 3152 but u=227  $ S Bottom Corner Pebble Shell
3692 like 3153 but u=227  $ Middle Bottom Fuel Zone
3693 like 3154 but u=227  $ Middle Bottom Pebble Shell
3694 like 3139 but u=229  $ NW Middle Edge Fuel Zone
3695 like 3140 but u=229  $ NW Middle Edge Pebble Shell
3696 like 3141 but u=229  $ E Middle Edge Fuel Zone
3697 like 3142 but u=229  $ E Middle Edge Pebble Shell
3698 like 3145 but u=229  $ SE Middle Edge Fuel Zone
3699 like 3146 but u=229  $ SE Middle Edge Pebble Shell
3700 like 3149 but u=229  $ NE Bottom Corner Fuel Zone
3701 like 3150 but u=229  $ NE Bottom Corner Pebble Shell
3702 like 3151 but u=229  $ S Bottom Corner Fuel Zone
3703 like 3152 but u=229  $ S Bottom Corner Pebble Shell
3704 like 3153 but u=229  $ Middle Bottom Fuel Zone
3705 like 3154 but u=229  $ Middle Bottom Pebble Shell
3706 like 3145 but u=230  $ SE Middle Edge Fuel Zone
3707 like 3146 but u=230  $ SE Middle Edge Pebble Shell
3708 like 3141 but u=231  $ E Middle Edge Fuel Zone
3709 like 3142 but u=231  $ E Middle Edge Pebble Shell
3710 like 3145 but u=231  $ SE Middle Edge Fuel Zone
3711 like 3146 but u=231  $ SE Middle Edge Pebble Shell
3712 like 3149 but u=231  $ NE Bottom Corner Fuel Zone
3713 like 3150 but u=231  $ NE Bottom Corner Pebble Shell
3714 like 3151 but u=231  $ S Bottom Corner Fuel Zone
3715 like 3152 but u=231  $ S Bottom Corner Pebble Shell
3716 like 3153 but u=231  $ Middle Bottom Fuel Zone
3717 like 3154 but u=231  $ Middle Bottom Pebble Shell
3718 like 3145 but u=232  $ SE Middle Edge Fuel Zone
3719 like 3146 but u=232  $ SE Middle Edge Pebble Shell
3720 like 3151 but u=232  $ S Bottom Corner Fuel Zone
3721 like 3152 but u=232  $ S Bottom Corner Pebble Shell
3722 like 3139 but u=233  $ NW Middle Edge Fuel Zone
3723 like 3140 but u=233  $ NW Middle Edge Pebble Shell
3724 like 3141 but u=233  $ E Middle Edge Fuel Zone
3725 like 3142 but u=233  $ E Middle Edge Pebble Shell
3726 like 3143 but u=233  $ W Middle Edge Fuel Zone
3727 like 3144 but u=233  $ W Middle Edge Pebble Shell
3728 like 3145 but u=233  $ SE Middle Edge Fuel Zone
3729 like 3146 but u=233  $ SE Middle Edge Pebble Shell
3730 like 3147 but u=233  $ NW Bottom Corner Fuel Zone
3731 like 3148 but u=233  $ NW Bottom Corner Pebble Shell
3732 like 3149 but u=233  $ NE Bottom Corner Fuel Zone
3733 like 3150 but u=233  $ NE Bottom Corner Pebble Shell
3734 like 3151 but u=233  $ S Bottom Corner Fuel Zone
3735 like 3152 but u=233  $ S Bottom Corner Pebble Shell
3736 like 3153 but u=233  $ Middle Bottom Fuel Zone
3737 like 3154 but u=233  $ Middle Bottom Pebble Shell
3738 like 3145 but u=234  $ SE Middle Edge Fuel Zone
3739 like 3146 but u=234  $ SE Middle Edge Pebble Shell
3740 like 3151 but u=234  $ S Bottom Corner Fuel Zone
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3741 like 3152 but u=234  $ S Bottom Corner Pebble Shell
3742 like 3151 but u=235  $ S Bottom Corner Fuel Zone
3743 like 3152 but u=235  $ S Bottom Corner Pebble Shell
3744 like 3143 but u=236  $ W Middle Edge Fuel Zone
3745 like 3144 but u=236  $ W Middle Edge Pebble Shell
3746 like 3145 but u=236  $ SE Middle Edge Fuel Zone
3747 like 3146 but u=236  $ SE Middle Edge Pebble Shell
3748 like 3147 but u=236  $ NW Bottom Corner Fuel Zone
3749 like 3148 but u=236  $ NW Bottom Corner Pebble Shell
3750 like 3151 but u=236  $ S Bottom Corner Fuel Zone
3751 like 3152 but u=236  $ S Bottom Corner Pebble Shell
3752 like 3153 but u=236  $ Middle Bottom Fuel Zone
3753 like 3154 but u=236  $ Middle Bottom Pebble Shell
3754 like 3151 but u=237  $ S Bottom Corner Fuel Zone
3755 like 3152 but u=237  $ S Bottom Corner Pebble Shell
3756 like 3139 but u=238  $ NW Middle Edge Fuel Zone
3757 like 3140 but u=238  $ NW Middle Edge Pebble Shell
3758 like 3141 but u=238  $ E Middle Edge Fuel Zone
3759 like 3142 but u=238  $ E Middle Edge Pebble Shell
3760 like 3143 but u=238  $ W Middle Edge Fuel Zone
3761 like 3144 but u=238  $ W Middle Edge Pebble Shell
3762 like 3145 but u=238  $ SE Middle Edge Fuel Zone
3763 like 3146 but u=238  $ SE Middle Edge Pebble Shell
3764 like 3147 but u=238  $ NW Bottom Corner Fuel Zone
3765 like 3148 but u=238  $ NW Bottom Corner Pebble Shell
3766 like 3149 but u=238  $ NE Bottom Corner Fuel Zone
3767 like 3150 but u=238  $ NE Bottom Corner Pebble Shell
3768 like 3151 but u=238  $ S Bottom Corner Fuel Zone
3769 like 3152 but u=238  $ S Bottom Corner Pebble Shell
3770 like 3153 but u=238  $ Middle Bottom Fuel Zone
3771 like 3154 but u=238  $ Middle Bottom Pebble Shell
3772 like 3139 but u=240  $ NW Middle Edge Fuel Zone
3773 like 3140 but u=240  $ NW Middle Edge Pebble Shell
3774 like 3141 but u=240  $ E Middle Edge Fuel Zone
3775 like 3142 but u=240  $ E Middle Edge Pebble Shell
3776 like 3143 but u=240  $ W Middle Edge Fuel Zone
3777 like 3144 but u=240  $ W Middle Edge Pebble Shell
3778 like 3145 but u=240  $ SE Middle Edge Fuel Zone
3779 like 3146 but u=240  $ SE Middle Edge Pebble Shell
3780 like 3147 but u=240  $ NW Bottom Corner Fuel Zone
3781 like 3148 but u=240  $ NW Bottom Corner Pebble Shell
3782 like 3151 but u=240  $ S Bottom Corner Fuel Zone
3783 like 3152 but u=240  $ S Bottom Corner Pebble Shell
3784 like 3153 but u=240  $ Middle Bottom Fuel Zone
3785 like 3154 but u=240  $ Middle Bottom Pebble Shell
3786 like 3143 but u=241  $ W Middle Edge Fuel Zone
3787 like 3144 but u=241  $ W Middle Edge Pebble Shell
3788 like 3139 but u=242  $ NW Middle Edge Fuel Zone
3789 like 3140 but u=242  $ NW Middle Edge Pebble Shell
3790 like 3143 but u=242  $ W Middle Edge Fuel Zone
3791 like 3144 but u=242  $ W Middle Edge Pebble Shell
3792 like 3147 but u=242  $ NW Bottom Corner Fuel Zone
3793 like 3148 but u=242  $ NW Bottom Corner Pebble Shell
3794 like 3151 but u=242  $ S Bottom Corner Fuel Zone
3795 like 3152 but u=242  $ S Bottom Corner Pebble Shell
3796 like 3153 but u=242  $ Middle Bottom Fuel Zone
3797 like 3154 but u=242  $ Middle Bottom Pebble Shell
3798 like 3143 but u=243  $ W Middle Edge Fuel Zone
3799 like 3144 but u=243  $ W Middle Edge Pebble Shell
3800 like 3147 but u=243  $ NW Bottom Corner Fuel Zone
3801 like 3148 but u=243  $ NW Bottom Corner Pebble Shell
3802 like 3143 but u=244  $ W Middle Edge Fuel Zone
3803 like 3144 but u=244  $ W Middle Edge Pebble Shell
3804 like 3147 but u=244  $ NW Bottom Corner Fuel Zone
3805 like 3148 but u=244  $ NW Bottom Corner Pebble Shell
3806 like 3139 but u=245  $ NW Middle Edge Fuel Zone
3807 like 3140 but u=245  $ NW Middle Edge Pebble Shell
3808 like 3141 but u=245  $ E Middle Edge Fuel Zone
3809 like 3142 but u=245  $ E Middle Edge Pebble Shell
3810 like 3143 but u=245  $ W Middle Edge Fuel Zone
3811 like 3144 but u=245  $ W Middle Edge Pebble Shell
3812 like 3147 but u=245  $ NW Bottom Corner Fuel Zone
3813 like 3148 but u=245  $ NW Bottom Corner Pebble Shell
3814 like 3149 but u=245  $ NE Bottom Corner Fuel Zone
3815 like 3150 but u=245  $ NE Bottom Corner Pebble Shell
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3816 like 3151 but u=245  $ S Bottom Corner Fuel Zone
3817 like 3152 but u=245  $ S Bottom Corner Pebble Shell
3818 like 3153 but u=245  $ Middle Bottom Fuel Zone
3819 like 3154 but u=245  $ Middle Bottom Pebble Shell
3820 like 3147 but u=246  $ NW Bottom Corner Fuel Zone
3821 like 3148 but u=246  $ NW Bottom Corner Pebble Shell
3822 like 3139 but u=247  $ NW Middle Edge Fuel Zone
3823 like 3140 but u=247  $ NW Middle Edge Pebble Shell
3824 like 3143 but u=247  $ W Middle Edge Fuel Zone
3825 like 3144 but u=247  $ W Middle Edge Pebble Shell
3826 like 3147 but u=247  $ NW Bottom Corner Fuel Zone
3827 like 3148 but u=247  $ NW Bottom Corner Pebble Shell
3828 like 3149 but u=247  $ NE Bottom Corner Fuel Zone
3829 like 3150 but u=247  $ NE Bottom Corner Pebble Shell
3830 like 3153 but u=247  $ Middle Bottom Fuel Zone
3831 like 3154 but u=247  $ Middle Bottom Pebble Shell
3832 like 3139 but u=248  $ NW Middle Edge Fuel Zone
3833 like 3140 but u=248  $ NW Middle Edge Pebble Shell
3834 like 3141 but u=248  $ E Middle Edge Fuel Zone
3835 like 3142 but u=248  $ E Middle Edge Pebble Shell
3836 like 3143 but u=248  $ W Middle Edge Fuel Zone
3837 like 3144 but u=248  $ W Middle Edge Pebble Shell
3838 like 3147 but u=248  $ NW Bottom Corner Fuel Zone
3839 like 3148 but u=248  $ NW Bottom Corner Pebble Shell
3840 like 3149 but u=248  $ NE Bottom Corner Fuel Zone
3841 like 3150 but u=248  $ NE Bottom Corner Pebble Shell
3842 like 3151 but u=248  $ S Bottom Corner Fuel Zone
3843 like 3152 but u=248  $ S Bottom Corner Pebble Shell
3844 like 3153 but u=248  $ Middle Bottom Fuel Zone
3845 like 3154 but u=248  $ Middle Bottom Pebble Shell
3846 like 3147 but u=249  $ NW Bottom Corner Fuel Zone
3847 like 3148 but u=249  $ NW Bottom Corner Pebble Shell
3848 like 3139 but u=252  $ NW Middle Edge Fuel Zone
3849 like 3140 but u=252  $ NW Middle Edge Pebble Shell
3850 like 3141 but u=252  $ E Middle Edge Fuel Zone
3851 like 3142 but u=252  $ E Middle Edge Pebble Shell
3852 like 3143 but u=252  $ W Middle Edge Fuel Zone
3853 like 3144 but u=252  $ W Middle Edge Pebble Shell
3854 like 3147 but u=252  $ NW Bottom Corner Fuel Zone
3855 like 3148 but u=252  $ NW Bottom Corner Pebble Shell
3856 like 3149 but u=252  $ NE Bottom Corner Fuel Zone
3857 like 3150 but u=252  $ NE Bottom Corner Pebble Shell
3858 like 3153 but u=252  $ Middle Bottom Fuel Zone
3859 like 3154 but u=252  $ Middle Bottom Pebble Shell
3860 like 3139 but u=253  $ NW Middle Edge Fuel Zone
3861 like 3140 but u=253  $ NW Middle Edge Pebble Shell
3862 like 3141 but u=253  $ E Middle Edge Fuel Zone
3863 like 3142 but u=253  $ E Middle Edge Pebble Shell
3864 like 3147 but u=253  $ NW Bottom Corner Fuel Zone
3865 like 3148 but u=253  $ NW Bottom Corner Pebble Shell
3866 like 3149 but u=253  $ NE Bottom Corner Fuel Zone
3867 like 3150 but u=253  $ NE Bottom Corner Pebble Shell
3868 like 3153 but u=253  $ Middle Bottom Fuel Zone
3869 like 3154 but u=253  $ Middle Bottom Pebble Shell
3870 like 3149 but u=254  $ NE Bottom Corner Fuel Zone
3871 like 3150 but u=254  $ NE Bottom Corner Pebble Shell
3872 like 3149 but u=255  $ NE Bottom Corner Fuel Zone
3873 like 3150 but u=255  $ NE Bottom Corner Pebble Shell
3874 like 3139 but u=256  $ NW Middle Edge Fuel Zone
3875 like 3140 but u=256  $ NW Middle Edge Pebble Shell
3876 like 3141 but u=256  $ E Middle Edge Fuel Zone
3877 like 3142 but u=256  $ E Middle Edge Pebble Shell
3878 like 3145 but u=256  $ SE Middle Edge Fuel Zone
3879 like 3146 but u=256  $ SE Middle Edge Pebble Shell
3880 like 3147 but u=256  $ NW Bottom Corner Fuel Zone
3881 like 3148 but u=256  $ NW Bottom Corner Pebble Shell
3882 like 3149 but u=256  $ NE Bottom Corner Fuel Zone
3883 like 3150 but u=256  $ NE Bottom Corner Pebble Shell
3884 like 3151 but u=256  $ S Bottom Corner Fuel Zone
3885 like 3152 but u=256  $ S Bottom Corner Pebble Shell
3886 like 3153 but u=256  $ Middle Bottom Fuel Zone
3887 like 3154 but u=256  $ Middle Bottom Pebble Shell
3888 like 3149 but u=257  $ NE Bottom Corner Fuel Zone
3889 like 3150 but u=257  $ NE Bottom Corner Pebble Shell
c
```

```
c --------- Top Layer Only Lattices ---------
3890 like 3131 but u=324  $ Middle Top Fuel Zone
3891 like 3132 but u=324  $ Middle Top Pebble Shell
3892 like 3133 but u=324  $ NW Top Corner Fuel Zone
3893 like 3134 but u=324  $ NW Top Corner Pebble Shell
3894 like 3135 but u=324  $ NE Top Corner Fuel Zone
3895 like 3136 but u=324  $ NE Top Corner Pebble Shell
3896 like 3137 but u=324  $ S Top Corner Fuel Zone
3897 like 3138 but u=324  $ S Top Corner Pebble Shell
3898 like 3135 but u=325  $ NE Top Corner Fuel Zone
3899 like 3136 but u=325  $ NE Top Corner Pebble Shell
3900 like 3131 but u=326  $ Middle Top Fuel Zone
3901 like 3132 but u=326  $ Middle Top Pebble Shell
3902 like 3133 but u=326  $ NW Top Corner Fuel Zone
3903 like 3134 but u=326  $ NW Top Corner Pebble Shell
3904 like 3135 but u=326  $ NE Top Corner Fuel Zone
3905 like 3136 but u=326  $ NE Top Corner Pebble Shell
3906 like 3137 but u=326  $ S Top Corner Fuel Zone
3907 like 3138 but u=326  $ S Top Corner Pebble Shell
3908 like 3131 but u=327  $ Middle Top Fuel Zone
3909 like 3132 but u=327  $ Middle Top Pebble Shell
3910 like 3135 but u=327  $ NE Top Corner Fuel Zone
3911 like 3136 but u=327  $ NE Top Corner Pebble Shell
3912 like 3137 but u=327  $ S Top Corner Fuel Zone
3913 like 3138 but u=327  $ S Top Corner Pebble Shell
3914 like 3131 but u=329  $ Middle Top Fuel Zone
3915 like 3132 but u=329  $ Middle Top Pebble Shell
3916 like 3135 but u=329  $ NE Top Corner Fuel Zone
3917 like 3136 but u=329  $ NE Top Corner Pebble Shell
3918 like 3137 but u=329  $ S Top Corner Fuel Zone
3919 like 3138 but u=329  $ S Top Corner Pebble Shell
3920 like 3131 but u=331  $ Middle Top Fuel Zone
3921 like 3132 but u=331  $ Middle Top Pebble Shell
3922 like 3135 but u=331  $ NE Top Corner Fuel Zone
3923 like 3136 but u=331  $ NE Top Corner Pebble Shell
3924 like 3137 but u=331  $ S Top Corner Fuel Zone
3925 like 3138 but u=331  $ S Top Corner Pebble Shell
3926 like 3137 but u=332  $ S Top Corner Fuel Zone
3927 like 3138 but u=332  $ S Top Corner Pebble Shell
3928 like 3131 but u=333  $ Middle Top Fuel Zone
3929 like 3132 but u=333  $ Middle Top Pebble Shell
3930 like 3133 but u=333  $ NW Top Corner Fuel Zone
3931 like 3134 but u=333  $ NW Top Corner Pebble Shell
3932 like 3135 but u=333  $ NE Top Corner Fuel Zone
3933 like 3136 but u=333  $ NE Top Corner Pebble Shell
3934 like 3137 but u=333  $ S Top Corner Fuel Zone
3935 like 3138 but u=333  $ S Top Corner Pebble Shell
3936 like 3137 but u=334  $ S Top Corner Fuel Zone
3937 like 3138 but u=334  $ S Top Corner Pebble Shell
3938 like 3137 but u=335  $ S Top Corner Fuel Zone
3939 like 3138 but u=335  $ S Top Corner Pebble Shell
3940 like 3131 but u=336  $ Middle Top Fuel Zone
3941 like 3132 but u=336  $ Middle Top Pebble Shell
3942 like 3133 but u=336  $ NW Top Corner Fuel Zone
3943 like 3134 but u=336  $ NW Top Corner Pebble Shell
3944 like 3137 but u=336  $ S Top Corner Fuel Zone
3945 like 3138 but u=336  $ S Top Corner Pebble Shell
3946 like 3137 but u=337  $ S Top Corner Fuel Zone
3947 like 3138 but u=337  $ S Top Corner Pebble Shell
3948 like 3131 but u=338  $ Middle Top Fuel Zone
3949 like 3132 but u=338  $ Middle Top Pebble Shell
3950 like 3133 but u=338  $ NW Top Corner Fuel Zone
3951 like 3134 but u=338  $ NW Top Corner Pebble Shell
3952 like 3135 but u=338  $ NE Top Corner Fuel Zone
3953 like 3136 but u=338  $ NE Top Corner Pebble Shell
3954 like 3137 but u=338  $ S Top Corner Fuel Zone
3955 like 3138 but u=338  $ S Top Corner Pebble Shell
3956 like 3131 but u=340  $ Middle Top Fuel Zone
3957 like 3132 but u=340  $ Middle Top Pebble Shell
3958 like 3133 but u=340  $ NW Top Corner Fuel Zone
3959 like 3134 but u=340  $ NW Top Corner Pebble Shell
3960 like 3137 but u=340  $ S Top Corner Fuel Zone
3961 like 3138 but u=340  $ S Top Corner Pebble Shell
3962 like 3131 but u=342  $ Middle Top Fuel Zone
3963 like 3132 but u=342  $ Middle Top Pebble Shell
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3964 like 3133 but u=342  $ NW Top Corner Fuel Zone
3965 like 3134 but u=342  $ NW Top Corner Pebble Shell
3966 like 3137 but u=342  $ S Top Corner Fuel Zone
3967 like 3138 but u=342  $ S Top Corner Pebble Shell
3968 like 3133 but u=343  $ NW Top Corner Fuel Zone
3969 like 3134 but u=343  $ NW Top Corner Pebble Shell
3970 like 3133 but u=344  $ NW Top Corner Fuel Zone
3971 like 3134 but u=344  $ NW Top Corner Pebble Shell
3972 like 3131 but u=345  $ Middle Top Fuel Zone
3973 like 3132 but u=345  $ Middle Top Pebble Shell
3974 like 3133 but u=345  $ NW Top Corner Fuel Zone
3975 like 3134 but u=345  $ NW Top Corner Pebble Shell
3976 like 3135 but u=345  $ NE Top Corner Fuel Zone
3977 like 3136 but u=345  $ NE Top Corner Pebble Shell
3978 like 3137 but u=345  $ S Top Corner Fuel Zone
3979 like 3138 but u=345  $ S Top Corner Pebble Shell
3980 like 3133 but u=346  $ NW Top Corner Fuel Zone
3981 like 3134 but u=346  $ NW Top Corner Pebble Shell
3982 like 3131 but u=347  $ Middle Top Fuel Zone
3983 like 3132 but u=347  $ Middle Top Pebble Shell
3984 like 3133 but u=347  $ NW Top Corner Fuel Zone
3985 like 3134 but u=347  $ NW Top Corner Pebble Shell
3986 like 3135 but u=347  $ NE Top Corner Fuel Zone
3987 like 3136 but u=347  $ NE Top Corner Pebble Shell
3988 like 3131 but u=348  $ Middle Top Fuel Zone
3989 like 3132 but u=348  $ Middle Top Pebble Shell
3990 like 3133 but u=348  $ NW Top Corner Fuel Zone
3991 like 3134 but u=348  $ NW Top Corner Pebble Shell
3992 like 3135 but u=348  $ NE Top Corner Fuel Zone
3993 like 3136 but u=348  $ NE Top Corner Pebble Shell
3994 like 3137 but u=348  $ S Top Corner Fuel Zone
3995 like 3138 but u=348  $ S Top Corner Pebble Shell
3996 like 3133 but u=349  $ NW Top Corner Fuel Zone
3997 like 3134 but u=349  $ NW Top Corner Pebble Shell
3998 like 3131 but u=352  $ Middle Top Fuel Zone
3999 like 3132 but u=352  $ Middle Top Pebble Shell
4000 like 3133 but u=352  $ NW Top Corner Fuel Zone
4001 like 3134 but u=352  $ NW Top Corner Pebble Shell
4002 like 3135 but u=352  $ NE Top Corner Fuel Zone
4003 like 3136 but u=352  $ NE Top Corner Pebble Shell
4004 like 3131 but u=353  $ Middle Top Fuel Zone
4005 like 3132 but u=353  $ Middle Top Pebble Shell
4006 like 3133 but u=353  $ NW Top Corner Fuel Zone
4007 like 3134 but u=353  $ NW Top Corner Pebble Shell
4008 like 3135 but u=353  $ NE Top Corner Fuel Zone
4009 like 3136 but u=353  $ NE Top Corner Pebble Shell
4010 like 3135 but u=354  $ NE Top Corner Fuel Zone
4011 like 3136 but u=354  $ NE Top Corner Pebble Shell
4012 like 3135 but u=355  $ NE Top Corner Fuel Zone
4013 like 3136 but u=355  $ NE Top Corner Pebble Shell
4014 like 3131 but u=356  $ Middle Top Fuel Zone
4015 like 3132 but u=356  $ Middle Top Pebble Shell
4016 like 3133 but u=356  $ NW Top Corner Fuel Zone
4017 like 3134 but u=356  $ NW Top Corner Pebble Shell
4018 like 3135 but u=356  $ NE Top Corner Fuel Zone
4019 like 3136 but u=356  $ NE Top Corner Pebble Shell
4020 like 3137 but u=356  $ S Top Corner Fuel Zone
4021 like 3138 but u=356  $ S Top Corner Pebble Shell
4022 like 3135 but u=357  $ NE Top Corner Fuel Zone
4023 like 3136 but u=357  $ NE Top Corner Pebble Shell
c
c --------- All Moderator Lattices ---------
c    *No Fuel Pebbles
c
c --------- Bottom Layer of Moderator Only Lattices ---------
c    *No Fuel Pebbles
c
c --------- Bottom and Middle Fuel with Top Moderator Lattices ---------
7001 like 3139 but u=624  $ NW Middle Edge Fuel Zone
7002 like 3140 but u=624  $ NW Middle Edge Pebble Shell
7003 like 3141 but u=624  $ E Middle Edge Fuel Zone
7004 like 3142 but u=624  $ E Middle Edge Pebble Shell
7005 like 3143 but u=624  $ W Middle Edge Fuel Zone
7006 like 3144 but u=624  $ W Middle Edge Pebble Shell
7007 like 3145 but u=624  $ SE Middle Edge Fuel Zone
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7008 like 3146 but u=624  $ SE Middle Edge Pebble Shell
7009 like 3147 but u=624  $ NW Bottom Corner Fuel Zone
7010 like 3148 but u=624  $ NW Bottom Corner Pebble Shell
7011 like 3149 but u=624  $ NE Bottom Corner Fuel Zone
7012 like 3150 but u=624  $ NE Bottom Corner Pebble Shell
7013 like 3151 but u=624  $ S Bottom Corner Fuel Zone
7014 like 3152 but u=624  $ S Bottom Corner Pebble Shell
7015 like 3153 but u=624  $ Middle Bottom Fuel Zone
7016 like 3154 but u=624  $ Middle Bottom Pebble Shell
7017 like 3149 but u=625  $ NE Bottom Corner Fuel Zone
7018 like 3150 but u=625  $ NE Bottom Corner Pebble Shell
7019 like 3139 but u=626  $ NW Middle Edge Fuel Zone
7020 like 3140 but u=626  $ NW Middle Edge Pebble Shell
7021 like 3141 but u=626  $ E Middle Edge Fuel Zone
7022 like 3142 but u=626  $ E Middle Edge Pebble Shell
7023 like 3145 but u=626  $ SE Middle Edge Fuel Zone
7024 like 3146 but u=626  $ SE Middle Edge Pebble Shell
7025 like 3147 but u=626  $ NW Bottom Corner Fuel Zone
7026 like 3148 but u=626  $ NW Bottom Corner Pebble Shell
7027 like 3149 but u=626  $ NE Bottom Corner Fuel Zone
7028 like 3150 but u=626  $ NE Bottom Corner Pebble Shell
7029 like 3151 but u=626  $ S Bottom Corner Fuel Zone
7030 like 3152 but u=626  $ S Bottom Corner Pebble Shell
7031 like 3153 but u=626  $ Middle Bottom Fuel Zone
7032 like 3154 but u=626  $ Middle Bottom Pebble Shell
7033 like 3141 but u=627  $ E Middle Edge Fuel Zone
7034 like 3142 but u=627  $ E Middle Edge Pebble Shell
7035 like 3143 but u=627  $ W Middle Edge Fuel Zone
7036 like 3144 but u=627  $ W Middle Edge Pebble Shell
7037 like 3145 but u=627  $ SE Middle Edge Fuel Zone
7038 like 3146 but u=627  $ SE Middle Edge Pebble Shell
7039 like 3149 but u=627  $ NE Bottom Corner Fuel Zone
7040 like 3150 but u=627  $ NE Bottom Corner Pebble Shell
7041 like 3151 but u=627  $ S Bottom Corner Fuel Zone
7042 like 3152 but u=627  $ S Bottom Corner Pebble Shell
7043 like 3153 but u=627  $ Middle Bottom Fuel Zone
7044 like 3154 but u=627  $ Middle Bottom Pebble Shell
7045 like 3139 but u=629  $ NW Middle Edge Fuel Zone
7046 like 3140 but u=629  $ NW Middle Edge Pebble Shell
7047 like 3141 but u=629  $ E Middle Edge Fuel Zone
7048 like 3142 but u=629  $ E Middle Edge Pebble Shell
7049 like 3145 but u=629  $ SE Middle Edge Fuel Zone
7050 like 3146 but u=629  $ SE Middle Edge Pebble Shell
7051 like 3149 but u=629  $ NE Bottom Corner Fuel Zone
7052 like 3150 but u=629  $ NE Bottom Corner Pebble Shell
7053 like 3151 but u=629  $ S Bottom Corner Fuel Zone
7054 like 3152 but u=629  $ S Bottom Corner Pebble Shell
7055 like 3153 but u=629  $ Middle Bottom Fuel Zone
7056 like 3154 but u=629  $ Middle Bottom Pebble Shell
7057 like 3145 but u=630  $ SE Middle Edge Fuel Zone
7058 like 3146 but u=630  $ SE Middle Edge Pebble Shell
7059 like 3141 but u=631  $ E Middle Edge Fuel Zone
7060 like 3142 but u=631  $ E Middle Edge Pebble Shell
7061 like 3145 but u=631  $ SE Middle Edge Fuel Zone
7062 like 3146 but u=631  $ SE Middle Edge Pebble Shell
7063 like 3149 but u=631  $ NE Bottom Corner Fuel Zone
7064 like 3150 but u=631  $ NE Bottom Corner Pebble Shell
7065 like 3151 but u=631  $ S Bottom Corner Fuel Zone
7066 like 3152 but u=631  $ S Bottom Corner Pebble Shell
7067 like 3153 but u=631  $ Middle Bottom Fuel Zone
7068 like 3154 but u=631  $ Middle Bottom Pebble Shell
7069 like 3145 but u=632  $ SE Middle Edge Fuel Zone
7070 like 3146 but u=632  $ SE Middle Edge Pebble Shell
7071 like 3151 but u=632  $ S Bottom Corner Fuel Zone
7072 like 3152 but u=632  $ S Bottom Corner Pebble Shell
7073 like 3139 but u=633  $ NW Middle Edge Fuel Zone
7074 like 3140 but u=633  $ NW Middle Edge Pebble Shell
7075 like 3141 but u=633  $ E Middle Edge Fuel Zone
7076 like 3142 but u=633  $ E Middle Edge Pebble Shell
7077 like 3143 but u=633  $ W Middle Edge Fuel Zone
7078 like 3144 but u=633  $ W Middle Edge Pebble Shell
7079 like 3145 but u=633  $ SE Middle Edge Fuel Zone
7080 like 3146 but u=633  $ SE Middle Edge Pebble Shell
7081 like 3147 but u=633  $ NW Bottom Corner Fuel Zone
7082 like 3148 but u=633  $ NW Bottom Corner Pebble Shell
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7083 like 3149 but u=633  $ NE Bottom Corner Fuel Zone
7084 like 3150 but u=633  $ NE Bottom Corner Pebble Shell
7085 like 3151 but u=633  $ S Bottom Corner Fuel Zone
7086 like 3152 but u=633  $ S Bottom Corner Pebble Shell
7087 like 3153 but u=633  $ Middle Bottom Fuel Zone
7088 like 3154 but u=633  $ Middle Bottom Pebble Shell
7089 like 3145 but u=634  $ SE Middle Edge Fuel Zone
7090 like 3146 but u=634  $ SE Middle Edge Pebble Shell
7091 like 3151 but u=634  $ S Bottom Corner Fuel Zone
7092 like 3152 but u=634  $ S Bottom Corner Pebble Shell
7093 like 3151 but u=635  $ S Bottom Corner Fuel Zone
7094 like 3152 but u=635  $ S Bottom Corner Pebble Shell
7095 like 3143 but u=636  $ W Middle Edge Fuel Zone
7096 like 3144 but u=636  $ W Middle Edge Pebble Shell
7097 like 3145 but u=636  $ SE Middle Edge Fuel Zone
7098 like 3146 but u=636  $ SE Middle Edge Pebble Shell
7099 like 3147 but u=636  $ NW Bottom Corner Fuel Zone
7100 like 3148 but u=636  $ NW Bottom Corner Pebble Shell
7101 like 3151 but u=636  $ S Bottom Corner Fuel Zone
7102 like 3152 but u=636  $ S Bottom Corner Pebble Shell
7103 like 3153 but u=636  $ Middle Bottom Fuel Zone
7104 like 3154 but u=636  $ Middle Bottom Pebble Shell
7105 like 3151 but u=637  $ S Bottom Corner Fuel Zone
7106 like 3152 but u=637  $ S Bottom Corner Pebble Shell
7107 like 3139 but u=638  $ NW Middle Edge Fuel Zone
7108 like 3140 but u=638  $ NW Middle Edge Pebble Shell
7109 like 3141 but u=638  $ E Middle Edge Fuel Zone
7110 like 3142 but u=638  $ E Middle Edge Pebble Shell
7111 like 3143 but u=638  $ W Middle Edge Fuel Zone
7112 like 3144 but u=638  $ W Middle Edge Pebble Shell
7113 like 3145 but u=638  $ SE Middle Edge Fuel Zone
7114 like 3146 but u=638  $ SE Middle Edge Pebble Shell
7115 like 3147 but u=638  $ NW Bottom Corner Fuel Zone
7116 like 3148 but u=638  $ NW Bottom Corner Pebble Shell
7117 like 3149 but u=638  $ NE Bottom Corner Fuel Zone
7118 like 3150 but u=638  $ NE Bottom Corner Pebble Shell
7119 like 3151 but u=638  $ S Bottom Corner Fuel Zone
7120 like 3152 but u=638  $ S Bottom Corner Pebble Shell
7121 like 3153 but u=638  $ Middle Bottom Fuel Zone
7122 like 3154 but u=638  $ Middle Bottom Pebble Shell
7123 like 3139 but u=640  $ NW Middle Edge Fuel Zone
7124 like 3140 but u=640  $ NW Middle Edge Pebble Shell
7125 like 3141 but u=640  $ E Middle Edge Fuel Zone
7126 like 3142 but u=640  $ E Middle Edge Pebble Shell
7127 like 3143 but u=640  $ W Middle Edge Fuel Zone
7128 like 3144 but u=640  $ W Middle Edge Pebble Shell
7129 like 3145 but u=640  $ SE Middle Edge Fuel Zone
7130 like 3146 but u=640  $ SE Middle Edge Pebble Shell
7131 like 3147 but u=640  $ NW Bottom Corner Fuel Zone
7132 like 3148 but u=640  $ NW Bottom Corner Pebble Shell
7133 like 3151 but u=640  $ S Bottom Corner Fuel Zone
7134 like 3152 but u=640  $ S Bottom Corner Pebble Shell
7135 like 3153 but u=640  $ Middle Bottom Fuel Zone
7136 like 3154 but u=640  $ Middle Bottom Pebble Shell
7137 like 3143 but u=641  $ W Middle Edge Fuel Zone
7138 like 3144 but u=641  $ W Middle Edge Pebble Shell
7139 like 3139 but u=642  $ NW Middle Edge Fuel Zone
7140 like 3140 but u=642  $ NW Middle Edge Pebble Shell
7141 like 3143 but u=642  $ W Middle Edge Fuel Zone
7142 like 3144 but u=642  $ W Middle Edge Pebble Shell
7143 like 3147 but u=642  $ NW Bottom Corner Fuel Zone
7144 like 3148 but u=642  $ NW Bottom Corner Pebble Shell
7145 like 3151 but u=642  $ S Bottom Corner Fuel Zone
7146 like 3152 but u=642  $ S Bottom Corner Pebble Shell
7147 like 3153 but u=642  $ Middle Bottom Fuel Zone
7148 like 3154 but u=642  $ Middle Bottom Pebble Shell
7149 like 3143 but u=643  $ W Middle Edge Fuel Zone
7150 like 3144 but u=643  $ W Middle Edge Pebble Shell
7151 like 3147 but u=643  $ NW Bottom Corner Fuel Zone
7152 like 3148 but u=643  $ NW Bottom Corner Pebble Shell
7153 like 3143 but u=644  $ W Middle Edge Fuel Zone
7154 like 3144 but u=644  $ W Middle Edge Pebble Shell
7155 like 3147 but u=644  $ NW Bottom Corner Fuel Zone
7156 like 3148 but u=644  $ NW Bottom Corner Pebble Shell
7157 like 3139 but u=645  $ NW Middle Edge Fuel Zone
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7158 like 3140 but u=645  $ NW Middle Edge Pebble Shell
7159 like 3141 but u=645  $ E Middle Edge Fuel Zone
7160 like 3142 but u=645  $ E Middle Edge Pebble Shell
7161 like 3143 but u=645  $ W Middle Edge Fuel Zone
7162 like 3144 but u=645  $ W Middle Edge Pebble Shell
7163 like 3147 but u=645  $ NW Bottom Corner Fuel Zone
7164 like 3148 but u=645  $ NW Bottom Corner Pebble Shell
7165 like 3149 but u=645  $ NE Bottom Corner Fuel Zone
7166 like 3150 but u=645  $ NE Bottom Corner Pebble Shell
7167 like 3151 but u=645  $ S Bottom Corner Fuel Zone
7168 like 3152 but u=645  $ S Bottom Corner Pebble Shell
7169 like 3153 but u=645  $ Middle Bottom Fuel Zone
7170 like 3154 but u=645  $ Middle Bottom Pebble Shell
7171 like 3147 but u=646  $ NW Bottom Corner Fuel Zone
7172 like 3148 but u=646  $ NW Bottom Corner Pebble Shell
7173 like 3139 but u=647  $ NW Middle Edge Fuel Zone
7174 like 3140 but u=647  $ NW Middle Edge Pebble Shell
7175 like 3143 but u=647  $ W Middle Edge Fuel Zone
7176 like 3144 but u=647  $ W Middle Edge Pebble Shell
7177 like 3147 but u=647  $ NW Bottom Corner Fuel Zone
7178 like 3148 but u=647  $ NW Bottom Corner Pebble Shell
7179 like 3149 but u=647  $ NE Bottom Corner Fuel Zone
7180 like 3150 but u=647  $ NE Bottom Corner Pebble Shell
7181 like 3153 but u=647  $ Middle Bottom Fuel Zone
7182 like 3154 but u=647  $ Middle Bottom Pebble Shell
7183 like 3139 but u=648  $ NW Middle Edge Fuel Zone
7184 like 3140 but u=648  $ NW Middle Edge Pebble Shell
7185 like 3141 but u=648  $ E Middle Edge Fuel Zone
7186 like 3142 but u=648  $ E Middle Edge Pebble Shell
7187 like 3143 but u=648  $ W Middle Edge Fuel Zone
7188 like 3144 but u=648  $ W Middle Edge Pebble Shell
7189 like 3147 but u=648  $ NW Bottom Corner Fuel Zone
7190 like 3148 but u=648  $ NW Bottom Corner Pebble Shell
7191 like 3149 but u=648  $ NE Bottom Corner Fuel Zone
7192 like 3150 but u=648  $ NE Bottom Corner Pebble Shell
7193 like 3151 but u=648  $ S Bottom Corner Fuel Zone
7194 like 3152 but u=648  $ S Bottom Corner Pebble Shell
7195 like 3153 but u=648  $ Middle Bottom Fuel Zone
7196 like 3154 but u=648  $ Middle Bottom Pebble Shell
7197 like 3147 but u=649  $ NW Bottom Corner Fuel Zone
7198 like 3148 but u=649  $ NW Bottom Corner Pebble Shell
7199 like 3139 but u=652  $ NW Middle Edge Fuel Zone
7200 like 3140 but u=652  $ NW Middle Edge Pebble Shell
7201 like 3141 but u=652  $ E Middle Edge Fuel Zone
7202 like 3142 but u=652  $ E Middle Edge Pebble Shell
7203 like 3143 but u=652  $ W Middle Edge Fuel Zone
7204 like 3144 but u=652  $ W Middle Edge Pebble Shell
7205 like 3147 but u=652  $ NW Bottom Corner Fuel Zone
7206 like 3148 but u=652  $ NW Bottom Corner Pebble Shell
7207 like 3149 but u=652  $ NE Bottom Corner Fuel Zone
7208 like 3150 but u=652  $ NE Bottom Corner Pebble Shell
7209 like 3153 but u=652  $ Middle Bottom Fuel Zone
7210 like 3154 but u=652  $ Middle Bottom Pebble Shell
7211 like 3139 but u=653  $ NW Middle Edge Fuel Zone
7212 like 3140 but u=653  $ NW Middle Edge Pebble Shell
7213 like 3141 but u=653  $ E Middle Edge Fuel Zone
7214 like 3142 but u=653  $ E Middle Edge Pebble Shell
7215 like 3147 but u=653  $ NW Bottom Corner Fuel Zone
7216 like 3148 but u=653  $ NW Bottom Corner Pebble Shell
7217 like 3149 but u=653  $ NE Bottom Corner Fuel Zone
7218 like 3150 but u=653  $ NE Bottom Corner Pebble Shell
7219 like 3153 but u=653  $ Middle Bottom Fuel Zone
7220 like 3154 but u=653  $ Middle Bottom Pebble Shell
7221 like 3149 but u=654  $ NE Bottom Corner Fuel Zone
7222 like 3150 but u=654  $ NE Bottom Corner Pebble Shell
7223 like 3149 but u=655  $ NE Bottom Corner Fuel Zone
7224 like 3150 but u=655  $ NE Bottom Corner Pebble Shell
7225 like 3139 but u=656  $ NW Middle Edge Fuel Zone
7226 like 3140 but u=656  $ NW Middle Edge Pebble Shell
7227 like 3141 but u=656  $ E Middle Edge Fuel Zone
7228 like 3142 but u=656  $ E Middle Edge Pebble Shell
7229 like 3145 but u=656  $ SE Middle Edge Fuel Zone
7230 like 3146 but u=656  $ SE Middle Edge Pebble Shell
7231 like 3147 but u=656  $ NW Bottom Corner Fuel Zone
7232 like 3148 but u=656  $ NW Bottom Corner Pebble Shell
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7233 like 3149 but u=656  $ NE Bottom Corner Fuel Zone
7234 like 3150 but u=656  $ NE Bottom Corner Pebble Shell
7235 like 3151 but u=656  $ S Bottom Corner Fuel Zone
7236 like 3152 but u=656  $ S Bottom Corner Pebble Shell
7237 like 3153 but u=656  $ Middle Bottom Fuel Zone
7238 like 3154 but u=656  $ Middle Bottom Pebble Shell
7239 like 3149 but u=657  $ NE Bottom Corner Fuel Zone
7240 like 3150 but u=657  $ NE Bottom Corner Pebble Shell
c
c --------- Regular Lattice with Polyethylene Rods ---------
8001 like 3131 but u=724  $ Middle Top Fuel Zone
8002 like 3132 but u=724  $ Middle Top Pebble Shell
8003 like 3133 but u=724  $ NW Top Corner Fuel Zone
8004 like 3134 but u=724  $ NW Top Corner Pebble Shell
8005 like 3135 but u=724  $ NE Top Corner Fuel Zone
8006 like 3136 but u=724  $ NE Top Corner Pebble Shell
8007 like 3137 but u=724  $ S Top Corner Fuel Zone
8008 like 3138 but u=724  $ S Top Corner Pebble Shell
8009 like 3139 but u=724  $ NW Middle Edge Fuel Zone
8010 like 3140 but u=724  $ NW Middle Edge Pebble Shell
8011 like 3141 but u=724  $ E Middle Edge Fuel Zone
8012 like 3142 but u=724  $ E Middle Edge Pebble Shell
8013 like 3143 but u=724  $ W Middle Edge Fuel Zone
8014 like 3144 but u=724  $ W Middle Edge Pebble Shell
8015 like 3145 but u=724  $ SE Middle Edge Fuel Zone
8016 like 3146 but u=724  $ SE Middle Edge Pebble Shell
8017 like 3147 but u=724  $ NW Bottom Corner Fuel Zone
8018 like 3148 but u=724  $ NW Bottom Corner Pebble Shell
8019 like 3149 but u=724  $ NE Bottom Corner Fuel Zone
8020 like 3150 but u=724  $ NE Bottom Corner Pebble Shell
8021 like 3151 but u=724  $ S Bottom Corner Fuel Zone
8022 like 3152 but u=724  $ S Bottom Corner Pebble Shell
8023 like 3153 but u=724  $ Middle Bottom Fuel Zone
8024 like 3154 but u=724  $ Middle Bottom Pebble Shell
8025 like 3135 but u=725  $ NE Top Corner Fuel Zone
8026 like 3136 but u=725  $ NE Top Corner Pebble Shell
8027 like 3149 but u=725  $ NE Bottom Corner Fuel Zone
8028 like 3150 but u=725  $ NE Bottom Corner Pebble Shell
8029 like 3131 but u=726  $ Middle Top Fuel Zone
8030 like 3132 but u=726  $ Middle Top Pebble Shell
8031 like 3133 but u=726  $ NW Top Corner Fuel Zone
8032 like 3134 but u=726  $ NW Top Corner Pebble Shell
8033 like 3135 but u=726  $ NE Top Corner Fuel Zone
8034 like 3136 but u=726  $ NE Top Corner Pebble Shell
8035 like 3137 but u=726  $ S Top Corner Fuel Zone
8036 like 3138 but u=726  $ S Top Corner Pebble Shell
8037 like 3139 but u=726  $ NW Middle Edge Fuel Zone
8038 like 3140 but u=726  $ NW Middle Edge Pebble Shell
8039 like 3141 but u=726  $ E Middle Edge Fuel Zone
8040 like 3142 but u=726  $ E Middle Edge Pebble Shell
8041 like 3145 but u=726  $ SE Middle Edge Fuel Zone
8042 like 3146 but u=726  $ SE Middle Edge Pebble Shell
8043 like 3147 but u=726  $ NW Bottom Corner Fuel Zone
8044 like 3148 but u=726  $ NW Bottom Corner Pebble Shell
8045 like 3149 but u=726  $ NE Bottom Corner Fuel Zone
8046 like 3150 but u=726  $ NE Bottom Corner Pebble Shell
8047 like 3151 but u=726  $ S Bottom Corner Fuel Zone
8048 like 3152 but u=726  $ S Bottom Corner Pebble Shell
8049 like 3153 but u=726  $ Middle Bottom Fuel Zone
8050 like 3154 but u=726  $ Middle Bottom Pebble Shell
8051 like 3131 but u=727  $ Middle Top Fuel Zone
8052 like 3132 but u=727  $ Middle Top Pebble Shell
8053 like 3135 but u=727  $ NE Top Corner Fuel Zone
8054 like 3136 but u=727  $ NE Top Corner Pebble Shell
8055 like 3137 but u=727  $ S Top Corner Fuel Zone
8056 like 3138 but u=727  $ S Top Corner Pebble Shell
8059 like 3141 but u=727  $ E Middle Edge Fuel Zone
8060 like 3142 but u=727  $ E Middle Edge Pebble Shell
8061 like 3143 but u=727  $ W Middle Edge Fuel Zone
8062 like 3144 but u=727  $ W Middle Edge Pebble Shell
8063 like 3145 but u=727  $ SE Middle Edge Fuel Zone
8064 like 3146 but u=727  $ SE Middle Edge Pebble Shell
8065 like 3149 but u=727  $ NE Bottom Corner Fuel Zone
8066 like 3150 but u=727  $ NE Bottom Corner Pebble Shell
8067 like 3151 but u=727  $ S Bottom Corner Fuel Zone
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8068 like 3152 but u=727  $ S Bottom Corner Pebble Shell
8069 like 3153 but u=727  $ Middle Bottom Fuel Zone
8070 like 3154 but u=727  $ Middle Bottom Pebble Shell
8071 like 3131 but u=729  $ Middle Top Fuel Zone
8072 like 3132 but u=729  $ Middle Top Pebble Shell
8073 like 3135 but u=729  $ NE Top Corner Fuel Zone
8074 like 3136 but u=729  $ NE Top Corner Pebble Shell
8075 like 3137 but u=729  $ S Top Corner Fuel Zone
8076 like 3138 but u=729  $ S Top Corner Pebble Shell
8077 like 3139 but u=729  $ NW Middle Edge Fuel Zone
8078 like 3140 but u=729  $ NW Middle Edge Pebble Shell
8079 like 3141 but u=729  $ E Middle Edge Fuel Zone
8080 like 3142 but u=729  $ E Middle Edge Pebble Shell
8081 like 3145 but u=729  $ SE Middle Edge Fuel Zone
8082 like 3146 but u=729  $ SE Middle Edge Pebble Shell
8083 like 3149 but u=729  $ NE Bottom Corner Fuel Zone
8084 like 3150 but u=729  $ NE Bottom Corner Pebble Shell
8085 like 3151 but u=729  $ S Bottom Corner Fuel Zone
8086 like 3152 but u=729  $ S Bottom Corner Pebble Shell
8087 like 3153 but u=729  $ Middle Bottom Fuel Zone
8088 like 3154 but u=729  $ Middle Bottom Pebble Shell
8089 like 3145 but u=730  $ SE Middle Edge Fuel Zone
8090 like 3146 but u=730  $ SE Middle Edge Pebble Shell
8091 like 3131 but u=731  $ Middle Top Fuel Zone
8092 like 3132 but u=731  $ Middle Top Pebble Shell
8093 like 3135 but u=731  $ NE Top Corner Fuel Zone
8094 like 3136 but u=731  $ NE Top Corner Pebble Shell
8095 like 3137 but u=731  $ S Top Corner Fuel Zone
8096 like 3138 but u=731  $ S Top Corner Pebble Shell
8097 like 3141 but u=731  $ E Middle Edge Fuel Zone
8098 like 3142 but u=731  $ E Middle Edge Pebble Shell
8099 like 3145 but u=731  $ SE Middle Edge Fuel Zone
8100 like 3146 but u=731  $ SE Middle Edge Pebble Shell
8101 like 3149 but u=731  $ NE Bottom Corner Fuel Zone
8102 like 3150 but u=731  $ NE Bottom Corner Pebble Shell
8103 like 3151 but u=731  $ S Bottom Corner Fuel Zone
8104 like 3152 but u=731  $ S Bottom Corner Pebble Shell
8105 like 3153 but u=731  $ Middle Bottom Fuel Zone
8106 like 3154 but u=731  $ Middle Bottom Pebble Shell
8107 like 3137 but u=732  $ S Top Corner Fuel Zone
8108 like 3138 but u=732  $ S Top Corner Pebble Shell
8109 like 3145 but u=732  $ SE Middle Edge Fuel Zone
8110 like 3146 but u=732  $ SE Middle Edge Pebble Shell
8111 like 3151 but u=732  $ S Bottom Corner Fuel Zone
8112 like 3152 but u=732  $ S Bottom Corner Pebble Shell
8113 like 3131 but u=733  $ Middle Top Fuel Zone
8114 like 3132 but u=733  $ Middle Top Pebble Shell
8115 like 3133 but u=733  $ NW Top Corner Fuel Zone
8116 like 3134 but u=733  $ NW Top Corner Pebble Shell
8117 like 3135 but u=733  $ NE Top Corner Fuel Zone
8118 like 3136 but u=733  $ NE Top Corner Pebble Shell
8119 like 3137 but u=733  $ S Top Corner Fuel Zone
8120 like 3138 but u=733  $ S Top Corner Pebble Shell
8121 like 3139 but u=733  $ NW Middle Edge Fuel Zone
8122 like 3140 but u=733  $ NW Middle Edge Pebble Shell
8123 like 3141 but u=733  $ E Middle Edge Fuel Zone
8124 like 3142 but u=733  $ E Middle Edge Pebble Shell
8125 like 3143 but u=733  $ W Middle Edge Fuel Zone
8126 like 3144 but u=733  $ W Middle Edge Pebble Shell
8127 like 3145 but u=733  $ SE Middle Edge Fuel Zone
8128 like 3146 but u=733  $ SE Middle Edge Pebble Shell
8129 like 3147 but u=733  $ NW Bottom Corner Fuel Zone
8130 like 3148 but u=733  $ NW Bottom Corner Pebble Shell
8131 like 3149 but u=733  $ NE Bottom Corner Fuel Zone
8132 like 3150 but u=733  $ NE Bottom Corner Pebble Shell
8133 like 3151 but u=733  $ S Bottom Corner Fuel Zone
8134 like 3152 but u=733  $ S Bottom Corner Pebble Shell
8135 like 3153 but u=733  $ Middle Bottom Fuel Zone
8136 like 3154 but u=733  $ Middle Bottom Pebble Shell
8138 like 3137 but u=734  $ S Top Corner Fuel Zone
8139 like 3138 but u=734  $ S Top Corner Pebble Shell
8140 like 3145 but u=734  $ SE Middle Edge Fuel Zone
8141 like 3146 but u=734  $ SE Middle Edge Pebble Shell
8142 like 3151 but u=734  $ S Bottom Corner Fuel Zone
8143 like 3152 but u=734  $ S Bottom Corner Pebble Shell
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8144 like 3137 but u=735  $ S Top Corner Fuel Zone
8145 like 3138 but u=735  $ S Top Corner Pebble Shell
8146 like 3151 but u=735  $ S Bottom Corner Fuel Zone
8147 like 3152 but u=735  $ S Bottom Corner Pebble Shell
8148 like 3131 but u=736  $ Middle Top Fuel Zone
8149 like 3132 but u=736  $ Middle Top Pebble Shell
8150 like 3133 but u=736  $ NW Top Corner Fuel Zone
8151 like 3134 but u=736  $ NW Top Corner Pebble Shell
8152 like 3137 but u=736  $ S Top Corner Fuel Zone
8153 like 3138 but u=736  $ S Top Corner Pebble Shell
8154 like 3143 but u=736  $ W Middle Edge Fuel Zone
8155 like 3144 but u=736  $ W Middle Edge Pebble Shell
8156 like 3145 but u=736  $ SE Middle Edge Fuel Zone
8157 like 3146 but u=736  $ SE Middle Edge Pebble Shell
8158 like 3147 but u=736  $ NW Bottom Corner Fuel Zone
8159 like 3148 but u=736  $ NW Bottom Corner Pebble Shell
8160 like 3151 but u=736  $ S Bottom Corner Fuel Zone
8161 like 3152 but u=736  $ S Bottom Corner Pebble Shell
8162 like 3153 but u=736  $ Middle Bottom Fuel Zone
8163 like 3154 but u=736  $ Middle Bottom Pebble Shell
8164 like 3137 but u=737  $ S Top Corner Fuel Zone
8165 like 3138 but u=737  $ S Top Corner Pebble Shell
8166 like 3151 but u=737  $ S Bottom Corner Fuel Zone
8167 like 3152 but u=737  $ S Bottom Corner Pebble Shell
8168 like 3131 but u=738  $ Middle Top Fuel Zone
8169 like 3132 but u=738  $ Middle Top Pebble Shell
8170 like 3133 but u=738  $ NW Top Corner Fuel Zone
8171 like 3134 but u=738  $ NW Top Corner Pebble Shell
8172 like 3135 but u=738  $ NE Top Corner Fuel Zone
8173 like 3136 but u=738  $ NE Top Corner Pebble Shell
8174 like 3137 but u=738  $ S Top Corner Fuel Zone
8175 like 3138 but u=738  $ S Top Corner Pebble Shell
8176 like 3139 but u=738  $ NW Middle Edge Fuel Zone
8177 like 3140 but u=738  $ NW Middle Edge Pebble Shell
8178 like 3141 but u=738  $ E Middle Edge Fuel Zone
8179 like 3142 but u=738  $ E Middle Edge Pebble Shell
8180 like 3143 but u=738  $ W Middle Edge Fuel Zone
8181 like 3144 but u=738  $ W Middle Edge Pebble Shell
8182 like 3145 but u=738  $ SE Middle Edge Fuel Zone
8183 like 3146 but u=738  $ SE Middle Edge Pebble Shell
8184 like 3147 but u=738  $ NW Bottom Corner Fuel Zone
8185 like 3148 but u=738  $ NW Bottom Corner Pebble Shell
8186 like 3149 but u=738  $ NE Bottom Corner Fuel Zone
8187 like 3150 but u=738  $ NE Bottom Corner Pebble Shell
8188 like 3151 but u=738  $ S Bottom Corner Fuel Zone
8189 like 3152 but u=738  $ S Bottom Corner Pebble Shell
8190 like 3153 but u=738  $ Middle Bottom Fuel Zone
8191 like 3154 but u=738  $ Middle Bottom Pebble Shell
8192 like 3131 but u=740  $ Middle Top Fuel Zone
8193 like 3132 but u=740  $ Middle Top Pebble Shell
8194 like 3133 but u=740  $ NW Top Corner Fuel Zone
8195 like 3134 but u=740  $ NW Top Corner Pebble Shell
8196 like 3137 but u=740  $ S Top Corner Fuel Zone
8197 like 3138 but u=740  $ S Top Corner Pebble Shell
8198 like 3139 but u=740  $ NW Middle Edge Fuel Zone
8199 like 3140 but u=740  $ NW Middle Edge Pebble Shell
8200 like 3141 but u=740  $ E Middle Edge Fuel Zone
8201 like 3142 but u=740  $ E Middle Edge Pebble Shell
8202 like 3143 but u=740  $ W Middle Edge Fuel Zone
8203 like 3144 but u=740  $ W Middle Edge Pebble Shell
8204 like 3145 but u=740  $ SE Middle Edge Fuel Zone
8205 like 3146 but u=740  $ SE Middle Edge Pebble Shell
8206 like 3147 but u=740  $ NW Bottom Corner Fuel Zone
8207 like 3148 but u=740  $ NW Bottom Corner Pebble Shell
8208 like 3151 but u=740  $ S Bottom Corner Fuel Zone
8209 like 3152 but u=740  $ S Bottom Corner Pebble Shell
8210 like 3153 but u=740  $ Middle Bottom Fuel Zone
8211 like 3154 but u=740  $ Middle Bottom Pebble Shell
8212 like 3143 but u=741  $ W Middle Edge Fuel Zone
8213 like 3144 but u=741  $ W Middle Edge Pebble Shell
8214 like 3131 but u=742  $ Middle Top Fuel Zone
8215 like 3132 but u=742  $ Middle Top Pebble Shell
8216 like 3133 but u=742  $ NW Top Corner Fuel Zone
8217 like 3134 but u=742  $ NW Top Corner Pebble Shell
8218 like 3137 but u=742  $ S Top Corner Fuel Zone
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8219 like 3138 but u=742  $ S Top Corner Pebble Shell
8220 like 3139 but u=742  $ NW Middle Edge Fuel Zone
8221 like 3140 but u=742  $ NW Middle Edge Pebble Shell
8222 like 3143 but u=742  $ W Middle Edge Fuel Zone
8223 like 3144 but u=742  $ W Middle Edge Pebble Shell
8224 like 3147 but u=742  $ NW Bottom Corner Fuel Zone
8225 like 3148 but u=742  $ NW Bottom Corner Pebble Shell
8226 like 3151 but u=742  $ S Bottom Corner Fuel Zone
8227 like 3152 but u=742  $ S Bottom Corner Pebble Shell
8228 like 3153 but u=742  $ Middle Bottom Fuel Zone
8229 like 3154 but u=742  $ Middle Bottom Pebble Shell
8230 like 3133 but u=743  $ NW Top Corner Fuel Zone
8231 like 3134 but u=743  $ NW Top Corner Pebble Shell
8232 like 3143 but u=743  $ W Middle Edge Fuel Zone
8233 like 3144 but u=743  $ W Middle Edge Pebble Shell
8234 like 3147 but u=743  $ NW Bottom Corner Fuel Zone
8235 like 3148 but u=743  $ NW Bottom Corner Pebble Shell
8236 like 3133 but u=744  $ NW Top Corner Fuel Zone
8237 like 3134 but u=744  $ NW Top Corner Pebble Shell
8238 like 3143 but u=744  $ W Middle Edge Fuel Zone
8239 like 3144 but u=744  $ W Middle Edge Pebble Shell
8240 like 3147 but u=744  $ NW Bottom Corner Fuel Zone
8241 like 3148 but u=744  $ NW Bottom Corner Pebble Shell
8242 like 3131 but u=745  $ Middle Top Fuel Zone
8243 like 3132 but u=745  $ Middle Top Pebble Shell
8244 like 3133 but u=745  $ NW Top Corner Fuel Zone
8245 like 3134 but u=745  $ NW Top Corner Pebble Shell
8246 like 3135 but u=745  $ NE Top Corner Fuel Zone
8247 like 3136 but u=745  $ NE Top Corner Pebble Shell
8248 like 3137 but u=745  $ S Top Corner Fuel Zone
8249 like 3138 but u=745  $ S Top Corner Pebble Shell
8250 like 3139 but u=745  $ NW Middle Edge Fuel Zone
8251 like 3140 but u=745  $ NW Middle Edge Pebble Shell
8252 like 3141 but u=745  $ E Middle Edge Fuel Zone
8253 like 3142 but u=745  $ E Middle Edge Pebble Shell
8254 like 3143 but u=745  $ W Middle Edge Fuel Zone
8255 like 3144 but u=745  $ W Middle Edge Pebble Shell
8256 like 3147 but u=745  $ NW Bottom Corner Fuel Zone
8257 like 3148 but u=745  $ NW Bottom Corner Pebble Shell
8258 like 3149 but u=745  $ NE Bottom Corner Fuel Zone
8259 like 3150 but u=745  $ NE Bottom Corner Pebble Shell
8260 like 3151 but u=745  $ S Bottom Corner Fuel Zone
8261 like 3152 but u=745  $ S Bottom Corner Pebble Shell
8262 like 3153 but u=745  $ Middle Bottom Fuel Zone
8263 like 3154 but u=745  $ Middle Bottom Pebble Shell
8264 like 3133 but u=746  $ NW Top Corner Fuel Zone
8265 like 3134 but u=746  $ NW Top Corner Pebble Shell
8266 like 3147 but u=746  $ NW Bottom Corner Fuel Zone
8267 like 3148 but u=746  $ NW Bottom Corner Pebble Shell
8268 like 3131 but u=747  $ Middle Top Fuel Zone
8269 like 3132 but u=747  $ Middle Top Pebble Shell
8270 like 3133 but u=747  $ NW Top Corner Fuel Zone
8271 like 3134 but u=747  $ NW Top Corner Pebble Shell
8272 like 3135 but u=747  $ NE Top Corner Fuel Zone
8273 like 3136 but u=747  $ NE Top Corner Pebble Shell
8274 like 3139 but u=747  $ NW Middle Edge Fuel Zone
8275 like 3140 but u=747  $ NW Middle Edge Pebble Shell
8276 like 3143 but u=747  $ W Middle Edge Fuel Zone
8277 like 3144 but u=747  $ W Middle Edge Pebble Shell
8278 like 3147 but u=747  $ NW Bottom Corner Fuel Zone
8279 like 3148 but u=747  $ NW Bottom Corner Pebble Shell
8280 like 3149 but u=747  $ NE Bottom Corner Fuel Zone
8281 like 3150 but u=747  $ NE Bottom Corner Pebble Shell
8282 like 3153 but u=747  $ Middle Bottom Fuel Zone
8283 like 3154 but u=747  $ Middle Bottom Pebble Shell
8284 like 3131 but u=748  $ Middle Top Fuel Zone
8285 like 3132 but u=748  $ Middle Top Pebble Shell
8286 like 3133 but u=748  $ NW Top Corner Fuel Zone
8287 like 3134 but u=748  $ NW Top Corner Pebble Shell
8288 like 3135 but u=748  $ NE Top Corner Fuel Zone
8289 like 3136 but u=748  $ NE Top Corner Pebble Shell
8290 like 3137 but u=748  $ S Top Corner Fuel Zone
8291 like 3138 but u=748  $ S Top Corner Pebble Shell
8292 like 3139 but u=748  $ NW Middle Edge Fuel Zone
8293 like 3140 but u=748  $ NW Middle Edge Pebble Shell
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8294 like 3141 but u=748  $ E Middle Edge Fuel Zone
8295 like 3142 but u=748  $ E Middle Edge Pebble Shell
8296 like 3143 but u=748  $ W Middle Edge Fuel Zone
8297 like 3144 but u=748  $ W Middle Edge Pebble Shell
8298 like 3147 but u=748  $ NW Bottom Corner Fuel Zone
8299 like 3148 but u=748  $ NW Bottom Corner Pebble Shell
8300 like 3149 but u=748  $ NE Bottom Corner Fuel Zone
8301 like 3150 but u=748  $ NE Bottom Corner Pebble Shell
8302 like 3151 but u=748  $ S Bottom Corner Fuel Zone
8303 like 3152 but u=748  $ S Bottom Corner Pebble Shell
8304 like 3153 but u=748  $ Middle Bottom Fuel Zone
8305 like 3154 but u=748  $ Middle Bottom Pebble Shell
8306 like 3133 but u=749  $ NW Top Corner Fuel Zone
8307 like 3134 but u=749  $ NW Top Corner Pebble Shell
8308 like 3147 but u=749  $ NW Bottom Corner Fuel Zone
8309 like 3148 but u=749  $ NW Bottom Corner Pebble Shell
8310 like 3131 but u=752  $ Middle Top Fuel Zone
8311 like 3132 but u=752  $ Middle Top Pebble Shell
8312 like 3133 but u=752  $ NW Top Corner Fuel Zone
8313 like 3134 but u=752  $ NW Top Corner Pebble Shell
8314 like 3135 but u=752  $ NE Top Corner Fuel Zone
8315 like 3136 but u=752  $ NE Top Corner Pebble Shell
8316 like 3139 but u=752  $ NW Middle Edge Fuel Zone
8317 like 3140 but u=752  $ NW Middle Edge Pebble Shell
8318 like 3141 but u=752  $ E Middle Edge Fuel Zone
8319 like 3142 but u=752  $ E Middle Edge Pebble Shell
8320 like 3143 but u=752  $ W Middle Edge Fuel Zone
8321 like 3144 but u=752  $ W Middle Edge Pebble Shell
8322 like 3147 but u=752  $ NW Bottom Corner Fuel Zone
8323 like 3148 but u=752  $ NW Bottom Corner Pebble Shell
8324 like 3149 but u=752  $ NE Bottom Corner Fuel Zone
8325 like 3150 but u=752  $ NE Bottom Corner Pebble Shell
8326 like 3153 but u=752  $ Middle Bottom Fuel Zone
8327 like 3154 but u=752  $ Middle Bottom Pebble Shell
8328 like 3131 but u=753  $ Middle Top Fuel Zone
8329 like 3132 but u=753  $ Middle Top Pebble Shell
8330 like 3133 but u=753  $ NW Top Corner Fuel Zone
8331 like 3134 but u=753  $ NW Top Corner Pebble Shell
8332 like 3135 but u=753  $ NE Top Corner Fuel Zone
8333 like 3136 but u=753  $ NE Top Corner Pebble Shell
8334 like 3139 but u=753  $ NW Middle Edge Fuel Zone
8335 like 3140 but u=753  $ NW Middle Edge Pebble Shell
8336 like 3141 but u=753  $ E Middle Edge Fuel Zone
8337 like 3142 but u=753  $ E Middle Edge Pebble Shell
8338 like 3147 but u=753  $ NW Bottom Corner Fuel Zone
8339 like 3148 but u=753  $ NW Bottom Corner Pebble Shell
8340 like 3149 but u=753  $ NE Bottom Corner Fuel Zone
8341 like 3150 but u=753  $ NE Bottom Corner Pebble Shell
8342 like 3153 but u=753  $ Middle Bottom Fuel Zone
8343 like 3154 but u=753  $ Middle Bottom Pebble Shell
8344 like 3135 but u=754  $ NE Top Corner Fuel Zone
8345 like 3136 but u=754  $ NE Top Corner Pebble Shell
8346 like 3149 but u=754  $ NE Bottom Corner Fuel Zone
8347 like 3150 but u=754  $ NE Bottom Corner Pebble Shell
8348 like 3135 but u=755  $ NE Top Corner Fuel Zone
8349 like 3136 but u=755  $ NE Top Corner Pebble Shell
8350 like 3149 but u=755  $ NE Bottom Corner Fuel Zone
8351 like 3150 but u=755  $ NE Bottom Corner Pebble Shell
8352 like 3131 but u=756  $ Middle Top Fuel Zone
8353 like 3132 but u=756  $ Middle Top Pebble Shell
8354 like 3133 but u=756  $ NW Top Corner Fuel Zone
8355 like 3134 but u=756  $ NW Top Corner Pebble Shell
8356 like 3135 but u=756  $ NE Top Corner Fuel Zone
8357 like 3136 but u=756  $ NE Top Corner Pebble Shell
8358 like 3137 but u=756  $ S Top Corner Fuel Zone
8359 like 3138 but u=756  $ S Top Corner Pebble Shell
8360 like 3139 but u=756  $ NW Middle Edge Fuel Zone
8361 like 3140 but u=756  $ NW Middle Edge Pebble Shell
8362 like 3141 but u=756  $ E Middle Edge Fuel Zone
8363 like 3142 but u=756  $ E Middle Edge Pebble Shell
8364 like 3145 but u=756  $ SE Middle Edge Fuel Zone
8365 like 3146 but u=756  $ SE Middle Edge Pebble Shell
8366 like 3147 but u=756  $ NW Bottom Corner Fuel Zone
8367 like 3148 but u=756  $ NW Bottom Corner Pebble Shell
8368 like 3149 but u=756  $ NE Bottom Corner Fuel Zone
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8369 like 3150 but u=756  $ NE Bottom Corner Pebble Shell
8370 like 3151 but u=756  $ S Bottom Corner Fuel Zone
8371 like 3152 but u=756  $ S Bottom Corner Pebble Shell
8372 like 3153 but u=756  $ Middle Bottom Fuel Zone
8373 like 3154 but u=756  $ Middle Bottom Pebble Shell
8374 like 3135 but u=757  $ NE Top Corner Fuel Zone
8375 like 3136 but u=757  $ NE Top Corner Pebble Shell
8376 like 3149 but u=757  $ NE Bottom Corner Fuel Zone
8377 like 3150 but u=757  $ NE Bottom Corner Pebble Shell
c
c --------- Bottom Layer Only Lattices with Polyethylene Rods ---------
8507 like 3147 but u=824  $ NW Bottom Corner Fuel Zone
8508 like 3148 but u=824  $ NW Bottom Corner Pebble Shell
8509 like 3149 but u=824  $ NE Bottom Corner Fuel Zone
8510 like 3150 but u=824  $ NE Bottom Corner Pebble Shell
8511 like 3151 but u=824  $ S Bottom Corner Fuel Zone
8512 like 3152 but u=824  $ S Bottom Corner Pebble Shell
8513 like 3153 but u=824  $ Middle Bottom Fuel Zone
8514 like 3154 but u=824  $ Middle Bottom Pebble Shell
8515 like 3149 but u=825  $ NE Bottom Corner Fuel Zone
8516 like 3150 but u=825  $ NE Bottom Corner Pebble Shell
8517 like 3147 but u=826  $ NW Bottom Corner Fuel Zone
8518 like 3148 but u=826  $ NW Bottom Corner Pebble Shell
8519 like 3149 but u=826  $ NE Bottom Corner Fuel Zone
8520 like 3150 but u=826  $ NE Bottom Corner Pebble Shell
8521 like 3151 but u=826  $ S Bottom Corner Fuel Zone
8522 like 3152 but u=826  $ S Bottom Corner Pebble Shell
8523 like 3153 but u=826  $ Middle Bottom Fuel Zone
8524 like 3154 but u=826  $ Middle Bottom Pebble Shell
8525 like 3149 but u=827  $ NE Bottom Corner Fuel Zone
8526 like 3150 but u=827  $ NE Bottom Corner Pebble Shell
8527 like 3151 but u=827  $ S Bottom Corner Fuel Zone
8528 like 3152 but u=827  $ S Bottom Corner Pebble Shell
8529 like 3153 but u=827  $ Middle Bottom Fuel Zone
8530 like 3154 but u=827  $ Middle Bottom Pebble Shell
8531 like 3149 but u=829  $ NE Bottom Corner Fuel Zone
8532 like 3150 but u=829  $ NE Bottom Corner Pebble Shell
8533 like 3151 but u=829  $ S Bottom Corner Fuel Zone
8534 like 3152 but u=829  $ S Bottom Corner Pebble Shell
8535 like 3153 but u=829  $ Middle Bottom Fuel Zone
8536 like 3154 but u=829  $ Middle Bottom Pebble Shell
8537 like 3149 but u=831  $ NE Bottom Corner Fuel Zone
8538 like 3150 but u=831  $ NE Bottom Corner Pebble Shell
8539 like 3151 but u=831  $ S Bottom Corner Fuel Zone
8540 like 3152 but u=831  $ S Bottom Corner Pebble Shell
8541 like 3153 but u=831  $ Middle Bottom Fuel Zone
8542 like 3154 but u=831  $ Middle Bottom Pebble Shell
8543 like 3151 but u=832  $ S Bottom Corner Fuel Zone
8544 like 3152 but u=832  $ S Bottom Corner Pebble Shell
8545 like 3147 but u=833  $ NW Bottom Corner Fuel Zone
8546 like 3148 but u=833  $ NW Bottom Corner Pebble Shell
8547 like 3149 but u=833  $ NE Bottom Corner Fuel Zone
8548 like 3150 but u=833  $ NE Bottom Corner Pebble Shell
8549 like 3151 but u=833  $ S Bottom Corner Fuel Zone
8550 like 3152 but u=833  $ S Bottom Corner Pebble Shell
8551 like 3153 but u=833  $ Middle Bottom Fuel Zone
8552 like 3154 but u=833  $ Middle Bottom Pebble Shell
8553 like 3151 but u=834  $ S Bottom Corner Fuel Zone
8554 like 3152 but u=834  $ S Bottom Corner Pebble Shell
8555 like 3151 but u=835  $ S Bottom Corner Fuel Zone
8556 like 3152 but u=835  $ S Bottom Corner Pebble Shell
8557 like 3147 but u=836  $ NW Bottom Corner Fuel Zone
8558 like 3148 but u=836  $ NW Bottom Corner Pebble Shell
8559 like 3151 but u=836  $ S Bottom Corner Fuel Zone
8560 like 3152 but u=836  $ S Bottom Corner Pebble Shell
8561 like 3153 but u=836  $ Middle Bottom Fuel Zone
8562 like 3154 but u=836  $ Middle Bottom Pebble Shell
8563 like 3151 but u=837  $ S Bottom Corner Fuel Zone
8564 like 3152 but u=837  $ S Bottom Corner Pebble Shell
8565 like 3147 but u=838  $ NW Bottom Corner Fuel Zone
8566 like 3148 but u=838  $ NW Bottom Corner Pebble Shell
8567 like 3149 but u=838  $ NE Bottom Corner Fuel Zone
8568 like 3150 but u=838  $ NE Bottom Corner Pebble Shell
8569 like 3151 but u=838  $ S Bottom Corner Fuel Zone
8570 like 3152 but u=838  $ S Bottom Corner Pebble Shell
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8571 like 3153 but u=838  $ Middle Bottom Fuel Zone
8572 like 3154 but u=838  $ Middle Bottom Pebble Shell
8573 like 3147 but u=840  $ NW Bottom Corner Fuel Zone
8574 like 3148 but u=840  $ NW Bottom Corner Pebble Shell
8575 like 3151 but u=840  $ S Bottom Corner Fuel Zone
8576 like 3152 but u=840  $ S Bottom Corner Pebble Shell
8577 like 3153 but u=840  $ Middle Bottom Fuel Zone
8578 like 3154 but u=840  $ Middle Bottom Pebble Shell
8579 like 3147 but u=842  $ NW Bottom Corner Fuel Zone
8580 like 3148 but u=842  $ NW Bottom Corner Pebble Shell
8581 like 3151 but u=842  $ S Bottom Corner Fuel Zone
8582 like 3152 but u=842  $ S Bottom Corner Pebble Shell
8583 like 3153 but u=842  $ Middle Bottom Fuel Zone
8584 like 3154 but u=842  $ Middle Bottom Pebble Shell
8585 like 3147 but u=843  $ NW Bottom Corner Fuel Zone
8586 like 3148 but u=843  $ NW Bottom Corner Pebble Shell
8587 like 3147 but u=844  $ NW Bottom Corner Fuel Zone
8588 like 3148 but u=844  $ NW Bottom Corner Pebble Shell
8589 like 3147 but u=845  $ NW Bottom Corner Fuel Zone
8590 like 3148 but u=845  $ NW Bottom Corner Pebble Shell
8591 like 3149 but u=845  $ NE Bottom Corner Fuel Zone
8592 like 3150 but u=845  $ NE Bottom Corner Pebble Shell
8593 like 3151 but u=845  $ S Bottom Corner Fuel Zone
8594 like 3152 but u=845  $ S Bottom Corner Pebble Shell
8595 like 3153 but u=845  $ Middle Bottom Fuel Zone
8596 like 3154 but u=845  $ Middle Bottom Pebble Shell
8597 like 3147 but u=846  $ NW Bottom Corner Fuel Zone
8598 like 3148 but u=846  $ NW Bottom Corner Pebble Shell
8599 like 3147 but u=847  $ NW Bottom Corner Fuel Zone
8600 like 3148 but u=847  $ NW Bottom Corner Pebble Shell
8601 like 3149 but u=847  $ NE Bottom Corner Fuel Zone
8602 like 3150 but u=847  $ NE Bottom Corner Pebble Shell
8603 like 3153 but u=847  $ Middle Bottom Fuel Zone
8604 like 3154 but u=847  $ Middle Bottom Pebble Shell
8605 like 3147 but u=848  $ NW Bottom Corner Fuel Zone
8606 like 3148 but u=848  $ NW Bottom Corner Pebble Shell
8607 like 3149 but u=848  $ NE Bottom Corner Fuel Zone
8608 like 3150 but u=848  $ NE Bottom Corner Pebble Shell
8609 like 3151 but u=848  $ S Bottom Corner Fuel Zone
8610 like 3152 but u=848  $ S Bottom Corner Pebble Shell
8611 like 3153 but u=848  $ Middle Bottom Fuel Zone
8612 like 3154 but u=848  $ Middle Bottom Pebble Shell
8613 like 3147 but u=849  $ NW Bottom Corner Fuel Zone
8614 like 3148 but u=849  $ NW Bottom Corner Pebble Shell
8615 like 3147 but u=852  $ NW Bottom Corner Fuel Zone
8616 like 3148 but u=852  $ NW Bottom Corner Pebble Shell
8617 like 3149 but u=852  $ NE Bottom Corner Fuel Zone
8618 like 3150 but u=852  $ NE Bottom Corner Pebble Shell
8619 like 3153 but u=852  $ Middle Bottom Fuel Zone
8620 like 3154 but u=852  $ Middle Bottom Pebble Shell
8621 like 3147 but u=853  $ NW Bottom Corner Fuel Zone
8622 like 3148 but u=853  $ NW Bottom Corner Pebble Shell
8623 like 3149 but u=853  $ NE Bottom Corner Fuel Zone
8624 like 3150 but u=853  $ NE Bottom Corner Pebble Shell
8625 like 3153 but u=853  $ Middle Bottom Fuel Zone
8626 like 3154 but u=853  $ Middle Bottom Pebble Shell
8627 like 3149 but u=854  $ NE Bottom Corner Fuel Zone
8628 like 3150 but u=854  $ NE Bottom Corner Pebble Shell
8629 like 3149 but u=855  $ NE Bottom Corner Fuel Zone
8630 like 3150 but u=855  $ NE Bottom Corner Pebble Shell
8631 like 3147 but u=856  $ NW Bottom Corner Fuel Zone
8632 like 3148 but u=856  $ NW Bottom Corner Pebble Shell
8633 like 3149 but u=856  $ NE Bottom Corner Fuel Zone
8634 like 3150 but u=856  $ NE Bottom Corner Pebble Shell
8635 like 3151 but u=856  $ S Bottom Corner Fuel Zone
8636 like 3152 but u=856  $ S Bottom Corner Pebble Shell
8637 like 3153 but u=856  $ Middle Bottom Fuel Zone
8638 like 3154 but u=856  $ Middle Bottom Pebble Shell
8639 like 3149 but u=857  $ NE Bottom Corner Fuel Zone
8640 like 3150 but u=857  $ NE Bottom Corner Pebble Shell
c
c --------- Top Layer Only Lattices with Polyethylene Rods ---------
8692 like 3131 but u=924  $ Middle Top Fuel Zone
8693 like 3132 but u=924  $ Middle Top Pebble Shell
8694 like 3133 but u=924  $ NW Top Corner Fuel Zone
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8695 like 3134 but u=924  $ NW Top Corner Pebble Shell
8696 like 3135 but u=924  $ NE Top Corner Fuel Zone
8697 like 3136 but u=924  $ NE Top Corner Pebble Shell
8698 like 3137 but u=924  $ S Top Corner Fuel Zone
8699 like 3138 but u=924  $ S Top Corner Pebble Shell
8700 like 3135 but u=925  $ NE Top Corner Fuel Zone
8701 like 3136 but u=925  $ NE Top Corner Pebble Shell
8702 like 3131 but u=926  $ Middle Top Fuel Zone
8703 like 3132 but u=926  $ Middle Top Pebble Shell
8704 like 3133 but u=926  $ NW Top Corner Fuel Zone
8705 like 3134 but u=926  $ NW Top Corner Pebble Shell
8706 like 3135 but u=926  $ NE Top Corner Fuel Zone
8707 like 3136 but u=926  $ NE Top Corner Pebble Shell
8708 like 3137 but u=926  $ S Top Corner Fuel Zone
8709 like 3138 but u=926  $ S Top Corner Pebble Shell
8710 like 3131 but u=927  $ Middle Top Fuel Zone
8711 like 3132 but u=927  $ Middle Top Pebble Shell
8712 like 3135 but u=927  $ NE Top Corner Fuel Zone
8713 like 3136 but u=927  $ NE Top Corner Pebble Shell
8714 like 3137 but u=927  $ S Top Corner Fuel Zone
8715 like 3138 but u=927  $ S Top Corner Pebble Shell
8716 like 3131 but u=929  $ Middle Top Fuel Zone
8717 like 3132 but u=929  $ Middle Top Pebble Shell
8718 like 3135 but u=929  $ NE Top Corner Fuel Zone
8719 like 3136 but u=929  $ NE Top Corner Pebble Shell
8720 like 3137 but u=929  $ S Top Corner Fuel Zone
8721 like 3138 but u=929  $ S Top Corner Pebble Shell
8722 like 3131 but u=931  $ Middle Top Fuel Zone
8723 like 3132 but u=931  $ Middle Top Pebble Shell
8724 like 3135 but u=931  $ NE Top Corner Fuel Zone
8725 like 3136 but u=931  $ NE Top Corner Pebble Shell
8726 like 3137 but u=931  $ S Top Corner Fuel Zone
8727 like 3138 but u=931  $ S Top Corner Pebble Shell
8728 like 3137 but u=932  $ S Top Corner Fuel Zone
8729 like 3138 but u=932  $ S Top Corner Pebble Shell
8730 like 3131 but u=933  $ Middle Top Fuel Zone
8731 like 3132 but u=933  $ Middle Top Pebble Shell
8732 like 3133 but u=933  $ NW Top Corner Fuel Zone
8733 like 3134 but u=933  $ NW Top Corner Pebble Shell
8734 like 3135 but u=933  $ NE Top Corner Fuel Zone
8735 like 3136 but u=933  $ NE Top Corner Pebble Shell
8736 like 3137 but u=933  $ S Top Corner Fuel Zone
8737 like 3138 but u=933  $ S Top Corner Pebble Shell
8738 like 3137 but u=934  $ S Top Corner Fuel Zone
8739 like 3138 but u=934  $ S Top Corner Pebble Shell
8740 like 3137 but u=935  $ S Top Corner Fuel Zone
8741 like 3138 but u=935  $ S Top Corner Pebble Shell
8742 like 3131 but u=936  $ Middle Top Fuel Zone
8743 like 3132 but u=936  $ Middle Top Pebble Shell
8744 like 3133 but u=936  $ NW Top Corner Fuel Zone
8745 like 3134 but u=936  $ NW Top Corner Pebble Shell
8746 like 3137 but u=936  $ S Top Corner Fuel Zone
8747 like 3138 but u=936  $ S Top Corner Pebble Shell
8748 like 3137 but u=937  $ S Top Corner Fuel Zone
8749 like 3138 but u=937  $ S Top Corner Pebble Shell
8750 like 3131 but u=938  $ Middle Top Fuel Zone
8751 like 3132 but u=938  $ Middle Top Pebble Shell
8752 like 3133 but u=938  $ NW Top Corner Fuel Zone
8753 like 3134 but u=938  $ NW Top Corner Pebble Shell
8754 like 3135 but u=938  $ NE Top Corner Fuel Zone
8755 like 3136 but u=938  $ NE Top Corner Pebble Shell
8756 like 3137 but u=938  $ S Top Corner Fuel Zone
8757 like 3138 but u=938  $ S Top Corner Pebble Shell
8758 like 3131 but u=940  $ Middle Top Fuel Zone
8759 like 3132 but u=940  $ Middle Top Pebble Shell
8760 like 3133 but u=940  $ NW Top Corner Fuel Zone
8761 like 3134 but u=940  $ NW Top Corner Pebble Shell
8762 like 3137 but u=940  $ S Top Corner Fuel Zone
8763 like 3138 but u=940  $ S Top Corner Pebble Shell
8764 like 3131 but u=942  $ Middle Top Fuel Zone
8765 like 3132 but u=942  $ Middle Top Pebble Shell
8766 like 3133 but u=942  $ NW Top Corner Fuel Zone
8767 like 3134 but u=942  $ NW Top Corner Pebble Shell
8768 like 3137 but u=942  $ S Top Corner Fuel Zone
8769 like 3138 but u=942  $ S Top Corner Pebble Shell
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8770 like 3133 but u=943  $ NW Top Corner Fuel Zone
8771 like 3134 but u=943  $ NW Top Corner Pebble Shell
8772 like 3133 but u=944  $ NW Top Corner Fuel Zone
8773 like 3134 but u=944  $ NW Top Corner Pebble Shell
8774 like 3131 but u=945  $ Middle Top Fuel Zone
8775 like 3132 but u=945  $ Middle Top Pebble Shell
8776 like 3133 but u=945  $ NW Top Corner Fuel Zone
8777 like 3134 but u=945  $ NW Top Corner Pebble Shell
8778 like 3135 but u=945  $ NE Top Corner Fuel Zone
8779 like 3136 but u=945  $ NE Top Corner Pebble Shell
8780 like 3137 but u=945  $ S Top Corner Fuel Zone
8781 like 3138 but u=945  $ S Top Corner Pebble Shell
8782 like 3133 but u=946  $ NW Top Corner Fuel Zone
8783 like 3134 but u=946  $ NW Top Corner Pebble Shell
8784 like 3131 but u=947  $ Middle Top Fuel Zone
8785 like 3132 but u=947  $ Middle Top Pebble Shell
8786 like 3133 but u=947  $ NW Top Corner Fuel Zone
8787 like 3134 but u=947  $ NW Top Corner Pebble Shell
8788 like 3135 but u=947  $ NE Top Corner Fuel Zone
8789 like 3136 but u=947  $ NE Top Corner Pebble Shell
8790 like 3131 but u=948  $ Middle Top Fuel Zone
8791 like 3132 but u=948  $ Middle Top Pebble Shell
8792 like 3133 but u=948  $ NW Top Corner Fuel Zone
8793 like 3134 but u=948  $ NW Top Corner Pebble Shell
8794 like 3135 but u=948  $ NE Top Corner Fuel Zone
8795 like 3136 but u=948  $ NE Top Corner Pebble Shell
8796 like 3137 but u=948  $ S Top Corner Fuel Zone
8797 like 3138 but u=948  $ S Top Corner Pebble Shell
8798 like 3133 but u=949  $ NW Top Corner Fuel Zone
8799 like 3134 but u=949  $ NW Top Corner Pebble Shell
8800 like 3131 but u=952  $ Middle Top Fuel Zone
8801 like 3132 but u=952  $ Middle Top Pebble Shell
8802 like 3133 but u=952  $ NW Top Corner Fuel Zone
8803 like 3134 but u=952  $ NW Top Corner Pebble Shell
8804 like 3135 but u=952  $ NE Top Corner Fuel Zone
8805 like 3136 but u=952  $ NE Top Corner Pebble Shell
8806 like 3131 but u=953  $ Middle Top Fuel Zone
8807 like 3132 but u=953  $ Middle Top Pebble Shell
8808 like 3133 but u=953  $ NW Top Corner Fuel Zone
8809 like 3134 but u=953  $ NW Top Corner Pebble Shell
8810 like 3135 but u=953  $ NE Top Corner Fuel Zone
8811 like 3136 but u=953  $ NE Top Corner Pebble Shell
8812 like 3135 but u=954  $ NE Top Corner Fuel Zone
8813 like 3136 but u=954  $ NE Top Corner Pebble Shell
8814 like 3135 but u=955  $ NE Top Corner Fuel Zone
8815 like 3136 but u=955  $ NE Top Corner Pebble Shell
8816 like 3131 but u=956  $ Middle Top Fuel Zone
8817 like 3132 but u=956  $ Middle Top Pebble Shell
8818 like 3133 but u=956  $ NW Top Corner Fuel Zone
8819 like 3134 but u=956  $ NW Top Corner Pebble Shell
8820 like 3135 but u=956  $ NE Top Corner Fuel Zone
8821 like 3136 but u=956  $ NE Top Corner Pebble Shell
8822 like 3137 but u=956  $ S Top Corner Fuel Zone
8823 like 3138 but u=956  $ S Top Corner Pebble Shell
8824 like 3135 but u=957  $ NE Top Corner Fuel Zone
8825 like 3136 but u=957  $ NE Top Corner Pebble Shell
c
c ------ Moderator Pebbles ------
c --------- Regular (Full) Lattice ---------
4131 26 8.4461E-02  -4131 imp:n=1 u=24  $ N Top Corner Pebble
4132 26 8.4461E-02  -4132 imp:n=1 u=24  $ SE Top Corner Pebble
4133 26 8.4461E-02  -4133 imp:n=1 u=24  $ SW Top Corner Pebble
4134 26 8.4461E-02  -4134 imp:n=1 u=24  $ NE Middle Edge Pebble
4135 26 8.4461E-02  -4135 imp:n=1 u=24  $ SW Middle Edge Pebble
4136 26 8.4461E-02  -4136 imp:n=1 u=24  $ N Bottom Corner Pebble
4137 26 8.4461E-02  -4137 imp:n=1 u=24  $ SE Bottom Corner Pebble
4138 26 8.4461E-02  -4138 imp:n=1 u=24  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 1 ---------
4139 like 4132 but u=25  $ SE Top Corner Pebble
4140 like 4137 but u=25  $ SE Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 2 ---------
4141 like 4131 but u=26  $ N Top Corner Pebble
4142 like 4132 but u=26  $ SE Top Corner Pebble
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4143 like 4133 but u=26  $ SW Top Corner Pebble
4144 like 4134 but u=26  $ NE Middle Edge Pebble
4145 like 4135 but u=26  $ SW Middle Edge Pebble
4146 like 4136 but u=26  $ N Bottom Corner Pebble
4147 like 4137 but u=26  $ SE Bottom Corner Pebble
4148 like 4138 but u=26  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 3 ---------
4149 like 4131 but u=27  $ N Top Corner Pebble
4150 like 4132 but u=27  $ SE Top Corner Pebble
4151 like 4134 but u=27  $ NE Middle Edge Pebble
4152 like 4136 but u=27  $ N Bottom Corner Pebble
4153 like 4137 but u=27  $ SE Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 4 ---------
4154 like 4132 but u=28  $ SE Top Corner Pebble
4155 like 4137 but u=28  $ SE Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 5 ---------
4156 like 4131 but u=29  $ N Top Corner Pebble
4157 like 4132 but u=29  $ SE Top Corner Pebble
4158 like 4133 but u=29  $ SW Top Corner Pebble
4159 like 4134 but u=29  $ NE Middle Edge Pebble
4160 like 4135 but u=29  $ SW Middle Edge Pebble
4161 like 4136 but u=29  $ N Bottom Corner Pebble
4162 like 4137 but u=29  $ SE Bottom Corner Pebble
4163 like 4138 but u=29  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 6 ---------
4164 like 4132 but u=30  $ SE Top Corner Pebble
4165 like 4137 but u=30  $ SE Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 7 ---------
4166 like 4132 but u=31  $ SE Top Corner Pebble
4167 like 4133 but u=31  $ SW Top Corner Pebble
4168 like 4135 but u=31  $ SW Middle Edge Pebble
4169 like 4137 but u=31  $ SE Bottom Corner Pebble
4170 like 4138 but u=31  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 8 ---------
4171 like 4132 but u=32  $ SE Top Corner Pebble
4172 like 4137 but u=32  $ SE Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 9 ---------
4173 like 4132 but u=33  $ SE Top Corner Pebble
4174 like 4133 but u=33  $ SW Top Corner Pebble
4175 like 4135 but u=33  $ SW Middle Edge Pebble
4176 like 4137 but u=33  $ SE Bottom Corner Pebble
4177 like 4138 but u=33  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 10 ---------
c    *No Moderator Pebbles
c
c --------- Regular (Partial) Lattice 11 ---------
c    *No Moderator Pebbles
c
c --------- Regular (Partial) Lattice 12 ---------
4178 like 4132 but u=36  $ SE Top Corner Pebble
4179 like 4133 but u=36  $ SW Top Corner Pebble
4180 like 4135 but u=36  $ SW Middle Edge Pebble
4181 like 4137 but u=36  $ SE Bottom Corner Pebble
4182 like 4138 but u=36  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 13 ---------
4183 like 4133 but u=37  $ SW Top Corner Pebble
4184 like 4138 but u=37  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 14 ---------
4185 like 4131 but u=38  $ N Top Corner Pebble
4186 like 4132 but u=38  $ SE Top Corner Pebble
4187 like 4133 but u=38  $ SW Top Corner Pebble
4188 like 4135 but u=38  $ SW Middle Edge Pebble
4189 like 4136 but u=38  $ N Bottom Corner Pebble
4190 like 4137 but u=38  $ SE Bottom Corner Pebble
4191 like 4138 but u=38  $ SW Bottom Corner Pebble
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c
c --------- Regular (Partial) Lattice 15 ---------
4192 like 4133 but u=39  $ SW Top Corner Pebble
4193 like 4138 but u=39  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 16 ---------
4194 like 4131 but u=40  $ N Top Corner Pebble
4195 like 4132 but u=40  $ SE Top Corner Pebble
4196 like 4133 but u=40  $ SW Top Corner Pebble
4197 like 4135 but u=40  $ SW Middle Edge Pebble
4198 like 4136 but u=40  $ N Bottom Corner Pebble
4199 like 4137 but u=40  $ SE Bottom Corner Pebble
4200 like 4138 but u=40  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 17 ---------
4201 like 4133 but u=41  $ SW Top Corner Pebble
4202 like 4138 but u=41  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 18 ---------
4203 like 4131 but u=42  $ N Top Corner Pebble
4204 like 4133 but u=42  $ SW Top Corner Pebble
4205 like 4135 but u=42  $ SW Middle Edge Pebble
4206 like 4136 but u=42  $ N Bottom Corner Pebble
4207 like 4138 but u=42  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 19 ---------
4208 like 4133 but u=43  $ SW Top Corner Pebble
4209 like 4138 but u=43  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 20 ---------
c    *No Moderator Pebbles
c
c --------- Regular (Partial) Lattice 21 ---------
4210 like 4131 but u=45  $ N Top Corner Pebble
4211 like 4133 but u=45  $ SW Top Corner Pebble
4212 like 4134 but u=45  $ NE Middle Edge Pebble
4213 like 4135 but u=45  $ SW Middle Edge Pebble
4214 like 4136 but u=45  $ N Bottom Corner Pebble
4215 like 4138 but u=45  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 22 ---------
c    *No Moderator Pebbles
c
c --------- Regular (Partial) Lattice 23 ---------
4216 like 4131 but u=47  $ N Top Corner Pebble
4217 like 4133 but u=47  $ SW Top Corner Pebble
4218 like 4134 but u=47  $ NE Middle Edge Pebble
4219 like 4136 but u=47  $ N Bottom Corner Pebble
4220 like 4138 but u=47  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 24 ---------
4221 like 4131 but u=48  $ N Top Corner Pebble
4222 like 4132 but u=48  $ SE Top Corner Pebble
4223 like 4133 but u=48  $ SW Top Corner Pebble
4224 like 4134 but u=48  $ NE Middle Edge Pebble
4225 like 4135 but u=48  $ SW Middle Edge Pebble
4226 like 4136 but u=48  $ N Bottom Corner Pebble
4227 like 4137 but u=48  $ SE Bottom Corner Pebble
4228 like 4138 but u=48  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 25 ---------
4229 like 4131 but u=49  $ N Top Corner Pebble
4230 like 4136 but u=49  $ N Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 26 ---------
4231 like 4131 but u=50  $ N Top Corner Pebble
4232 like 4136 but u=50  $ N Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 27 ---------
4233 like 4131 but u=51  $ N Top Corner Pebble
4234 like 4134 but u=51  $ NE Middle Edge Pebble
4235 like 4136 but u=51  $ N Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 28 ---------
4236 like 4131 but u=52  $ N Top Corner Pebble
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4237 like 4132 but u=52  $ SE Top Corner Pebble
4238 like 4133 but u=52  $ SW Top Corner Pebble
4239 like 4134 but u=52  $ NE Middle Edge Pebble
4240 like 4135 but u=52  $ SW Middle Edge Pebble
4241 like 4136 but u=52  $ N Bottom Corner Pebble
4242 like 4137 but u=52  $ SE Bottom Corner Pebble
4243 like 4138 but u=52  $ SW Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 29 ---------
4244 like 4131 but u=53  $ N Top Corner Pebble
4245 like 4132 but u=53  $ SE Top Corner Pebble
4246 like 4134 but u=53  $ NE Middle Edge Pebble
4247 like 4136 but u=53  $ N Bottom Corner Pebble
4248 like 4137 but u=53  $ SE Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 30 ---------
4249 like 4131 but u=54  $ N Top Corner Pebble
4250 like 4134 but u=54  $ NE Middle Edge Pebble
4251 like 4136 but u=54  $ N Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 31 ---------
4252 like 4134 but u=55  $ NE Middle Edge Pebble
c
c --------- Regular (Partial) Lattice 32 ---------
4253 like 4131 but u=56  $ N Top Corner Pebble
4254 like 4132 but u=56  $ SE Top Corner Pebble
4255 like 4134 but u=56  $ NE Middle Edge Pebble
4256 like 4135 but u=56  $ SW Middle Edge Pebble
4257 like 4136 but u=56  $ N Bottom Corner Pebble
4258 like 4137 but u=56  $ SE Bottom Corner Pebble
c
c --------- Regular (Partial) Lattice 33 ---------
c    *No Moderator Pebbles
c
c --------- Bottom Layer Only Lattices ---------
4259 like 4136 but u=124  $ N Bottom Corner Pebble
4260 like 4137 but u=124  $ SE Bottom Corner Pebble
4261 like 4138 but u=124  $ SW Bottom Corner Pebble
4262 like 4137 but u=125  $ SE Bottom Corner Pebble
4263 like 4136 but u=126  $ N Bottom Corner Pebble
4264 like 4137 but u=126  $ SE Bottom Corner Pebble
4265 like 4138 but u=126  $ SW Bottom Corner Pebble
4266 like 4136 but u=127  $ N Bottom Corner Pebble
4267 like 4137 but u=127  $ SE Bottom Corner Pebble
4268 like 4137 but u=128  $ SE Bottom Corner Pebble
4269 like 4136 but u=129  $ N Bottom Corner Pebble
4270 like 4137 but u=129  $ SE Bottom Corner Pebble
4271 like 4138 but u=129  $ SW Bottom Corner Pebble
4272 like 4137 but u=130  $ SE Bottom Corner Pebble
4273 like 4137 but u=131  $ SE Bottom Corner Pebble
4274 like 4138 but u=131  $ SW Bottom Corner Pebble
4275 like 4137 but u=132  $ SE Bottom Corner Pebble
4276 like 4137 but u=133  $ SE Bottom Corner Pebble
4277 like 4138 but u=133  $ SW Bottom Corner Pebble
4278 like 4137 but u=136  $ SE Bottom Corner Pebble
4279 like 4138 but u=136  $ SW Bottom Corner Pebble
4280 like 4138 but u=137  $ SW Bottom Corner Pebble
4281 like 4136 but u=138  $ N Bottom Corner Pebble
4282 like 4137 but u=138  $ SE Bottom Corner Pebble
4283 like 4138 but u=138  $ SW Bottom Corner Pebble
4284 like 4138 but u=139  $ SW Bottom Corner Pebble
4285 like 4136 but u=140  $ N Bottom Corner Pebble
4286 like 4137 but u=140  $ SE Bottom Corner Pebble
4287 like 4138 but u=140  $ SW Bottom Corner Pebble
4288 like 4138 but u=141  $ SW Bottom Corner Pebble
4289 like 4136 but u=142  $ N Bottom Corner Pebble
4290 like 4138 but u=142  $ SW Bottom Corner Pebble
4291 like 4138 but u=143  $ SW Bottom Corner Pebble
4292 like 4136 but u=145  $ N Bottom Corner Pebble
4293 like 4138 but u=145  $ SW Bottom Corner Pebble
4294 like 4136 but u=147  $ N Bottom Corner Pebble
4295 like 4138 but u=147  $ SW Bottom Corner Pebble
4296 like 4136 but u=148  $ N Bottom Corner Pebble
4297 like 4137 but u=148  $ SE Bottom Corner Pebble
4298 like 4138 but u=148  $ SW Bottom Corner Pebble
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4299 like 4136 but u=149  $ N Bottom Corner Pebble
4300 like 4136 but u=150  $ N Bottom Corner Pebble
4301 like 4136 but u=151  $ N Bottom Corner Pebble
4302 like 4136 but u=152  $ N Bottom Corner Pebble
4303 like 4137 but u=152  $ SE Bottom Corner Pebble
4304 like 4138 but u=152  $ SW Bottom Corner Pebble
4305 like 4136 but u=153  $ N Bottom Corner Pebble
4306 like 4137 but u=153  $ SE Bottom Corner Pebble
4307 like 4136 but u=154  $ N Bottom Corner Pebble
4308 like 4136 but u=156  $ N Bottom Corner Pebble
4309 like 4137 but u=156  $ SE Bottom Corner Pebble
c
c --------- Bottom and Middle Layers Only Lattices ---------
4310 like 4134 but u=224  $ NE Middle Edge Pebble
4311 like 4135 but u=224  $ SW Middle Edge Pebble
4312 like 4136 but u=224  $ N Bottom Corner Pebble
4313 like 4137 but u=224  $ SE Bottom Corner Pebble
4314 like 4138 but u=224  $ SW Bottom Corner Pebble
4315 like 4137 but u=225  $ SE Bottom Corner Pebble
4316 like 4134 but u=226  $ NE Middle Edge Pebble
4317 like 4135 but u=226  $ SW Middle Edge Pebble
4318 like 4136 but u=226  $ N Bottom Corner Pebble
4319 like 4137 but u=226  $ SE Bottom Corner Pebble
4320 like 4138 but u=226  $ SW Bottom Corner Pebble
4321 like 4134 but u=227  $ NE Middle Edge Pebble
4322 like 4136 but u=227  $ N Bottom Corner Pebble
4323 like 4137 but u=227  $ SE Bottom Corner Pebble
4324 like 4137 but u=228  $ SE Bottom Corner Pebble
4325 like 4134 but u=229  $ NE Middle Edge Pebble
4326 like 4135 but u=229  $ SW Middle Edge Pebble
4327 like 4136 but u=229  $ N Bottom Corner Pebble
4328 like 4137 but u=229  $ SE Bottom Corner Pebble
4329 like 4138 but u=229  $ SW Bottom Corner Pebble
4330 like 4137 but u=230  $ SE Bottom Corner Pebble
4331 like 4135 but u=231  $ SW Middle Edge Pebble
4332 like 4137 but u=231  $ SE Bottom Corner Pebble
4333 like 4138 but u=231  $ SW Bottom Corner Pebble
4334 like 4137 but u=232  $ SE Bottom Corner Pebble
4335 like 4135 but u=233  $ SW Middle Edge Pebble
4336 like 4137 but u=233  $ SE Bottom Corner Pebble
4337 like 4138 but u=233  $ SW Bottom Corner Pebble
4338 like 4135 but u=236  $ SW Middle Edge Pebble
4339 like 4137 but u=236  $ SE Bottom Corner Pebble
4340 like 4138 but u=236  $ SW Bottom Corner Pebble
4341 like 4138 but u=237  $ SW Bottom Corner Pebble
4342 like 4135 but u=238  $ SW Middle Edge Pebble
4343 like 4136 but u=238  $ N Bottom Corner Pebble
4344 like 4137 but u=238  $ SE Bottom Corner Pebble
4345 like 4138 but u=238  $ SW Bottom Corner Pebble
4346 like 4138 but u=239  $ SW Bottom Corner Pebble
4347 like 4135 but u=240  $ SW Middle Edge Pebble
4348 like 4136 but u=240  $ N Bottom Corner Pebble
4349 like 4137 but u=240  $ SE Bottom Corner Pebble
4350 like 4138 but u=240  $ SW Bottom Corner Pebble
4351 like 4138 but u=241  $ SW Bottom Corner Pebble
4352 like 4135 but u=242  $ SW Middle Edge Pebble
4353 like 4136 but u=242  $ N Bottom Corner Pebble
4354 like 4138 but u=242  $ SW Bottom Corner Pebble
4355 like 4138 but u=243  $ SW Bottom Corner Pebble
4356 like 4134 but u=245  $ NE Middle Edge Pebble
4357 like 4135 but u=245  $ SW Middle Edge Pebble
4358 like 4136 but u=245  $ N Bottom Corner Pebble
4359 like 4138 but u=245  $ SW Bottom Corner Pebble
4360 like 4134 but u=247  $ NE Middle Edge Pebble
4361 like 4136 but u=247  $ N Bottom Corner Pebble
4362 like 4138 but u=247  $ SW Bottom Corner Pebble
4363 like 4134 but u=248  $ NE Middle Edge Pebble
4364 like 4135 but u=248  $ SW Middle Edge Pebble
4365 like 4136 but u=248  $ N Bottom Corner Pebble
4366 like 4137 but u=248  $ SE Bottom Corner Pebble
4367 like 4138 but u=248  $ SW Bottom Corner Pebble
4368 like 4136 but u=249  $ N Bottom Corner Pebble
4369 like 4136 but u=250  $ N Bottom Corner Pebble
4370 like 4134 but u=251  $ NE Middle Edge Pebble
4371 like 4136 but u=251  $ N Bottom Corner Pebble
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4372 like 4134 but u=252  $ NE Middle Edge Pebble
4373 like 4135 but u=252  $ SW Middle Edge Pebble
4374 like 4136 but u=252  $ N Bottom Corner Pebble
4375 like 4137 but u=252  $ SE Bottom Corner Pebble
4376 like 4138 but u=252  $ SW Bottom Corner Pebble
4377 like 4134 but u=253  $ NE Middle Edge Pebble
4378 like 4136 but u=253  $ N Bottom Corner Pebble
4379 like 4137 but u=253  $ SE Bottom Corner Pebble
4380 like 4134 but u=254  $ NE Middle Edge Pebble
4381 like 4136 but u=254  $ N Bottom Corner Pebble
4382 like 4134 but u=255  $ NE Middle Edge Pebble
4383 like 4134 but u=256  $ NE Middle Edge Pebble
4384 like 4135 but u=256  $ SW Middle Edge Pebble
4385 like 4136 but u=256  $ N Bottom Corner Pebble
4386 like 4137 but u=256  $ SE Bottom Corner Pebble
c
c --------- Top Layer Only Lattices ---------
4387 like 4131 but u=324  $ N Top Corner Pebble
4388 like 4132 but u=324  $ SE Top Corner Pebble
4389 like 4133 but u=324  $ SW Top Corner Pebble
4390 like 4132 but u=325  $ SE Top Corner Pebble
4391 like 4131 but u=326  $ N Top Corner Pebble
4392 like 4132 but u=326  $ SE Top Corner Pebble
4393 like 4133 but u=326  $ SW Top Corner Pebble
4394 like 4131 but u=327  $ N Top Corner Pebble
4395 like 4132 but u=327  $ SE Top Corner Pebble
4396 like 4132 but u=328  $ SE Top Corner Pebble
4397 like 4131 but u=329  $ N Top Corner Pebble
4398 like 4132 but u=329  $ SE Top Corner Pebble
4399 like 4133 but u=329  $ SW Top Corner Pebble
4401 like 4132 but u=330  $ SE Top Corner Pebble
4402 like 4132 but u=331  $ SE Top Corner Pebble
4403 like 4133 but u=331  $ SW Top Corner Pebble
4404 like 4132 but u=332  $ SE Top Corner Pebble
4405 like 4132 but u=333  $ SE Top Corner Pebble
4406 like 4133 but u=333  $ SW Top Corner Pebble
4407 like 4132 but u=336  $ SE Top Corner Pebble
4408 like 4133 but u=336  $ SW Top Corner Pebble
4409 like 4133 but u=337  $ SW Top Corner Pebble
4410 like 4131 but u=338  $ N Top Corner Pebble
4411 like 4132 but u=338  $ SE Top Corner Pebble
4412 like 4133 but u=338  $ SW Top Corner Pebble
4413 like 4133 but u=339  $ SW Top Corner Pebble
4414 like 4131 but u=340  $ N Top Corner Pebble
4415 like 4132 but u=340  $ SE Top Corner Pebble
4416 like 4133 but u=340  $ SW Top Corner Pebble
4417 like 4133 but u=341  $ SW Top Corner Pebble
4418 like 4131 but u=342  $ N Top Corner Pebble
4419 like 4133 but u=342  $ SW Top Corner Pebble
4420 like 4133 but u=343  $ SW Top Corner Pebble
4421 like 4131 but u=345  $ N Top Corner Pebble
4422 like 4133 but u=345  $ SW Top Corner Pebble
4423 like 4131 but u=347  $ N Top Corner Pebble
4424 like 4133 but u=347  $ SW Top Corner Pebble
4425 like 4131 but u=348  $ N Top Corner Pebble
4426 like 4132 but u=348  $ SE Top Corner Pebble
4427 like 4133 but u=348  $ SW Top Corner Pebble
4428 like 4131 but u=349  $ N Top Corner Pebble
4429 like 4131 but u=350  $ N Top Corner Pebble
4430 like 4131 but u=351  $ N Top Corner Pebble
4431 like 4131 but u=352  $ N Top Corner Pebble
4432 like 4132 but u=352  $ SE Top Corner Pebble
4433 like 4133 but u=352  $ SW Top Corner Pebble
4434 like 4131 but u=353  $ N Top Corner Pebble
4435 like 4132 but u=353  $ SE Top Corner Pebble
4436 like 4131 but u=354  $ N Top Corner Pebble
4437 like 4131 but u=356  $ N Top Corner Pebble
4438 like 4132 but u=356  $ SE Top Corner Pebble
c
c --------- All Moderator Lattices ---------
7332 26 8.4461E-02  -3132 imp:n=1 u=424  $ Middle Top Pebble
7334 26 8.4461E-02  -3134 imp:n=1 u=424  $ NW Top Corner Pebble
7336 26 8.4461E-02  -3136 imp:n=1 u=424  $ NE Top Corner Pebble
7338 26 8.4461E-02  -3138 imp:n=1 u=424  $ S Top Corner Pebble
7340 26 8.4461E-02  -3140 imp:n=1 u=424  $ NW Middle Edge Pebble
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7342 26 8.4461E-02  -3142 imp:n=1 u=424  $ E Middle Edge Pebble
7344 26 8.4461E-02  -3144 imp:n=1 u=424  $ W Middle Edge Pebble
7346 26 8.4461E-02  -3146 imp:n=1 u=424  $ SE Middle Edge Pebble
7348 26 8.4461E-02  -3148 imp:n=1 u=424  $ NW Bottom Corner Pebble
7350 26 8.4461E-02  -3150 imp:n=1 u=424  $ NE Bottom Corner Pebble
7352 26 8.4461E-02  -3152 imp:n=1 u=424  $ S Bottom Corner Pebble
7354 26 8.4461E-02  -3154 imp:n=1 u=424  $ Middle Bottom Pebble
7355 like 7336 but u=425  $ NE Top Corner Pebble
7356 like 7350 but u=425  $ NE Bottom Corner Pebble
7357 like 7332 but u=426  $ Middle Top Pebble
7358 like 7334 but u=426  $ NW Top Corner Pebble
7359 like 7336 but u=426  $ NE Top Corner Pebble
7360 like 7338 but u=426  $ S Top Corner Pebble
7361 like 7340 but u=426  $ NW Middle Edge Pebble
7362 like 7342 but u=426  $ E Middle Edge Pebble
7363 like 7346 but u=426  $ SE Middle Edge Pebble
7364 like 7348 but u=426  $ NW Bottom Corner Pebble
7365 like 7350 but u=426  $ NE Bottom Corner Pebble
7366 like 7352 but u=426  $ S Bottom Corner Pebble
7367 like 7354 but u=426  $ Middle Bottom Pebble
7368 like 7332 but u=427  $ Middle Top Pebble
7369 like 7336 but u=427  $ NE Top Corner Pebble
7370 like 7338 but u=427  $ S Top Corner Pebble
7371 like 7342 but u=427  $ E Middle Edge Pebble
7372 like 7344 but u=427  $ W Middle Edge Pebble
7373 like 7346 but u=427  $ SE Middle Edge Pebble
7374 like 7350 but u=427  $ NE Bottom Corner Pebble
7375 like 7352 but u=427  $ S Bottom Corner Pebble
7376 like 7354 but u=427  $ Middle Bottom Pebble
7377 like 7332 but u=429  $ Middle Top Pebble
7378 like 7336 but u=429  $ NE Top Corner Pebble
7379 like 7338 but u=429  $ S Top Corner Pebble
7380 like 7340 but u=429  $ NW Middle Edge Pebble
7381 like 7342 but u=429  $ E Middle Edge Pebble
7382 like 7346 but u=429  $ SE Middle Edge Pebble
7383 like 7350 but u=429  $ NE Bottom Corner Pebble
7384 like 7352 but u=429  $ S Bottom Corner Pebble
7385 like 7354 but u=429  $ Middle Bottom Pebble
7386 like 7346 but u=430  $ SE Middle Edge Pebble
7387 like 7332 but u=431  $ Middle Top Pebble
7388 like 7336 but u=431  $ NE Top Corner Pebble
7389 like 7338 but u=431  $ S Top Corner Pebble
7390 like 7342 but u=431  $ E Middle Edge Pebble
7391 like 7346 but u=431  $ SE Middle Edge Pebble
7392 like 7350 but u=431  $ NE Bottom Corner Pebble
7393 like 7352 but u=431  $ S Bottom Corner Pebble
7394 like 7354 but u=431  $ Middle Bottom Pebble
7395 like 7338 but u=432  $ S Top Corner Pebble
7396 like 7346 but u=432  $ SE Middle Edge Pebble
7397 like 7352 but u=432  $ S Bottom Corner Pebble
7398 like 7332 but u=433  $ Middle Top Pebble
7399 like 7334 but u=433  $ NW Top Corner Pebble
7400 like 7336 but u=433  $ NE Top Corner Pebble
7401 like 7338 but u=433  $ S Top Corner Pebble
7402 like 7340 but u=433  $ NW Middle Edge Pebble
7403 like 7342 but u=433  $ E Middle Edge Pebble
7404 like 7344 but u=433  $ W Middle Edge Pebble
7405 like 7346 but u=433  $ SE Middle Edge Pebble
7406 like 7348 but u=433  $ NW Bottom Corner Pebble
7407 like 7350 but u=433  $ NE Bottom Corner Pebble
7408 like 7352 but u=433  $ S Bottom Corner Pebble
7409 like 7354 but u=433  $ Middle Bottom Pebble
7410 like 7338 but u=434  $ S Top Corner Pebble
7411 like 7346 but u=434  $ SE Middle Edge Pebble
7412 like 7352 but u=434  $ S Bottom Corner Pebble
7413 like 7338 but u=435  $ S Top Corner Pebble
7414 like 7352 but u=435  $ S Bottom Corner Pebble
7415 like 7332 but u=436  $ Middle Top Pebble
7416 like 7334 but u=436  $ NW Top Corner Pebble
7417 like 7338 but u=436  $ S Top Corner Pebble
7418 like 7344 but u=436  $ W Middle Edge Pebble
7419 like 7346 but u=436  $ SE Middle Edge Pebble
7420 like 7348 but u=436  $ NW Bottom Corner Pebble
7421 like 7352 but u=436  $ S Bottom Corner Pebble
7422 like 7354 but u=436  $ Middle Bottom Pebble
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7423 like 7338 but u=437  $ S Top Corner Pebble
7424 like 7352 but u=437  $ S Bottom Corner Pebble
7425 like 7332 but u=438  $ Middle Top Pebble
7426 like 7334 but u=438  $ NW Top Corner Pebble
7427 like 7336 but u=438  $ NE Top Corner Pebble
7428 like 7338 but u=438  $ S Top Corner Pebble
7429 like 7340 but u=438  $ NW Middle Edge Pebble
7430 like 7342 but u=438  $ E Middle Edge Pebble
7431 like 7344 but u=438  $ W Middle Edge Pebble
7432 like 7346 but u=438  $ SE Middle Edge Pebble
7433 like 7348 but u=438  $ NW Bottom Corner Pebble
7434 like 7350 but u=438  $ NE Bottom Corner Pebble
7435 like 7352 but u=438  $ S Bottom Corner Pebble
7436 like 7354 but u=438  $ Middle Bottom Pebble
7437 like 7332 but u=440  $ Middle Top Pebble
7438 like 7334 but u=440  $ NW Top Corner Pebble
7439 like 7338 but u=440  $ S Top Corner Pebble
7440 like 7340 but u=440  $ NW Middle Edge Pebble
7441 like 7342 but u=440  $ E Middle Edge Pebble
7442 like 7344 but u=440  $ W Middle Edge Pebble
7443 like 7346 but u=440  $ SE Middle Edge Pebble
7444 like 7348 but u=440  $ NW Bottom Corner Pebble
7445 like 7352 but u=440  $ S Bottom Corner Pebble
7446 like 7354 but u=440  $ Middle Bottom Pebble
7447 like 7344 but u=441  $ W Middle Edge Pebble
7448 like 7332 but u=442  $ Middle Top Pebble
7449 like 7334 but u=442  $ NW Top Corner Pebble
7450 like 7338 but u=442  $ S Top Corner Pebble
7451 like 7340 but u=442  $ NW Middle Edge Pebble
7452 like 7344 but u=442  $ W Middle Edge Pebble
7453 like 7348 but u=442  $ NW Bottom Corner Pebble
7454 like 7352 but u=442  $ S Bottom Corner Pebble
7455 like 7354 but u=442  $ Middle Bottom Pebble
7456 like 7334 but u=443  $ NW Top Corner Pebble
7457 like 7344 but u=443  $ W Middle Edge Pebble
7458 like 7348 but u=443  $ NW Bottom Corner Pebble
7459 like 7334 but u=444  $ NW Top Corner Pebble
7460 like 7344 but u=444  $ W Middle Edge Pebble
7461 like 7348 but u=444  $ NW Bottom Corner Pebble
7462 like 7332 but u=445  $ Middle Top Pebble
7463 like 7334 but u=445  $ NW Top Corner Pebble
7464 like 7336 but u=445  $ NE Top Corner Pebble
7465 like 7338 but u=445  $ S Top Corner Pebble
7466 like 7340 but u=445  $ NW Middle Edge Pebble
7467 like 7342 but u=445  $ E Middle Edge Pebble
7468 like 7344 but u=445  $ W Middle Edge Pebble
7469 like 7348 but u=445  $ NW Bottom Corner Pebble
7470 like 7350 but u=445  $ NE Bottom Corner Pebble
7471 like 7352 but u=445  $ S Bottom Corner Pebble
7472 like 7354 but u=445  $ Middle Bottom Pebble
7473 like 7334 but u=446  $ NW Top Corner Pebble
7474 like 7348 but u=446  $ NW Bottom Corner Pebble
7475 like 7332 but u=447  $ Middle Top Pebble
7476 like 7334 but u=447  $ NW Top Corner Pebble
7477 like 7336 but u=447  $ NE Top Corner Pebble
7478 like 7340 but u=447  $ NW Middle Edge Pebble
7479 like 7344 but u=447  $ W Middle Edge Pebble
7480 like 7348 but u=447  $ NW Bottom Corner Pebble
7481 like 7350 but u=447  $ NE Bottom Corner Pebble
7482 like 7354 but u=447  $ Middle Bottom Pebble
7483 like 7332 but u=448  $ Middle Top Pebble
7484 like 7334 but u=448  $ NW Top Corner Pebble
7485 like 7336 but u=448  $ NE Top Corner Pebble
7486 like 7338 but u=448  $ S Top Corner Pebble
7487 like 7340 but u=448  $ NW Middle Edge Pebble
7488 like 7342 but u=448  $ E Middle Edge Pebble
7489 like 7344 but u=448  $ W Middle Edge Pebble
7490 like 7348 but u=448  $ NW Bottom Corner Pebble
7491 like 7350 but u=448  $ NE Bottom Corner Pebble
7492 like 7352 but u=448  $ S Bottom Corner Pebble
7493 like 7354 but u=448  $ Middle Bottom Pebble
7494 like 7334 but u=449  $ NW Top Corner Pebble
7495 like 7348 but u=449  $ NW Bottom Corner Pebble
7496 like 7332 but u=452  $ Middle Top Pebble
7497 like 7334 but u=452  $ NW Top Corner Pebble
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7498 like 7336 but u=452  $ NE Top Corner Pebble
7499 like 7340 but u=452  $ NW Middle Edge Pebble
7500 like 7342 but u=452  $ E Middle Edge Pebble
7501 like 7344 but u=452  $ W Middle Edge Pebble
7502 like 7348 but u=452  $ NW Bottom Corner Pebble
7503 like 7350 but u=452  $ NE Bottom Corner Pebble
7504 like 7354 but u=452  $ Middle Bottom Pebble
7505 like 7332 but u=453  $ Middle Top Pebble
7506 like 7334 but u=453  $ NW Top Corner Pebble
7507 like 7336 but u=453  $ NE Top Corner Pebble
7508 like 7340 but u=453  $ NW Middle Edge Pebble
7509 like 7342 but u=453  $ E Middle Edge Pebble
7510 like 7348 but u=453  $ NW Bottom Corner Pebble
7511 like 7350 but u=453  $ NE Bottom Corner Pebble
7512 like 7354 but u=453  $ Middle Bottom Pebble
7513 like 7336 but u=454  $ NE Top Corner Pebble
7514 like 7350 but u=454  $ NE Bottom Corner Pebble
7515 like 7336 but u=455  $ NE Top Corner Pebble
7516 like 7350 but u=455  $ NE Bottom Corner Pebble
7517 like 7332 but u=456  $ Middle Top Pebble
7518 like 7334 but u=456  $ NW Top Corner Pebble
7519 like 7336 but u=456  $ NE Top Corner Pebble
7520 like 7338 but u=456  $ S Top Corner Pebble
7521 like 7340 but u=456  $ NW Middle Edge Pebble
7522 like 7342 but u=456  $ E Middle Edge Pebble
7523 like 7346 but u=456  $ SE Middle Edge Pebble
7524 like 7348 but u=456  $ NW Bottom Corner Pebble
7525 like 7350 but u=456  $ NE Bottom Corner Pebble
7526 like 7352 but u=456  $ S Bottom Corner Pebble
7527 like 7354 but u=456  $ Middle Bottom Pebble
7528 like 7336 but u=457  $ NE Top Corner Pebble
7529 like 7350 but u=457  $ NE Bottom Corner Pebble
7530 like 4131 but u=424  $ N Top Corner Pebble
7531 like 4132 but u=424  $ SE Top Corner Pebble
7532 like 4133 but u=424  $ SW Top Corner Pebble
7533 like 4134 but u=424  $ NE Middle Edge Pebble
7534 like 4135 but u=424  $ SW Middle Edge Pebble
7535 like 4136 but u=424  $ N Bottom Corner Pebble
7536 like 4137 but u=424  $ SE Bottom Corner Pebble
7537 like 4138 but u=424  $ SW Bottom Corner Pebble
7538 like 4132 but u=425  $ SE Top Corner Pebble
7539 like 4137 but u=425  $ SE Bottom Corner Pebble
7540 like 4131 but u=426  $ N Top Corner Pebble
7541 like 4132 but u=426  $ SE Top Corner Pebble
7542 like 4133 but u=426  $ SW Top Corner Pebble
7543 like 4134 but u=426  $ NE Middle Edge Pebble
7544 like 4135 but u=426  $ SW Middle Edge Pebble
7545 like 4136 but u=426  $ N Bottom Corner Pebble
7546 like 4137 but u=426  $ SE Bottom Corner Pebble
7547 like 4138 but u=426  $ SW Bottom Corner Pebble
7548 like 4131 but u=427  $ N Top Corner Pebble
7549 like 4132 but u=427  $ SE Top Corner Pebble
7550 like 4134 but u=427  $ NE Middle Edge Pebble
7551 like 4136 but u=427  $ N Bottom Corner Pebble
7552 like 4137 but u=427  $ SE Bottom Corner Pebble
7553 like 4132 but u=428  $ SE Top Corner Pebble
7554 like 4137 but u=428  $ SE Bottom Corner Pebble
7555 like 4131 but u=429  $ N Top Corner Pebble
7556 like 4132 but u=429  $ SE Top Corner Pebble
7557 like 4133 but u=429  $ SW Top Corner Pebble
7558 like 4134 but u=429  $ NE Middle Edge Pebble
7559 like 4135 but u=429  $ SW Middle Edge Pebble
7560 like 4136 but u=429  $ N Bottom Corner Pebble
7561 like 4137 but u=429  $ SE Bottom Corner Pebble
7562 like 4138 but u=429  $ SW Bottom Corner Pebble
7563 like 4132 but u=430  $ SE Top Corner Pebble
7564 like 4137 but u=430  $ SE Bottom Corner Pebble
7565 like 4132 but u=431  $ SE Top Corner Pebble
7566 like 4133 but u=431  $ SW Top Corner Pebble
7567 like 4135 but u=431  $ SW Middle Edge Pebble
7568 like 4137 but u=431  $ SE Bottom Corner Pebble
7569 like 4138 but u=431  $ SW Bottom Corner Pebble
7570 like 4132 but u=432  $ SE Top Corner Pebble
7571 like 4137 but u=432  $ SE Bottom Corner Pebble
7572 like 4132 but u=433  $ SE Top Corner Pebble
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7573 like 4133 but u=433  $ SW Top Corner Pebble
7574 like 4135 but u=433  $ SW Middle Edge Pebble
7575 like 4137 but u=433  $ SE Bottom Corner Pebble
7576 like 4138 but u=433  $ SW Bottom Corner Pebble
7577 like 4132 but u=436  $ SE Top Corner Pebble
7578 like 4133 but u=436  $ SW Top Corner Pebble
7579 like 4135 but u=436  $ SW Middle Edge Pebble
7580 like 4137 but u=436  $ SE Bottom Corner Pebble
7581 like 4138 but u=436  $ SW Bottom Corner Pebble
7582 like 4133 but u=437  $ SW Top Corner Pebble
7583 like 4138 but u=437  $ SW Bottom Corner Pebble
7584 like 4131 but u=438  $ N Top Corner Pebble
7585 like 4132 but u=438  $ SE Top Corner Pebble
7586 like 4133 but u=438  $ SW Top Corner Pebble
7587 like 4135 but u=438  $ SW Middle Edge Pebble
7588 like 4136 but u=438  $ N Bottom Corner Pebble
7589 like 4137 but u=438  $ SE Bottom Corner Pebble
7590 like 4138 but u=438  $ SW Bottom Corner Pebble
7591 like 4133 but u=439  $ SW Top Corner Pebble
7592 like 4138 but u=439  $ SW Bottom Corner Pebble
7593 like 4131 but u=440  $ N Top Corner Pebble
7594 like 4132 but u=440  $ SE Top Corner Pebble
7595 like 4133 but u=440  $ SW Top Corner Pebble
7596 like 4135 but u=440  $ SW Middle Edge Pebble
7597 like 4136 but u=440  $ N Bottom Corner Pebble
7598 like 4137 but u=440  $ SE Bottom Corner Pebble
7599 like 4138 but u=440  $ SW Bottom Corner Pebble
7600 like 4133 but u=441  $ SW Top Corner Pebble
7601 like 4138 but u=441  $ SW Bottom Corner Pebble
7602 like 4131 but u=442  $ N Top Corner Pebble
7603 like 4133 but u=442  $ SW Top Corner Pebble
7604 like 4135 but u=442  $ SW Middle Edge Pebble
7605 like 4136 but u=442  $ N Bottom Corner Pebble
7606 like 4138 but u=442  $ SW Bottom Corner Pebble
7607 like 4133 but u=443  $ SW Top Corner Pebble
7608 like 4138 but u=443  $ SW Bottom Corner Pebble
7609 like 4131 but u=445  $ N Top Corner Pebble
7610 like 4133 but u=445  $ SW Top Corner Pebble
7611 like 4134 but u=445  $ NE Middle Edge Pebble
7612 like 4135 but u=445  $ SW Middle Edge Pebble
7613 like 4136 but u=445  $ N Bottom Corner Pebble
7614 like 4138 but u=445  $ SW Bottom Corner Pebble
7615 like 4131 but u=447  $ N Top Corner Pebble
7616 like 4133 but u=447  $ SW Top Corner Pebble
7617 like 4134 but u=447  $ NE Middle Edge Pebble
7618 like 4136 but u=447  $ N Bottom Corner Pebble
7619 like 4138 but u=447  $ SW Bottom Corner Pebble
7620 like 4131 but u=448  $ N Top Corner Pebble
7621 like 4132 but u=448  $ SE Top Corner Pebble
7622 like 4133 but u=448  $ SW Top Corner Pebble
7623 like 4134 but u=448  $ NE Middle Edge Pebble
7624 like 4135 but u=448  $ SW Middle Edge Pebble
7625 like 4136 but u=448  $ N Bottom Corner Pebble
7626 like 4137 but u=448  $ SE Bottom Corner Pebble
7627 like 4138 but u=448  $ SW Bottom Corner Pebble
7628 like 4131 but u=449  $ N Top Corner Pebble
7629 like 4136 but u=449  $ N Bottom Corner Pebble
7630 like 4131 but u=450  $ N Top Corner Pebble
7631 like 4136 but u=450  $ N Bottom Corner Pebble
7632 like 4131 but u=451  $ N Top Corner Pebble
7633 like 4134 but u=451  $ NE Middle Edge Pebble
7634 like 4136 but u=451  $ N Bottom Corner Pebble
7635 like 4131 but u=452  $ N Top Corner Pebble
7636 like 4132 but u=452  $ SE Top Corner Pebble
7637 like 4133 but u=452  $ SW Top Corner Pebble
7638 like 4134 but u=452  $ NE Middle Edge Pebble
7639 like 4135 but u=452  $ SW Middle Edge Pebble
7640 like 4136 but u=452  $ N Bottom Corner Pebble
7641 like 4137 but u=452  $ SE Bottom Corner Pebble
7642 like 4138 but u=452  $ SW Bottom Corner Pebble
7643 like 4131 but u=453  $ N Top Corner Pebble
7644 like 4132 but u=453  $ SE Top Corner Pebble
7645 like 4134 but u=453  $ NE Middle Edge Pebble
7646 like 4136 but u=453  $ N Bottom Corner Pebble
7647 like 4137 but u=453  $ SE Bottom Corner Pebble
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7648 like 4131 but u=454  $ N Top Corner Pebble
7649 like 4134 but u=454  $ NE Middle Edge Pebble
7650 like 4136 but u=454  $ N Bottom Corner Pebble
7651 like 4134 but u=455  $ NE Middle Edge Pebble
7652 like 4131 but u=456  $ N Top Corner Pebble
7653 like 4132 but u=456  $ SE Top Corner Pebble
7654 like 4134 but u=456  $ NE Middle Edge Pebble
7655 like 4135 but u=456  $ SW Middle Edge Pebble
7656 like 4136 but u=456  $ N Bottom Corner Pebble
7657 like 4137 but u=456  $ SE Bottom Corner Pebble
c
c --------- Bottom Layer of Moderator Only Lattices ---------
7658 like 7348 but u=524  $ NW Bottom Corner Pebble
7659 like 7350 but u=524  $ NE Bottom Corner Pebble
7660 like 7352 but u=524  $ S Bottom Corner Pebble
7661 like 7354 but u=524  $ Middle Bottom Pebble
7669 like 7350 but u=525  $ NE Bottom Corner Pebble
7662 like 7348 but u=526  $ NW Bottom Corner Pebble
7663 like 7350 but u=526  $ NE Bottom Corner Pebble
7664 like 7352 but u=526  $ S Bottom Corner Pebble
7665 like 7354 but u=526  $ Middle Bottom Pebble
7666 like 7350 but u=527  $ NE Bottom Corner Pebble
7667 like 7352 but u=527  $ S Bottom Corner Pebble
7668 like 7354 but u=527  $ Middle Bottom Pebble
7670 like 7350 but u=529  $ NE Bottom Corner Pebble
7671 like 7352 but u=529  $ S Bottom Corner Pebble
7672 like 7354 but u=529  $ Middle Bottom Pebble
7673 like 7350 but u=531  $ NE Bottom Corner Pebble
7674 like 7352 but u=531  $ S Bottom Corner Pebble
7675 like 7354 but u=531  $ Middle Bottom Pebble
7676 like 7352 but u=532  $ S Bottom Corner Pebble
7677 like 7348 but u=533  $ NW Bottom Corner Pebble
7678 like 7350 but u=533  $ NE Bottom Corner Pebble
7679 like 7352 but u=533  $ S Bottom Corner Pebble
7680 like 7354 but u=533  $ Middle Bottom Pebble
7681 like 7352 but u=534  $ S Bottom Corner Pebble
7682 like 7352 but u=535  $ S Bottom Corner Pebble
7683 like 7348 but u=536  $ NW Bottom Corner Pebble
7684 like 7352 but u=536  $ S Bottom Corner Pebble
7685 like 7354 but u=536  $ Middle Bottom Pebble
7686 like 7352 but u=537  $ S Bottom Corner Pebble
7687 like 7348 but u=538  $ NW Bottom Corner Pebble
7688 like 7350 but u=538  $ NE Bottom Corner Pebble
7689 like 7352 but u=538  $ S Bottom Corner Pebble
7690 like 7354 but u=538  $ Middle Bottom Pebble
7691 like 7348 but u=540  $ NW Bottom Corner Pebble
7692 like 7352 but u=540  $ S Bottom Corner Pebble
7693 like 7354 but u=540  $ Middle Bottom Pebble
7694 like 7348 but u=542  $ NW Bottom Corner Pebble
7695 like 7352 but u=542  $ S Bottom Corner Pebble
7696 like 7354 but u=542  $ Middle Bottom Pebble
7697 like 7348 but u=543  $ NW Bottom Corner Pebble
7698 like 7348 but u=544  $ NW Bottom Corner Pebble
7699 like 7348 but u=545  $ NW Bottom Corner Pebble
7700 like 7350 but u=545  $ NE Bottom Corner Pebble
7701 like 7352 but u=545  $ S Bottom Corner Pebble
7702 like 7354 but u=545  $ Middle Bottom Pebble
7703 like 7348 but u=546  $ NW Bottom Corner Pebble
7704 like 7348 but u=547  $ NW Bottom Corner Pebble
7705 like 7350 but u=547  $ NE Bottom Corner Pebble
7706 like 7354 but u=547  $ Middle Bottom Pebble
7708 like 7348 but u=548  $ NW Bottom Corner Pebble
7709 like 7350 but u=548  $ NE Bottom Corner Pebble
7710 like 7352 but u=548  $ S Bottom Corner Pebble
7711 like 7354 but u=548  $ Middle Bottom Pebble
7712 like 7348 but u=549  $ NW Bottom Corner Pebble
7713 like 7348 but u=552  $ NW Bottom Corner Pebble
7714 like 7350 but u=552  $ NE Bottom Corner Pebble
7715 like 7354 but u=552  $ Middle Bottom Pebble
7716 like 7348 but u=553  $ NW Bottom Corner Pebble
7717 like 7350 but u=553  $ NE Bottom Corner Pebble
7718 like 7354 but u=553  $ Middle Bottom Pebble
7720 like 7350 but u=554  $ NE Bottom Corner Pebble
7721 like 7350 but u=555  $ NE Bottom Corner Pebble
7722 like 7348 but u=556  $ NW Bottom Corner Pebble
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7723 like 7350 but u=556  $ NE Bottom Corner Pebble
7724 like 7352 but u=556  $ S Bottom Corner Pebble
7725 like 7354 but u=556  $ Middle Bottom Pebble
7726 like 7350 but u=557  $ NE Bottom Corner Pebble
7727 like 4136 but u=524  $ N Bottom Corner Pebble
7728 like 4137 but u=524  $ SE Bottom Corner Pebble
7729 like 4138 but u=524  $ SW Bottom Corner Pebble
7730 like 4137 but u=525  $ SE Bottom Corner Pebble
7731 like 4136 but u=526  $ N Bottom Corner Pebble
7732 like 4137 but u=526  $ SE Bottom Corner Pebble
7733 like 4138 but u=526  $ SW Bottom Corner Pebble
7734 like 4136 but u=527  $ N Bottom Corner Pebble
7735 like 4137 but u=527  $ SE Bottom Corner Pebble
7736 like 4137 but u=528  $ SE Bottom Corner Pebble
7737 like 4136 but u=529  $ N Bottom Corner Pebble
7738 like 4137 but u=529  $ SE Bottom Corner Pebble
7739 like 4138 but u=529  $ SW Bottom Corner Pebble
7740 like 4137 but u=530  $ SE Bottom Corner Pebble
7741 like 4137 but u=531  $ SE Bottom Corner Pebble
7742 like 4138 but u=531  $ SW Bottom Corner Pebble
7743 like 4137 but u=532  $ SE Bottom Corner Pebble
7744 like 4137 but u=533  $ SE Bottom Corner Pebble
7745 like 4138 but u=533  $ SW Bottom Corner Pebble
7746 like 4137 but u=536  $ SE Bottom Corner Pebble
7747 like 4138 but u=536  $ SW Bottom Corner Pebble
7748 like 4138 but u=537  $ SW Bottom Corner Pebble
7749 like 4136 but u=538  $ N Bottom Corner Pebble
7750 like 4137 but u=538  $ SE Bottom Corner Pebble
7751 like 4138 but u=538  $ SW Bottom Corner Pebble
7752 like 4138 but u=539  $ SW Bottom Corner Pebble
7753 like 4136 but u=540  $ N Bottom Corner Pebble
7754 like 4137 but u=540  $ SE Bottom Corner Pebble
7755 like 4138 but u=540  $ SW Bottom Corner Pebble
7756 like 4138 but u=541  $ SW Bottom Corner Pebble
7757 like 4136 but u=542  $ N Bottom Corner Pebble
7758 like 4138 but u=542  $ SW Bottom Corner Pebble
7759 like 4138 but u=543  $ SW Bottom Corner Pebble
7760 like 4136 but u=545  $ N Bottom Corner Pebble
7761 like 4138 but u=545  $ SW Bottom Corner Pebble
7762 like 4136 but u=547  $ N Bottom Corner Pebble
7763 like 4138 but u=547  $ SW Bottom Corner Pebble
7764 like 4136 but u=548  $ N Bottom Corner Pebble
7765 like 4137 but u=548  $ SE Bottom Corner Pebble
7766 like 4138 but u=548  $ SW Bottom Corner Pebble
7767 like 4136 but u=549  $ N Bottom Corner Pebble
7768 like 4136 but u=550  $ N Bottom Corner Pebble
7769 like 4136 but u=551  $ N Bottom Corner Pebble
7770 like 4136 but u=552  $ N Bottom Corner Pebble
7771 like 4137 but u=552  $ SE Bottom Corner Pebble
7772 like 4138 but u=552  $ SW Bottom Corner Pebble
7773 like 4136 but u=553  $ N Bottom Corner Pebble
7774 like 4137 but u=553  $ SE Bottom Corner Pebble
7775 like 4136 but u=554  $ N Bottom Corner Pebble
7776 like 4136 but u=556  $ N Bottom Corner Pebble
7777 like 4137 but u=556  $ SE Bottom Corner Pebble
c
c --------- Bottom and Middle Fuel with Top Moderator Lattices ---------
7778 like 7332 but u=624  $ Middle Top Pebble
7779 like 7334 but u=624  $ NW Top Corner Pebble
7780 like 7336 but u=624  $ NE Top Corner Pebble
7781 like 7338 but u=624  $ S Top Corner Pebble
7782 like 7336 but u=625  $ NE Top Corner Pebble
7783 like 7332 but u=626  $ Middle Top Pebble
7784 like 7334 but u=626  $ NW Top Corner Pebble
7785 like 7336 but u=626  $ NE Top Corner Pebble
7786 like 7338 but u=626  $ S Top Corner Pebble
7787 like 7332 but u=627  $ Middle Top Pebble
7788 like 7336 but u=627  $ NE Top Corner Pebble
7789 like 7338 but u=627  $ S Top Corner Pebble
7790 like 7332 but u=629  $ Middle Top Pebble
7791 like 7336 but u=629  $ NE Top Corner Pebble
7792 like 7338 but u=629  $ S Top Corner Pebble
7793 like 7332 but u=631  $ Middle Top Pebble
7794 like 7336 but u=631  $ NE Top Corner Pebble
7795 like 7338 but u=631  $ S Top Corner Pebble
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7796 like 7338 but u=632  $ S Top Corner Pebble
7797 like 7332 but u=633  $ Middle Top Pebble
7798 like 7334 but u=633  $ NW Top Corner Pebble
7799 like 7336 but u=633  $ NE Top Corner Pebble
7800 like 7338 but u=633  $ S Top Corner Pebble
7801 like 7338 but u=634  $ S Top Corner Pebble
7802 like 7338 but u=635  $ S Top Corner Pebble
7803 like 7332 but u=636  $ Middle Top Pebble
7804 like 7334 but u=636  $ NW Top Corner Pebble
7805 like 7338 but u=636  $ S Top Corner Pebble
7806 like 7338 but u=637  $ S Top Corner Pebble
7807 like 7332 but u=638  $ Middle Top Pebble
7808 like 7334 but u=638  $ NW Top Corner Pebble
7809 like 7336 but u=638  $ NE Top Corner Pebble
7810 like 7338 but u=638  $ S Top Corner Pebble
7811 like 7332 but u=640  $ Middle Top Pebble
7812 like 7334 but u=640  $ NW Top Corner Pebble
7813 like 7338 but u=640  $ S Top Corner Pebble
7814 like 7332 but u=642  $ Middle Top Pebble
7815 like 7334 but u=642  $ NW Top Corner Pebble
7816 like 7338 but u=642  $ S Top Corner Pebble
7817 like 7334 but u=643  $ NW Top Corner Pebble
7818 like 7334 but u=644  $ NW Top Corner Pebble
7819 like 7332 but u=645  $ Middle Top Pebble
7820 like 7334 but u=645  $ NW Top Corner Pebble
7821 like 7336 but u=645  $ NE Top Corner Pebble
7822 like 7338 but u=645  $ S Top Corner Pebble
7823 like 7334 but u=646  $ NW Top Corner Pebble
7824 like 7332 but u=647  $ Middle Top Pebble
7825 like 7334 but u=647  $ NW Top Corner Pebble
7826 like 7336 but u=647  $ NE Top Corner Pebble
7827 like 7332 but u=648  $ Middle Top Pebble
7828 like 7334 but u=648  $ NW Top Corner Pebble
7829 like 7336 but u=648  $ NE Top Corner Pebble
7830 like 7338 but u=648  $ S Top Corner Pebble
7831 like 7334 but u=649  $ NW Top Corner Pebble
7832 like 7332 but u=652  $ Middle Top Pebble
7833 like 7334 but u=652  $ NW Top Corner Pebble
7834 like 7336 but u=652  $ NE Top Corner Pebble
7835 like 7332 but u=653  $ Middle Top Pebble
7836 like 7334 but u=653  $ NW Top Corner Pebble
7837 like 7336 but u=653  $ NE Top Corner Pebble
7838 like 7336 but u=654  $ NE Top Corner Pebble
7839 like 7336 but u=655  $ NE Top Corner Pebble
7840 like 7332 but u=656  $ Middle Top Pebble
7841 like 7334 but u=656  $ NW Top Corner Pebble
7842 like 7336 but u=656  $ NE Top Corner Pebble
7843 like 7338 but u=656  $ S Top Corner Pebble
7844 like 7336 but u=657  $ NE Top Corner Pebble
7845 like 4131 but u=624  $ N Top Corner Pebble
7846 like 4132 but u=624  $ SE Top Corner Pebble
7847 like 4133 but u=624  $ SW Top Corner Pebble
7848 like 4134 but u=624  $ NE Middle Edge Pebble
7849 like 4135 but u=624  $ SW Middle Edge Pebble
7850 like 4136 but u=624  $ N Bottom Corner Pebble
7851 like 4137 but u=624  $ SE Bottom Corner Pebble
7852 like 4138 but u=624  $ SW Bottom Corner Pebble
7853 like 4132 but u=625  $ SE Top Corner Pebble
7854 like 4137 but u=625  $ SE Bottom Corner Pebble
7855 like 4131 but u=626  $ N Top Corner Pebble
7856 like 4132 but u=626  $ SE Top Corner Pebble
7857 like 4133 but u=626  $ SW Top Corner Pebble
7858 like 4134 but u=626  $ NE Middle Edge Pebble
7859 like 4135 but u=626  $ SW Middle Edge Pebble
7860 like 4136 but u=626  $ N Bottom Corner Pebble
7861 like 4137 but u=626  $ SE Bottom Corner Pebble
7862 like 4138 but u=626  $ SW Bottom Corner Pebble
7863 like 4131 but u=627  $ N Top Corner Pebble
7864 like 4132 but u=627  $ SE Top Corner Pebble
7865 like 4134 but u=627  $ NE Middle Edge Pebble
7866 like 4136 but u=627  $ N Bottom Corner Pebble
7867 like 4137 but u=627  $ SE Bottom Corner Pebble
7868 like 4132 but u=628  $ SE Top Corner Pebble
7869 like 4137 but u=628  $ SE Bottom Corner Pebble
7870 like 4131 but u=629  $ N Top Corner Pebble
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7871 like 4132 but u=629  $ SE Top Corner Pebble
7872 like 4133 but u=629  $ SW Top Corner Pebble
7873 like 4134 but u=629  $ NE Middle Edge Pebble
7874 like 4135 but u=629  $ SW Middle Edge Pebble
7875 like 4136 but u=629  $ N Bottom Corner Pebble
7876 like 4137 but u=629  $ SE Bottom Corner Pebble
7877 like 4138 but u=629  $ SW Bottom Corner Pebble
7878 like 4132 but u=630  $ SE Top Corner Pebble
7879 like 4137 but u=630  $ SE Bottom Corner Pebble
7880 like 4132 but u=631  $ SE Top Corner Pebble
7881 like 4133 but u=631  $ SW Top Corner Pebble
7882 like 4135 but u=631  $ SW Middle Edge Pebble
7883 like 4137 but u=631  $ SE Bottom Corner Pebble
7884 like 4138 but u=631  $ SW Bottom Corner Pebble
7885 like 4132 but u=632  $ SE Top Corner Pebble
7886 like 4137 but u=632  $ SE Bottom Corner Pebble
7887 like 4132 but u=633  $ SE Top Corner Pebble
7888 like 4133 but u=633  $ SW Top Corner Pebble
7889 like 4135 but u=633  $ SW Middle Edge Pebble
7890 like 4137 but u=633  $ SE Bottom Corner Pebble
7891 like 4138 but u=633  $ SW Bottom Corner Pebble
7892 like 4132 but u=636  $ SE Top Corner Pebble
7893 like 4133 but u=636  $ SW Top Corner Pebble
7894 like 4135 but u=636  $ SW Middle Edge Pebble
7895 like 4137 but u=636  $ SE Bottom Corner Pebble
7896 like 4138 but u=636  $ SW Bottom Corner Pebble
7897 like 4133 but u=637  $ SW Top Corner Pebble
7898 like 4138 but u=637  $ SW Bottom Corner Pebble
7899 like 4131 but u=638  $ N Top Corner Pebble
7900 like 4132 but u=638  $ SE Top Corner Pebble
7901 like 4133 but u=638  $ SW Top Corner Pebble
7902 like 4135 but u=638  $ SW Middle Edge Pebble
7903 like 4136 but u=638  $ N Bottom Corner Pebble
7904 like 4137 but u=638  $ SE Bottom Corner Pebble
7905 like 4138 but u=638  $ SW Bottom Corner Pebble
7906 like 4133 but u=639  $ SW Top Corner Pebble
7907 like 4138 but u=639  $ SW Bottom Corner Pebble
7908 like 4131 but u=640  $ N Top Corner Pebble
7909 like 4132 but u=640  $ SE Top Corner Pebble
7910 like 4133 but u=640  $ SW Top Corner Pebble
7911 like 4135 but u=640  $ SW Middle Edge Pebble
7912 like 4136 but u=640  $ N Bottom Corner Pebble
7913 like 4137 but u=640  $ SE Bottom Corner Pebble
7914 like 4138 but u=640  $ SW Bottom Corner Pebble
7915 like 4133 but u=641  $ SW Top Corner Pebble
7916 like 4138 but u=641  $ SW Bottom Corner Pebble
7917 like 4131 but u=642  $ N Top Corner Pebble
7918 like 4133 but u=642  $ SW Top Corner Pebble
7919 like 4135 but u=642  $ SW Middle Edge Pebble
7920 like 4136 but u=642  $ N Bottom Corner Pebble
7921 like 4138 but u=642  $ SW Bottom Corner Pebble
7922 like 4133 but u=643  $ SW Top Corner Pebble
7923 like 4138 but u=643  $ SW Bottom Corner Pebble
7924 like 4131 but u=645  $ N Top Corner Pebble
7925 like 4133 but u=645  $ SW Top Corner Pebble
7926 like 4134 but u=645  $ NE Middle Edge Pebble
7927 like 4135 but u=645  $ SW Middle Edge Pebble
7928 like 4136 but u=645  $ N Bottom Corner Pebble
7929 like 4138 but u=645  $ SW Bottom Corner Pebble
7930 like 4131 but u=647  $ N Top Corner Pebble
7931 like 4133 but u=647  $ SW Top Corner Pebble
7932 like 4134 but u=647  $ NE Middle Edge Pebble
7933 like 4136 but u=647  $ N Bottom Corner Pebble
7934 like 4138 but u=647  $ SW Bottom Corner Pebble
7935 like 4131 but u=648  $ N Top Corner Pebble
7936 like 4132 but u=648  $ SE Top Corner Pebble
7937 like 4133 but u=648  $ SW Top Corner Pebble
7938 like 4134 but u=648  $ NE Middle Edge Pebble
7939 like 4135 but u=648  $ SW Middle Edge Pebble
7940 like 4136 but u=648  $ N Bottom Corner Pebble
7941 like 4137 but u=648  $ SE Bottom Corner Pebble
7942 like 4138 but u=648  $ SW Bottom Corner Pebble
7943 like 4131 but u=649  $ N Top Corner Pebble
7944 like 4136 but u=649  $ N Bottom Corner Pebble
7945 like 4131 but u=650  $ N Top Corner Pebble
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7946 like 4136 but u=650  $ N Bottom Corner Pebble
7947 like 4131 but u=651  $ N Top Corner Pebble
7948 like 4134 but u=651  $ NE Middle Edge Pebble
7949 like 4136 but u=651  $ N Bottom Corner Pebble
7950 like 4131 but u=652  $ N Top Corner Pebble
7951 like 4132 but u=652  $ SE Top Corner Pebble
7952 like 4133 but u=652  $ SW Top Corner Pebble
7953 like 4134 but u=652  $ NE Middle Edge Pebble
7954 like 4135 but u=652  $ SW Middle Edge Pebble
7955 like 4136 but u=652  $ N Bottom Corner Pebble
7956 like 4137 but u=652  $ SE Bottom Corner Pebble
7957 like 4138 but u=652  $ SW Bottom Corner Pebble
7958 like 4131 but u=653  $ N Top Corner Pebble
7959 like 4132 but u=653  $ SE Top Corner Pebble
7960 like 4134 but u=653  $ NE Middle Edge Pebble
7961 like 4136 but u=653  $ N Bottom Corner Pebble
7962 like 4137 but u=653  $ SE Bottom Corner Pebble
7963 like 4131 but u=654  $ N Top Corner Pebble
7964 like 4134 but u=654  $ NE Middle Edge Pebble
7965 like 4136 but u=654  $ N Bottom Corner Pebble
7966 like 4134 but u=655  $ NE Middle Edge Pebble
7967 like 4131 but u=656  $ N Top Corner Pebble
7968 like 4132 but u=656  $ SE Top Corner Pebble
7969 like 4134 but u=656  $ NE Middle Edge Pebble
7970 like 4135 but u=656  $ SW Middle Edge Pebble
7971 like 4136 but u=656  $ N Bottom Corner Pebble
7972 like 4137 but u=656  $ SE Bottom Corner Pebble
c
c --------- Regular Lattice with Polyethylene Rods ---------
8378 like 4131 but u=724  $ N Top Corner Pebble
8379 like 4132 but u=724  $ SE Top Corner Pebble
8380 like 4133 but u=724  $ SW Top Corner Pebble
8381 like 4134 but u=724  $ NE Middle Edge Pebble
8382 like 4135 but u=724  $ SW Middle Edge Pebble
8383 like 4136 but u=724  $ N Bottom Corner Pebble
8384 like 4137 but u=724  $ SE Bottom Corner Pebble
8385 like 4138 but u=724  $ SW Bottom Corner Pebble
8386 like 4132 but u=725  $ SE Top Corner Pebble
8387 like 4137 but u=725  $ SE Bottom Corner Pebble
8388 like 4131 but u=726  $ N Top Corner Pebble
8389 like 4132 but u=726  $ SE Top Corner Pebble
8390 like 4133 but u=726  $ SW Top Corner Pebble
8391 like 4134 but u=726  $ NE Middle Edge Pebble
8392 like 4135 but u=726  $ SW Middle Edge Pebble
8393 like 4136 but u=726  $ N Bottom Corner Pebble
8394 like 4137 but u=726  $ SE Bottom Corner Pebble
8395 like 4138 but u=726  $ SW Bottom Corner Pebble
8396 like 4131 but u=727  $ N Top Corner Pebble
8397 like 4132 but u=727  $ SE Top Corner Pebble
8398 like 4134 but u=727  $ NE Middle Edge Pebble
8399 like 4136 but u=727  $ N Bottom Corner Pebble
8400 like 4137 but u=727  $ SE Bottom Corner Pebble
8401 like 4132 but u=728  $ SE Top Corner Pebble
8402 like 4137 but u=728  $ SE Bottom Corner Pebble
8403 like 4131 but u=729  $ N Top Corner Pebble
8404 like 4132 but u=729  $ SE Top Corner Pebble
8405 like 4133 but u=729  $ SW Top Corner Pebble
8406 like 4134 but u=729  $ NE Middle Edge Pebble
8407 like 4135 but u=729  $ SW Middle Edge Pebble
8408 like 4136 but u=729  $ N Bottom Corner Pebble
8409 like 4137 but u=729  $ SE Bottom Corner Pebble
8410 like 4138 but u=729  $ SW Bottom Corner Pebble
8411 like 4132 but u=730  $ SE Top Corner Pebble
8412 like 4137 but u=730  $ SE Bottom Corner Pebble
8413 like 4132 but u=731  $ SE Top Corner Pebble
8414 like 4133 but u=731  $ SW Top Corner Pebble
8415 like 4135 but u=731  $ SW Middle Edge Pebble
8416 like 4137 but u=731  $ SE Bottom Corner Pebble
8417 like 4138 but u=731  $ SW Bottom Corner Pebble
8418 like 4132 but u=732  $ SE Top Corner Pebble
8419 like 4137 but u=732  $ SE Bottom Corner Pebble
8420 like 4132 but u=733  $ SE Top Corner Pebble
8421 like 4133 but u=733  $ SW Top Corner Pebble
8422 like 4135 but u=733  $ SW Middle Edge Pebble
8423 like 4137 but u=733  $ SE Bottom Corner Pebble
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8424 like 4138 but u=733  $ SW Bottom Corner Pebble
8425 like 4132 but u=736  $ SE Top Corner Pebble
8426 like 4133 but u=736  $ SW Top Corner Pebble
8427 like 4135 but u=736  $ SW Middle Edge Pebble
8428 like 4137 but u=736  $ SE Bottom Corner Pebble
8429 like 4138 but u=736  $ SW Bottom Corner Pebble
8430 like 4133 but u=737  $ SW Top Corner Pebble
8431 like 4138 but u=737  $ SW Bottom Corner Pebble
8432 like 4131 but u=738  $ N Top Corner Pebble
8433 like 4132 but u=738  $ SE Top Corner Pebble
8434 like 4133 but u=738  $ SW Top Corner Pebble
8435 like 4135 but u=738  $ SW Middle Edge Pebble
8436 like 4136 but u=738  $ N Bottom Corner Pebble
8437 like 4137 but u=738  $ SE Bottom Corner Pebble
8438 like 4138 but u=738  $ SW Bottom Corner Pebble
8439 like 4133 but u=739  $ SW Top Corner Pebble
8440 like 4138 but u=739  $ SW Bottom Corner Pebble
8441 like 4131 but u=740  $ N Top Corner Pebble
8442 like 4132 but u=740  $ SE Top Corner Pebble
8443 like 4133 but u=740  $ SW Top Corner Pebble
8444 like 4135 but u=740  $ SW Middle Edge Pebble
8445 like 4136 but u=740  $ N Bottom Corner Pebble
8446 like 4137 but u=740  $ SE Bottom Corner Pebble
8447 like 4138 but u=740  $ SW Bottom Corner Pebble
8448 like 4133 but u=741  $ SW Top Corner Pebble
8449 like 4138 but u=741  $ SW Bottom Corner Pebble
8450 like 4131 but u=742  $ N Top Corner Pebble
8451 like 4133 but u=742  $ SW Top Corner Pebble
8452 like 4135 but u=742  $ SW Middle Edge Pebble
8453 like 4136 but u=742  $ N Bottom Corner Pebble
8454 like 4138 but u=742  $ SW Bottom Corner Pebble
8455 like 4133 but u=743  $ SW Top Corner Pebble
8456 like 4138 but u=743  $ SW Bottom Corner Pebble
8457 like 4131 but u=745  $ N Top Corner Pebble
8458 like 4133 but u=745  $ SW Top Corner Pebble
8459 like 4134 but u=745  $ NE Middle Edge Pebble
8460 like 4135 but u=745  $ SW Middle Edge Pebble
8461 like 4136 but u=745  $ N Bottom Corner Pebble
8462 like 4138 but u=745  $ SW Bottom Corner Pebble
8463 like 4131 but u=747  $ N Top Corner Pebble
8464 like 4133 but u=747  $ SW Top Corner Pebble
8465 like 4134 but u=747  $ NE Middle Edge Pebble
8466 like 4136 but u=747  $ N Bottom Corner Pebble
8467 like 4138 but u=747  $ SW Bottom Corner Pebble
8468 like 4131 but u=748  $ N Top Corner Pebble
8469 like 4132 but u=748  $ SE Top Corner Pebble
8470 like 4133 but u=748  $ SW Top Corner Pebble
8471 like 4134 but u=748  $ NE Middle Edge Pebble
8472 like 4135 but u=748  $ SW Middle Edge Pebble
8473 like 4136 but u=748  $ N Bottom Corner Pebble
8474 like 4137 but u=748  $ SE Bottom Corner Pebble
8475 like 4138 but u=748  $ SW Bottom Corner Pebble
8476 like 4131 but u=749  $ N Top Corner Pebble
8477 like 4136 but u=749  $ N Bottom Corner Pebble
8478 like 4131 but u=750  $ N Top Corner Pebble
8479 like 4136 but u=750  $ N Bottom Corner Pebble
8480 like 4131 but u=751  $ N Top Corner Pebble
8481 like 4134 but u=751  $ NE Middle Edge Pebble
8482 like 4136 but u=751  $ N Bottom Corner Pebble
8483 like 4131 but u=752  $ N Top Corner Pebble
8484 like 4132 but u=752  $ SE Top Corner Pebble
8485 like 4133 but u=752  $ SW Top Corner Pebble
8486 like 4134 but u=752  $ NE Middle Edge Pebble
8487 like 4135 but u=752  $ SW Middle Edge Pebble
8488 like 4136 but u=752  $ N Bottom Corner Pebble
8489 like 4137 but u=752  $ SE Bottom Corner Pebble
8490 like 4138 but u=752  $ SW Bottom Corner Pebble
8491 like 4131 but u=753  $ N Top Corner Pebble
8492 like 4132 but u=753  $ SE Top Corner Pebble
8493 like 4134 but u=753  $ NE Middle Edge Pebble
8494 like 4136 but u=753  $ N Bottom Corner Pebble
8495 like 4137 but u=753  $ SE Bottom Corner Pebble
8496 like 4131 but u=754  $ N Top Corner Pebble
8497 like 4134 but u=754  $ NE Middle Edge Pebble
8498 like 4136 but u=754  $ N Bottom Corner Pebble
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8499 like 4134 but u=755  $ NE Middle Edge Pebble
8501 like 4131 but u=756  $ N Top Corner Pebble
8502 like 4132 but u=756  $ SE Top Corner Pebble
8503 like 4134 but u=756  $ NE Middle Edge Pebble
8504 like 4135 but u=756  $ SW Middle Edge Pebble
8505 like 4136 but u=756  $ N Bottom Corner Pebble
8506 like 4137 but u=756  $ SE Bottom Corner Pebble
c
c --------- Bottom Layer Only Lattices with Polyethylene Rods ---------
8641 like 4136 but u=824  $ N Bottom Corner Pebble
8642 like 4137 but u=824  $ SE Bottom Corner Pebble
8643 like 4138 but u=824  $ SW Bottom Corner Pebble
8644 like 4137 but u=825  $ SE Bottom Corner Pebble
8645 like 4136 but u=826  $ N Bottom Corner Pebble
8646 like 4137 but u=826  $ SE Bottom Corner Pebble
8647 like 4138 but u=826  $ SW Bottom Corner Pebble
8648 like 4136 but u=827  $ N Bottom Corner Pebble
8649 like 4137 but u=827  $ SE Bottom Corner Pebble
8650 like 4137 but u=828  $ SE Bottom Corner Pebble
8651 like 4136 but u=829  $ N Bottom Corner Pebble
8652 like 4137 but u=829  $ SE Bottom Corner Pebble
8653 like 4138 but u=829  $ SW Bottom Corner Pebble
8654 like 4137 but u=830  $ SE Bottom Corner Pebble
8655 like 4137 but u=831  $ SE Bottom Corner Pebble
8656 like 4138 but u=831  $ SW Bottom Corner Pebble
8657 like 4137 but u=832  $ SE Bottom Corner Pebble
8658 like 4137 but u=833  $ SE Bottom Corner Pebble
8659 like 4138 but u=833  $ SW Bottom Corner Pebble
8660 like 4137 but u=836  $ SE Bottom Corner Pebble
8661 like 4138 but u=836  $ SW Bottom Corner Pebble
8662 like 4138 but u=837  $ SW Bottom Corner Pebble
8663 like 4136 but u=838  $ N Bottom Corner Pebble
8664 like 4137 but u=838  $ SE Bottom Corner Pebble
8665 like 4138 but u=838  $ SW Bottom Corner Pebble
8666 like 4138 but u=839  $ SW Bottom Corner Pebble
8667 like 4136 but u=840  $ N Bottom Corner Pebble
8668 like 4137 but u=840  $ SE Bottom Corner Pebble
8669 like 4138 but u=840  $ SW Bottom Corner Pebble
8670 like 4138 but u=841  $ SW Bottom Corner Pebble
8671 like 4136 but u=842  $ N Bottom Corner Pebble
8672 like 4138 but u=842  $ SW Bottom Corner Pebble
8673 like 4138 but u=843  $ SW Bottom Corner Pebble
8674 like 4136 but u=845  $ N Bottom Corner Pebble
8675 like 4138 but u=845  $ SW Bottom Corner Pebble
8676 like 4136 but u=847  $ N Bottom Corner Pebble
8677 like 4138 but u=847  $ SW Bottom Corner Pebble
8678 like 4136 but u=848  $ N Bottom Corner Pebble
8679 like 4137 but u=848  $ SE Bottom Corner Pebble
8680 like 4138 but u=848  $ SW Bottom Corner Pebble
8681 like 4136 but u=849  $ N Bottom Corner Pebble
8682 like 4136 but u=850  $ N Bottom Corner Pebble
8683 like 4136 but u=851  $ N Bottom Corner Pebble
8684 like 4136 but u=852  $ N Bottom Corner Pebble
8685 like 4137 but u=852  $ SE Bottom Corner Pebble
8686 like 4138 but u=852  $ SW Bottom Corner Pebble
8687 like 4136 but u=853  $ N Bottom Corner Pebble
8688 like 4137 but u=853  $ SE Bottom Corner Pebble
8689 like 4136 but u=854  $ N Bottom Corner Pebble
8690 like 4136 but u=856  $ N Bottom Corner Pebble
8691 like 4137 but u=856  $ SE Bottom Corner Pebble
c
c --------- Top Layer Only Lattices with Polyethylene Rods ---------
8826 like 4131 but u=924  $ N Top Corner Pebble
8827 like 4132 but u=924  $ SE Top Corner Pebble
8828 like 4133 but u=924  $ SW Top Corner Pebble
8829 like 4132 but u=925  $ SE Top Corner Pebble
8830 like 4131 but u=926  $ N Top Corner Pebble
8831 like 4132 but u=926  $ SE Top Corner Pebble
8832 like 4133 but u=926  $ SW Top Corner Pebble
8833 like 4131 but u=927  $ N Top Corner Pebble
8834 like 4132 but u=927  $ SE Top Corner Pebble
8835 like 4132 but u=928  $ SE Top Corner Pebble
8836 like 4131 but u=929  $ N Top Corner Pebble
8837 like 4132 but u=929  $ SE Top Corner Pebble
8838 like 4133 but u=929  $ SW Top Corner Pebble
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8839 like 4132 but u=930  $ SE Top Corner Pebble
8840 like 4132 but u=931  $ SE Top Corner Pebble
8841 like 4133 but u=931  $ SW Top Corner Pebble
8842 like 4132 but u=932  $ SE Top Corner Pebble
8843 like 4132 but u=933  $ SE Top Corner Pebble
8844 like 4133 but u=933  $ SW Top Corner Pebble
8845 like 4132 but u=936  $ SE Top Corner Pebble
8846 like 4133 but u=936  $ SW Top Corner Pebble
8847 like 4133 but u=937  $ SW Top Corner Pebble
8848 like 4131 but u=938  $ N Top Corner Pebble
8849 like 4132 but u=938  $ SE Top Corner Pebble
8850 like 4133 but u=938  $ SW Top Corner Pebble
8851 like 4133 but u=939  $ SW Top Corner Pebble
8852 like 4131 but u=940  $ N Top Corner Pebble
8853 like 4132 but u=940  $ SE Top Corner Pebble
8854 like 4133 but u=940  $ SW Top Corner Pebble
8855 like 4133 but u=941  $ SW Top Corner Pebble
8856 like 4131 but u=942  $ N Top Corner Pebble
8857 like 4133 but u=942  $ SW Top Corner Pebble
8858 like 4133 but u=943  $ SW Top Corner Pebble
8859 like 4131 but u=945  $ N Top Corner Pebble
8860 like 4133 but u=945  $ SW Top Corner Pebble
8861 like 4131 but u=947  $ N Top Corner Pebble
8862 like 4133 but u=947  $ SW Top Corner Pebble
8863 like 4131 but u=948  $ N Top Corner Pebble
8864 like 4132 but u=948  $ SE Top Corner Pebble
8865 like 4133 but u=948  $ SW Top Corner Pebble
8866 like 4131 but u=949  $ N Top Corner Pebble
8867 like 4131 but u=950  $ N Top Corner Pebble
8868 like 4131 but u=951  $ N Top Corner Pebble
8869 like 4131 but u=952  $ N Top Corner Pebble
8870 like 4132 but u=952  $ SE Top Corner Pebble
8871 like 4133 but u=952  $ SW Top Corner Pebble
8872 like 4131 but u=953  $ N Top Corner Pebble
8873 like 4132 but u=953  $ SE Top Corner Pebble
8874 like 4131 but u=954  $ N Top Corner Pebble
8875 like 4131 but u=956  $ N Top Corner Pebble
8876 like 4132 but u=956  $ SE Top Corner Pebble
c
c
c
c ------ Air ------
c --------- Regular (Full) Lattice ---------
5131 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3144 3146 3148 3150 3152 3154
          4131 4132 4133 4134 4135 4136 4137 4138 imp:n=1 u=24
c
c --------- Regular (Partial) Lattices ---------
5132 10 4.8129E-05  3136 3150 4132 4137 imp:n=1 u=25  $ 1
5133 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3146 3148 3150 3152 3154
          4131 4132 4133 4134 4135 4136 4137 4138 imp:n=1 u=26  $ 2
5134 10 4.8129E-05  3132 3136 3138 3142 3144 3146 3150 3152 3154
          4131 4132 4134 4136 4137 imp:n=1 u=27  $ 3
5135 10 4.8129E-05  4132 4137 imp:n=1 u=28  $ 4
5136 10 4.8129E-05  3132 3136 3138 3140 3142 3146 3150 3152 3154
          4131 4132 4133 4134 4135 4136 4137 4138 imp:n=1 u=29  $ 5
5137 10 4.8129E-05  3146 4132 4137 imp:n=1 u=30  $ 6
5138 10 4.8129E-05  3132 3136 3138 3142 3146 3150 3152 3154
          4132 4133 4135 4137 4138 imp:n=1 u=31  $ 7
5139 10 4.8129E-05  3138 3146 3152 4132 4137 imp:n=1 u=32  $ 8
5140 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3144 3146 3148 3150 3152 3154
          4132 4133 4135 4137 4138 imp:n=1 u=33  $ 9
5141 10 4.8129E-05  3138 3146 3152 imp:n=1 u=34  $ 10
5142 10 4.8129E-05  3138 3152 imp:n=1 u=35  $ 11
5143 10 4.8129E-05  3132 3134 3138 3144 3146 3148 3152 3154
          4132 4133 4135 4137 4138 imp:n=1 u=36  $ 12
5144 10 4.8129E-05  3138 3152 4133 4138 imp:n=1 u=37  $ 13
5145 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3144 3146 3148 3150 3152 3154
          4131 4132 4133 4135 4136 4137 4138 imp:n=1 u=38  $ 14
5146 10 4.8129E-05  4133 4138 imp:n=1 u=39  $ 15
5147 10 4.8129E-05  3132 3134 3138 3140 3142 3144 3146 3148 3152 3154
          4131 4132 4133 4135 4136 4137 4138 imp:n=1 u=40  $ 16
5148 10 4.8129E-05  3144 4133 4138 imp:n=1 u=41  $ 17
5149 10 4.8129E-05  3132 3134 3138 3140 3144 3148 3152 3154
          4131 4133 4135 4136 4138 imp:n=1 u=42  $ 18
5150 10 4.8129E-05  3134 3144 3148 4133 4138 imp:n=1 u=43  $ 19
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5151 10 4.8129E-05  3134 3144 3148 imp:n=1 u=44  $ 20
5152 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3144 3148 3150 3152 3154
          4131 4133 4134 4135 4136 4138 imp:n=1 u=45  $ 21
5153 10 4.8129E-05  3134 3148 imp:n=1 u=46  $ 22
5154 10 4.8129E-05  3132 3134 3136 3140 3144 3148 3150 3154
          4131 4133 4134 4136 4138 imp:n=1 u=47  $ 23
5155 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3144 3148 3150 3152 3154
          4131 4132 4133 4134 4135 4136 4137 4138 imp:n=1 u=48  $ 24
5156 10 4.8129E-05  3134 3148 4131 4136 imp:n=1 u=49  $ 25
5157 10 4.8129E-05  4131 4136 imp:n=1 u=50  $ 26
5158 10 4.8129E-05  4131 4134 4136 imp:n=1 u=51  $ 27
5159 10 4.8129E-05  3132 3134 3136 3140 3142 3144 3148 3150 3154
          4131 4132 4133 4134 4135 4136 4137 4138 imp:n=1 u=52  $ 28
5160 10 4.8129E-05  3132 3134 3136 3140 3142 3148 3150 3154
          4131 4132 4134 4136 4137 imp:n=1 u=53  $ 29
5161 10 4.8129E-05  3136 3150 4131 4134 4136 imp:n=1 u=54  $ 30
5162 10 4.8129E-05  3136 3150 4134 imp:n=1 u=55  $ 31
5163 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3146 3148 3150 3152 3154
          4131 4132 4134 4135 4136 4137 imp:n=1 u=56  $ 32
5164 10 4.8129E-05  3136 3150 imp:n=1 u=57  $ 33
c
c --------- Bottom Layer Only Lattices ---------
5165 10 4.8129E-05  3148 3150 3152 3154 4136 4137 4138 imp:n=1 u=124  $ regular
5166 10 4.8129E-05  3150 4137 imp:n=1 u=125  $ 1
5167 10 4.8129E-05  3148 3150 3152 3154 4136 4137 4138 imp:n=1 u=126  $ 2
5168 10 4.8129E-05  3150 3152 3154 4136 4137 imp:n=1 u=127  $ 3
5169 10 4.8129E-05  4137 imp:n=1 u=128  $ 4
5170 10 4.8129E-05  3150 3152 3154 4136 4137 4138 imp:n=1 u=129  $ 5
5171 10 4.8129E-05  4137 imp:n=1 u=130  $ 6
5172 10 4.8129E-05  3150 3152 3154 4137 4138 imp:n=1 u=131  $ 7
5173 10 4.8129E-05  3152 4137 imp:n=1 u=132  $ 8
5174 10 4.8129E-05  3148 3150 3152 3154 4137 4138 imp:n=1 u=133  $ 9
5175 10 4.8129E-05  3152 imp:n=1 u=134  $ 10
5176 10 4.8129E-05  3152 imp:n=1 u=135  $ 11
5177 10 4.8129E-05  3148 3152 3154 4137 4138 imp:n=1 u=136  $ 12
5178 10 4.8129E-05  3152 4138 imp:n=1 u=137  $ 13
5179 10 4.8129E-05  3148 3150 3152 3154 4136 4137 4138 imp:n=1 u=138  $ 14
5180 10 4.8129E-05  4138 imp:n=1 u=139  $ 15
5181 10 4.8129E-05  3148 3152 3154 4136 4137 4138 imp:n=1 u=140  $ 16
5182 10 4.8129E-05  4138 imp:n=1 u=141  $ 17
5183 10 4.8129E-05  3148 3152 3154 4136 4138 imp:n=1 u=142  $ 18
5184 10 4.8129E-05  3148 4138 imp:n=1 u=143  $ 19
5185 10 4.8129E-05  3148 imp:n=1 u=144  $ 20
5186 10 4.8129E-05  3148 3150 3152 3154 4136 4138 imp:n=1 u=145  $ 21
5187 10 4.8129E-05  3148 imp:n=1 u=146  $ 22
5188 10 4.8129E-05  3148 3150 3154 4136 4138 imp:n=1 u=147  $ 23
5189 10 4.8129E-05  3148 3150 3152 3154 4136 4137 4138 imp:n=1 u=148  $ 24
5190 10 4.8129E-05  3148 4136 imp:n=1 u=149  $ 25
5191 10 4.8129E-05  4136 imp:n=1 u=150  $ 26
5192 10 4.8129E-05  4136 imp:n=1 u=151  $ 27
5193 10 4.8129E-05  3148 3150 3154 4136 4137 4138 imp:n=1 u=152  $ 28
5194 10 4.8129E-05  3148 3150 3154 4136 4137 imp:n=1 u=153  $ 29
5195 10 4.8129E-05  3150 4136 imp:n=1 u=154  $ 30
5196 10 4.8129E-05  3150 imp:n=1 u=155  $ 31
5197 10 4.8129E-05  3148 3150 3152 3154 4136 4137 imp:n=1 u=156  $ 32
5198 10 4.8129E-05  3150 imp:n=1 u=157  $ 33
c
c --------- Bottom and Middle Layers Only Lattices ---------
5199 10 4.8129E-05  3140 3142 3144 3146 3148 3150 3152 3154
          4134 4135 4136 4137 4138 imp:n=1 u=224  $ regular
5200 10 4.8129E-05  3150 4137 imp:n=1 u=225  $ 1
5201 10 4.8129E-05  3140 3142 3146 3148 3150 3152 3154
          4134 4135 4136 4137 4138 imp:n=1 u=226  $ 2
5202 10 4.8129E-05  3142 3144 3146 3150 3152 3154 4134 4136 4137 imp:n=1 u=227  $ 3
5203 10 4.8129E-05  4137 imp:n=1 u=228  $ 4
5204 10 4.8129E-05  3140 3142 3146 3150 3152 3154 4134 4135 4136 4137 4138
           imp:n=1 u=229  $ 5
5205 10 4.8129E-05  3146 4137 imp:n=1 u=230  $ 6
5206 10 4.8129E-05  3142 3146 3150 3152 3154 4135 4137 4138 imp:n=1 u=231  $ 7
5207 10 4.8129E-05  3146 3152 4137 imp:n=1 u=232  $ 8
5208 10 4.8129E-05  3140 3142 3144 3146 3148 3150 3152 3154
          4135 4137 4138 imp:n=1 u=233  $ 9
5209 10 4.8129E-05  3146 3152 imp:n=1 u=234  $ 10
5210 10 4.8129E-05  3152 imp:n=1 u=235  $ 11
5211 10 4.8129E-05  3144 3146 3148 3152 3154 4135 4137 4138 imp:n=1 u=236  $ 12
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5212 10 4.8129E-05  3152 4138 imp:n=1 u=237  $ 13
5213 10 4.8129E-05  3140 3142 3144 3146 3148 3150 3152 3154
          4135 4136 4137 4138 imp:n=1 u=238  $ 14
5214 10 4.8129E-05  4138 imp:n=1 u=239  $ 15
5215 10 4.8129E-05  3140 3142 3144 3146 3148 3152 3154
          4135 4136 4137 4138 imp:n=1 u=240  $ 16
5216 10 4.8129E-05  3144 4138 imp:n=1 u=241  $ 17
5217 10 4.8129E-05  3140 3144 3148 3152 3154 4135 4136 4138 imp:n=1 u=242  $ 18
5218 10 4.8129E-05  3144 3148 4138 imp:n=1 u=243  $ 19
5219 10 4.8129E-05  3144 3148 imp:n=1 u=244  $ 20
5220 10 4.8129E-05  3140 3142 3144 3148 3150 3152 3154
          4134 4135 4136 4138 imp:n=1 u=245  $ 21
5221 10 4.8129E-05  3148 imp:n=1 u=246  $ 22
5222 10 4.8129E-05  3140 3144 3148 3150 3154 4134 4136 4138 imp:n=1 u=247  $ 23
5223 10 4.8129E-05  3140 3142 3144 3148 3150 3152 3154
          4134 4135 4136 4137 4138 imp:n=1 u=248  $ 24
5224 10 4.8129E-05  3148 4136 imp:n=1 u=249  $ 25
5225 10 4.8129E-05  4136 imp:n=1 u=250  $ 26
5226 10 4.8129E-05  4134 4136 imp:n=1 u=251  $ 27
5227 10 4.8129E-05  3140 3142 3144 3148 3150 3154
          4134 4135 4136 4137 4138 imp:n=1 u=252  $ 28
5228 10 4.8129E-05  3140 3142 3148 3150 3154 4134 4136 4137 imp:n=1 u=253  $ 29
5229 10 4.8129E-05  3150 4134 4136 imp:n=1 u=254  $ 30
5230 10 4.8129E-05  3150 4134 imp:n=1 u=255  $ 3`
5231 10 4.8129E-05  3140 3142 3146 3148 3150 3152 3154
          4134 4135 4136 4137 imp:n=1 u=256  $ 31
5232 10 4.8129E-05  3150 imp:n=1 u=257  $ 32
c
c --------- Top Layer Only Lattices ---------
5233 10 4.8129E-05  3132 3134 3136 3138 4131 4132 4133 imp:n=1 u=324  $ regular
5234 10 4.8129E-05  3136 4132 imp:n=1 u=325  $ 1
5235 10 4.8129E-05  3132 3134 3136 3138 4131 4132 4133 imp:n=1 u=326  $ 2
5236 10 4.8129E-05  3132 3136 3138 4131 4132 imp:n=1 u=327  $ 3
5237 10 4.8129E-05  4132 imp:n=1 u=328  $ 4
5238 10 4.8129E-05  3132 3136 3138 4131 4132 4133 imp:n=1 u=329  $ 5
5239 10 4.8129E-05  4132 imp:n=1 u=330  $ 6
5240 10 4.8129E-05  3132 3136 3138 4132 4133 imp:n=1 u=331  $ 7
5241 10 4.8129E-05  3138 4132 imp:n=1 u=332  $ 8
5242 10 4.8129E-05  3132 3134 3136 3138 4132 4133 imp:n=1 u=333  $ 9
5243 10 4.8129E-05  3138 imp:n=1 u=334  $ 10
5244 10 4.8129E-05  3138 imp:n=1 u=335  $ 11
5245 10 4.8129E-05  3132 3134 3138 4132 4133 imp:n=1 u=336  $ 12
5246 10 4.8129E-05  3138 4133 imp:n=1 u=337  $ 13
5247 10 4.8129E-05  3132 3134 3136 3138 4131 4132 4133 imp:n=1 u=338  $ 14
5248 10 4.8129E-05  4133 imp:n=1 u=339  $ 15
5249 10 4.8129E-05  3132 3134 3138 4131 4132 4133 imp:n=1 u=340  $ 16
5250 10 4.8129E-05  4133 imp:n=1 u=341  $ 17
5251 10 4.8129E-05  3132 3134 3138 4131 4133 imp:n=1 u=342  $ 18
5252 10 4.8129E-05  3134 4133 imp:n=1 u=343  $ 19
5253 10 4.8129E-05  3134 imp:n=1 u=344  $ 20
5254 10 4.8129E-05  3132 3134 3136 3138 4131 4133 imp:n=1 u=345  $ 21
5255 10 4.8129E-05  3134 imp:n=1 u=346  $ 22
5256 10 4.8129E-05  3132 3134 3136 4131 4133 imp:n=1 u=347  $ 23
5257 10 4.8129E-05  3132 3134 3136 3138 4131 4132 4133 imp:n=1 u=348  $ 24
5258 10 4.8129E-05  3134 4131 imp:n=1 u=349  $ 25
5259 10 4.8129E-05  4131 imp:n=1 u=350  $ 26
5260 10 4.8129E-05  4131 imp:n=1 u=351  $ 27
5261 10 4.8129E-05  3132 3134 3136 4131 4132 4133 imp:n=1 u=352  $ 28
5262 10 4.8129E-05  3132 3134 3136 4131 4132 imp:n=1 u=353  $ 29
5263 10 4.8129E-05  3136 4131 imp:n=1 u=354  $ 30
5264 10 4.8129E-05  3136 imp:n=1 u=355  $ 31
5265 10 4.8129E-05  3132 3134 3136 3138 4131 4132 imp:n=1 u=356  $ 32
5266 10 4.8129E-05  3136 imp:n=1 u=357  $ 33
c
c --------- All Moderator Lattices ---------
5267 like 5131 but u=424  $ regular
5268 like 5132 but u=425  $ 1
5269 like 5133 but u=426  $ 2
5270 like 5134 but u=427  $ 3
5271 like 5135 but u=428  $ 4
5272 like 5136 but u=429  $ 5
5273 like 5137 but u=430  $ 6
5274 like 5138 but u=431  $ 7
5275 like 5139 but u=432  $ 8
5276 like 5140 but u=433  $ 9
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5277 like 5141 but u=434  $ 10
5278 like 5142 but u=435  $ 11
5279 like 5143 but u=436  $ 12
5280 like 5144 but u=437  $ 13
5281 like 5145 but u=438  $ 14
5282 like 5146 but u=439  $ 15
5283 like 5147 but u=440  $ 16
5284 like 5148 but u=441  $ 17
5285 like 5149 but u=442  $ 18
5286 like 5150 but u=443  $ 19
5287 like 5151 but u=444  $ 20
5288 like 5152 but u=445  $ 21
5289 like 5153 but u=446  $ 22
5290 like 5154 but u=447  $ 23
5291 like 5155 but u=448  $ 24
5292 like 5156 but u=449  $ 25
5293 like 5157 but u=450  $ 26
5294 like 5158 but u=451  $ 27
5295 like 5159 but u=452  $ 28
5296 like 5160 but u=453  $ 29
5297 like 5161 but u=454  $ 30
5298 like 5162 but u=455  $ 31
5299 like 5163 but u=456  $ 32
5300 like 5164 but u=457  $ 33
c
c --------- Bottom Layer of Moderator Only Lattices ---------
5301 like 5165 but u=524  $ regular
5302 like 5166 but u=525  $ 1
5303 like 5167 but u=526  $ 2
5304 like 5168 but u=527  $ 3
5305 like 5169 but u=528  $ 4
5306 like 5170 but u=529  $ 5
5307 like 5171 but u=530  $ 6
5308 like 5172 but u=531  $ 7
5309 like 5173 but u=532  $ 8
5310 like 5174 but u=533  $ 9
5311 like 5175 but u=534  $ 10
5312 like 5176 but u=535  $ 11
5313 like 5177 but u=536  $ 12
5314 like 5178 but u=537  $ 13
5315 like 5179 but u=538  $ 14
5316 like 5180 but u=539  $ 15
5317 like 5181 but u=540  $ 16
5318 like 5182 but u=541  $ 17
5319 like 5183 but u=542  $ 18
5320 like 5184 but u=543  $ 19
5321 like 5185 but u=544  $ 20
5322 like 5186 but u=545  $ 21
5323 like 5187 but u=546  $ 22
5324 like 5188 but u=547  $ 23
5325 like 5189 but u=548  $ 24
5326 like 5190 but u=549  $ 25
5327 like 5191 but u=550  $ 26
5328 like 5192 but u=551  $ 27
5329 like 5193 but u=552  $ 28
5330 like 5194 but u=553  $ 29
5331 like 5195 but u=554  $ 30
5332 like 5196 but u=555  $ 31
5333 like 5197 but u=556  $ 32
5334 like 5198 but u=557  $ 33
c
c --------- Bottom and Middle Fuel with Top Moderator Lattices ---------
5335 like 5131 but u=624  $ regular
5336 like 5132 but u=625  $ 1
5337 like 5133 but u=626  $ 2
5338 like 5134 but u=627  $ 3
5339 like 5135 but u=628  $ 4
5340 like 5136 but u=629  $ 5
5341 like 5137 but u=630  $ 6
5342 like 5138 but u=631  $ 7
5343 like 5139 but u=632  $ 8
5344 like 5140 but u=633  $ 9
5345 like 5141 but u=634  $ 10
5346 like 5142 but u=635  $ 11
5347 like 5143 but u=636  $ 12
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5348 like 5144 but u=637  $ 13
5349 like 5145 but u=638  $ 14
5350 like 5146 but u=639  $ 15
5351 like 5147 but u=640  $ 16
5352 like 5148 but u=641  $ 17
5353 like 5149 but u=642  $ 18
5354 like 5150 but u=643  $ 19
5355 like 5151 but u=644  $ 20
5356 like 5152 but u=645  $ 21
5357 like 5153 but u=646  $ 22
5358 like 5154 but u=647  $ 23
5359 like 5155 but u=648  $ 24
5360 like 5156 but u=649  $ 25
5361 like 5157 but u=650  $ 26
5362 like 5158 but u=651  $ 27
5363 like 5159 but u=652  $ 28
5364 like 5160 but u=653  $ 29
5365 like 5161 but u=654  $ 30
5366 like 5162 but u=655  $ 31
5367 like 5163 but u=656  $ 32
5368 like 5164 but u=657  $ 33
c
c ------ Polyethylene Rods ------
c    *Polyethylene Rods are Only in Core 3
c
c --------- Polyethylene Rods in Regular Lattices ---------
6201 34 1.2242E-01  -7021 imp:n=1 u=724  $ W Rod
6202 34 1.2242E-01  -7022 imp:n=1 u=724  $ NE Rod
6203 34 1.2242E-01  -7023 imp:n=1 u=724  $ SE Rod
6204 like 6201 but u=726  $ W Rod
6205 like 6202 but u=726  $ NE Rod
6206 like 6203 but u=726  $ SE Rod
6207 like 6202 but u=727  $ NE Rod
6208 like 6203 but u=727  $ SE Rod
6209 like 6202 but u=729  $ NE Rod
6210 like 6203 but u=729  $ SE Rod
6211 like 6203 but u=731  $ SE Rod
6212 like 6201 but u=733  $ W Rod
6213 like 6203 but u=733  $ SE Rod
6214 like 6201 but u=736  $ W Rod
6215 like 6203 but u=736  $ SE Rod
6216 like 6201 but u=738  $ W Rod
6217 like 6202 but u=738  $ NE Rod
6218 like 6203 but u=738  $ SE Rod
6219 like 6201 but u=740  $ W Rod
6220 like 6203 but u=740  $ SE Rod
6221 like 6201 but u=742  $ W Rod
6222 like 6201 but u=745  $ W Rod
6223 like 6202 but u=745  $ NE Rod
6224 like 6201 but u=747  $ W Rod
6225 like 6202 but u=747  $ NE Rod
6226 like 6201 but u=748  $ W Rod
6227 like 6202 but u=748  $ NE Rod
6228 like 6203 but u=748  $ SE Rod
6229 like 6201 but u=752  $ W Rod
6230 like 6202 but u=752  $ NE Rod
6231 like 6202 but u=753  $ NE Rod
6232 like 6202 but u=756  $ NE Rod
6233 like 6203 but u=756  $ SE Rod
c
c --------- Polyethylene Rods in Bottom Only Lattices ---------
6234 34 1.2242E-01  -7021 -7024 imp:n=1 u=824  $ W Rod
6235 34 1.2242E-01  -7022 -7024 imp:n=1 u=824  $ NE Rod
6236 34 1.2242E-01  -7023 -7024 imp:n=1 u=824  $ SE Rod
6237 like 6234 but u=826  $ W Rod
6238 like 6235 but u=826  $ NE Rod
6239 like 6236 but u=826  $ SE Rod
6240 like 6235 but u=827  $ NE Rod
6241 like 6236 but u=827  $ SE Rod
6242 like 6235 but u=829  $ NE Rod
6243 like 6236 but u=829  $ SE Rod
6244 like 6236 but u=831  $ SE Rod
6245 like 6234 but u=833  $ W Rod
6246 like 6236 but u=833  $ SE Rod
6247 like 6234 but u=836  $ W Rod
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6248 like 6236 but u=836  $ SE Rod
6249 like 6234 but u=838  $ W Rod
6250 like 6235 but u=838  $ NE Rod
6251 like 6236 but u=838  $ SE Rod
6252 like 6234 but u=840  $ W Rod
6253 like 6236 but u=840  $ SE Rod
6254 like 6234 but u=842  $ W Rod
6255 like 6234 but u=845  $ W Rod
6256 like 6235 but u=845  $ NE Rod
6257 like 6234 but u=847  $ W Rod
6258 like 6235 but u=847  $ NE Rod
6259 like 6234 but u=848  $ W Rod
6260 like 6235 but u=848  $ NE Rod
6261 like 6236 but u=848  $ SE Rod
6262 like 6234 but u=852  $ W Rod
6263 like 6235 but u=852  $ NE Rod
6264 like 6235 but u=853  $ NE Rod
6265 like 6235 but u=856  $ NE Rod
6266 like 6236 but u=856  $ SE Rod
c
c --------- Polyethylene Rods in Top Only Lattices ---------
6267 like 6201 but u=924  $ W Rod
6268 like 6202 but u=924  $ NE Rod
6269 like 6203 but u=924  $ SE Rod
6270 like 6201 but u=926  $ W Rod
6271 like 6202 but u=926  $ NE Rod
6272 like 6203 but u=926  $ SE Rod
6273 like 6202 but u=927  $ NE Rod
6274 like 6203 but u=927  $ SE Rod
6275 like 6202 but u=929  $ NE Rod
6276 like 6203 but u=929  $ SE Rod
6277 like 6203 but u=931  $ SE Rod
6278 like 6201 but u=933  $ W Rod
6279 like 6203 but u=933  $ SE Rod
6280 like 6201 but u=936  $ W Rod
6281 like 6203 but u=936  $ SE Rod
6282 like 6201 but u=938  $ W Rod
6283 like 6202 but u=938  $ NE Rod
6284 like 6203 but u=938  $ SE Rod
6285 like 6201 but u=940  $ W Rod
6286 like 6203 but u=940  $ SE Rod
6287 like 6201 but u=942  $ W Rod
6288 like 6201 but u=945  $ W Rod
6289 like 6202 but u=945  $ NE Rod
6290 like 6201 but u=947  $ W Rod
6291 like 6202 but u=947  $ NE Rod
6292 like 6201 but u=948  $ W Rod
6293 like 6202 but u=948  $ NE Rod
6294 like 6203 but u=948  $ SE Rod
6295 like 6201 but u=952  $ W Rod
6296 like 6202 but u=952  $ NE Rod
6297 like 6202 but u=953  $ NE Rod
6298 like 6202 but u=956  $ NE Rod
6299 like 6203 but u=956  $ SE Rod
c
c --------- Regular Lattices with Polyethylene Rods ---------
5369 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3144 3146 3148 3150 3152 3154
          4131 4132 4133 4134 4135 4136 4137 4138 7021 7022 7023 imp:n=1 u=724  $ regular
5370 10 4.8129E-05  3136 3150 4132 4137 imp:n=1 u=725  $ 1
5371 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3146 3148 3150 3152 3154
          4131 4132 4133 4134 4135 4136 4137 4138 7021 7022 7023 imp:n=1 u=726  $ 2
5372 10 4.8129E-05  3132 3136 3138 3142 3144 3146 3150 3152 3154
          4131 4132 4134 4136 4137 7022 7023 imp:n=1 u=727  $ 3
5373 10 4.8129E-05  4132 4137 imp:n=1 u=728  $ 4
5374 10 4.8129E-05  3132 3136 3138 3140 3142 3146 3150 3152 3154
          4131 4132 4133 4134 4135 4136 4137 4138 7022 7023 imp:n=1 u=729  $ 5
5375 10 4.8129E-05  3146 4132 4137 imp:n=1 u=730  $ 6
5376 10 4.8129E-05  3132 3136 3138 3142 3146 3150 3152 3154
          4132 4133 4135 4137 4138 7023 imp:n=1 u=731  $ 7
5377 10 4.8129E-05  3138 3146 3152 4132 4137 imp:n=1 u=732  $ 8
5378 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3144 3146 3148 3150 3152 3154
          4132 4133 4135 4137 4138 7021 7023 imp:n=1 u=733  $ 9
5379 10 4.8129E-05  3138 3146 3152 imp:n=1 u=734  $ 10
5380 10 4.8129E-05  3138 3152 imp:n=1 u=735  $ 11
5381 10 4.8129E-05  3132 3134 3138 3144 3146 3148 3152 3154
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          4132 4133 4135 4137 4138 7021 7023 imp:n=1 u=736  $ 12
5382 10 4.8129E-05  3138 3152 4133 4138 imp:n=1 u=737  $ 13
5383 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3144 3146 3148 3150 3152 3154
          4131 4132 4133 4135 4136 4137 4138 7021 7022 7023 imp:n=1 u=738  $ 14
5384 10 4.8129E-05  4133 4138 imp:n=1 u=739  $ 15
5385 10 4.8129E-05  3132 3134 3138 3140 3142 3144 3146 3148 3152 3154
          4131 4132 4133 4135 4136 4137 4138 7021 7023 imp:n=1 u=740  $ 16
5386 10 4.8129E-05  3144 4133 4138 imp:n=1 u=741  $ 17
5387 10 4.8129E-05  3132 3134 3138 3140 3144 3148 3152 3154
          4131 4133 4135 4136 4138 7021 imp:n=1 u=742  $ 18
5388 10 4.8129E-05  3134 3144 3148 4133 4138 imp:n=1 u=743  $ 19
5389 10 4.8129E-05  3134 3144 3148 imp:n=1 u=744  $ 20
5390 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3144 3148 3150 3152 3154
          4131 4133 4134 4135 4136 4138 7021 7022 imp:n=1 u=745  $ 21
5391 10 4.8129E-05  3134 3148 imp:n=1 u=746  $ 22
5392 10 4.8129E-05  3132 3134 3136 3140 3144 3148 3150 3154
          4131 4133 4134 4136 4138 7021 7022 imp:n=1 u=747  $ 23
5393 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3144 3148 3150 3152 3154
          4131 4132 4133 4134 4135 4136 4137 4138 7021 7022 7023 imp:n=1 u=748  $ 24
5394 10 4.8129E-05  3134 3148 4131 4136 imp:n=1 u=749  $ 25
5395 10 4.8129E-05  4131 4136 imp:n=1 u=750  $ 26
5396 10 4.8129E-05  4131 4134 4136 imp:n=1 u=751  $ 27
5397 10 4.8129E-05  3132 3134 3136 3140 3142 3144 3148 3150 3154
          4131 4132 4133 4134 4135 4136 4137 4138 7021 7022 imp:n=1 u=752  $ 28
5398 10 4.8129E-05  3132 3134 3136 3140 3142 3148 3150 3154
          4131 4132 4134 4136 4137 7022 imp:n=1 u=753  $ 29
5399 10 4.8129E-05  3136 3150 4131 4134 4136 imp:n=1 u=754  $ 30
5400 10 4.8129E-05  3136 3150 4134 imp:n=1 u=755  $ 31
5401 10 4.8129E-05  3132 3134 3136 3138 3140 3142 3146 3148 3150 3152 3154
          4131 4132 4134 4135 4136 4137 7022 7023 imp:n=1 u=756  $ 32
5402 10 4.8129E-05  3136 3150 imp:n=1 u=757  $ 33
c
c --------- Bottom Only Lattice with Polyethylene Rods Layer ---------
5403 10 4.8129E-05  3148 3150 3152 3154 4136 4137 4138
          (7021:7024) (7022:7024) (7023:7024) imp:n=1 u=824  $ regular
5404 10 4.8129E-05  3150 4137 imp:n=1 u=825  $ 1
5405 10 4.8129E-05  3148 3150 3152 3154 4136 4137 4138
          (7021:7024) (7022:7024) (7023:7024) imp:n=1 u=826  $ 2
5406 10 4.8129E-05  3150 3152 3154 4136 4137 (7022:7024) (7023:7024)
           imp:n=1 u=827  $ 3
5407 10 4.8129E-05  4137 imp:n=1 u=828  $ 4
5408 10 4.8129E-05  3150 3152 3154 4136 4137 4138 (7022:7024) (7023:7024)
           imp:n=1 u=829  $ 5
5409 10 4.8129E-05  4137 imp:n=1 u=830  $ 6
5410 10 4.8129E-05  3150 3152 3154 4137 4138 (7023:7024) imp:n=1 u=831  $ 7
5411 10 4.8129E-05  3152 4137 imp:n=1 u=832  $ 8
5412 10 4.8129E-05  3148 3150 3152 3154 4137 4138 (7021:7024) (7023:7024)
           imp:n=1 u=833  $ 9
5413 10 4.8129E-05  3152 imp:n=1 u=834  $ 10
5414 10 4.8129E-05  3152 imp:n=1 u=835  $ 11
5415 10 4.8129E-05  3148 3152 3154 4137 4138 (7021:7024) (7023:7024)
           imp:n=1 u=836  $ 12
5416 10 4.8129E-05  3152 4138 imp:n=1 u=837  $ 13
5417 10 4.8129E-05  3148 3150 3152 3154 4136 4137 4138
          (7021:7024) (7022:7024) (7023:7024) imp:n=1 u=838  $ 14
5418 10 4.8129E-05  4138 imp:n=1 u=839  $ 15
5419 10 4.8129E-05  3148 3152 3154 4136 4137 4138 (7021:7024) (7023:7024)
           imp:n=1 u=840  $ 16
5420 10 4.8129E-05  4138 imp:n=1 u=841  $ 17
5421 10 4.8129E-05  3148 3152 3154 4136 4138 (7021:7024) imp:n=1 u=842  $ 18
5422 10 4.8129E-05  3148 4138 imp:n=1 u=843  $ 19
5423 10 4.8129E-05  3148 imp:n=1 u=844  $ 20
5424 10 4.8129E-05  3148 3150 3152 3154 4136 4138 (7021:7024) (7022:7024)
           imp:n=1 u=845  $ 21
5425 10 4.8129E-05  3148 imp:n=1 u=846  $ 22
5426 10 4.8129E-05  3148 3150 3154 4136 4138 (7021:7024) (7022:7024)
           imp:n=1 u=847  $ 23
5427 10 4.8129E-05  3148 3150 3152 3154 4136 4137 4138
          (7021:7024) (7022:7024) (7023:7024) imp:n=1 u=848  $ 24
5428 10 4.8129E-05  3148 4136 imp:n=1 u=849  $ 25
5429 10 4.8129E-05  4136 imp:n=1 u=850  $ 26
5430 10 4.8129E-05  4136 imp:n=1 u=851  $ 27
5431 10 4.8129E-05  3148 3150 3154 4136 4137 4138 (7021:7024) (7022:7024)
           imp:n=1 u=852  $ 28
5432 10 4.8129E-05  3148 3150 3154 4136 4137 (7022:7024) imp:n=1 u=853  $ 29
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5433 10 4.8129E-05  3150 4136 imp:n=1 u=854  $ 30
5434 10 4.8129E-05  3150 imp:n=1 u=855  $ 31
5435 10 4.8129E-05  3148 3150 3152 3154 4136 4137 (7022:7024) (7023:7024)
           imp:n=1 u=856  $ 32
5436 10 4.8129E-05  3150 imp:n=1 u=857  $ 33
c
c --------- Top Only Lattice with Polyethylene Rods Layer ---------
5437 10 4.8129E-05  3132 3134 3136 3138 4131 4132 4133 7021 7022 7023
           imp:n=1 u=924  $ regular
5438 10 4.8129E-05  3136 4132 imp:n=1 u=925  $ 1
5439 10 4.8129E-05  3132 3134 3136 3138 4131 4132 4133 7021 7022 7023
           imp:n=1 u=926  $ 2
5440 10 4.8129E-05  3132 3136 3138 4131 4132 7022 7023 imp:n=1 u=927  $ 3
5441 10 4.8129E-05  4132 imp:n=1 u=928  $ 4
5442 10 4.8129E-05  3132 3136 3138 4131 4132 4133 7022 7023 imp:n=1 u=929  $ 5
5443 10 4.8129E-05  4132 imp:n=1 u=930  $ 6
5444 10 4.8129E-05  3132 3136 3138 4132 4133 7023 imp:n=1 u=931  $ 7
5445 10 4.8129E-05  3138 4132 imp:n=1 u=932  $ 8
5446 10 4.8129E-05  3132 3134 3136 3138 4132 4133 7021 7023 imp:n=1 u=933  $ 9
5447 10 4.8129E-05  3138 imp:n=1 u=934  $ 10
5448 10 4.8129E-05  3138 imp:n=1 u=935  $ 11
5449 10 4.8129E-05  3132 3134 3138 4132 4133 7021 7023 imp:n=1 u=936  $ 12
5450 10 4.8129E-05  3138 4133 imp:n=1 u=937  $ 13
5451 10 4.8129E-05  3132 3134 3136 3138 4131 4132 4133 7021 7022 7023
           imp:n=1 u=938  $ 14
5452 10 4.8129E-05  4133 imp:n=1 u=939  $ 15
5453 10 4.8129E-05  3132 3134 3138 4131 4132 4133 7021 7023 imp:n=1 u=940  $ 16
5454 10 4.8129E-05  4133 imp:n=1 u=941  $ 17
5455 10 4.8129E-05  3132 3134 3138 4131 4133 7021 imp:n=1 u=942  $ 18
5456 10 4.8129E-05  3134 4133 imp:n=1 u=943  $ 19
5457 10 4.8129E-05  3134 imp:n=1 u=944  $ 20
5458 10 4.8129E-05  3132 3134 3136 3138 4131 4133 7021 7022 imp:n=1 u=945  $ 21
5459 10 4.8129E-05  3134 imp:n=1 u=946  $ 22
5460 10 4.8129E-05  3132 3134 3136 4131 4133 7021 7022 imp:n=1 u=947  $ 23
5461 10 4.8129E-05  3132 3134 3136 3138 4131 4132 4133 7021 7022 7023
           imp:n=1 u=948  $ 24
5462 10 4.8129E-05  3134 4131 imp:n=1 u=949  $ 25
5463 10 4.8129E-05  4131 imp:n=1 u=950  $ 26
5464 10 4.8129E-05  4131 imp:n=1 u=951  $ 27
5465 10 4.8129E-05  3132 3134 3136 4131 4132 4133 7021 7022 imp:n=1 u=952  $ 28
5466 10 4.8129E-05  3132 3134 3136 4131 4132 7022 imp:n=1 u=953  $ 29
5467 10 4.8129E-05  3136 4131 imp:n=1 u=954  $ 30
5468 10 4.8129E-05  3136 imp:n=1 u=955  $ 31
5469 10 4.8129E-05  3132 3134 3136 3138 4131 4132 7022 7023 imp:n=1 u=956  $ 32
5470 10 4.8129E-05  3136 imp:n=1 u=957  $ 33c
c
c
c ------ Pebble Layers -------------------------------------------------------
6000 10 4.8129E-05  -9999 imp:n=1 u=99  $ Air
c
c --------- Regular Lattice Description ---------
6001 10 4.8129E-05  -6001 imp:n=1 u=100 lat=2 fill=-8:8 -8:8 0:0
     99  16r
     99   9r                      51  51  51  50                         99  2r
     99   7r                54  53  52  52  52  47  49                   99  1r
     99   5r          55  53  24  24  24  24  24  48  47  46                99
     99   4r        55  56  24  24  24  24  24  24  24  45  44              99
     99   3r      55  56  24  24  24  24  24  24  24  24  45  44            99
     99   2r    57  56  24  24  24  24  24  24  24  24  24  45  44          99
     99   2r      27  24  24  24  24  24  24  24  24  24  24  42         99  1r
     99   1r    25  26  24  24  24  24  24  24  24  24  24  24  43       99  1r
     99   1r      27  24  24  24  24  24  24  24  24  24  24  42         99  2r
     99         28  29  24  24  24  24  24  24  24  24  24  40  41       99  2r
     99           30  29  24  24  24  24  24  24  24  24  40  41         99  3r
     99             30  29  24  24  24  24  24  24  24  40  41           99  4r
     99               30  31  24  24  24  24  24  38  36  39             99  5r
     99   1r                32  31  33  33  33  36  37                   99  7r
     99   2r                      34  34  34  35                         99  9r
     99  16r
c
c --------- Bottom Layer Only Lattice Description ---------
6002 10 4.8129E-05  -6001 imp:n=1 u=102 lat=2 fill=-8:8 -8:8 0:0
     99  16r
     99   9r                     151 151 151 150                         99  2r
     99   7r               154 153 152 152 152 147 149                   99  1r
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     99   5r          155 153 124 124 124 124 124 148 147 146                99
     99   4r        155 156 124 124 124 124 124 124 124 145 144              99
     99   3r      155 156 124 124 124 124 124 124 124 124 145 144            99
     99   2r    157 156 124 124 124 124 124 124 124 124 124 145 144          99
     99   2r      127 124 124 124 124 124 124 124 124 124 124 142        99  1r
     99   1r    125 126 124 124 124 124 124 124 124 124 124 124 143      99  1r
     99   1r      127 124 124 124 124 124 124 124 124 124 124 142        99  2r
     99         128 129 124 124 124 124 124 124 124 124 124 140 141      99  2r
     99           130 129 124 124 124 124 124 124 124 124 140 141        99  3r
     99             130 129 124 124 124 124 124 124 124 140 141          99  4r
     99               130 131 124 124 124 124 124 138 136 139            99  5r
     99   1r                132 131 133 133 133 136 137                  99  7r
     99   2r                      134 134 134 135                        99  9r
     99  16r
c
c --------- Bottom and Middle Layers Only Lattice Description ---------
6003 10 4.8129E-05  -6001 imp:n=1 u=104 lat=2 fill=-8:8 -8:8 0:0
     99  16r
     99   9r                      251 251 251 250                        99  2r
     99   7r                254 253 252 252 252 247 249                  99  1r
     99   5r          255 253 224 224 224 224 224 248 247 246                99
     99   4r        255 256 224 224 224 224 224 224 224 245 244              99
     99   3r      255 256 224 224 224 224 224 224 224 224 245 244            99
     99   2r    257 256 224 224 224 224 224 224 224 224 224 245 244          99
     99   2r      227 224 224 224 224 224 224 224 224 224 224 242        99  1r
     99   1r    225 226 224 224 224 224 224 224 224 224 224 224 243      99  1r
     99   1r      227 224 224 224 224 224 224 224 224 224 224 242        99  2r
     99         228 229 224 224 224 224 224 224 224 224 224 240 241      99  2r
     99           230 229 224 224 224 224 224 224 224 224 240 241        99  3r
     99             230 229 224 224 224 224 224 224 224 240 241          99  4r
     99               230 231 224 224 224 224 224 238 236 239            99  5r
     99   1r                232 231 233 233 233 236 237                  99  7r
     99   2r                      234 234 234 235                        99  9r
     99  16r
c
c --------- Top Layer Only Lattice Description ---------
6004 10 4.8129E-05  -6001 imp:n=1 u=106 lat=2 fill=-8:8 -8:8 0:0
     99  16r
     99   9r                      351 351 351 350                        99  2r
     99   7r                354 353 352 352 352 347 349                  99  1r
     99   5r          355 353 324 324 324 324 324 348 347 346                99
     99   4r        355 356 324 324 324 324 324 324 324 345 344              99
     99   3r      355 356 324 324 324 324 324 324 324 324 345 344            99
     99   2r    357 356 324 324 324 324 324 324 324 324 324 345 344          99
     99   2r      327 324 324 324 324 324 324 324 324 324 324 342        99  1r
     99   1r    325 326 324 324 324 324 324 324 324 324 324 324 343      99  1r
     99   1r      327 324 324 324 324 324 324 324 324 324 324 342        99  2r
     99         328 329 324 324 324 324 324 324 324 324 324 340 341      99  2r
     99           330 329 324 324 324 324 324 324 324 324 340 341        99  3r
     99             330 329 324 324 324 324 324 324 324 340 341          99  4r
     99               330 331 324 324 324 324 324 338 336 339            99  5r
     99   1r                332 331 333 333 333 336 337                  99  7r
     99   2r                      334 334 334 335                        99  9r
     99  16r
c
c --------- All Moderator Lattice Description ---------
6005 10 4.8129E-05  -6001 imp:n=1 u=108 lat=2 fill=-8:8 -8:8 0:0
     99  16r
     99   9r                      451 451 451 450                        99  2r
     99   7r                454 453 452 452 452 447 449                  99  1r
     99   5r          455 453 424 424 424 424 424 448 447 446                99
     99   4r        455 456 424 424 424 424 424 424 424 445 444              99
     99   3r      455 456 424 424 424 424 424 424 424 424 445 444            99
     99   2r    457 456 424 424 424 424 424 424 424 424 424 445 444          99
     99   2r      427 424 424 424 424 424 424 424 424 424 424 442        99  1r
     99   1r    425 426 424 424 424 424 424 424 424 424 424 424 443      99  1r
     99   1r      427 424 424 424 424 424 424 424 424 424 424 442        99  2r
     99         428 429 424 424 424 424 424 424 424 424 424 440 441      99  2r
     99           430 429 424 424 424 424 424 424 424 424 440 441        99  3r
     99             430 429 424 424 424 424 424 424 424 440 441          99  4r
     99               430 431 424 424 424 424 424 438 436 439            99  5r
     99   1r                432 431 433 433 433 436 437                  99  7r
     99   2r                      434 434 434 435                        99  9r
     99  16r
c
```

```
c --------- Bottom Layer of Moderator Only Lattice Description ---------
6006 10 4.8129E-05  -6001 imp:n=1 u=110 lat=2 fill=-8:8 -8:8 0:0
     99  16r
     99   9r                   551 551 551 550                          99  2r
     99   7r             554 553 552 552 552 547 549                    99  1r
     99   5r       555 553 524 524 524 524 524 548 547 546                  99
     99   4r     555 556 524 524 524 524 524 524 524 545 544                99
     99   3r   555 556 524 524 524 524 524 524 524 524 545 544              99
     99   2r 557 556 524 524 524 524 524 524 524 524 524 545 544            99
     99   2r   527 524 524 524 524 524 524 524 524 524 524 542          99  1r
     99   1r 525 526 524 524 524 524 524 524 524 524 524 524 543        99  1r
     99   1r   527 524 524 524 524 524 524 524 524 524 524 542          99  2r
     99      528 529 524 524 524 524 524 524 524 524 524 540 541        99  2r
     99        530 529 524 524 524 524 524 524 524 524 540 541          99  3r
     99          530 529 524 524 524 524 524 524 524 540 541            99  4r
     99            530 531 524 524 524 524 524 538 536 539              99  5r
     99   1r             532 531 533 533 533 536 537                    99  7r
     99   2r                   534 534 534 535                          99  9r
     99  16r
c
c --------- Bottom and Middle Fuel with Top Moderator Lattice Description ---------
6007 10 4.8129E-05  -6001 imp:n=1 u=112 lat=2 fill=-8:8 -8:8 0:0
     99  16r
     99   9r                   651 651 651 650                          99  2r
     99   7r             654 653 652 652 652 647 649                    99  1r
     99   5r       655 653 624 624 624 624 624 648 647 646                  99
     99   4r     655 656 624 624 624 624 624 624 624 645 644                99
     99   3r   655 656 624 624 624 624 624 624 624 624 645 644              99
     99   2r 657 656 624 624 624 624 624 624 624 624 624 645 644            99
     99   2r   627 624 624 624 624 624 624 624 624 624 624 642          99  1r
     99   1r 625 626 624 624 624 624 624 624 624 624 624 624 643        99  1r
     99   1r   627 624 624 624 624 624 624 624 624 624 624 642          99  2r
     99      628 629 624 624 624 624 624 624 624 624 624 640 641        99  2r
     99        630 629 624 624 624 624 624 624 624 624 640 641          99  3r
     99          630 629 624 624 624 624 624 624 624 640 641            99  4r
     99            630 631 624 624 624 624 624 638 636 639              99  5r
     99   1r             632 631 633 633 633 636 637                    99  7r
     99   2r                   634 634 634 635                          99  9r
     99  16r
c
c --------- Regular Lattice with Polyethylene Rods Description ---------
6008 10 4.8129E-05  -6001 imp:n=1 u=114 lat=2 fill=-8:8 -8:8 0:0
     99  16r
     99   9r                   751 751 751 750                          99  2r
     99   7r             754 753 752 752 752 747 749                    99  1r
     99   5r       755 753 724 724 724 724 724 748 747 746                  99
     99   4r     755 756 724 724 724 724 724 724 724 745 744                99
     99   3r   755 756 724 724 724 724 724 724 724 724 745 744              99
     99   2r 757 756 724 724 724 724 724 724 724 724 724 745 744            99
     99   2r   727 724 724 724 724 724 724 724 724 724 724 742          99  1r
     99   1r 725 726 724 724 724 724 724 724 724 724 724 724 743        99  1r
     99   1r   727 724 724 724 724 724 724 724 724 724 724 742          99  2r
     99      728 729 724 724 724 724 724 724 724 724 724 740 741        99  2r
     99        730 729 724 724 724 724 724 724 724 724 740 741          99  3r
     99          730 729 724 724 724 724 724 724 724 740 741            99  4r
     99            730 731 724 724 724 724 724 738 736 739              99  5r
     99   1r             732 731 733 733 733 736 737                    99  7r
     99   2r                   734 734 734 735                          99  9r
     99  16r
c
c --------- Bottom Only Lattice with Polyethylene Rods Description ---------
6009 10 4.8129E-05  -6001 imp:n=1 u=116 lat=2 fill=-8:8 -8:8 0:0
     99  16r
     99   9r                   851 851 851 850                          99  2r
     99   7r             854 853 852 852 852 847 849                    99  1r
     99   5r       855 853 824 824 824 824 824 848 847 846                  99
     99   4r     855 856 824 824 824 824 824 824 824 845 844                99
     99   3r   855 856 824 824 824 824 824 824 824 824 845 844              99
     99   2r 857 856 824 824 824 824 824 824 824 824 824 845 844            99
     99   2r   827 824 824 824 824 824 824 824 824 824 824 842          99  1r
     99   1r 825 826 824 824 824 824 824 824 824 824 824 824 843        99  1r
     99   1r   827 824 824 824 824 824 824 824 824 824 824 842          99  2r
     99      828 829 824 824 824 824 824 824 824 824 824 840 841        99  2r
     99        830 829 824 824 824 824 824 824 824 824 840 841          99  3r
     99          830 829 824 824 824 824 824 824 824 840 841            99  4r
```

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     99               830 831 824 824 824 824 824 838 836 839           99  5r
     99   1r                832 831 833 833 833 836 837                 99  7r
     99   2r                      834 834 834 835                       99  9r
     99  16r
c
c --------- Top Only Lattice with Polyethylene Rods Description ---------
6010 10 4.8129E-05  -6001 imp:n=1 u=118 lat=2 fill=-8:8 -8:8 0:0
     99  16r
     99   9r                      951 951 951 950                       99  2r
     99   7r                954 953 952 952 952 947 949                 99  1r
     99   5r          955 953 924 924 924 924 924 948 947 946               99
     99   4r        955 956 924 924 924 924 924 924 924 945 944             99
     99   3r      955 956 924 924 924 924 924 924 924 924 945 944           99
     99   2r    957 956 924 924 924 924 924 924 924 924 924 945 944         99
     99   2r      927 924 924 924 924 924 924 924 924 924 924 942       99  1r
     99   1r    925 926 924 924 924 924 924 924 924 924 924 924 943     99  1r
     99   1r      927 924 924 924 924 924 924 924 924 924 924 942       99  2r
     99         928 929 924 924 924 924 924 924 924 924 924 940 941     99  2r
     99           930 929 924 924 924 924 924 924 924 924 940 941       99  3r
     99             930 929 924 924 924 924 924 924 924 940 941         99  4r
     99               930 931 924 924 924 924 924 938 936 939           99  5r
     99   1r                932 931 933 933 933 936 937                 99  7r
     99   2r                      934 934 934 935                       99  9r
     99  16r
c
c
c
c --------- Regular Lattice Layer ---------
6011 10 4.8129E-05  -6002 imp:n=1 u=101 fill=100
c
c --------- Bottom Only Lattice Layer ---------
6012 10 4.8129E-05  -6002 imp:n=1 u=103 fill=102
c
c --------- Bottom and Middle Only Lattice Layer ---------
6013 10 4.8129E-05  -6002 imp:n=1 u=105 fill=104
c
c --------- Top Only Lattice Layer ---------
6014 10 4.8129E-05  -6002 imp:n=1 u=107 fill=106
c
c --------- All Moderator Lattice Layer ---------
6015 10 4.8129E-05  -6002 imp:n=1 u=109 fill=108
c
c --------- Bottom Moderator Only Lattice Layer ---------
6016 10 4.8129E-05  -6002 imp:n=1 u=111 fill=110
c
c --------- Bottom and Middle Fuel with Top Moderator Lattice Layer ---------
6017 10 4.8129E-05  -6002 imp:n=1 u=113 fill=112
c
c --------- Regular Lattice with Polyethylene Rods Layer ---------
6018 10 4.8129E-05  -6002 imp:n=1 u=115 fill=114
c
c --------- Bottom Only Lattice with Polyethylene Rods Layer ---------
6019 10 4.8129E-05  -6002 imp:n=1 u=117 fill=116
c
c --------- Top Only Lattice with Polyethylene Rods Layer ---------
6020 10 4.8129E-05  -6002 imp:n=1 u=119 fill=118
c
c --------- Air Layer ---------
6021 10 4.8129E-05  -6002 imp:n=1 u=120
c
c --------- Pebbled Core Layers ---------
6101 10 4.8129E-05  -6003 imp:n=1 u=121 lat=2 fill=0:0 0:0 -1:21  $ Core 1
            120 1r 107 101 9r 105 120 8r
c 6101 10 4.8129E-05  -6003 imp:n=1 u=121 lat=2 fill=0:0 0:0 -1:21  $ Core 1A
c             120 1r 107 101 9r 103 120 8r
c 6101 10 4.8129E-05  -6003 imp:n=1 u=121 lat=2 fill=0:0 0:0 -1:21  $ Core 2
c             120 1r 107 101 6r 113 109 7r 111 120 2r
c 6101 10 4.8129E-05  -6003 imp:n=1 u=121 lat=2 fill=0:0 0:0 -1:21  $ Core 3
c             120 1r 119 115 7r 117 120 10r
c
c --------- Pebble-Filled Core Cavity ---------
6102 10 4.8129E-05  -7001 -7002 -9001 #9011 #9012 #9013 #9014 #9015 #9016 #9017
         #9018 #9019 #9020 #9021 #9022 #9023 #9024 #9025 #9026 #9027 #9028 #9029
          #9030 #9031 #9032 #9033 #9034
          imp:n=1 *fill=121 (0 0 66.30306154 30 120 90  60 30 90  90 90 0)
```

```
6103 10 4.8129E-05  -7001 -7002 9001 -9002  #9035 #9036 #9037 #9038 #9039 #9040
         #9041 #9042 #9043 #9044 #9045 #9046 #9047 #9048 #9049 #9050 #9051 #9052
          #9053 #9054 #9055 #9056 #9057 #9058
          imp:n=1 *fill=121 (0 0 66.30306154 30 120 90  60 30 90  90 90 0)
6104 10 4.8129E-05  -7001 -7002 9002 -9003  #9059 #9060 #9061 #9062 #9063 #9064
         #9065 #9066 #9067 #9068 #9069 #9070 #9071 #9072 #9073 #9074 #9075 #9076
          #9077 #9078 #9079 #9080 #9081 #9082
          imp:n=1 *fill=121 (0 0 66.30306154 30 120 90  60 30 90  90 90 0)
6105 10 4.8129E-05  -7001 -7002 9003 (-1804:1805) #9083 #9084 #9085 #9086 #9087
         #9088 #9089 #9090 #9091 #9092 #9093 #9094 #9095 #9096 #9097 #9098
          #9099 #9100 #9101 #9102 #9103 #9104 #9105 #9106
          imp:n=1 *fill=121 (0 0 66.30306154 30 120 90  60 30 90  90 90 0)
c
c ------ Lattice Spacers ------
c --------- Cores 1, 1A, 2, & 3 ---------
9011 32 8.7390E-02  7031 -7032 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 2
9012 32 8.7390E-02  7131 -7132 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 2
9013 32 8.7390E-02  7031 -7032 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 2
9014 32 8.7390E-02  7131 -7132 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 2
9015 32 8.7390E-02  7031 -7032 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 2
9016 32 8.7390E-02  7131 -7132 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 2
9017 32 8.7390E-02  7033 -7034 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 4
9018 32 8.7390E-02  7133 -7134 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 4
9019 32 8.7390E-02  7033 -7034 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 4
9020 32 8.7390E-02  7133 -7134 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 4
9021 32 8.7390E-02  7033 -7034 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 4
9022 32 8.7390E-02  7133 -7134 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 4
9023 32 8.7390E-02  7035 -7036 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 6
9024 32 8.7390E-02  7135 -7136 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 6
9025 32 8.7390E-02  7035 -7036 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 6
9026 32 8.7390E-02  7135 -7136 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 6
9027 32 8.7390E-02  7035 -7036 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 6
9028 32 8.7390E-02  7135 -7136 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 6
9029 32 8.7390E-02  7037 -7038 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 8
9030 32 8.7390E-02  7137 -7138 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 8
9031 32 8.7390E-02  7037 -7038 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 8
9032 32 8.7390E-02  7137 -7138 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 8
9033 32 8.7390E-02  7037 -7038 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 8
9034 32 8.7390E-02  7137 -7138 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 8
9035 32 8.7390E-02  7039 -7040 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 10
9036 32 8.7390E-02  7139 -7140 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 10
9037 32 8.7390E-02  7039 -7040 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 10
9038 32 8.7390E-02  7139 -7140 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 10
9039 32 8.7390E-02  7039 -7040 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 10
9040 32 8.7390E-02  7139 -7140 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 10
9041 32 8.7390E-02  7041 -7042 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 12
9042 32 8.7390E-02  7141 -7142 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 12
9043 32 8.7390E-02  7041 -7042 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 12
9044 32 8.7390E-02  7141 -7142 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 12
9045 32 8.7390E-02  7041 -7042 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 12
9046 32 8.7390E-02  7141 -7142 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 12
9047 32 8.7390E-02  7043 -7044 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 14
9048 32 8.7390E-02  7143 -7144 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 14
9049 32 8.7390E-02  7043 -7044 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 14
9050 32 8.7390E-02  7143 -7144 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 14
9051 32 8.7390E-02  7043 -7044 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 14
9052 32 8.7390E-02  7143 -7144 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 14
9053 32 8.7390E-02  7045 -7046 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 16
9054 32 8.7390E-02  7145 -7146 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 16
9055 32 8.7390E-02  7045 -7046 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 16
9056 32 8.7390E-02  7145 -7146 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 16
9057 32 8.7390E-02  7045 -7046 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 16
9058 32 8.7390E-02  7145 -7146 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 16
c
c --------- Core 1 ---------
9059 32 8.7390E-02  7047 -7048 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 18
9060 32 8.7390E-02  7147 -7148 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 18
9061 32 8.7390E-02  7047 -7048 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 18
9062 32 8.7390E-02  7147 -7148 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 18
9063 32 8.7390E-02  7047 -7048 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 18
9064 32 8.7390E-02  7147 -7148 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 18
9065 32 8.7390E-02  7049 -7050 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 20
9066 32 8.7390E-02  7149 -7150 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 20
9067 32 8.7390E-02  7049 -7050 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 20
9068 32 8.7390E-02  7149 -7150 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 20
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9069 32 8.7390E-02  7049 -7050 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 20
9070 32 8.7390E-02  7149 -7150 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 20
9071 32 8.7390E-02  7051 -7052 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 22
9072 32 8.7390E-02  7151 -7152 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 22
9073 32 8.7390E-02  7051 -7052 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 22
9074 32 8.7390E-02  7151 -7152 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 22
9075 32 8.7390E-02  7051 -7052 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 22
9076 32 8.7390E-02  7151 -7152 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 22
9077 10 4.8129E-05  7053 -7054 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 24
9078 10 4.8129E-05  7153 -7154 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 24
9079 10 4.8129E-05  7053 -7054 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 24
9080 10 4.8129E-05  7153 -7154 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 24
9081 10 4.8129E-05  7053 -7054 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 24
9082 10 4.8129E-05  7153 -7154 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 24
9083 10 4.8129E-05  7055 -7056 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 26
9084 10 4.8129E-05  7155 -7156 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 26
9085 10 4.8129E-05  7055 -7056 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 26
9086 10 4.8129E-05  7155 -7156 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 26
9087 10 4.8129E-05  7055 -7056 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 26
9088 10 4.8129E-05  7155 -7156 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 26
9089 10 4.8129E-05  7057 -7058 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 28
9090 10 4.8129E-05  7157 -7158 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 28
9091 10 4.8129E-05  7057 -7058 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 28
9092 10 4.8129E-05  7157 -7158 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 28
9093 10 4.8129E-05  7057 -7058 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 28
9094 10 4.8129E-05  7157 -7158 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 28
9095 10 4.8129E-05  7059 -7060 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 30
9096 10 4.8129E-05  7159 -7160 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 30
9097 10 4.8129E-05  7059 -7060 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 30
9098 10 4.8129E-05  7159 -7160 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 30
9099 10 4.8129E-05  7059 -7060 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 30
9100 10 4.8129E-05  7159 -7160 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 30
9101 10 4.8129E-05  7061 -7062 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 32
9102 10 4.8129E-05  7161 -7162 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 32
9103 10 4.8129E-05  7061 -7062 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 32
9104 10 4.8129E-05  7161 -7162 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 32
9105 10 4.8129E-05  7061 -7062 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 32
9106 10 4.8129E-05  7161 -7162 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 32
c
c --------- Core 1A ---------
c 9059 32 8.7390E-02  7047 -7048 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 18
c 9060 32 8.7390E-02  7147 -7148 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 18
c 9061 32 8.7390E-02  7047 -7048 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 18
c 9062 32 8.7390E-02  7147 -7148 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 18
c 9063 32 8.7390E-02  7047 -7048 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 18
c 9064 32 8.7390E-02  7147 -7148 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 18
c 9065 32 8.7390E-02  7049 -7050 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 20
c 9066 32 8.7390E-02  7149 -7150 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 20
c 9067 32 8.7390E-02  7049 -7050 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 20
c 9068 32 8.7390E-02  7149 -7150 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 20
c 9069 32 8.7390E-02  7049 -7050 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 20
c 9070 32 8.7390E-02  7149 -7150 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 20
c 9071 10 4.8129E-05  7051 -7052 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 22
c 9072 10 4.8129E-05  7151 -7152 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 22
c 9073 10 4.8129E-05  7051 -7052 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 22
c 9074 10 4.8129E-05  7151 -7152 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 22
c 9075 10 4.8129E-05  7051 -7052 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 22
c 9076 10 4.8129E-05  7151 -7152 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 22
c 9077 10 4.8129E-05  7053 -7054 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 24
c 9078 10 4.8129E-05  7153 -7154 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 24
c 9079 10 4.8129E-05  7053 -7054 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 24
c 9080 10 4.8129E-05  7153 -7154 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 24
c 9081 10 4.8129E-05  7053 -7054 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 24
c 9082 10 4.8129E-05  7153 -7154 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 24
c 9083 10 4.8129E-05  7055 -7056 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 26
c 9084 10 4.8129E-05  7155 -7156 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 26
c 9085 10 4.8129E-05  7055 -7056 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 26
c 9086 10 4.8129E-05  7155 -7156 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 26
c 9087 10 4.8129E-05  7055 -7056 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 26
c 9088 10 4.8129E-05  7155 -7156 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 26
c 9089 10 4.8129E-05  7057 -7058 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 28
c 9090 10 4.8129E-05  7157 -7158 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 28
c 9091 10 4.8129E-05  7057 -7058 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 28
c 9092 10 4.8129E-05  7157 -7158 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 28
c 9093 10 4.8129E-05  7057 -7058 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 28
```

```
c 9094 10 4.8129E-05  7157 -7158 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 28
c 9095 10 4.8129E-05  7059 -7060 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 30
c 9096 10 4.8129E-05  7159 -7160 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 30
c 9097 10 4.8129E-05  7059 -7060 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 30
c 9098 10 4.8129E-05  7159 -7160 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 30
c 9099 10 4.8129E-05  7059 -7060 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 30
c 9100 10 4.8129E-05  7159 -7160 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 30
c 9101 10 4.8129E-05  7061 -7062 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 32
c 9102 10 4.8129E-05  7161 -7162 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 32
c 9103 10 4.8129E-05  7061 -7062 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 32
c 9104 10 4.8129E-05  7161 -7162 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 32
c 9105 10 4.8129E-05  7061 -7062 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 32
c 9106 10 4.8129E-05  7161 -7162 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 32
c
c --------- Core 2 ---------
c 9059 32 8.7390E-02  7047 -7048 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 18
c 9060 32 8.7390E-02  7147 -7148 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 18
c 9061 32 8.7390E-02  7047 -7048 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 18
c 9062 32 8.7390E-02  7147 -7148 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 18
c 9063 32 8.7390E-02  7047 -7048 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 18
c 9064 32 8.7390E-02  7147 -7148 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 18
c 9065 32 8.7390E-02  7049 -7050 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 20
c 9066 32 8.7390E-02  7149 -7150 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 20
c 9067 32 8.7390E-02  7049 -7050 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 20
c 9068 32 8.7390E-02  7149 -7150 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 20
c 9069 32 8.7390E-02  7049 -7050 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 20
c 9070 32 8.7390E-02  7149 -7150 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 20
c 9071 32 8.7390E-02  7051 -7052 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 22
c 9072 32 8.7390E-02  7151 -7152 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 22
c 9073 32 8.7390E-02  7051 -7052 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 22
c 9074 32 8.7390E-02  7151 -7152 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 22
c 9075 32 8.7390E-02  7051 -7052 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 22
c 9076 32 8.7390E-02  7151 -7152 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 22
c 9077 32 8.7390E-02  7053 -7054 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 24
c 9078 32 8.7390E-02  7153 -7154 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 24
c 9079 32 8.7390E-02  7053 -7054 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 24
c 9080 32 8.7390E-02  7153 -7154 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 24
c 9081 32 8.7390E-02  7053 -7054 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 24
c 9082 32 8.7390E-02  7153 -7154 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 24
c 9083 32 8.7390E-02  7055 -7056 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 26
c 9084 32 8.7390E-02  7155 -7156 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 26
c 9085 32 8.7390E-02  7055 -7056 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 26
c 9086 32 8.7390E-02  7155 -7156 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 26
c 9087 32 8.7390E-02  7055 -7056 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 26
c 9088 32 8.7390E-02  7155 -7156 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 26
c 9089 32 8.7390E-02  7057 -7058 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 28
c 9090 32 8.7390E-02  7157 -7158 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 28
c 9091 32 8.7390E-02  7057 -7058 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 28
c 9092 32 8.7390E-02  7157 -7158 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 28
c 9093 32 8.7390E-02  7057 -7058 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 28
c 9094 32 8.7390E-02  7157 -7158 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 28
c 9095 32 8.7390E-02  7059 -7060 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 30
c 9096 32 8.7390E-02  7159 -7160 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 30
c 9097 32 8.7390E-02  7059 -7060 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 30
c 9098 32 8.7390E-02  7159 -7160 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 30
c 9099 32 8.7390E-02  7059 -7060 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 30
c 9100 32 8.7390E-02  7159 -7160 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 30
c 9101 32 8.7390E-02  7061 -7062 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 32
c 9102 32 8.7390E-02  7161 -7162 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 32
c 9103 32 8.7390E-02  7061 -7062 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 32
c 9104 32 8.7390E-02  7161 -7162 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 32
c 9105 32 8.7390E-02  7061 -7062 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 32
c 9106 32 8.7390E-02  7161 -7162 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 32
c
c --------- Core 3 ---------
c 9059 10 4.8129E-05  7047 -7048 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 18
c 9060 10 4.8129E-05  7147 -7148 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 18
c 9061 10 4.8129E-05  7047 -7048 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 18
c 9062 10 4.8129E-05  7147 -7148 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 18
c 9063 10 4.8129E-05  7047 -7048 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 18
c 9064 10 4.8129E-05  7147 -7148 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 18
c 9065 10 4.8129E-05  7049 -7050 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 20
c 9066 10 4.8129E-05  7149 -7150 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 20
c 9067 10 4.8129E-05  7049 -7050 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 20
c 9068 10 4.8129E-05  7149 -7150 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 20
```

```
c 9069 10 4.8129E-05  7049 -7050 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 20
c 9070 10 4.8129E-05  7149 -7150 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 20
c 9071 10 4.8129E-05  7051 -7052 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 22
c 9072 10 4.8129E-05  7151 -7152 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 22
c 9073 10 4.8129E-05  7051 -7052 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 22
c 9074 10 4.8129E-05  7151 -7152 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 22
c 9075 10 4.8129E-05  7051 -7052 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 22
c 9076 10 4.8129E-05  7151 -7152 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 22
c 9077 10 4.8129E-05  7053 -7054 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 24
c 9078 10 4.8129E-05  7153 -7154 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 24
c 9079 10 4.8129E-05  7053 -7054 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 24
c 9080 10 4.8129E-05  7153 -7154 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 24
c 9081 10 4.8129E-05  7053 -7054 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 24
c 9082 10 4.8129E-05  7153 -7154 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 24
c 9083 10 4.8129E-05  7055 -7056 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 26
c 9084 10 4.8129E-05  7155 -7156 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 26
c 9085 10 4.8129E-05  7055 -7056 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 26
c 9086 10 4.8129E-05  7155 -7156 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 26
c 9087 10 4.8129E-05  7055 -7056 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 26
c 9088 10 4.8129E-05  7155 -7156 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 26
c 9089 10 4.8129E-05  7057 -7058 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 28
c 9090 10 4.8129E-05  7157 -7158 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 28
c 9091 10 4.8129E-05  7057 -7058 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 28
c 9092 10 4.8129E-05  7157 -7158 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 28
c 9093 10 4.8129E-05  7057 -7058 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 28
c 9094 10 4.8129E-05  7157 -7158 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 28
c 9095 10 4.8129E-05  7059 -7060 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 30
c 9096 10 4.8129E-05  7159 -7160 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 30
c 9097 10 4.8129E-05  7059 -7060 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 30
c 9098 10 4.8129E-05  7159 -7160 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 30
c 9099 10 4.8129E-05  7059 -7060 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 30
c 9100 10 4.8129E-05  7159 -7160 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 30
c 9101 10 4.8129E-05  7061 -7062 7028 -7002 -7203 -7204  7030 imp:n=1  $ NW Large Spacer Layer 32
c 9102 10 4.8129E-05  7161 -7162 7029 -7002  7201 -7202  7030 imp:n=1  $ N  Small Spacer Layer 32
c 9103 10 4.8129E-05  7061 -7062 7028 -7002 -7205 -7206  7030 imp:n=1  $ NE Large Spacer Layer 32
c 9104 10 4.8129E-05  7161 -7162 7029 -7002 -7203 -7204 -7030 imp:n=1  $ SE Small Spacer Layer 32
c 9105 10 4.8129E-05  7061 -7062 7028 -7002  7201 -7202 -7030 imp:n=1  $ S  Large Spacer Layer 32
c 9106 10 4.8129E-05  7161 -7162 7029 -7002 -7205 -7206 -7030 imp:n=1  $ SW Small Spacer Layer 32
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
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
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
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
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
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
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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
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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
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
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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
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
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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
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
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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
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
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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
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
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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
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
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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
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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
1729  c/z  -49.28 -14.95  1.3715  $ Position 29
1730  c/z  -51.25  -5.05  1.3715  $ Position 30
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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
2107  c/z   -4.02  40.80  1.371  $ Position 7
```

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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
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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
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
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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 ------ Aluminum Plugs ------
c    *Exact Placement of 12 Aluminum Plugs Unknown
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 --------- Outer (Fixed) Sleeve ---------
c    *Same as Bottom of Steel Plate  $ Bottom of Tube
```

```
3041  pz   50.2    $ Bottom of Cadmium Sheath 1
3042  pz   66.2    $ Top of Cadmium Sheath 1
3043  pz   90.2    $ Bottom of Cadmium Sheath 2
3044  pz  106.2    $ Top of Cadmium Sheath 2
3045  pz  130.2    $ Bottom of Cadmium Sheath 3
3046  pz  146.2    $ Top of Cadmium Sheath 3
3047  pz  170.2    $ Bottom of Cadmium Sheath 4
3048  pz  186.2    $ Top of Cadmium Sheath 4
3049  pz  210.2    $ Bottom of Cadmium Sheath 5
3050  pz  226.2    $ Top of Cadmium Sheath 5
3051  pz  250.2    $ Bottom of Cadmium Sheath 6
3052  pz  266.2    $ Top of Cadmium Sheath 6
3053  pz  368.5    $ Top of Tube
3054  cz    1.785  $ Tube Inner Radius
3055  cz    2.1    $ Tube Outer Radius
3056  cz    2.125  $ Cadmium Sheath Radius
c
c --------- Inner (Moveable) Sleeve ---------
3061  pz  -15.85  $ Bottom of Tube
3062  pz   30.2   $ Bottom of Cadmium Sheath 1
3063  pz   46.2   $ Top of Cadmium Sheath 1
3064  pz   70.2   $ Bottom of Cadmium Sheath 2
3065  pz   86.2   $ Top of Cadmium Sheath 2
3066  pz  110.2   $ Bottom of Cadmium Sheath 3
3067  pz  126.2   $ Top of Cadmium Sheath 3
3068  pz  150.2   $ Bottom of Cadmium Sheath 4
3069  pz  166.2   $ Top of Cadmium Sheath 4
3070  pz  190.2   $ Bottom of Cadmium Sheath 5
3071  pz  206.2   $ Top of Cadmium Sheath 5
3072  pz  230.2   $ Bottom of Cadmium Sheath 6
3073  pz  246.2   $ Top of Cadmium Sheath 6
3074  pz  310.5   $ Top of Tube
3075  cz    1.5   $ Tube Inner Radius
3076  cz    1.75  $ Tube Outer Radius
3077  cz    1.775 $ Cadmium Sheath 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  4.898979486 2.35  $ Middle Top Fuel Zone
3132  s   0            0  4.898979486 3.00  $ Middle Top Pebble Shell
3133  s  -5.196152423  3  4.898979486 2.35  $ NW Top Corner Fuel Zone
3134  s  -5.196152423  3  4.898979486 3.00  $ NW Top Corner Pebble Shell
3135  s   5.196152423  3  4.898979486 2.35  $ NE Top Corner Fuel Zone
3136  s   5.196152423  3  4.898979486 3.00  $ NE Top Corner Pebble Shell
3137  s   0           -6  4.898979486 2.35  $ S Top Corner Fuel Zone
3138  s   0           -6  4.898979486 3.00  $ S Top Corner Pebble Shell
3139  s  -1.732050808  3  0           2.35  $ NW Middle Edge Fuel Zone
3140  s  -1.732050808  3  0           3.00  $ NW Middle Edge Pebble Shell
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```
3141  s   3.464101615  0  0           2.35  $ E Middle Edge Fuel Zone
3142  s   3.464101615  0  0           3.00  $ E Middle Edge Pebble Shell
3143  s  -6.928203230  0  0           2.35  $ W Middle Edge Fuel Zone
3144  s  -6.928203230  0  0           3.00  $ W Middle Edge Pebble Shell
3145  s   3.464101615 -6  0           2.35  $ SE Middle Edge Fuel Zone
3146  s   3.464101615 -6  0           3.00  $ SE Middle Edge Pebble Shell
3147  s  -5.196152423  3 -4.898979486 2.35  $ NW Bottom Corner Fuel Zone
3148  s  -5.196152423  3 -4.898979486 3.00  $ NW Bottom Corner Pebble Shell
3149  s   5.196152423  3 -4.898979486 2.35  $ NE Bottom Corner Fuel Zone
3150  s   5.196152423  3 -4.898979486 3.00  $ NE Bottom Corner Pebble Shell
3151  s   0           -6 -4.898979486 2.35  $ S Bottom Corner Fuel Zone
3152  s   0           -6 -4.898979486 3.00  $ S Bottom Corner Pebble Shell
3153  s   0            0 -4.898979486 2.35  $ Middle Bottom Fuel Zone
3154  s   0            0 -4.898979486 3.00  $ Middle Bottom Pebble Shell
c
c ------ Moderator Pebble ------
4131  s   0            6  4.898979486 3.00  $ N Top Corner Pebble
4132  s   5.196152423 -3  4.898979486 3.00  $ SE Top Corner Pebble
4133  s  -5.196152423 -3  4.898979486 3.00  $ SW Top Corner Pebble
4134  s   3.464101615  6  0           3.00  $ NE Middle Edge Pebble
4135  s  -1.732050808 -3  0           3.00  $ SW Middle Edge Pebble
4136  s   0            6 -4.898979486 3.00  $ N Bottom Corner Pebble
4137  s   5.196152423 -3 -4.898979486 3.00  $ SE Bottom Corner Pebble
4138  s  -5.196152423 -3 -4.898979486 3.00  $ SW Bottom Corner Pebble
c
c ------ HCP Pebble Lattice ------
6001  hex  0 0 -5.1  0 0 10.2  5.196152423 0 0
c
c ------ HCP Pebble Layer Lattice ------
6002  hex  0 0 -5  0 0 10  63 0 0
6003  hex  0 0 -4.898979486  0 0 9.797958971  61 0 0
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 ------
9001  pz 120
9002  pz 160
9003  pz 200
7028  hex  0 0 78  0 0 172.9  0 56.83 0  $ Inside Surface of Larger Spacers
7029  hex  0 0 78  0 0 172.9  0 58.57 0  $ Inside Surface of Small Spacers
7030  py   0
c
7031  pz   83.99897948  $ Bottom Large Spacer Layer 2
7032  pz   87.79897948  $ Top Large Spacer Layer 2
7033  pz   93.79693845  $ Bottom Large Spacer Layer 4
7034  pz   97.59693845  $ Top Large Spacer Layer 4
7035  pz  103.5948974   $ Bottom Large Spacer Layer 6
7036  pz  107.3948974   $ Top Large Spacer Layer 6
7037  pz  113.3928564   $ Bottom Large Spacer Layer 8
7038  pz  117.1928564   $ Top Large Spacer Layer 8
7039  pz  123.1908154   $ Bottom Large Spacer Layer 10
7040  pz  126.9908154   $ Top Large Spacer Layer 10
7041  pz  132.9887743   $ Bottom Large Spacer Layer 12
7042  pz  136.7887743   $ Top Large Spacer Layer 12
7043  pz  142.7867333   $ Bottom Large Spacer Layer 14
7044  pz  146.5867333   $ Top Large Spacer Layer 14
7045  pz  152.5846923   $ Bottom Large Spacer Layer 16
7046  pz  156.3846923   $ Top Large Spacer Layer 16
7047  pz  162.3826513   $ Bottom Large Spacer Layer 18
7048  pz  166.1826513   $ Top Large Spacer Layer 18
7049  pz  172.1806102   $ Bottom Large Spacer Layer 20
7050  pz  175.9806102   $ Top Large Spacer Layer 20
7051  pz  181.9785692   $ Bottom Large Spacer Layer 22
7052  pz  185.7785692   $ Top Large Spacer Layer 22
7053  pz  191.7765282   $ Bottom Large Spacer Layer 24
7054  pz  195.5765282   $ Top Large Spacer Layer 24
7055  pz  201.5744871   $ Bottom Large Spacer Layer 26
7056  pz  205.3744871   $ Top Large Spacer Layer 26
7057  pz  211.3724461   $ Bottom Large Spacer Layer 28
7058  pz  215.1724461   $ Top Large Spacer Layer 28
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7059  pz  221.1704051   $ Bottom Large Spacer Layer 30
7060  pz  224.9704051   $ Top Large Spacer Layer 30
7061  pz  230.968364    $ Bottom Large Spacer Layer 32
7062  pz  234.768364    $ Top Large Spacer Layer 32
c
7131  pz   83.71897948  $ Bottom Small Spacer Layer 2
7132  pz   88.07897948  $ Top Small Spacer Layer 2
7133  pz   93.51693845  $ Bottom Small Spacer Layer 4
7134  pz   97.87693845  $ Top Small Spacer Layer 4
7135  pz  103.3148974   $ Bottom Small Spacer Layer 6
7136  pz  107.6748974   $ Top Small Spacer Layer 6
7137  pz  113.1128564   $ Bottom Small Spacer Layer 8
7138  pz  117.4728564   $ Top Small Spacer Layer 8
7139  pz  122.9108154   $ Bottom Small Spacer Layer 10
7140  pz  127.2708154   $ Top Small Spacer Layer 10
7141  pz  132.7087743   $ Bottom Small Spacer Layer 12
7142  pz  137.0687743   $ Top Small Spacer Layer 12
7143  pz  142.5067333   $ Bottom Small Spacer Layer 14
7144  pz  146.8667333   $ Top Small Spacer Layer 14
7145  pz  152.3046923   $ Bottom Small Spacer Layer 16
7146  pz  156.6646923   $ Top Small Spacer Layer 16
7147  pz  162.1026513   $ Bottom Small Spacer Layer 18
7148  pz  166.4626513   $ Top Small Spacer Layer 18
7149  pz  171.9006102   $ Bottom Small Spacer Layer 20
7150  pz  176.2606102   $ Top Small Spacer Layer 20
7151  pz  181.6985692   $ Bottom Small Spacer Layer 22
7152  pz  186.0585692   $ Top Small Spacer Layer 22
7153  pz  191.4965282   $ Bottom Small Spacer Layer 24
7154  pz  195.8565282   $ Top Small Spacer Layer 24
7155  pz  201.2944871   $ Bottom Small Spacer Layer 26
7156  pz  205.6544871   $ Top Small Spacer Layer 26
7157  pz  211.0924461   $ Bottom Small Spacer Layer 28
7158  pz  215.4524461   $ Top Small Spacer Layer 28
7159  pz  220.8904051   $ Bottom Small Spacer Layer 30
7160  pz  225.2504051   $ Top Small Spacer Layer 30
7161  pz  230.688364    $ Bottom Small Spacer Layer 32
7162  pz  235.048364    $ Top Small Spacer Layer 32
c
7201  px -15.5  $ West Surface N/S Spacers
7202  px  15.5  $ East Surface N/S Spacers
7203  p  -44.471332 43.573394 0 -41.466224 41.838394 0 -41.463224 41.838394 1  $ North Surface of
NW/SE Spacers
7204  p  -59.971332 16.726606 0 -56.966224 14.991606 0 -56.966224 14.991606 1  $ South Surface of
NW/SE Spacers
7205  p   44.471332 43.573394 0  41.466224 41.838394 0  41.466224 41.838394 1  $ North Surface of
NE/SW Spacers
7206  p   59.971332 16.726606 0  56.966224 14.991606 0  56.966224 14.991606 1  $ South Surface of
NE/SW Spacers
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
7021  c/z  -3.464101615  0.0 0.445  $ W Rod
7022  c/z   1.732050808  3.0 0.445  $ NE Rod
7023  c/z   1.732050808 -3.0 0.445  $ SE Rod
7024  pz   -0.28265126              $ Top of Rods
c
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 ------ 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
      25055.70c 7.2621E-05  26054.70c 5.0109E-06  26056.70c 7.8660E-05
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      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 1) ------
m10    1001.70c 6.0466E-07   1002.70c 6.9543E-11   7014.70c 3.6902E-05
        7015.70c 1.3630E-07   8016.70c 1.0252E-05   8017.70c 3.8972E-09
       18036.70c 7.4540E-10  18038.70c 1.4000E-10  18040.70c 2.2063E-07
        6000.70c 9.0527E-09   2003.70c 1.7026E-16   2004.70c 1.2428E-10
       36078.70c 9.4630E-14  36080.70c 6.1645E-13  36082.70c 3.1309E-12
       36083.70c 3.1066E-12  36084.70c 1.5411E-11  36086.70c 4.6774E-12
c         Total 4.8129E-05
c
c ------ Air (Core 1A) ------
c m10    1001.70c 5.7091E-07   1002.70c 6.5663E-11   7014.70c 3.7225E-05
c        7015.70c 1.3749E-07   8016.70c 1.0322E-05   8017.70c 3.9239E-09
c       18036.70c 7.5192E-10  18038.70c 1.4122E-10  18040.70c 2.2256E-07
c        6000.70c 9.1319E-09   2003.70c 1.7175E-16   2004.70c 1.2536E-10
c       36078.70c 9.5458E-14  36080.70c 6.2184E-13  36082.70c 3.1583E-12
c       36083.70c 3.1338E-12  36084.70c 1.5546E-11  36086.70c 4.7184E-12
c         Total 4.8492E-05
c
c ------ Air (Core 2) ------
c m10    1001.70c 6.2731E-07   1002.70c 7.2149E-11   7014.70c 3.7492E-05
c        7015.70c 1.3848E-07   8016.70c 1.0422E-05   8017.70c 3.9620E-09
c       18036.70c 7.5732E-10  18038.70c 1.4224E-10  18040.70c 2.2416E-07
c        6000.70c 9.1975E-09   2003.70c 1.7298E-16   2004.70c 1.2626E-10
c       36078.70c 9.6143E-14  36080.70c 6.2630E-13  36082.70c 3.1810E-12
c       36083.70c 3.1562E-12  36084.70c 1.5658E-11  36086.70c 4.7522E-12
c         Total 4.8918E-05
c
c ------ Air (Core 3) ------
c m10    1001.70c 4.5789E-07   1002.70c 5.2663E-11   7014.70c 3.7571E-05
c        7015.70c 1.3877E-07   8016.70c 1.0359E-05   8017.70c 3.9379E-09
c       18036.70c 7.5892E-10  18038.70c 1.4254E-10  18040.70c 2.2463E-07
c        6000.70c 9.2169E-09   2003.70c 1.7335E-16   2004.70c 1.2653E-10
c       36078.70c 9.6346E-14  36080.70c 6.2763E-13  36082.70c 3.1877E-12
c       36083.70c 3.1629E-12  36084.70c 1.5691E-11  36086.70c 4.7623E-12
c         Total 4.8765E-05
mt10  lwtr.10t hwtr.10t
c
c ------ Aluminum Plugs ------
c    *Aluminum Plug Information Unknown
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
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      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 ------ Cadmium (i.e. 5N) ------
m15   48106.70c 5.7924E-04  48108.70c 4.1242E-04  48110.70c 5.7878E-03
      48111.70c 5.9315E-03  48112.70c 1.1182E-02  48113.70c 5.6627E-03
      48114.70c 1.3313E-02  48116.70c 3.4708E-03  29063.70c 2.8351E-09
      29065.70c 1.2636E-09  26054.70c 5.4521E-10  26056.70c 8.5586E-09
      26057.70c 1.9766E-10  26058.70c 2.6304E-11  82204.70c 7.0393E-10
      82206.70c 1.2118E-08  82207.70c 1.1112E-08  82208.70c 2.6347E-08
      12024.70c 5.0788E-07  12025.70c 6.4297E-08  12026.70c 7.0791E-08
      13027.70c 3.8612E-08  14028.70c 3.4212E-08  14029.70c 1.7372E-09
      14030.70c 1.1452E-09  47107.70c 1.2517E-09  47109.70c 1.1629E-09
      22046.70c 1.7956E-09  22047.70c 1.6193E-09  22048.70c 1.6045E-08
      22049.70c 1.1775E-09  22050.70c 1.1274E-09  83209.70c 7.4779E-08
      20040.70c 1.2600E-08  20042.70c 8.4093E-11  20043.70c 1.7547E-11
      20044.70c 2.7113E-10  20046.70c 5.1990E-13  20048.70c 2.4305E-11
c         Total 4.6340E-02
mt15  al27.12t fe56.12t
c
c ------ Peraluman R-257 (ZEBRA Rods) ------
m16    5010.70c 1.4688E-07   5011.70c 5.9119E-07  12024.70c 7.2610E-04
      12025.70c 9.1923E-05  12026.70c 1.0121E-04  13027.70c 5.8004E-02
      14028.70c 1.0481E-04  14029.70c 5.3221E-06  14030.70c 3.5084E-06
      25055.70c 1.4524E-06  26054.70c 3.3406E-06  26056.70c 5.2440E-05
      26057.70c 1.2111E-06  26058.70c 1.6117E-07  29063.70c 3.4742E-06
      29065.70c 1.5485E-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 5.9127E-02
mt16  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) ------
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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
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      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 ------
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 ------ Cavity Floor ------
c    *Cavity Floor Fillers Not Used
c
c --- Water Ingress Simulation ------------------------------------------------
c ------ Polyethylene Rods ------
m34    5010.70c 5.2270E-09   5011.70c 2.1039E-08   1001.70c 8.2007E-02
       1002.70c 9.4319E-06   6000.70c 4.0402E-02
c         Total 1.2242E-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.

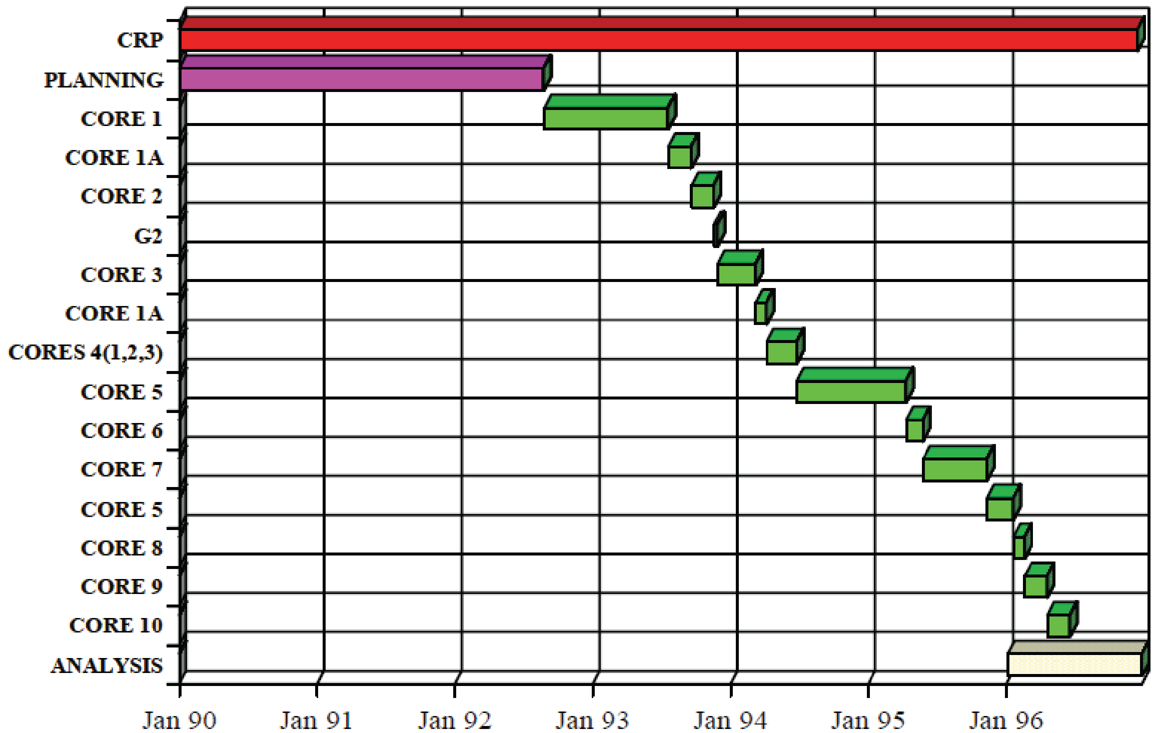

Figure D.3-1. Time Allocation for HTR-PROTEUS Experiments (Ref. 3).

Table D.3-1. Test Matrix for Cores 1 through 10 (Ref. 3).

	CRITICAL LOADING	Σ_a	SUBCRIT CORE	SHUTDOWN RODS		CONTROL RODS		UPPER REFL.	β/Λ	MEAS. RODS	CENT. CONT. ROD	TEMP. COEFF	COM-PONENT WORTHS	MISC	REACTION RATE DISTRIBUTIONS					REACTION RATE RATIOS		
															IN CORE			IN PEBBLE		AT CORE CENTRE		
METHOD / CORE	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 C:8				
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.). Summary of Data Employed from the 16th Ed. of the Chart of the Nuclides.

Isotope or Element	Atomic Weight (g/mol)	Isotopic Abundance (at.%)
Mn	54.938049	--
Fe	55.845	--
^{54}Fe	--	5.845
^{56}Fe	--	91.754
^{57}Fe	--	2.119
^{58}Fe	--	0.282
Co	58.933200	--
Ni	58.6934	--
^{58}Ni	--	68.0769
^{60}Ni	--	26.2231
^{61}Ni	--	1.1399
^{62}Ni	--	3.6345
^{64}Ni	--	0.9256
Cu	63.546	--
^{63}Cu	--	69.17
^{65}Cu	--	30.83
Zn[(a)]	65.409	--
Ga	69.723	--
^{69}Ga	--	60.108
^{71}Ga	--	39.892
Kr	83.798	--
^{78}Kr	--	0.35
^{80}Kr	--	2.28
^{82}Kr	--	11.58
^{83}Kr	--	11.49
^{84}Kr	--	57
^{86}Kr	--	17.3

Isotope or Element	Atomic Weight (g/mol)	Isotopic Abundance (at.%)
Mo	95.94	--
^{92}Mo	--	14.84
^{94}Mo	--	9.25
^{95}Mo	--	15.92
^{96}Mo	--	16.68
^{97}Mo	--	9.55
^{98}Mo	--	24.13
^{100}Mo	--	9.63
Ag	107.8682	--
^{107}Ag	--	51.839
^{109}Ag	--	48.161
Cd	112.411	--
^{106}Cd	--	1.25
^{108}Cd	--	0.89
^{110}Cd	--	12.49
^{111}Cd	--	12.8
^{112}Cd	--	24.13
^{113}Cd	--	12.22
^{114}Cd	--	28.73
^{116}Cd	--	7.49
Sn	118.710	--
^{112}Sn	--	0.97
^{114}Sn	--	0.66
^{115}Sn	--	0.34
^{116}Sn	--	14.54
^{117}Sn	--	7.68
^{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.). 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.