INL/EXT-15-34971

EXPERIMENTS WITH HEU (93.14 wt.%) METAL ANNULI WITH INTERNAL GRAPHITE CYLINDER

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April 2015

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Assistant Secretary for ____, OR Office of _____
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

NEA/NSC/DOC(95)03/II
Volume II

HEU-MET-FAST-077

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Evaluator

Xiaobo Liu
The Institute of Nuclear Physics and Chemistry
Chinese Academy of Engineering Physics

Internal Reviewers
John D. Bess
Idaho National Laboratory

Independent Reviewer

Udo Wehmann
OECD/NEA Consultant

John T. Mihalczo
Oak Ridge National Laboratory

HEU-MET-FAST-077

EXPERIMENTS WITH HEU (93.14 wt.%) METAL ANNULI WITH INTERNAL GRAPHITE CYLINDER

IDENTIFICATION NUMBER: HEU-MET-FAST-077 SPECTRA

KEY WORDS: acceptable, annular fuel, graphite moderator, highly enriched uranium, metal fuel

1.0 DETAILED DESCRIPTION

1.1 Overview of Experiment

A variety of critical experiments were performed with enriched uranium metal (oralloy[a]) during the 1960s and 1970s at the Oak Ridge Critical Experiments Facility (ORCEF) in support of criticality safety operations at the Y-12 Plant. The purposes of these experiments included the evaluation of storage, casting, and handling limits for the Y-12 Plant and providing data for verification of calculation methods and cross-sections for nuclear criticality safety applications. These experiments included solid cylinders of various diameters, annuli of various inner and outer diameters, two and three interacting cylinders of various diameters, and graphite and polyethylene reflected cylinders and annuli.

Of the hundreds of delayed critical experiments, some of these experiments have been evaluated. Unreflected and unmoderated experiments with the same set of highly enriched uranium metal parts were performed at ORCEF in the 1960s and are evaluated in HEU-MET-FAST-051. Thin graphite reflected (2 inches or less) experiments also using the same set of highly enriched uranium metal parts are evaluated in HEU-MET-FAST-071. Polyethylene-reflected configurations are evaluated in HEU-MET-FAST-076. A stack of highly enriched metal discs with a thick beryllium top reflector is evaluated in HEU-MET-FAST-069, two additional highly enriched uranium annuli with beryllium cores are evaluated in HEU-MET-FAST-059, and one case of uranium metal annuli surrounding potassium-filled, stainless steel cans is evaluated in HEU-MET-FAST-099.

In this report, only three experimental configurations are described. They are internal graphite reflected metal uranium assemblies with three different diameter HEU annuli (15-9 inches, 15-7 inches and 13-7 inches). These experiments can be found in Reference 1 and in their associated logbook.[b]

All the cases with fast neutron spectra assemblies were determined to be acceptable benchmark experiments.

The uncertainty in both mass and size measurements was “one in the last significant digit given”.

1.2 Description of the Experimental Configuration

1.2.1 Basic Information and General Assembly Procedure

These experiments were performed on a vertical assembly machine (previously described by Rohrer et al[c]) in the east experimental cell of the Oak Ridge Critical Experiments Facility (ORCEF). Safety mechanisms of

[a] Oralloy stands for Oak Ridge Alloy, and consists of HEU metal with a ^{235}U enrichment of more than 93 %.
[b] Experimental data for these experiments can be found in ORNL logbook 12R(East cell-logbook1, E-19) on page 72-84, 123-127, and 135-139.
[c] E. R. ROHRER et al., *Neutron Phys. Div. Ann. Progr. Rept. Sept. 1, 1961*, ORNL-3193, p. 168, Oak Ridge National Laboratory (1961).

the device and the facility are discussed in the facility safety review.[a] The machine was located such that the center of the core was 3.67 m from the 1.5-m-thick west wall, 3.9 m from the 0.6-m-thick north wall, and 2.8 m above the concrete floor in the 10.7×10.7-m-square, 9.1-m-tall room.[b] Figure 1 is a photograph of the vertical assembly machine.

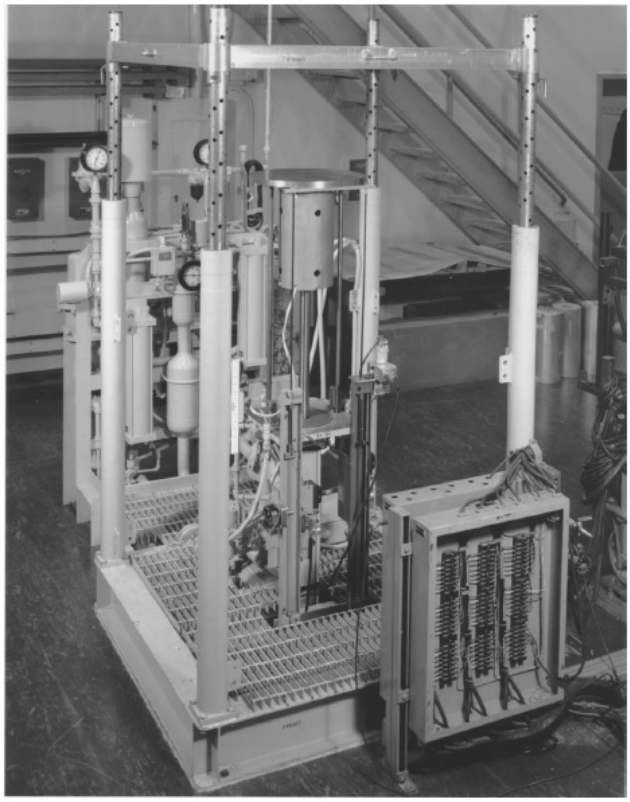


Figure 1. Photograph of the Vertical Assembly Machine.[a]

Each assembly is coaxially composed of three or four thinner highly enriched uranium (HEU) metal annuli with outside diameters varying in two-inch steps from 9 to 15 inches and the inside diameters varying in two-inches steps from 7 to 13 inches, that for instance the assembly of 15-9 inches (Case 1) in diameter contains the annuli 11-9 inches, 13-11 inches and 15-13 inches in diameter, and had only an internal graphite cylinder without external reflector. The basic information for the three cases is summarized in Table 1.

A typical 3-D figure for the core configuration of Case 2 is shown in Figure 2 to show how these types of assemblies were constituted.

It should be noted that all dimensions were measured and recorded in inches. When dimensions are rounded to the nearest inch, they are nominal dimensions.

[a] *Safety Review of the Oak Ridge Critical Experiments Facility*, Union Carbide Nuclear Corporation, Oak Ridge National Laboratory (1962).
[b] J.T. Mihalczo, "A Small Graphite-Reflected UO2 Assembly", *Proc. 5th Int. Conf. Nucl. Crit. Safety*, Albuquerque, NM, September 17-21 (1995).

Table 1. Basic Information of the Three Experiments.

Case Number	HEU Nominal Dimensions (in.)			Material Inside Annuli	Reactivity of Assembly (cents)[(a)]
	OD	ID	Height		
1	15	9	5-5/16	graphite	-2.19
2	15	7	4-1/16	graphite	-15.02
3	13	7	5-1/4	graphite	+18.7

(a) Measured reactivity values listed here are for the assembled experiment not corrected for support structure including the diaphragm support ring, stainless steel diaphragm and lower support stand. These values can be converted to k_{eff} by using an effective delayed-neutron fraction of 0.0066. A reactivity of 100 cents or one dollar is equal to the effective delayed-neutron fraction. Original reactivity and the contribution of the support structure are given in Table 6.

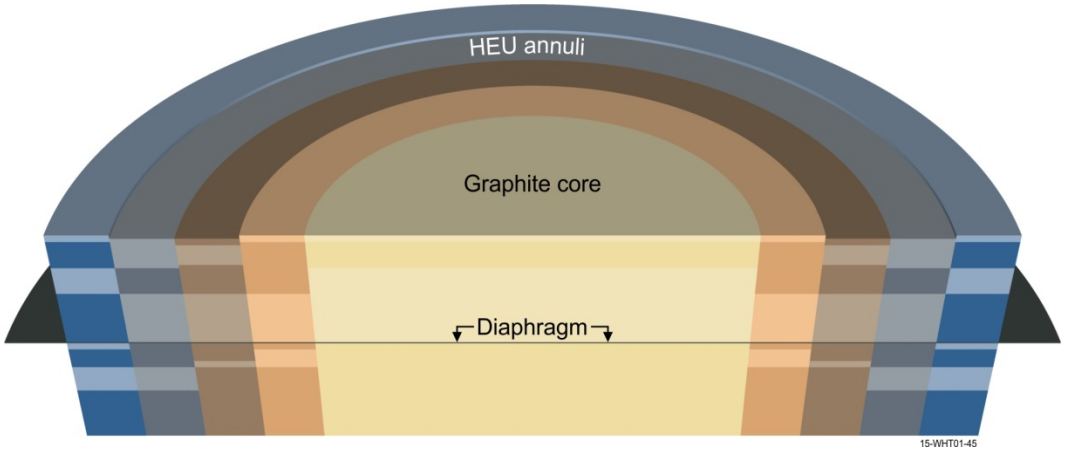


Figure 2. 3-D Figure for Core Configuration of Case 2.

In general, the uranium metal assemblies were constructed on a vertical assembly machine (shown in Figure 1 and Figure 3), which primarily consisted of a hydraulic lift with 22-inch (55.88-cm) vertical motion, to support the lower section and a stationary upper section. Note that Figure 3 shows an unreflected uranium metal assembly; these critical experiments were assembled on the same vertical lift with the same support structure as shown in this figure. Except the compositions of both upper and lower section of assembly core, all the support structure is the same.

The lower support stand held the uranium metal and graphite of the lower section in place. The lower section was supported on 0.125-inch-(0.3175-cm)-thick aluminum edges, oriented vertically 120 degrees apart (visible in Figure 3). The upper section was supported by four vertical posts, which held a low-mass support consisting of two 30-inch-(76.2-cm)-ID, 2-inch (5.08-cm) wide, 0.5-inch-(1.27-cm)-thick, aluminum clamping rings bolted together and supported off vertical poles by aluminum tubing; see Figure 3. The 30-inch-diameter clamping rings held a 0.010-inch-(0.0254-cm)-thick stainless steel (304L) diaphragm on which the upper section with uranium metal and graphite was supported. The lower section was supported on a low-mass support stand (sometimes referred to as a support tower) mounted in the vertical position and also shown in Figure 3. The 0.5-inch-(1.27-cm)-thick, 18-inch-(45.72-cm)-diameter aluminum base of this support stand was bolted to the 1-inch-(2.54-cm)-thick, 18-inch-(45.72-cm)-diameter stainless steel table of the vertical lift as shown in Figure 3. The lower surface of the uranium was at a height of 36 inches (91.44 cm) above the aluminum base. Small aluminum pieces bolted to the 120° vertical members restrained lateral motion of the lower section. These low mass supports were used to minimize the reflection effects of support structure. The aluminum base of the support stand is type Al6061 and the stainless steel table is

Type 304L.[a] Additional structural details for the lower support stand and diaphragm clamping ring are given in Appendix C.

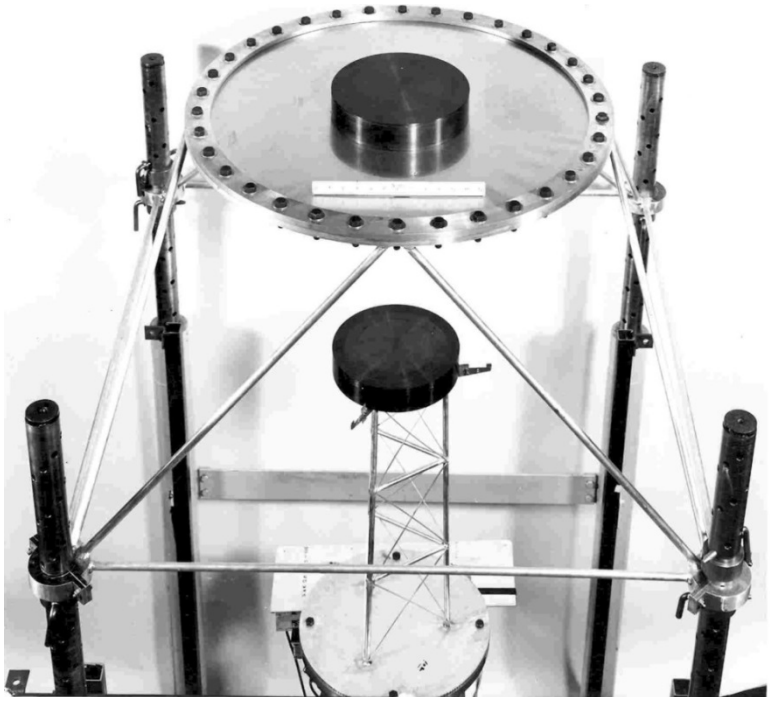


Figure 3. A Typical Uranium Metal Assembly of Two Interacting 11-inch-Diameter Cylinders at Close Spacing on the Vertical Assembly Machine (Not a Photo of the Current Experiment).[b] (Similar supports were used in these measurements and are described in Appendix C.)

Experiments were assembled by mounting a fixed height of uranium metal parts mounted on the lower section with graphite cylinder, and then uranium was added to the upper section until near delayed criticality was achieved. For these experiments, the lower section was raised until it made contact with the diaphragm and actually slightly lifted the upper section of material mounted on the diaphragm. The lifting of the top section slightly by the bottom section was used to compensate for the sag of the diaphragm due to the weight of the upper material. The lifting of the diaphragm was monitored to the nearest 0.001 inches (0.00254 cm) and the lower section was moved up only until the diaphragm was level. Due to the smallest thickness of the uranium parts, the system could rarely be adjusted to exactly delayed criticality. For most assemblies the uranium mass of the upper section was adjusted until a self-sustaining fission chain reaction occurred with a measurable positive stable reactor period. For assemblies that were slightly subcritical, an additional hydrogenous reflector (small piece of Plexiglas) was added as a reflector to achieve a self-sustaining chain reaction. When the fission rate achieved a value from which a negative reactor period could be measured, the Plexiglas was quickly (within a fraction of a second)[c] removed to measure the resulting negative reactor period. The reactivity was determined with an analog computer system based on inverse kinetics which uses point kinetics with 6 delayed neutron groups to obtain the reactivity from the fission density as a function of time.[d]

[a] Personal communication with John T. Mihalczo in HEU-MET-FAST-099, February 2010.
[b] Photo 39380, Oak Ridge National Laboratory photo of a bare uranium assembly. This same support structure was used for these measurements.
[c] Personal communication with John T. Mihalczo in HEU-MET-FAST-076 (ICSBEP Handbook), June 2006.
[d] Cesar A. Sartre, "The Measurement of Reactivity," Nuclear Sci. & Eng., Vol. 8, No. 5, Pages 443-447 (1960).

Detectors used for reactor period measurements were placed 10 to 15 ft (3.048 to 4.572 m) away and consisted of BF_3 proportional counters and boron-lined ionization chambers. The inhour equation was then used to convert reactor period to reactivity. A neutron source was near the assemblies for startup only and was withdrawn ~4 ft (~1.2192 m) away into a borated paraffin shield during the measurements. Measurements were performed at fission rates such that the neutrons coming out of the shield from the startup source were insignificant.[a]

The reactivity was obtained from the stable period measurements using a 12-group inhour equation (six groups for ^{235}U and six groups for ^{238}U) with parameters from the delayed-neutron data of Keepin, Wimett, and Ziegler and the fraction of fissions occurring in ^{235}U and ^{238}U. It was assumed that half the fissions that actually occurred in ^{234}U and ^{236}U occurred in ^{235}U and the other half in ^{238}U. Using an effective delayed neutron fraction, β_{eff}, of 0.0066, the reactivity in cents can be converted to Δk_{eff} since one dollar or 100 cents equals a Δk_{eff} of 0.0066. The principal experimentalist assigned an uncertainty of ± 5% to the value of β_{eff}[b].

1.2.2 Masses and Dimensions of Uranium Components

The average dimensions and masses of the uranium metal annuli for these experiments are given in Table 2; the dimensions are measured to within $1x10^{-4}$ inches with an uncertainty of $5x10^{-5}$ inches and the masses of the parts are accurate to 0.5 grams. All dimensional measurements for the parts were measured at 70° F at the Y-12 plant.

[a] Personal communication with John T. Mihalczo in HEU-MET-FAST-099, March 2010.
[b] Personal communication with John T. Mihalczo in HEU-MET-FAST-071, January 2001.

Table 2. Masses and Dimensions of Uranium (93.14 wt.% ^{235}U) Metal Annuli.

Part Number	Measured Mass (g)	Measured Height (in)	Measured ID (in)	Measured OD (in)
2735	13409	0.9985	13.0020	14.9935
2738	7710	1.0012	7.00375	8.99575
2739	13461	0.9945	13.0027	14.9955
2740	11568	1.5000	7.0025	8.99625
2741	11568	1.5003	7.0025	8.9965
2742	3617	0.3751	9.0015	10.9968
2743	3621	0.3740	9.0025	10.9965
2744	1223	0.12675	9.0065	10.9968
2745	9634	0.9990	9.0010	10.9965
2746	1238	0.12865	9.00175	10.9965
2747	14436	1.4999	9.0020	10.9968
2748	14462	1.5000	9.0025	10.9975
2749	4360	0.3774	11.0030	12.9955
2750	4336	0.37545	11.0015	12.9945
2751	5822	0.50355	11.0015	12.9958
2752	5811	0.50325	11.0025	12.9955
2753	5782	0.5013	11.0030	12.9968
2754	5826	0.5036	11.0040	12.9953
2755	6514	0.5635	11.0030	12.9960
2756	11567	1.0002	11.0036	12.9967
2757	11575	1.00155	11.0025	12.9960
2758	1685	0.1245	12.9965	14.9967
2760	6743	0.5000	13.0020	14.9950
2761	1706	0.1265	13.0010	14.99475
2762	7703	0.99925	7.00375	8.99625
2763	953	0.1243	7.0038	8.9958
2767	5410	0.5620	9.0010	10.9960
2773	962	0.1250	7.0015	8.9970

Table 2 (cont'd.). Masses and Dimensions of Uranium (93.14 wt.% 235U) Metal Annuli.

Part Number	Measured Mass (g)	Measured Height (in)	Measured ID (in)	Measured OD (in)
2775	1917	0.2485	7.0040	8.99675
2776	9644	1.0015	9.0015	10.9965
2778	2411	0.2510	9.0020	10.9965
2779	2417	0.2510	9.0015	10.9970
2780	1440	0.12485	11.0020	12.9961
2781	1449	0.1252	11.0025	12.9968
2782	2914	0.25175	11.0035	12.9956
2784	5039	0.3725	13.0015	14.9945
2785	5043	0.3747	13.0029	14.9958
2786	6717	0.49465	13.0025	14.9950
2787	6788	0.5044	13.0015	14.9950
2829	2895	0.37625	7.00315	8.99625
2848	6748	0.5019	13.0031	14.9964
2885	3415	0.25365	13.0032	14.9963
2886	3384	0.25145	13.0025	14.9966

1.2.3 Masses and Dimensions of Graphite Parts

The graphite parts were National Carbon Type HLM graphite and also carefully machined at the Oak Ridge Y-12 Plant. HLM graphite was chosen for these experiments rather than more pure graphite since it was the material used for casting uranium. The dimensions and masses of the parts, which were annuli for side reflector and discs for top and bottom reflector or for filling the central annuli in the appropriate experiments, were measured (Please note that only discs were used in these three assemblies, as shown in Table 3). The masses were measured in grams with an uncertainty of 0.5 grams. The dimensions and masses of the individual graphite parts are given in Table 3.

Table 3. Masses and Dimensions of Graphite Cylinder Parts.[a]

Reference Number	Part Description (nominal dimensions)		Measured Mass and Dimension		
	OD (in.)	Height (in.)	mass (g)	OD (in.)	Height (in.)
1	7	1/8	130	6.9985	0.1250
3	7	1/4	266	6.9985	0.2500
7	7	1/2	536	6.9985	0.5000
15	7	1	1065	6.9985	1.0000
27	7	1.5	1618	6.9985	1.5000
29	9	1	1763	8.9985	1.0000
36	7	2	2131	6.9985	2.0000
42	9	1.5	2675	8.9985	1.5000
44	9	2	3533	8.9985	2.0000
61	9	1/4	445	8.9985	0.2500
70	9	9/16	998	8.9985	0.5625

(a) Data are cited from HEU-MET-FAST-071.

1.2.4 Stack Height of Annuli and Core and Gaps

The assembly heights of the annular sections for a given experiment were measured to ±0.001 in. as follows. For example, all of the 13-inch-OD, 11-inch-ID annular rings of an assembly were stacked on a precision flat surface, and the distance between the upper surface and the precision flat surface was measured. In stacking, all parts in the assemblies of the various annuli were in the same vertical order and orientation as in the critical experiment. The azimuthal orientation of the parts was such that the location of the part numbers on the upper surface was always oriented toward the north wall of the experimental cell. This assured reproducibility when restacking assemblies or parts of assemblies for height measurements or repeated measurements. The parts were always positioned on the surface with the scribed part number facing up. Thus, for the height measurements on the precision flat surface, the orientation of the uranium metal annuli was as in the experimental assembly. The height of the total stack of a given one-inch-wide radial increment was normally measured at azimuthal locations N, E, S, W, SW, and NE, and the values were averaged. This operation presented no criticality safety problems in hand stacking since the annuli were only one-inch-thick radially. Values for the measured height of the annulus sets for the three experiments both in upper and lower section are given in Table 4. The sum of the thickness for the concentric annuli and core is also given in Table 4 as “Material Height” with 4 decimal significances.

Table 4. Stack Height of Annuli and Core.

	Measured Height of Uranium Annuli and Graphite Core as Assembled (in.)[a]					**Material Height of Uranium Annuli and Graphite Core (in.)**				
	7-9	**9-11**	**11-13**	**13-15**	**core**	**7-9**	**9-11**	**11-13**	**13-15**	**core**
1-upper	-	3.3127	3.3232	3.3845	3.3175	-	3.31450	3.32395	3.37115	3.31250
1-lower	-	2.0040	2.0052	2.0066	2.0000		2.00365	2.00735	2.00160	2.00000
2-upper	2.1266	2.0679	2.0691	2.1278	2.1306	2.12475	2.06425	2.06830	2.11365	2.12500
2-lower	2.0043	2.0040	2.0052	2.0066	2.0000	2.00125	2.00375	2.00735	2.00160	2.00000
3-upper	2.2493	2.2506	2.2590	-	-[b]	2.24895	2.25150	2.25815	-	2.25000
3-lower	3.0026	3.0043	3.0094	-	-[b]	3.00030	2.99990	3.00995	-	3.00000

(a) Average of several measurements.
(b) This data is not available.

The average vertical gaps between annular parts and graphite core parts can be obtained from the measured stack heights by subtracting the sum of the thickness of the individual parts both given in Table 4 and dividing by the number of parts less one in the stack. These average gaps between the flat surfaces of the annular sections and graphite core sections are given in Table 5.

There is no gap between the bottom of the top uranium annuli stacks and the stainless steel diaphragm. The tallest stack of uranium annuli in the lower section was "in contact with" the bottom of the stainless steel diaphragm.

Table 5. Average Gap Height of Annuli and Core.

	Number of Annuli					Average Gap Height of Annuli and Core (in.)				
	7-9	9-11	11-13	13-15	core	7-9	9-11	11-13	13-15	core
1-upper	-	4	7	7	4	-	0.00000[a]	0.00000[a]	0.00223	0.00167
1-lower	-	3	3	4	1	-	0.00018	0.00000[a]	0.00166	-
2-upper	3	4	3	4	3	0.00094	0.00123	0.00039	0.00472	0.00279
2-lower	3	3	3	4	1	0.00154	0.00012	0.00000[a]	0.00166	-
3-upper	3	3	5	-	3[c]	0.00023	0.00000[a]	0.00021	-	0.00223[b]
3-lower	2	2	6	-	2[c]	0.00232	0.00435	0.00000a	-	0.00223[b]

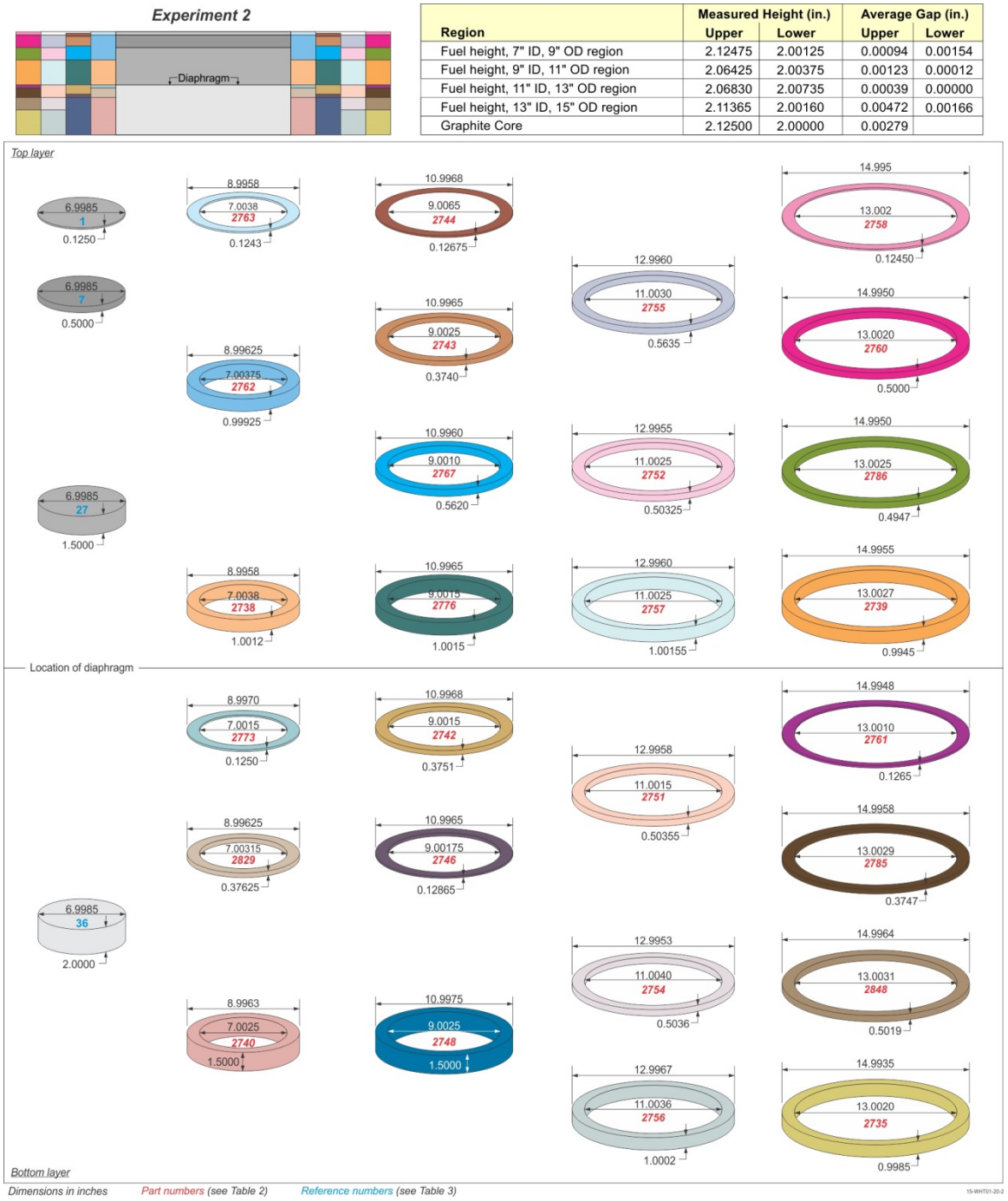
(a) The sum of the heights of the individual parts was greater than the measured stack height.
(b) This value is the average one from the gaps of Case 1 and Case 2.
(c) The part arrangement is not available. This is the most probable combination from the graphite part in Table 3.

1.2.5 Drawings of Experimental Configurations

Assemblage of each experiment is illustrated in Figure 4, Figure 5 and Figure 6.

Region	Measured Height (in.) Upper	Measured Height (in.) Lower	Average Gap (in.) Upper	Average Gap (in.) Lower
Fuel height, 9" ID, 11" OD region	3.31450	2.00365	0.00000	0.00018
Fuel height, 11" ID, 13" OD region	3.32395	2.00735	0.00000	0.00000
Fuel height, 13" ID, 15" OD region	3.37115	2.00160	0.00223	0.00166
Graphite Core	3.31250	2.00000	0.00167	

Figure 4. Experiment 1 – Configuration.



Region	Measured Height (in.) Upper	Measured Height (in.) Lower	Average Gap (in.) Upper	Average Gap (in.) Lower
Fuel height, 7" ID, 9" OD region	2.12475	2.00125	0.00094	0.00154
Fuel height, 9" ID, 11" OD region	2.06425	2.00375	0.00123	0.00012
Fuel height, 11" ID, 13" OD region	2.06830	2.00735	0.00039	0.00000
Fuel height, 13" ID, 15" OD region	2.11365	2.00160	0.00472	0.00166
Graphite Core	2.12500	2.00000	0.00279	

Figure 5. Experiment 2 – Configuration.

Region	Measured Height (in.) Upper	Measured Height (in.) Lower	Average Gap (in.) Upper	Average Gap (in.) Lower
Fuel height, 7" ID, 9" OD region	2.24895	3.00030	0.00019	0.00232
Fuel height, 9" ID, 11" OD region	2.25150	2.99990	0.00000	0.00435
Fuel height, 11" ID, 13" OD region	2.25815	3.00995	0.00021	0.00000
Graphite Core	2.25000	3.00000	0.00223	0.00223

Figure 6. Experiment 3 – Configuration.

1.2.6 Assembly Alignment

1.2.6.1 Radial Alignment of Upper and Lower Section

Radial Alignment of Upper Section: For assembly of the upper section, uranium metal was placed on the Type 304L stainless steel diaphragm. Uranium was positioned, with a ruler, in the appropriate distance from the inside of the aluminum clamping ring, which held the 0.010-inch-(0.0254-cm)-thick stainless diaphragm. For example, a layer of uranium metal for an 11-inch-(27.94-cm)-outer diameter annulus typically consists of a 7-inch-(17.78-cm)-ID / 9-inch-(22.86-cm)-OD annulus, and a 9-inch-(22.86-cm)-ID / 11-inch-(27.94-cm)-OD annulus. About half of the material was added to the diaphragm and the location of the material was continuously adjusted with a precise high-quality level in one direction and then the level was rotated 90° on the top of the uranium. If the assembly was not exactly centered on the diaphragm, it would not be precisely level because of the sag in the diaphragm as it was loaded. Two precisely machined steel blocks (±0.0001 inches, ±0.000254 cm) were used to squeeze the outside radial surface of the uranium metal until it was aligned. An edge of the machined block was then held at one outside radial location, squeezing the uranium together until no light was visible between the machined block and the uranium metal. This process was repeated 90° from the position of the original adjustment, rechecked again at the original position, and small adjustments made if necessary. This process continued until the outside radii of the parts were precisely aligned and the upper section assembly was complete. The squeezing procedure was performed by one individual while another person observed the light coming through small gaps between the blocks and the uranium metal.[a] The alignment of outer radii of the upper or lower section was less than ±0.001 inches. Of course, if two positions 90° apart are adjusted, the positions at 180° and 270° can be off only by the difference in the diameters of the outside parts.

Radial Alignment of Lower Section: For the lower section, the uranium parts were centrally located on the lower support stand and the same procedure was used except that the leveling of the parts was accomplished by shimming with aluminum foil (various thicknesses of aluminum foil were available). The foil was placed between the three 120° upper edges of the lower support stand and the lowest parts.

Radial Alignment Accuracy Summary: Uncertainty in radial alignment of uranium metal parts on each half is ±0.001 inch.

1.2.6.2 Lateral Alignment of Upper Section with the Lower Section

For these experiments, the alignment of the upper and lower sections was adjusted and verified using the Lateral Alignment Fixture shown in Figure 7. There were two identical fixtures used for lateral alignment between the upper section and the lower section. They were U-shaped and were machined out of 0.375-inch-(0.9525-cm)-thick aluminum. The end pieces were carefully machined by the Y-12 shops to be perpendicular to the long direction of the fixture and coplanar with each other. When leveled properly, the front face of the 4×4×½-inch-(10.16×10.16×1.27-cm)-thick end pieces were vertical and in the same plane to within ±0.001 inch (±0.00254 cm). In use, the lower side of the upper leg rested on the top surface of the clamping ring for the diaphragm. The fixture was perpendicular to the outer radial surface of the annuli and was moved inward until it touched the uranium of the top section. The leveling screws were adjusted until the fixture was leveled.

The second fixture was placed 90° apart from the first in a similar manner. Both fixtures were moved back slightly, and the lower section was raised until it was at the height of the lower leg of the U-shaped fixtures. Both fixtures were then nearly adjusted properly. Removal or additions of material from the upper section sometimes required small leveling adjustments. The fixtures were moved in until they touched uranium (either on the upper or the lower section). When lack of contact was observed at either of the front faces of

[a] Personal communication with John T. Mihalczo, March 2010.

the fixture, the lower section was lowered to the full-out position, and the position of the uranium on the lower support stand was adjusted. Finally, the lower lift table was raised and the alignment was checked.

The process was repeated several times as necessary. The final 0.005-inch (0.0127-cm) adjustments were usually made by moving the upper section. This was a long and tedious procedure, which took one to two hours or more as needed but was always performed and resulted in uranium metal of the upper and lower sections being aligned within ±0.005 inch (±0.0127 cm).

Lateral Alignment Accuracy Summary: Upper and lower assembly uranium metal alignment uncertainty is ±0.005 inch (±0.0127 cm).

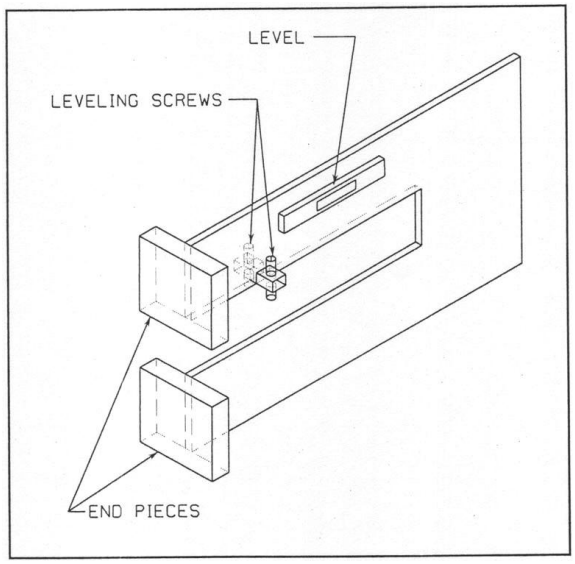


Figure 7. Sketch of Fixture for Lateral Alignment of Uranium.

1.2.7 Reactivity Effects of Support Structure

The support structure that was used to assemble these experiments was made up of the 0.010-inch-(0.0254-cm)-thick Type 304L stainless steel diaphragm, the low-mass aluminum support stand, and two 30-inch-diameter, 2-inch-(5.08-cm)-wide, 0.5-inch-(1.27-cm)-thick diaphragm clamping rings bolted together. The support structure reactivity worth consisted primarily of the reactivity effects of the diaphragm, the diaphragm support rings, and the low-mass support stand. The reactivity worth of each of these three parts of the support structure was measured.

Additional figures depicting the assembly support structure are provided in Appendix C.

A positive reactivity effect means that the reactivity of the critical assembly increased due to the inclusion of that item in the assembly. Therefore, removing that particular item from the experiment resulted in a decrease in the neutron multiplication factor. A negative reactivity effect means that the reactivity of the assembly decreased due to the item's inclusion. The Type 304L stainless steel diaphragm in all experiments typically reduced the k_{eff} of the system since it separated uranium metal halves and introduced neutron absorbing material between them. The presence of the diaphragm support ring and low-mass support stand of the lower section generally resulted in a positive reactivity addition because they provided neutron reflection to the system. The combined reactivity effect of all other supports, such as the four vertical poles and tubing for the diaphragm support ring, was reported to be less than one cent and was not evaluated.

The reactivity of the support structure, was evaluated by assembling the system to delayed criticality or a known measured reactivity, adding additional support structure, and obtaining the reactivity of the support structure from the measured reactor period for the assembly with and without the additional support structure. The effect of the lower support stand was evaluated using an inverted support stand, like that for the lower section, which was added to the top of the upper section. Care was taken in suspending it so that it would not compress the materials of the assembly. To estimate the effect of the diaphragm and clamping ring, their thicknesses were doubled and the reactivity change was measured and the effect was assumed to be linear. Where multiple instruments were used to measure the reactor period, the reactivity values obtained were averaged. These effects were measured for the components and listed in Table 6. The reactivity worth of the entire support structure is obtained by adding the worth of the three components of the support structure: annular diaphragm rings, stainless steel diaphragm, and low-mass support stand. Multiple measurements for the reactivity effects of the support structure were unavailable. The measured worth of the diaphragm includes the separation distance between the two halves of the experiment.[a]

The diaphragm bolts were not included in the experimental analysis of the support structure worth. The 304L stainless steel bolts are 0.5 in. (1.27 cm) in diameter and 1.5 in. (3.81 cm) long; their effective worth is believed to be negligible and within the measurement uncertainty of ±2¢, which is the reproducibility uncertainty for a given configuration.[b]

1.2.8 Measured Reactivity of the Three Cases

Table 6 summarizes the measured and corrected reactivity of the three cases. Since in HEU-MET-FAST-076, the uranium used (93.14 wt.% ^{235}U) is similar to this evaluation with fast spectra, the effective delayed neutron fraction, β_{eff}, of 0.00660 is taken over. The principal experimentalist assigned an uncertainty of ± 5% to the value of β_{eff}.[c]

[a] Personal communication with John T. Mihalczo, February 2010.
[b] Personal communication with John T. Mihalczo, June-July 2010.
[c] Personal communication with John T. Mihalczo in HEU-MET-FAST-076, January 2006.

Table 6. Measured and Corrected Reactivities.[(a)]

Case	HEU Nominal Diameter (in.)	Reactivity of the Assembly (cents)	Reactivity of Support Structure (cents)				Reactivity Corrected for Support Structure[(a)] (cents)
			Diaphragm Support Ring	Stainless Steel Diaphragm	Lower Support Stand	Total	
1	15-9	-2.19	6.29	-10.33	13.39	9.35	-11.54
2	15-7	-15.02	5.8	-16.36	20.02	9.64	-24.66
3	13-7	18.7	4.88	-11.68	9.9	3.1	15.6

(a) All the data are transcribed from the ORNL logbook 12R (East cell-logbook1, E-19) on page 140 for Case 1, page 126 for Case 2, and page 82 for Case 3. For Case 2, the original data were not calculated correctly in the logbook, and the corrected data are used in this table.

1.3 Description of Material Data

1.3.1 Uranium

The uranium material contained 0.9995 g of uranium per gram of material with very small amounts of impurities, consisting of those shown in Table 8.

The uranium metal parts for these critical experiments were carefully casted and machined at the Oak Ridge Y-12 Plant in the early 1960s. Each uranium metal part was a separate casting which was then machined. Dimensions, masses, uranium isotopic, and impurity content were measured after machining. Uranium annuli masses and dimensions can be found in Table 2.

The uranium isotopic contents obtained from Y-12 spectrographic analyses are given in Table 7, and the ^{238}U values were obtained by subtracting the sum of the other three from 100 %. The values given in Table 7 in weight percent with two decimal places were transcribed from the isotopic analysis report. So, based on the accuracy of isotopic ratios from the mass spectrometry laboratory at the Y-12 Plant, the uncertainty for the uranium isotopic contents is ±0.005 wt.% for ^{234}U, ^{235}U, and ^{236}U, which represents a rounding uncertainty.

Table 7. Uranium Isotopic Contents.

Part Number	Measured U-234 wt.%	Measured U-235 wt.%	Measured U-236 wt.%	Measured U-238 wt.%
2735	0.98	93.12	0.25	5.65
2738	0.98	93.15	0.24	5.63
2739	0.96	93.16	0.25	5.63
2740	0.97	93.17	0.24	5.62
2741	0.96	93.18	0.25	5.61
2742	0.98	93.14	0.23	5.65
2743	0.98	93.14	0.23	5.65
2744	0.98	93.14	0.23	5.65
2745	0.96	93.2	0.22	5.62
2746	1.00	93.09	0.22	5.69
2747	0.98	93.16	0.19	5.67
2748	1.00	93.09	0.22	5.69
2749	0.98	93.19	0.25	5.58
2750	0.95	93.12	0.25	5.68
2751	0.98	93.13	0.24	5.65
2752	0.98	93.13	0.24	5.65
2753	0.95	93.12	0.25	5.68
2754	0.96	93.1	0.28	5.66
2755	0.96	93.1	0.28	5.66
2756	0.93	93.18	0.25	5.64
2757	0.96	93.2	0.23	5.61
2758	0.98	93.16	0.27	5.59
2760	0.99	93.13	0.24	5.64
2761	0.96	93.12	0.27	5.65
2762	0.97	93.13	0.27	5.63
2763	0.96	93.18	0.25	5.61
2767	0.96	93.14	0.26	5.64

`

Table 7 (cont'd.). Uranium Isotopic Contents.

Part Number	Measured U-234 wt.%	Measured U-235 wt.%	Measured U-236 wt.%	Measured U-238 wt.%
2773	0.97	93.17	0.24	5.62
2775	0.98	93.15	0.24	5.63
2776	0.96	93.16	0.23	5.65
2778	0.96	93.16	0.23	5.65
2779	0.96	93.16	0.23	5.65
2780	0.98	93.13	0.25	5.64
2781	0.98	93.19	0.25	5.58
2782	0.96	93.2	0.23	5.61
2784	0.99	93.11	0.26	5.64
2785	0.98	93.14	0.24	5.64
2786	0.98	93.14	0.24	5.64
2787	0.98	93.14	0.24	5.64
2829	0.99	93.10	0.24	5.67
2848	0.99	93.18	0.24	5.59
2885	0.99	93.11	0.26	5.64
2886	0.99	93.11	0.26	5.64

The impurities from the 11 spectrographic analyses performed are given in Table 8 for uranium parts; only averages and variation information were initially recorded (see Reference 1). These 11 randomly sampled uranium parts include discs and annular parts (from the series of oralloy experiments and not solely from this HEU experiment). As such, the information presented is a representative average of the impurity content in all uranium parts. These values are consistent with the nominal impurity content of highly enriched uranium metal at the Oak Ridge Y-12 Plant at the time the parts were made (i.e., 99.95 g of U per l00 g of material). The oxygen and nitrogen content was assumed by the experimentalist to be 20 and 30 ppm, respectively, consistent with highly enriched uranium produced at the time of these experiments.[a]

The HEU parts were coated annually in a very thin film of lightweight fluorocarbon oil to decrease mass loss due to oxidation. This oil has negligible effect (according to experimenter) upon the experiment conditions. After oiling, the parts were wiped with a dry rag to remove most of the oil. The oralloy parts were then handled by leather gloves, which further reduced the oil on the surface.[b]

[a] HEU-MET-FAST-076 in the ICSBEP Handbook.
[b] Personal communication with John T. Mihalczo in HEU-MET-FAST-099, June-July 2010.

Table 8. Measured Impurity Content of Uranium Metal Cylinders, Annuli, and Plates.[a]

Element [a]	Parts per Million by Weight (ppm) [b]	Variation (ppm)	Standard Deviation (ppm) [c]
Ag	8	3-25	3.2
Ba	< 0.01 [d]	-	0.005
Bi	164	81-311	52.9
C	< 10	-	2.4
Ca	0.1	-	0.05
Cd	< 1	-	0.5
Co	5	2-15	1.9
Cr	7	4-12	1.9
Cu	25	10-40	8
K	< 0.2	0.2-0.8	0.1
Li	< 2	-	1
Mg	3	2-3	1.7
Mn	56	25-89	17.1
Mo	< 1	-	0.5
Na	27	15-50	7.7
Ni	100	-	10
Sb	38	10-80	17.4
Ti	1	-	0.5

(a) Mass spectrographic analysis except for oxygen and nitrogen using data in J. T. Mihalczo, "Graphite and Polyethylene Reflected Uranium-Metal Cylinders and Annuli", Union Carbide Corporation Nuclear Division, Oak Ridge Y-12 Plant, Y-DR-81 (April 28, 1972). Oxygen and nitrogen content was assumed by the principal experimentalist to be 20 and 30 ppm, respectively, consistent with highly enriched uranium produced at the time of these experiments. Total impurity content is consistent with stated values at that time of 500 ppm which gives 99.95 grams of U per 100 grams of material. Minor differences in the impurities exist between values listed in Table 8 and the impurity values provided in HEU-MET-FAST-051 in the ICSBEP Handbook.

(b) Except for the values shown as less than the detection limit, impurity data are average values from 11 randomly sampled uranium parts.

(c) Personal communication, J. A. Mullens to John Mihalczo in HEU-MET-FAST-076 in the ICSBEP Handbook, June 2004.

(d) Less than (<) indicates lower detection limit and not necessarily that the impurity is present.

1.3.2 Graphite

The results of spectrographic analyses for graphite impurities are given in Table 9, only averages and range information exist (Please see Reference 1 for more details). According to Reference 1, 11 randomly sampled graphite parts, including discs as well as annular parts and graphite parts that were not used in the critical assemblies discussed here, were analyzed for impurities. And the graphite parts were categorized in two groups: reflector thickness less than 15 inches and reflector thickness greater than 15 inches. As such, the information presented is a representative average of the impurity content in these graphite parts.

Table 9. Impurities of Graphite Parts.

Element	Parts per Million by Weight (ppm) (For Reflector Thickness < 15 inches)		Standard Deviation (ppm) [c]
	Measured [a]	Average Value [b]	
Ag	<1	<1	0.5
Al	200, 5, 50	85	42.5
B	3, 5, 15	7.7	3.85
Ba	50, 20, 20	30	15
Be	<1	<1	0.5
Bi	<3	<3	1.5
Ca	500	500	250
Cd	<10	<10	5
Co	<10	<10	5
Cr	<10	<10	5
Cu	2.33	2.33	1.165
Fe	283	283	141.5
K	10	10	5
Li	<1	<1	0.5
Mg	41.7	41.7	20.85
Mn	<2	<2	1
Mo	<1	<1	0.5
Na	10	10	5
Nb[d]	<10	<10	5
Ni	<3	<3	1.5
Pb	3	3	1.5
Rb	<10	<10	5
Sb	<10	<10	5
Si	70, 200, 500	257	128.5
Sn	<3	<3	1.5
Ta	30	30	15
Ti	12	12	6
V	40	40	20
W	<30	<30	15
Zn	<50	<50	25
Zr	<10	<10	5

(a) This column of data was documented in reference (see Reference 1). The results of three analyses are given. If only one value is listed, it was that in all three analyses. Less than (<) indicates lower detection limit and not necessarily that the impurity is present.
(b) If three analyses were given, the average value was calculated as such.
(c) Personal communication between J. A. Mullens and John Mihalczo, in HEU-MET-FAST-071, June 2004.
(d) The "Nb" was originally documented as Cb in reference (see Reference 1).

1.4 Temperature Data

Room and assembly temperature measurements were not recorded during the course of the experiments. The ORCEF operated in a controlled environment.[a] The fission rate in the measurements corresponded to usually much less than 0.01 watts, so there was no appreciable heating of the experiment components. The dimensions of the uranium were measured at 70 ºF and the experiments were generally performed at the ORCEF room temperature of 72 ºF. The reactivity coefficient for a temperature change for these assemblies is approximately -0.3¢/ºC.[b]

1.5 Supplemental Experimental Measurements

No any other supplemental measurements were made.

[a] Personal communication with John T. Mihalczo in HEU-MET-FAST-099, February 2010.
[b] Personal communication with John T. Mihalczo in HEU-MET-FAST-099, March 2010.

2.0 EVALUATION OF EXPERIMENTAL DATA

Uncertainties are evaluated using two approaches. Measured data are used where sufficient experimental information is available to analyze the uncertainties. Where experimental data are not available, Monte Carlo calculations were performed using the Monte Carlo N-Particle (MCNP) versions 5-1.60[a] and ENDF/B-VII.1[b] neutron cross section libraries. Models used to calculate uncertainties included 100,000 neutrons per generation with 2150 generations and 150 skipped generations. All models were calculated such that the statistical uncertainty, σ_{MC}, was no more than ±0.00004. Unless stated otherwise, the simple or detailed benchmark models, as described in Section 3, were used for the uncertainty analyses.

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 to a value corresponding to the given uncertainty using a scaling factor, assuming linearity, which should be adequate for these small changes in k_{eff}. Throughout Section 2, the difference in eigenvalues computed using the perturbation method described is denoted with Δk_{per}; 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 Table 31, Table 32 and Table 33.

When evaluating parameters such as measured diameters, heights, and masses, all parts of a given type are perturbed at the same time: e.g., the uranium mass in all annuli is simultaneously increased or decreased. The calculated uncertainty is then reduced by the square root of the number of components perturbed, representative of a random uncertainty. When appropriate, a systematic component of the evaluated uncertainty is retained, which is considered not to be impacted by the perturbation of the number of parts perturbed for its assessment. It should be noted, however, that typically when parameters of multiple parts are evaluated, the parts are nearly identical in every aspect. The uranium annuli utilized in this experiment vary in mass and dimensions; as such, the relative importance of the annuli varies throughout the assembly. In general, perturbation of many components of varying dimensions and mass would not be appropriate and should be replaced instead with multiple individualized perturbation analyses. In the case of the precisely-measured annuli for these experiments, perturbation of individual component parameters without their respective uncertainties would produce negligible results. Simultaneous perturbation of the various parameters for all annuli parts is performed, even though the parts are not identical, to demonstrate that the combined effect of the uncertainties is still negligible.

Uncertainties less than 0.00003 Δk_{eff} are treated as negligible. When calculated uncertainties in Δk_{eff} are less than or equal to their statistical uncertainties, and an increased parameter scaling cannot be performed, the statistical uncertainties are added to the calculated uncertainty to assess the magnitude of the total uncertainty; however, the absolute magnitude of any uncertainty combined in this way is less than 0.00003 Δk_{eff}, therefore they are treated as negligible.

The total evaluated uncertainty in k_{eff} for this experiment is provided in Section 2.4; the square root of the sum of the squares of all the individual uncertainties assessed in this section is used to obtain the total uncertainty in the experimental k_{eff}.

[a] Monte Carlo N-Particle (MCNP) versions 5-1.60.
[b] M. B. Chadwick, et al., "ENDF/B-VII.1: Nuclear Data for Science and Technology: Cross Sections, Covariances, Fission Product Yields and Decay Data," *Nucl. Data Sheets*, **112**: 2887-2996 (2011).

2.1 Evaluation of Critical Measurements

2.1.1 Temperature Data

Most of these experiments were performed at a room temperature of ~295 K. Some measurements were performed at a room temperature of ~294 K. The uncertainty in each of these two temperatures is unknown. Any variations in temperature for the experiments and room environment were small since heating effects in the experiment components were negligible. The temperature reactivity coefficient for these assemblies is approximately -0.3 ¢/ ºC .[a]

The temperature coefficient was estimated by using the different cross sections of 600 K (*.81c) and 250 K (*.86c) for HEU and graphite along with the corresponding thermal S(α , β) cross-section libraries for graphite (grph.13t for 600 K and grph.10t for 250 K) in the detailed benchmark model. Please note there is not thermal S(α, β) cross-section for graphite at 250 K in ENDF VII, so the grph.10t for 193.6 K was used. This calculated temperature coefficients for the three configurations are +0.0025±0.0010, +0.0010±0.0010, +0.0017±0.0010 ¢/ºC respectively which are much less than the absolute value of temperature coefficient (-0.3 ¢/ºC) used in HEU-MET-FAST-099. Conservatively, the -0.3 ¢/ºC, which has a larger magnitude, was still used for uncertainty analysis.

It is assumed that a temperature variation of 2 ºC (1σ) adequately describes the temperature uncertainty. A temperature uncertainty of ±2 ºC in k_{eff} results in a Δk_{eff} of ±0.00004 for all the cases.

2.1.2 Experiment Reproducibility and Measurement Uncertainty

The experimenter indicated that to completely dismantle a system and reassemble it on a different day, the reactivity differences were ~2 ¢ or less; measurements repeated on the same day exhibited much less of that difference.[b] The experimenter indicated that reproducibility of experiments performed with the vertical lift was even better. The corresponding uncertainty of ±2 ¢ or ±0.00013 Δk_{eff} is treated as a 1σ value for the three configurations.

The uncertainty in the actual measurement of the reactivity, which is determined by positive period measurements, is considered very accurate. There is some uncertainty in fitting data and evaluation of the period. Careful measurements and rigorous fitting procedures can yield estimated uncertainties of ~0.2 pcm, which is negligible.[c] It is assumed that the uncertainty in the actual measurement of the reactivity is already included in the reproducibility uncertainty already discussed in the previous paragraph.

2.1.3 Measured Reactivity of Support Structure Removal

Measured reactivity values for the worth of the support structure are given in Table 6. Multiple measurements to assess the uncertainty in the support structure worth were not performed. In this evaluation an approach introduced in HEU-MET-FAST-099 is utilized.

The individual worth measurements were obtained using modified experiments from the clean critical experimental configuration. Each of these configurations would have a repeatability uncertainty of, at most, ~2 ¢ if the assembly had been completely disassembled between measurements (as discussed in the previous section). Therefore the uncertainty in the adjustment for the removal of the assembly support structure from the experiment configuration would be obtained by taking the square root of the number of measured worths, multiplied by the square root of the number of experiment configurations needed to evaluate a given

[a] Personal communication with John T. Mihalczo in HEU-MET-FAST-099, March 2010.
[b] Personal communication with John T. Mihalczo, July 2014.
[c] Personal communication with Dick McKnight, July 2010.

measured worth, and multiplied by the reproducibility uncertainty for a single configuration. A total of four experimental configurations were needed to obtain three worth measurement corrections to represent the removal of the support structure from each configuration: $\sqrt{4}\times\sqrt{3}\times 2$ ¢ = 6.93 ¢.

The calculated uncertainty associated with the uncertainty in the measured reactivity for support structure removal is therefore ± 7 ¢ or ±0.00046 Δk_{eff} for the three configurations.

2.1.4 Effective Delayed Neutron Fraction, β_{eff}

A typical effective delayed neutron fraction for bare HEU metal systems is 0.0066 (see HEU-MET-FAST-051). Typically the uncertainty in β_{eff} is around 5 %, which, when propagated, results in a Δk_{eff} of approximately ±0.00005 for all the three cases. This uncertainty was obtained by taking the difference between the experimental eigenvalue calculated for the actual experiment using the reported delayed neutron fraction, and an eigenvalue calculated using the delayed neutron fraction perturbed by ±5 %.

2.1.5 Summary of Uncertainties in Reactivity Measurements

The uncertainties in reactivity measurements are listed in Table 10. Please note that all the three cases have the same values even though they had different reactivities respectively.

Table 10. Uncertainties in Reactivity Measurements.

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff}
Temperature (K)	294	±2	0.00004
Experiment reproducibility (¢)	--	±2	0.00013
Measured reactivity worth (¢)	--	$\pm\sqrt{4}\times\sqrt{3}\times 2$	0.00046
β_{eff}	0.0066	±5 %	0.00005

2.2 Evaluation of Dimension and Mass Uncertainties

2.2.1 Uranium Annuli Dimension and Mass Uncertainties

Traditionally, the uncertainties in the ORCEF Oralloy experiments have been established as follows in regards to geometrical properties. The measurement uncertainties in the stack heights can be calculated using the standard deviation of the average from multiple measurements, which are typically about ±0.001 inches (±0.00254 cm). The manufacturing tolerances of the Y-12 HEU parts are ±0.0001 inches (±0.000254 cm). When multiple measurements of the dimensions of a part were taken, the average was typically within ±0.00005 inches (±0.000127 cm) of all the individual measurements.[a]

More recently a document has been prepared to examine the uncertainties pertaining to critical experiments performed at ORCEF using HEU metal components.[b] This document will be the basis for the uncertainty analysis in this evaluation.

[a] Personal communication with John T. Mihalczo, March 2010.
[b] J. T. Mihalczo and T. Gregory Schaaff, "Uncertainties in Masses, Dimensions, Impurities, and Isotopics of HEU Metal Used in Critical Experiments at ORCEF," ORNL/TM-2012/32, Oak Ridge National Laboratory (2012).

There may be effects on the system k_{eff} values associated with correlations between uncertainties in stack heights, gap thicknesses, and the height of the individual parts in an assembly. However, except for the k_{eff} uncertainty associated with the uranium stack height uncertainties, the individual evaluated uncertainties in k_{eff} are negligible. Therefore, a possible increase in the uncertainty in k_{eff} due to correlation, if any, between the individual uncertainties is considered negligible.

There were 28, 27 and 21 individual uranium annuli in Configurations 1, 2 and 3 respectively. When evaluating the uncertainty for a given parameter, all uranium components are simultaneously modified. The calculated change in the eigenvalue for the perturbation of a given parameter should be scaled by the square root of the number of annuli, N, to represent the randomness of the actual variation amongst the individual pieces. However, it is assumed that these parts were manufactured in the same process, so the calculated changes in the eigenvalue for the perturbation of diameter and height were taken as systematic uncertainty and have not been scaled by the square root of the number of annuli, N.

Diameter

The diameters of each uranium annulus was measured after machining at the Y-12 Plant and reported to an accuracy of 0.0001 inches (0.000254 cm) at several locations (~8) and then averaged. All measurements were at 70° Fahrenheit using a Moore machine (high-performance ultra-precision manufacturing equipment, typically like a jig borer or jig grinder with accompanying high-accuracy measurement capability)[a]and are traceable back to the National Bureau of Standards (i.e., measurement systems were calibrated with standards produced by the NBS). The accuracy of the Moore machine utilized at that time was between 0.0003 and 0.0005 in. (0.000762 to 0.00127 cm). The maximum value is taken to represent the accuracy of the measurement of the diameter for the oralloy parts instead of the average. Additionally, the uncertainty in the reported diameter of each annulus included a rounding uncertainty of ±0.00005 inches (±0.000127 cm). These two uncertainties are both considered to represent bounding uncertainties with uniform probability distribution and are combined in quadrature to obtain a total bounding uncertainty of ±0.0005025 in. (±0.001276 cm).

To find the effect of these diametral uncertainties on the k_{eff} value, the diameters of the annuli (Table 2) were adjusted by a factor of 4.98 times the bounding uncertainty (larger perturbation would overlap with graphite cylinder). In order to keep the uranium mass of each experiment constant, the density of each of the uranium parts was adjusted accordingly. Effectively the entire uranium volume in the system was expanded and contracted while maintaining the total uranium mass constant. Outer and inner diameters were simultaneously increased to find an upper perturbation Δk_{per} value and then simultaneously decreased to find a lower perturbation Δk_{per} value. Half of the difference between the upper and lower perturbation Δk_{per} values was used to represent the variation in Δk_{per} due to perturbing the annuli diameters. The 1σ uncertainty in k_{eff} associated with the uncertainty in the diameter of the uranium annuli is found from the following formula, where Δk_{per} is one-half the difference between the upper and lower perturbation Δk_{per} values, SF is the scaling factor, and the factor of square root of two is present because the inner and outer diameters were simultaneously perturbed:

$$\Delta k_{eff}(1\sigma) = \frac{\Delta k_{per}}{\mathrm{SF}\sqrt{2}}$$

Results are provided in Table 11.

[a] Moore Precision Tools, http://mooretool.com/, Moore Tool Company, Bridgeport, CT, USA (last accessed September 18, 2014).

Table 11. Effect of Uncertainty in Uranium Annuli Diameters.

Case	Deviation (cm)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	±0.006350	0.00025	±	0.00006	4.98√3	0.00003	±	<0.00001
2	±0.006350	0.00024	±	0.00006	4.98√3	0.00003	±	<0.00001
3	±0.006350	0.00026	±	0.00006	4.98√3	0.00003	±	<0.00001

Height

The height of each uranium annulus was measured after machining at the Y-12 Plant to an accuracy of 0.0001 inches (0.000254 cm) at several radial locations (~8) and then averaged. The same detailed discussion of measurement uncertainties and the method of analysis provided regarding the analysis of the diameters of the uranium annuli in the previous subsection also apply to the uranium heights.

To find the effect of this uncertainty on the k_{eff} value, the heights of the annuli (Table 2) were adjusted by a factor of 3 times the bounding uncertainty, while reducing the effective gap thicknesses between each component. The measured stack height, where possible, was conserved. When the increase in the combined heights of the individual parts was greater than the stack height, the parts were modeled in contact, with no gaps, and the effective stack height was increased. In order to keep the uranium mass of each experiment constant, the density of each of the uranium parts was adjusted accordingly. Effectively the entire uranium volume in the system was expanded and contracted while maintaining the total uranium mass constant. Heights were simultaneously increased to find an upper perturbation Δk_{per} value and then simultaneously decreased to find a lower perturbation Δk_{per} value. Half of the difference between the upper and lower perturbation Δk_{per} values was used to represent the variation in Δk_{per} due to perturbing the annuli heights. The 1σ uncertainty in k_{eff} associated with the uncertainty in the heights of the uranium annuli is found from the following formula:

$$\Delta k_{eff}(1\sigma) = \frac{\Delta k_{per}}{\mathrm{SF}}$$

Results are provided in Table 12.

Table 12. Effect of Uncertainty in Uranium Annuli Heights.

Case	Deviation (cm)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	±0.003829	0.00054	±	0.00006	3√3	0.00010	±	0.00001
2	±0.003829	0.00054	±	0.00006	3√3	0.00010	±	0.00001
3	±0.003829	0.00024	±	0.00006	3√3	0.00005	±	0.00001

Stack Height

The stack heights of the uranium annuli placed above and below the stainless steel diaphragm were measured with a standard deviation of the average of approximately ±0.001 in. (±0.00254 cm) for most measurements, which is also the uncertainty of the measurement device for taking stack height measurements, and is assumed to represent a 1σ uncertainty. Additionally, the uncertainty in the reported stack height included a

rounding uncertainty of ±0.0005 inches (±0.00127 cm), which is considered to represent a bounding uncertainty with uniform probability distribution (i.e., ÷√3). It is assumed that the annuli were manufactured with a tolerance in flatness of 0.002 inches. So worst case scenario would be treating this tolerance of flatness as another bounding uncertainty of height with uniform distribution. These three uncertainty components are combined in quadrature to obtain a total 1σ uncertainty of ±0.001555 in. (±0.003949 cm).

To find the effect of this uncertainty on the k_{eff} value, the stack height of these annuli (Table 4) was adjusted by increasing the effective gap thicknesses between each component. The stack height was increased by a factor of 10 times the 1σ uncertainty to find an upper perturbation Δk_{per} value. The difference between the upper perturbation Δk_{per} value and the unperturbed model k_{eff} value was used to represent the variation in Δk_{per} due to perturbing the annuli stack heights. The 1σ uncertainty in k_{eff} associated with the uncertainty in the measured stack heights of the uranium annuli is found from the following formula, where Δk_{per} is the difference between the upper perturbation and unperturbed model k_{eff} values, and N is the number of uranium annuli stacks in each configuration, in which there are 6 HEU annuli stacks in Case 1, 8 in Case 2 and 6 in Case 3:

$$\Delta k_{eff}(1\sigma) = \frac{\Delta k_{per}}{\mathrm{SF}} \sqrt{\left[\gamma_{sys}\right]^2 + \left[\frac{\gamma_{ran}}{\sqrt{N}}\right]^2}.$$

It is estimated that the systematic component of this uncertainty is roughly equivalent to the ratio of the flatness uncertainty to the uncertainty in the measurement of the stack height; therefore, the systematic component of the uncertainty is estimated to be approximately 54 %. The fraction of the uncertainty attributed to the random component is then 46 %; it should be noted that the random component of the uncertainty is not computed using the ratio of non-systematic uncertainty to the total uncertainty. Results are provided in Table 13.

Table 13. Effect of Uncertainty in Uranium Stack Heights.

Case	Deviation (cm)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{sys} (γ_{sys}=54%)	Δk_{ran} (γ_{ran}=46%)	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	+0.02644	0.00138	±	0.00006	6.7	0.00006	0.00006	0.00012	±	<0.00001
2	+0.02644	0.00150	±	0.00006	6.7	0.00006	0.00006	0.00013	±	<0.00001
3	+0.02644	0.00144	±	0.00006	6.7	0.00006	0.00006	0.00012	±	<0.00001

Mass

The uranium mass of each part measured at the Y-12 Plant is traceable back to the Bureau of Standards to less than 0.5 gram accuracy and then rounded to the nearest gram, thus the uncertainty for the mass of each uranium annulus is ±0.5 g. Additionally, the scale in the metrology laboratory of the Y-12 Plant had a mass accuracy of 0.089 g and the plant scales had a mass accuracy of 0.30 g in 1960 for 20 kg calibration measurements.[a] Both the accuracy of metrology laboratory and the rounding uncertainty are considered to represent bounding uncertainties with uniform probability distribution and are combined in quadrature to obtain a total bounding uncertainty of ±0.507859 g. A mass measurement of multiple uranium annuli was not performed.

To find the effect of this uncertainty on the k_{eff} value, the masses of the annuli (Table 2) were adjusted by a factor of 10 times the bounding uncertainty. In order to keep the uranium volume of the experiment

[a] J. T. Mihalczo and T. Gregory Schaaff, "Uncertainties in Masses, Dimensions, Impurities, and Isotopics of HEU Metal Used in Critical Experiments at ORCEF," ORNL/TM-2012/32, Oak Ridge National Laboratory (2012).

constant, the density of each of the uranium annuli was adjusted accordingly. Uranium masses were simultaneously increased to find an upper perturbation Δk_{per} value and then simultaneously decreased to find a lower perturbation Δk_{per} value. Half of the difference between the upper and lower perturbation Δk_{per} values was used to represent the variation in Δk_{per} due to perturbing the annuli masses. The 1σ uncertainty in k_{eff} associated with the uncertainty in the mass of the uranium annuli is found from the following formula, where Δk_{per} is one-half the difference between the upper and lower perturbation k_{eff} values, N is the number of uranium annuli in each configuration, and SF is the parameter scaling factor:

$$\Delta k_{eff}(1\sigma) = \frac{\Delta k_{per}}{\mathrm{SF}} \sqrt{\left[\gamma_{sys}\right]^2 + \left[\frac{\gamma_{ran}}{\sqrt{N}}\right]^2}.$$

It is estimated that the systematic component of this uncertainty is roughly equivalent to the ratio of the accuracy of the plant scale to the rounding uncertainty of the final value after performing multiple measurements; therefore, the systematic component of the uncertainty is estimated to be approximately 60 %. The fraction of the uncertainty attributed to the random component is then 40 %; it should be noted that the random component of the uncertainty is not computed using the ratio of non-systematic uncertainty to the total uncertainty. The calculated uranium mass reactivity uncertainties are listed in Table 14, and are considered negligible ($\Delta k_{eff} < 0.00003$) for the three configurations.

Table 14. Effect of Uncertainty in Uranium Mass.

Case	Deviation per Annuli Part (g)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{sys} (γ_{sys}=60%)	Δk_{ran} (γ_{ran}=40%)	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	±5.078592	0.00057	±	0.00006	10√3	<0.00001	<0.00001	<0.00001	±	<0.00001
2	±5.078592	0.00063	±	0.00006	10√3	<0.00001	<0.00001	<0.00001	±	<0.00001
3	±5.078592	0.00044	±	0.00006	10√3	<0.00001	<0.00001	<0.00001	±	<0.00001

2.2.2 Graphite Dimension and Mass Uncertainties

There were 5, 4 and 5 individual graphite cylinders in Configurations 1, 2 and 3 respectively. When evaluating the uncertainty for a given parameter, all graphite components are simultaneously modified. The calculated change in the eigenvalue for the perturbation of a given parameter should be scaled by the square root of the number of cylinders, N, to represent the randomness of the actual variation amongst the individual pieces. However, it is assumed that these parts were manufactured in the same process, so the calculated change in the eigenvalue for the perturbation of diameter and height was taken as systematic uncertainty and have not been scaled by the square root of the number of cylinders, N.

Diameter

Since the manufacturing and measuring of the graphite parts were the same to the HEU parts in both procedure and tools, the uncertainty for graphite is the same to the HEU annuli as described in Chapter 2.2.1. As such, the total bounding uncertainty for graphite is ±0.0005025 in. (±0.001276 cm).

To find the effect of this diametral uncertainty on the k_{eff} value, the diameters of the cylinder (Table 2) were adjusted by a factor of 4.97 times the bounding uncertainty (larger perturbation would overlap with HEU annuli). In order to keep the graphite mass of each experiment constant, the density of each of the graphite

parts was adjusted accordingly. Effectively the entire graphite volume in the system was expanded and contracted while maintaining the total graphite mass constant. The diameters were simultaneously increased to find an upper perturbation Δk_{per} value and then simultaneously decreased to find a lower perturbation Δk_{per} value. Half of the difference between the upper and lower perturbation Δk_{per} values was used to represent the variation in Δk_{per} due to perturbing the cylinder diameters. The 1σ uncertainty in k_{eff} associated with the uncertainty in the diameter of the graphite cylinder is found from the following formula, where Δk_{per} is one-half the difference between the upper and lower perturbation Δk_{per} values, SF is the scaling factor:

$$\Delta k_{eff}(1\sigma) = \frac{\Delta k_{per}}{\mathrm{SF}}$$

Results are provided in Table 15, and are considered negligible ($\Delta k_{eff} < 0.00003$) for the three configurations.

Table 15. Effect of Uncertainty in Graphite Cylinder Diameters.

Case	Deviation (cm)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	±0.006348	<0.00001	±	0.00006	4.97√3	<0.00001	±	<0.00001
2	±0.006348	0.00003	±	0.00006	4.97√3	<0.00001	±	<0.00001
3	±0.006348	0.00002	±	0.00006	4.97√3	<0.00001	±	<0.00001

Height

The height of each graphite cylinder was measured after machining at the Y-12 Plant to an accuracy of 0.0001 inches (0.000254 cm) at several radial locations (~8) and then averaged. The same detailed discussion of measurement uncertainties and the method of analysis provided regarding the analysis of the diameters of the graphite cylinder in the previous subsection also apply to the graphite heights.

To find the effect of this uncertainty on the k_{eff} value, the heights of the cylinder (Table 3) were adjusted by a factor of 3 times the bounding uncertainty, while reducing the effective gap thicknesses between each component. The measured stack height, where possible, was conserved. When the increase in the combined heights of the individual parts was greater than the stack height, the parts were modeled in contact, with no gaps, and the effective stack height was increased. In order to keep the graphite mass of each experiment constant, the density of each of the graphite parts was adjusted accordingly. Effectively the entire graphite volume in the system was expanded and contracted while maintaining the total graphite mass constant. Heights were simultaneously increased to find an upper perturbation Δk_{per} value and then simultaneously decreased to find a lower perturbation Δk_{per} value. Half of the difference between the upper and lower perturbation Δk_{per} values was used to represent the variation in Δk_{per} due to perturbing the cylinder heights. The 1σ uncertainty in k_{eff} associated with the uncertainty in the heights of the graphite cylinder is found from the following formula:

$$\Delta k_{eff}(1\sigma) = \frac{\Delta k_{per}}{\mathrm{SF}}$$

Results are provided in Table 16, and are considered negligible ($\Delta k_{eff} < 0.00003$) for the three configurations.

Table 16. Effect of Uncertainty in Graphite Cylinder Heights.

Case	Deviation (cm)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	±0.003829	0.00002	±	0.00006	3√3	<0.00001	±	0.00001
2	±0.003829	0.00005	±	0.00006	3√3	0.00001	±	0.00001
3	±0.003829	0.00005	±	0.00006	3√3	0.00001	±	0.00001

Stack Height

The stack heights of the graphite cylinder placed above and below the stainless steel diaphragm were measured with a standard deviation of the average of approximately ±0.001 in. (±0.00254 cm) for most measurements, which is also the uncertainty of the measurement device for taking stack height measurements, and assumed to represent a 1σ uncertainty. Additionally, the uncertainty in the reported stack height included a rounding uncertainty of ±0.0005 inches (±0.00127 cm), which is considered to represent a bounding uncertainty with uniform probability distribution (i.e., ÷√3). It is assumed that the annuli were manufactured with a tolerance in flatness of 0.002 inches. So worst case scenario would be treating this tolerance of flatness as another bounding uncertainty of height with uniform distribution. These three uncertainty components are combined in quadrature to obtain a total 1σ uncertainty of ±0.001555 in. (±0.003949 cm).

To find the effect of this uncertainty on the k_{eff} value, the stack height of these cylinders (Table 4) was adjusted by increasing the effective gap thicknesses between each component. The stack height was increased by a factor of 10 times the 1σ uncertainty to find an upper perturbation Δk_{per} value. The difference between the upper perturbation Δk_{per} value and the unperturbed model k_{eff} value was used to represent the variation in Δk_{per} due to perturbing the cylinder stack heights. The 1σ uncertainty in k_{eff} associated with the uncertainty in the measured stack heights of the graphite cylinder is found from the following formula, where Δk_{per} is the difference between the upper perturbation and unperturbed model k_{eff} values, and N is the number of graphite cylinder stacks in each configuration. There is only 1 cylinder stack in Cases 1 and 2 because the bottom only has one piece, and 2 stacks in Case 3:

$$\Delta k_{eff}(1\sigma) = \frac{\Delta k_{per}}{\mathrm{SF}} \sqrt{\left[\gamma_{sys}\right]^2 + \left[\frac{\gamma_{ran}}{\sqrt{N}}\right]^2}.$$

Since there is only one graphite cylinder in the lower section for Case 1 and 2, only the graphite cylinders in upper section are perturbed for the uncertainty analysis.

It is estimated that the systematic component of this uncertainty is roughly equivalent to the ratio of the flatness uncertainty to the uncertainty in the measurement of the stack height; therefore, the systematic component of the uncertainty is estimated to be approximately 54 %. The fraction of the uncertainty attributed to the random component is then 46 %; it should be noted that the random component of the uncertainty is not computed using the ratio of non-systematic uncertainty to the total uncertainty. Results are provided in Table 17, and are considered negligible (Δk_{eff} < 0.00003) for the three configurations.

Table 17. Effect of Uncertainty in Graphite Stack Heights.

Case	Deviation (cm)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{sys} (γ_{sys}=54%)	Δk_{ran} (γ_{ran}=46%)	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	+0.02644	0.00004	±	0.00006	6.7	<0.00001	<0.00001	<0.00001	±	<0.00001
2	+0.02644	0.00014	±	0.00006	6.7	0.00001	0.00001	0.00001	±	<0.00001
3	+0.02644	0.00035	±	0.00006	6.7	0.00002	0.00003	0.00003	±	<0.00001

Mass

The uranium mass of each part measured at the Y-12 Plant is traceable back to the Bureau of Standards to less than 0.5 gram accuracy and then rounded to the nearest gram, thus the uncertainty for the mass of each uranium annulus is ±0.5 g. Additionally, the scale in the metrology laboratory of the Y-12 Plant had a mass accuracy of 0.089 g and the plant scales had a mass accuracy of 0.30 g in 1960 for 20 kg calibration measurements.[a] Both the accuracy of metrology laboratory and the rounding uncertainty are considered to represent bounding uncertainties with uniform probability distribution and are combined in quadrature to obtain a total bounding uncertainty of ±0.507859 g. A mass measurement of multiple uranium annuli was not performed.

To find the effect of this uncertainty on the k_{eff} value, the masses of the cylinders (Table 3) were adjusted by a factor of 10 times the bounding uncertainty. In order to keep the graphite volume of the experiment constant, the density of each graphite cylinder was adjusted accordingly. Graphite masses were simultaneously increased to find an upper perturbation Δk_{per} value and then simultaneously decreased to find a lower perturbation Δk_{per} value. Half of the difference between the upper and lower perturbation Δk_{per} values was used to represent the variation in Δk_{per} due to perturbing the cylinder masses. The 1σ uncertainty in k_{eff} associated with the uncertainty in the mass of the graphite cylinder is found from the following formula, where Δk_{per} is one-half the difference between the upper and lower perturbation k_{eff} values, N is the number of graphite cylinder in each configuration which 5, 4 and 5 respectively, and SF is the parameter scaling factor:

$$\Delta k_{eff}(1\sigma) = \frac{\Delta k_{per}}{\mathrm{SF}} \sqrt{\left[\gamma_{sys}\right]^2 + \left[\frac{\gamma_{ran}}{\sqrt{N}}\right]^2}.$$

It is estimated that the systematic component of this uncertainty is roughly equivalent to the ratio of the accuracy of the metrology laboratory scale to the rounding uncertainty of the final value after performing multiple measurements; therefore, the systematic component of the uncertainty is estimated to be approximately 60 %. The fraction of the uncertainty attributed to the random component is then 40 %; it should be noted that the random component of the uncertainty is not computed using the ratio of non-systematic uncertainty to the total uncertainty. The calculated graphite mass reactivity uncertainties are listed in Table 18 and are considered negligible (Δk_{eff} < 0.00003) for the three configurations.

[a] J. T. Mihalczo and T. Gregory Schaaff, "Uncertainties in Masses, Dimensions, Impurities, and Isotopics of HEU Metal Used in Critical Experiments at ORCEF," ORNL/TM-2012/32, Oak Ridge National Laboratory (2012).

Table 18. Effect of Uncertainty in Graphite Mass.

Case	Deviation per Graphite Part (g)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{sys} (γ_{sys}=60%)	Δk_{ran} (γ_{ran}=40%)	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	±5.078592	0.00013	±	0.00006	10√3	<0.00001	<0.00001	<0.00001	±	<0.00001
2	±5.078592	0.00019	±	0.00006	10√3	<0.00001	<0.00001	<0.00001	±	<0.00001
3	±5.078592	0.00020	±	0.00006	10√3	<0.00001	<0.00001	<0.00001	±	<0.00001

2.2.3 Alignment Uncertainties

Lateral Alignment

Lateral alignment measurements were made to within ±0.005 inches (±0.0127 cm). To find the effect of this uncertainty on the k_{eff} value, the lower half of each configuration was moved laterally (in a model) by a factor of 10 times this reported uncertainty to find a perturbed k_{eff} value. The difference between the perturbed Δk_{per} value and the unperturbed model k_{eff} value was used to represent the variation in k_{eff} due to perturbing the lateral assembly alignment. The 1σ uncertainty associated with the uncertainty in the lateral alignment is found from the following formula, where Δk_{per} is the difference between the upper perturbation and unperturbed model k_{eff} values, and SF is the parameter scaling factor:

$$\Delta k_{eff}(1\sigma) = \frac{\Delta k_{per}}{\mathrm{SF}}$$

This uncertainty is treated as a one-sided bounding uncertainty with uniform probability distribution (i.e., ÷2√3). Furthermore, this uncertainty is treated as 100 % systematic with no random uncertainty component. Results are provided in Table 19, and are considered negligible (Δk_{eff} < 0.00003) for the three configurations.

Table 19. Effect of Uncertainty in Assembly Lateral Alignment.

Case	Deviation (cm)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	+0.02644	0.00003	±	0.00006	10×2√3	<0.00001	±	<0.00001
2	+0.02644	0.00003	±	0.00006	10×2√3	<0.00001	±	<0.00001
3	+0.02644	0.00006	±	0.00006	10×2√3	<0.00001	±	<0.00001

Vertical Alignment

The uncertainty of axial symmetry was not considered in this evaluation since it is embedded within the uranium annular and graphite cylinder diameter uncertainties.

2.2.4 Other Uncertainties

Gaps between Parts

The uncertainty in gap heights was not considered since it is embedded within the uranium stack height and diameter uncertainties.

The total height of the gaps between the stacks of uranium annuli was obtained by taking the difference between the measured stack height and the summation of the heights of the individual uranium annuli in each stack. The total gap height was then divided by the number of annuli minus one, to represent the number of gaps between the uranium annuli. There is no gap between the bottom of the top uranium annuli stacks and the stainless steel diaphragm. The gap heights for the three cases can be seen in Figure 9, Figure 11 and Figure 13.

The tallest stack of uranium annuli in the lower section was modeled "in contact with" the bottom of the stainless steel diaphragm. The gaps between the diaphragm and the remaining stacks were adjusted such that the bottoms of all the lower stacks were collocated on the same plane. This effectively models each of these stacks as having been "raised" as a single configuration on a planar surface (as was performed in the actual experiment).

The measured worth of the diaphragm includes the separation distance between the two halves of the experiment. Therefore, when the diaphragm is removed from the model, the parts adjacent to the diaphragm are brought closer together and the separation distance of 0.010 in. (0.0254 cm) that represents the diaphragm thickness would be eliminated.[a]

Assembly Separation

The uncertainty for the separation of the upper and lower assemblies is based upon the accuracy of vertical placement measurement when bringing the two experiment halves into contact, ±0.001 in. (±0.00254 cm). This uncertainty, however, would be included within the measurement uncertainty of the worth of the stainless steel diaphragm.

Graphite Arrangement for Case 3

In the logbook, the graphite arrangement for Case 3 is not available. The uncertainty analysis mentioned above for Case 3 is based on the assumption of one sort of graphite arrangement that is most likely used from available parts listing in Table 3 and the gaps is taken from the average gap height of Cases 1 and 2. The graphite parts are swapped for Case 3 for an extra uncertainty analysis to account for the missing data of graphite arrangement. Two different graphite arrangements (see Table 20) were modeled, and the gaps between the parts in upper and lower section are conserved because the gap uncertainty is included when performing the uncertainty analysis through perturbing the graphite stack height (see Section 2.2.2). The maximum of Δk_{eff} for the two swaps is taken as the 1σ uncertainty for the graphite arrangement. Results are provided in Table 21.

[a] Personal communication with John T. Mihalczo, February 2010.

Table 20. Graphite Arrangements of Swapping the Graphite Parts for Case 3.

Benchmark Model		Swap 1		Swap 2	
upper	3	upper	27	upper	3
	7		7		36
	27		3	lower	7
lower	15	lower	36		15
	36		15		27

Table 21. Effect of Uncertainty in Graphite Arrangement for Case 3.

Case	Deviation	Δk_{per}	±	$\sigma_{\Delta kper}$
Swap1	Table 20	0.00006	±	0.00006
Swap2	Table 20	0.00006	±	0.00006
Maximum	-	0.00006	±	0.00006

2.3 Evaluation of Material Properties

When calculating atom densities, measured masses and calculated volumes were always used to find the material density even if a density was reported. When calculating atom densities from material impurity data and composition data, typically three types of values were given: a single value (i.e., 15 ppm or 20 wt.%), which gives the actual content of the element in the material, a maximum value (i.e., < 15 ppm or < 20 wt.%), which gives the maximum amount of an element present in the material, and a range of values (i.e., 15 -17 ppm or 20 – 22 wt.%), which gives the minimum and maximum amount of an element present in the material. When calculating atom densities for models, the actual content of the element, one half of the maximum element content, and/or the middle of the range of element content were used for the material composition.

2.3.1 Uranium

Isotopic Content

More recently a document[a] has been prepared to examine the uncertainties pertaining to critical experiments performed at ORCEF using HEU metal components. This document will be the basis for the uncertainty analysis in this evaluation. In this report, the uncertainty of the isotopic contents of ^{234}U, ^{235}U, and ^{236}U from metrology are 0.0017 wt.%, 0.0177 wt.% and 0.0130 wt.% respectively and the measured standard deviation for the 68 oralloy metal parts are 0.00203 wt.%, 0.00346 wt.% and 0.00218 wt.% respectively , and the total uncertainty is the quadrature sum of these two uncertainties and the rounding uncertainty (please see Table 22).

[a] J. T. Mihalczo and T. Gregory Schaaff, "Uncertainties in Masses, Dimensions, Impurities, and Isotopics of HEU Metal Used in Critical Experiments at ORCEF," ORNL/TM-2012/32, Oak Ridge National Laboratory (2012).

Table 22. Weight Percent (wt.%) Uncertainties (1σ) in Oralloy Isotopic Contents.

Isotope	Uncertainty in Traceable Standard Measurement[(a)]	Standard Deviation of the Mean for As-Measured Parts[(a)]	Rounding	Total Uncertainty
^{234}U	0.0017	0.00203	0.005/√3	0.003917
^{235}U	0.0177	0.00346	0.005/√3	0.018265
^{236}U	0.0130	0.00218	0.005/√3	0.013494

(a) J. T. Mihalczo and T. Gregory Schaaff, "Uncertainties in Masses, Dimensions, Impurities, and Isotopics of HEU Metal Used in Critical Experiments at ORCEF," ORNL/TM-2012/32, Oak Ridge National Laboratory (2012).

To find the effect of this uncertainty on the k_{eff} value, the isotopic contents of the annuli (Table 7) were adjusted by a factor of 10 times the 1σ uncertainty. An upper perturbation Δk_{per} value was found by simultaneously increasing the isotopic contents of ^{234}U, ^{235}U, or ^{236}U and adjusting the ^{238}U isotopic content accordingly. The isotopic contents of ^{234}U, ^{235}U, or ^{236}U were then simultaneously decreased, again with the ^{238}U content adjusted, to find the lower perturbation Δk_{per} value. Typically, the isotopic content of all components in a system would be varied individually so as to isolate any parts with significant merit. As this is a small system and relatively large perturbations of the combined isotopic content yield a negligible change in k_{eff}, all oralloy isotopic contents for a given isotope (^{234}U, ^{235}U, or ^{236}U) were adjusted simultaneously in all uranium parts. Half of the difference between the upper and lower perturbation Δk_{per} values was used to represent the variation in Δk_{per} due to perturbing the isotopic contents. The 1σ uncertainty in k_{eff} associated with the uncertainty in the isotopic contents of the uranium annuli is found from the following formula, where Δk_{per} is one-half the difference between the upper and lower perturbation k_p values and SF is the parameter scaling factor:

$$\Delta k_{eff}(1\sigma) = \frac{\Delta k_{per}}{SF}.$$

This uncertainty is treated as 100 % systematic with no random uncertainty component because the impact due to the variability in measurement of multiple oralloy components was already accounted for in the derivation of the standard deviation of the mean reported in

Table 22. Results are provided in Table 23, Table 24 and Table 25 for the uncertainties in ^{234}U, ^{235}U, and ^{236}U, respectively.

Table 23. Effect of Uncertainty in ^{234}U Isotopic Content.

Case	Deviation (wt.%)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	±0.039172	0.00028	±	0.00006	10	0.00003	±	<0.00001
2	±0.039172	0.00039	±	0.00006	10	0.00004	±	<0.00001
3	±0.039172	0.00034	±	0.00006	10	0.00003	±	<0.00001

Table 24. Effect of Uncertainty in ^{235}U Isotopic Content.

Case	Deviation (wt.%)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	±0.182646	0.00192	±	0.00006	10	0.00019	±	<0.00001
2	±0.182646	0.00191	±	0.00006	10	0.00019	±	<0.00001
3	±0.182646	0.00194	±	0.00006	10	0.00019	±	<0.00001

Table 25. Effect of Uncertainty in ^{236}U Isotopic Content.

Case	Deviation (wt.%)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	±0.134939	0.00015	±	0.00006	10	0.00002	±	<0.00001
2	±0.134939	0.00028	±	0.00006	10	0.00003	±	<0.00001
3	±0.134939	0.00023	±	0.00006	10	0.00002	±	<0.00001

Impurities

The uranium impurities listed in Table 8 are given as the average of a spectrographic analysis from randomly sampled components for each impurity (assuming the values to be normally distributed) or listed as less than a minimum value. The impurity content, as specified in Table 8, is accepted as the nominal composition for the oralloy parts utilized at ORCEF. The oxygen and nitrogen content was included as the experimentalist-specified quantities of 20 and 30 ppm, respectively. For impurities below a detectable limit, the content is selected as half the detectable limit and the detection limit as a bounding uncertainty.

The concentration of metallic impurities in the oralloy was determined by DC-Arc emission spectroscopy, and the concentration of "gas" species was determined by combustion analyses, similar to modern Leco-type measurements. It was established that the uncertainty in these methods was 70 % for values measured below 10 μg/g-U and 20 % for values measured above 10 μg/g-U. However, for the measurement of oralloy materials, the uncertainty was about 20 % and 6 %, respectively.[a] These two types of uncertainty were combined as the 1σ Uncertainty of impurity.

The mean content and revised uncertainty assessment are provided in Table 26, along with the deviation used in the uncertainty analysis, which is 3 times of the 1σ uncertainty.

[a] J. T. Mihalczo and T. Gregory Schaaff, "Uncertainties in Masses, Dimensions, Impurities, and Isotopics of HEU Metal Used in Critical Experiments at ORCEF," ORNL/TM-2012/32, Oak Ridge National Laboratory (2012).

Table 26. Impurity and Uncertainty of HEU Annuli.

Element	Impurity Content [(a)] (ppm)	Uncertainty of the Impurity Analysis [(b)]	Uncertainty of the Measured Oralloy HEU [(c)]	1σ Uncertainty (ppm)	Deviation (ppm) [(d)]
Ag	8	5.6	1.6	5.82	±17.47
Ba	0.005	-	--	0.005/√3	±0.005
Bi	164	32.8	9.84	34.24	±102.73
C	5	3.5	--	5/√3	±5
Ca	0.1	-	0.02	0.07	±0.22
Cd	0.5	-	--	0.5/√3	±0.5
Co	5	3.5	1	3.64	±10.92
Cr	7	4.9	1.4	5.10	±15.29
Cu	25	5	1.5	5.22	±15.66
K	0.1	-	--	0.1/√3	±0.1
Li	1	-	--	1/√3	±1
Mg	3	2.1	0.6	2.18	±6.55
Mn	56	11.2	3.36	11.69	±35.08
Mo	0.5	-	--	1/√3	±0.5
Na	27	5.4	1.62	5.64	±16.91
Ni	100	20	6	20.88	±62.64
Sb	38	7.6	2.28	7.93	±23.8
Ti	1	0.7	0.2	0.73	±2.18
O	20	6	1.8	4.18	±12.53
N	30	4	1.2	6.26	±18.79
Total	491.21			5.82	-

(a) Mass spectrographic analysis except for oxygen and nitrogen using data in J. T. Mihalczo, "Graphite and Polyethylene Reflected Uranium-Metal Cylinders and Annuli," Union Carbide Corporation Nuclear Division, Oak Ridge Y-12 Plant, Y-DR-81 (April 28, 1972). Oxygen and nitrogen content was assumed by the principal experimentalist to be 20 and 30 ppm, respectively.
(b) Data calculated using 70% uncertainty for elements detected below 10 μg/g-U and 20% uncertainty for elements above 10 μg/g-U.
(c) Data calculated using 20% uncertainty for elements detected below 10 μg/g-U and 6% uncertainty for elements above 10 μg/g-U.
(d) The deviation is 3 times of the 1σ uncertainty, which used in perturbed model. If in perturbed model the impurity value subtracted with lower deviation is less than 0, the value was set to 0.

To find the effect of this uncertainty on the k_{eff} value, the impurities were all simultaneously increased by 3σ to find an upper perturbation Δk_{per} value and then all simultaneously decreased to find a lower perturbation Δk_{per} value. Perturbation of the content of individual impurities was not performed as their content and the uncertainty in the content is already quite small; furthermore, the primary effect of this uncertainty would be the impact of adjusting the total uranium content in the oralloy metal. The weight fraction of the uranium metal was adjusted, as appropriate, to compensate for the adjustments in impurity content. Half of the difference between the upper and lower perturbation Δk_{per} values was used to represent the variation in Δk_{per} due to perturbing the uranium impurity content. The 1σ uncertainty in k_{eff} associated with the impurity content of the uranium annuli is found from the following formula, where Δk_{per} is one-half the difference between the upper and lower perturbation Δk_{per} values and SF is the parameter scaling factor:

$$\Delta k_{eff}(1\sigma) = \frac{\Delta k_{per}}{SF}$$

This uncertainty is treated as 100 % systematic with no random uncertainty component because there is insufficient information to assess any randomness in the impurity content between manufactured oralloy components. Results are provided in Table 27.

Table 27. Effect of Uncertainties in Uranium Impurity Content.

Case	Deviation (ppm)	Δk_p	±	$\sigma_{\Delta kp}$	SF	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	±3σ (see Table 26)	0.00012	±	0.00006	3	0.00004	±	0.00002
2	±3σ (see Table 26)	0.00017	±	0.00006	3	0.00006	±	0.00002
3	±3σ (see Table 26)	0.00020	±	0.00006	3	0.00007	±	0.00002

2.3.2 Graphite

Impurities

The graphite reflector impurities were documented in report (see Reference 1) for 11 randomly sampled graphite parts (see Table 28). Since the cylinder radius in all 3 experiments presented here is less than 15-inches, the impurity information listed for graphite reflector parts with a thickness of less than 15-inches was used. The impurities listed in Table 9 are the average of a spectrographic analysis or listed as less than a maximum specified value. It is assumed that the uncertainty is uniform distribution if the content value is stated as less than a specified value, and the uncertainty is normal distribution (3σ) if the content value is obtained from the average of a spectrographic analysis. The mean impurity contents and revised uncertainties assessment are provided in Table 28.

Table 28. Impurity Content of Graphite Cylinders.

Element	Impurity Content (ppm)	1σ Uncertainty (ppm)
Ag	0.5	0.5/√3
Al	85	42.5/3
B	7.7	3.85/3
Ba	30	15/3
Be	0.5	0.5/√3
Bi	1.5	1.5/√3
Ca	500	250/3
Cd	5	5/√3
Co	5	5/√3
Cr	5	5/√3
Cu	2.33	1.165/3
Fe	283	141.5/3
K	10	5/3
Li	0.5	0.5/√3
Mg	41.7	20.85/3
Mn	1	1/√3
Mo	0.5	0.5/√3
Na	10	5/3
Nb	10	5/√3
Ni	1.5	1.5/√3
Pb	3	1.5/3
Rb	5	5/√3
Sb	5	5/√3
Si	257	128.5/3
Sn	1.5	1.5/√3
Ta	30	15/3
Ti	12	6/3
V	40	20/3
W	15	15/√3
Zn	25	25/√3
Zr	5	5/√3

To find the effect of these uncertainties on the k_{eff} value, the impurities were all simultaneously increased by 3 sigma uncertainty to find an upper perturbation Δk_{per} value and then all simultaneously decreased to find a lower perturbation Δk_{per} value. Perturbation of the content of individual impurities was not performed as their content and the uncertainty in the content is already quite small; furthermore, the primary effect of this uncertainty would be the impact of adjusting the total graphite content. The weight fraction of the graphite was adjusted, as appropriate, to compensate for the adjustments in impurity content. Half of the difference between the upper and lower perturbation Δk_{per} values was used to represent the variation in Δk_{per} due to perturbing the graphite impurity content. The 1σ uncertainty in k_{eff} associated with the impurity content of the graphite cylinders is found from the following formula, where Δk_{per} is one-half the difference between the upper and lower perturbation Δk_{per} values, SF is the parameter scaling:

$$\Delta k_{eff}(1\sigma) = \frac{\Delta k_{per}}{SF}.$$

This uncertainty is treated as 100 % systematic with no random uncertainty component because there is insufficient information to assess any randomness in the impurity content between manufactured graphite components. The calculated graphite impurity reactivity uncertainties are listed in Table 29.

Table 29. Effect of Uncertainty in Graphite Impurity Content.

Case	Deviation (ppm)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	±3σ (see Table 28)	0.00007	±	0.00006	3	0.00002	±	0.00002
2	±3σ (see Table 28)	0.00011	±	0.00006	3	0.00004	±	0.00002
3	±3σ (see Table 28)	0.00001	±	0.00006	3	<0.00001	±	0.00002

Water Content

Contemporary graphite of that era from TREAT[a] had a water content of 0.02 wt.% ± 0.01 wt.%. The uncertainty is a 2-sigma value. In this report, +0.03 wt.% of water content in graphite was assumed as the bounding uncertainty with uniform distribution.

To find the effect of this uncertainty on the k_{eff} value, one-sided perturbation was used, that is the water content were all simultaneously increased by +0.03 wt.% in all graphite parts to find an upper perturbation Δk_{per} value. The weight fraction of the graphite was adjusted, as appropriate, to compensate for the adjustments of the water content. The difference between the upper perturbed and unperturbed k_{eff} values was used to represent the variation in Δk_{per} due to perturbing the water content. The 1σ uncertainty in k_{eff} associated with the water content of the graphite cylinders is found from the following formula, where Δk_{per} is the difference between the upper and unperturbed Δk_{per} values, SF is the parameter scaling:

$$\Delta k_{eff}(1\sigma) = \frac{\Delta k_{per}}{SF}$$

[a] H. P. Iskenderian, "Post Criticality Studies on the TREAT Reactor," ANL-6115, Argonne National Laboratory (1960).

This uncertainty is treated as 100 % systematic with no random uncertainty component because all graphite parts were in the same environment. The calculated graphite water content reactivity uncertainties are listed in Table 30.

Table 30. Effect of Uncertainty in Graphite Water Content.

Case	Deviation (wt.%)	Δk_{per}	±	$\sigma_{\Delta kper}$	SF	Δk_{eff} (1σ)	±	$\sigma_{\Delta keff}$
1	+0.03	0.00007	±	0.00006	1.73	0.00004	±	0.00003
2	+0.03	0.00014	±	0.00006	1.73	0.00008	±	0.00003
3	+0.03	0.00002	±	0.00006	1.73	0.00001	±	0.00003

2.4 Total Uncertainty of Critical Configurations

The total k_{eff} uncertainty for each experiment was calculated by taking the square root of the sum of the squares of all the individual uncertainties discussed before; they are summarized in Table 31, Table 32 and Table 33 for three cases, respectively; these are acceptable benchmark experiments. Uncertainties < 0.00003 Δk_{eff} are reported as negligible (NEG).

Table 31. Total Experimental Uncertainty for Configuration 1.

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff}
Temperature (K)	294	±2	0.00004
Experiment reproducibility (¢)	--	±2	0.00013
Measured reactivity worth (¢)	--	±√4×√3×2	0.00046
β_{eff}	0.0066	±5 %	0.00005
Uranium diameter (cm)	Table 2	±0.001276/√3	0.00003
Uranium height (cm)	Table 2	±0.001276/√3	0.00010
Uranium stack height (cm)	Table 4	±0.003949	0.00012
Uranium mass (g)	Table 2	±0.507859/√3	NEG
Graphite diameter (cm)	Table 3	±0.001276/√3	NEG
Graphite height (cm)	Table 3	±0.001276/√3	NEG
Graphite stack height (cm)	Table 4	±0.003949	NEG
Graphite mass (g)	Table 3	±0.507859/√3	NEG
Lateral assembly alignment (cm)	0	±0.0127/2√3	NEG
Vertical assembly alignment (cm)	Not Applicable – See Section 2.2.3		-
Gaps between parts (cm)	Not Applicable – See Section 2.2.4		-
Assembly separation (cm)	Not Applicable – See Section 2.2.4		-
^{234}U content (wt.%)	Table 7	±0.003917	0.00003
^{235}U content (wt.%)	Table 7	±0.018265	0.00019
^{236}U content (wt.%)	Table 7	±0.013494	NEG
Uranium impurities (ppm)	Table 26	Table 26	0.00004
Graphite impurities (ppm)	Table 28	Table 28	NEG
Water content in graphite (wt.%)	0	±0.03/√3	0.00004
Total Experimental Uncertainty	**--**	**--**	**0.00055**

Table 32. Total Experimental Uncertainty for Configuration 2.

Perturbed Parameter	Parameter Value	1σ Uncertainty	Δk_{eff}
Temperature (K)	294	±2	0.00004
Experiment reproducibility (¢)	--	±2	0.00013
Measured reactivity worth (¢)	--	±√4×√3×2	0.00046
β_{eff}	0.0066	±5 %	0.00005
Uranium diameter (cm)	Table 2	±0.001276/√3	0.00003
Uranium height (cm)	Table 2	±0.001276/√3	0.00010
Uranium stack height (cm)	Table 4	±0.003949	0.00013
Uranium mass (g)	Table 2	±0.507859/√3	NEG
Graphite diameter (cm)	Table 3	±0.001276/√3	NEG
Graphite height (cm)	Table 3	±0.001276/√3	NEG
Graphite stack height (cm)	Table 4	±0.003949	NEG
Graphite mass (g)	Table 3	±0.507859/√3	NEG
Lateral assembly alignment (cm)	0	±0.0127/2√3	NEG
Vertical assembly alignment (cm)	Not Applicable – See Section 2.2.3		-
Gaps between parts (cm)	Not Applicable – See Section 2.2.4		-
Assembly separation (cm)	Not Applicable – See Section 2.2.4		-
^{234}U content (wt.%)	Table 7	±0.003917	0.00004
^{235}U content (wt.%)	Table 7	±0.018265	0.00019
^{236}U content (wt.%)	Table 7	±0.013494	0.00003
Uranium impurities (ppm)	Table 26	Table 26	0.00006
Graphite impurities (ppm)	Table 28	Table 28	0.00004
Water content in graphite (wt.%)	0	±0.03/√3	0.00008
Total Experimental Uncertainty	--	--	**0.00055**

Table 33. Total Experimental Uncertainty for Configuration 3.

Perturbed Parameter	**Parameter Value**	**1σ Uncertainty**	**Δk_{eff}**
Temperature (K)	294	±2	0.00004
Experiment reproducibility (¢)	--	±2	0.00013
Measured reactivity worth (¢)	--	±√4×√3×2	0.00046
β_{eff}	0.0066	±5 %	0.00005
Uranium diameter (cm)	Table 2	±0.001276/√3	0.00003
Uranium height (cm)	Table 2	±0.001276/√3	0.00004
Uranium stack height (cm)	Table 4	±0.003949	0.00012
Uranium mass (g)	Table 2	±0.507859/√3	NEG
Graphite diameter (cm)	Table 3	±0.001276/√3	NEG
Graphite height (cm)	Table 3	±0.001276/√3	NEG
Graphite stack height (cm)	Table 4	±0.003949	0.00003
Graphite mass (g)	Table 3	±0.507859/√3	NEG
Lateral assembly alignment (cm)	0	±0.0127/2√3	NEG
Vertical assembly alignment (cm)	Not Applicable – See Section 2.2.3		-
Gaps between parts (cm)	Not Applicable – See Section 2.2.4		-
Assembly separation (cm)	Not Applicable – See Section 2.2.4		-
^{234}U content (wt.%)	Table 7	±0.003917	0.00003
^{235}U content (wt.%)	Table 7	±0.018265	0.00019
^{236}U content (wt.%)	Table 7	±0.013494	NEG
Uranium impurities (ppm)	Table 26	Table 26	0.00007
Graphite impurities (ppm)	Table 28	Table 28	NEG
Water content in graphite (wt.%)	0	±0.03/√3	NEG
Graphite Arrangement for Case 3	Table 20	-	0.00006
Total Experimental Uncertainty	--	--	**0.00055**

3.0 BENCHMARK SPECIFICATIONS

Detailed and simple benchmark models were created with MCNP5-1.60 using ENDF/B-VII.1 neutron cross section libraries. The biases of any simplifications or assumptions were calculated for both the detailed and simple models. All models were run in MCNP5 such that the statistical uncertainty (1σ) of k_{eff} was not more than 0.00004. Benchmark specifications for both the detailed and simple model are described in Sections 3.2 and 3.3.

The bias for the detailed model is comprised of the effect of room return and air and the effect of peripheral structures (stainless steel diaphragm, diaphragm support ring, support structure). The former was evaluated by comparing the detailed model with the changed model by modeling the room wall and adding air material to void, and the latter was obtained through the experiments (Table 6).

The method for determining the simplification bias was as follows. First, the detailed benchmark model was created. The biases of simplifications in the detailed benchmark model were calculated. This included the bias of room return, replacing air with void, and the support structure. Next, the biases of individual simplifications used to obtain the simple benchmark model were calculated. This included homogenization of the HEU annuli and graphite cylinder, and the removal of material impurities. The overall biases for the detailed and simple benchmark models were found by comparing the benchmark models to a model with no simplifications.

A simplification is considered negligible if the effect on k_{eff} is ≤0.00003.

3.1 Description of Model

3.1.1 Detailed and Simple Model

Two benchmark models were developed to represent each of the HEU metal annuli experiments. The detailed benchmark model represents, as much as possible, the experiment described in the report.[a] Some approximation is necessary to estimate the height of gaps between the individual components of the experiment and to reproduce the measured stack heights; however, any uncertainty in the gap height would be negligible compared with the total experimental uncertainty (see Section 2.2.1). The simple benchmark model reduces the experiments to a basic cylindrical structure comprised of two single materials: HEU annulus, graphite cylinder.

The experimental assembly, including the stainless steel diaphragm and the room itself, are not included in the benchmark models.

These three critical configurations have been evaluated as acceptable benchmark experiments.

3.1.1.1 Detailed Model

The detailed benchmark model is comprised of stacks of uranium metal annuli and the graphite cylinders in the center. Small gaps exist between adjacent components of the experiment and each component has unique dimensions and composition that reproduce, as closely as possible, the actual component dimensions and compositions (see Figure 8, Figure 9, Figure 10, Figure 11, Figure 12, Figure 13, Table 40 and Table 41).

Very small gaps exist between the components of the experiment, as the top and bottom surfaces of the discs are not perfectly smooth. However, it is not easy to exactly model the imperfect surfaces of the experiment

[a] J. T. Mihalczo, "Graphite and Polyethylene Reflected Uranium-Metal Cylinders and Annuli", Union Carbide Corporation Nuclear Division, Oak Ridge Y-12 Plant, Y-DR-81 (1972).

components. The measured stack height and individual heights of each part are preserved in the detailed benchmark model. To preserve the stack height, small gaps must be placed between the discs. These gap heights are exaggerated in Figure 9, Figure 11 and Figure 13 so that the gap heights can be easily noticed. The effect of eliminating the gaps between parts is quite small compared to effects such as adjusting the overall stacked height dimension of the experiment, which is then, much less than the uncertainty in the measurements of system reactivity and corrections for removal of experiment support structure (see section 2.4). Further discussion of the gaps between discs is provided in Section 2.2.4.

3.1.1.2 Simple Model

The simple benchmark model consists of a single HEU metal annulus with an inner graphite cylinder. The height of the HEU annulus is equal to the average of the all the upper stack height of HEU annuli plus the maximum height of lower stacks in each case, and the inner diameter and outer diameter are equal to the nominal of the inner and outer cylinder boundary. The height of graphite is adjusted to equal the height of the HEU annulus and the outer diameter is equal to the nominal OD of the graphite cylinder. The outer diameter of graphite cylinder is equal the inner diameter of HEU annulus and both bottoms of the graphite cylinder and HEU annulus are even. The total mass for the uranium and graphite is conserved in the simple model. Over all the simple model dimensions correspond to the nominal experimental dimensions. All the dimensions for the simple models are listed in Table 39 and are shown in Figure 14, Figure 15 and Figure 16.

3.1.2 Evaluation of Benchmark Model Biases

3.1.2.1 Biases for Detailed Model

Room Return and Effect of Air

The properties and dimensions of the room in which the experiment was performed were not provided in Reference 1, but they are well known and available from other ORCEF East Cell experiment reports. The dimensions were obtained from a similar benchmark report: HEU-MET-FAST-076. Room return effects were estimated using the room and experiment placement dimensions provided in Section 1.2 and assuming that the other concrete wall, floor, and ceiling thicknesses are 0.7m. The concrete was modeled as Oak Ridge Concrete with a density of 2.3 g/cm^3 and the room containing air with a density of 1.2 kg/m^3. The use of either Oak Ridge Concrete or Magnuson Concrete was previously demonstrated to provide similar results as shown in HEU-MET-FAST-076. Both concretes were prepared using crushed limestone instead of sand due to the unavailability of sand at the time.[a] Calculated results for these simplifications are shown in Table 34.

Support Structure Removal

The benchmark models do not include the support structure of the experimental assembly, the diaphragm support ring or the stainless steel diaphragm. Removal of the support structure materials was included in the experimental assessment of the reported eigenvalue and the uncertainty in their worth is discussed in Section 1.2.7.

The diaphragm bolts were not included in the experimental analysis of the support structure worth.[b] A calculation was performed previously in HEU-MET-FAST-069 of the ICSBEP Handbook to evaluate a "ring" of steel material where the bolts would have been located in the actual experiment. The calculated bias in that benchmark evaluation was negligible and is also assumed to have a negligible effect upon this set of experiments. Results for these corrections are also shown in Table 34.

[a] Personal communication with John T. Mihalczo, February 2010.
[b] Personal communication with John T. Mihalczo, June 2010.

Temperature

The temperature reactivity coefficient is reported by the experimenter to be approximately -0.3¢/ºC. The parts were measured at ~294 K and the original experiments were performed at ~295 K. The uncertainty in either of these two temperatures is unknown. The benchmark models use dimensions as measured at room temperature conditions, ~294 K, and ENDF/B-VII.1 cross sections evaluated at 293.6 K. No bias for temperature effects was included in the benchmark model, however an uncertainty in the temperature of the experiments and evaluation was provided in Section 2.1.1.

Total Bias Adjustment for Detailed Model

The total bias for the detailed benchmark model includes room return effects, replacing air with void, and experimentally measured corrections for the removal of support structure. A list of the individually evaluated biases, with their respective bias uncertainties, and the total bias for both detailed are provided in Table 34.

Table 34. Calculated Biases (Δk_{eff}) for Detailed Benchmark Model Simplifications.

Bias/*Correction*	**Case 1**	**Case 2**	**Case 3**
1. Room Return and Air Effects	-0.00117 ± 0.00006	-0.00125 ± 0.00006	-0.00094 ± 0.00006
2. Removal of Stainless Steel Diaphragm	0.00068 --[(b)]	0.00108 --[(b)]	0.00077 --[(b)]
3. Removal of Diaphragm Support Ring	-0.00042 --[(b)]	-0.00038 --[(b)]	-0.00032 --[(b)]
4. Removal of Support Structure	-0.00088 --[(b)]	-0.00133 --[(b)]	-0.00065 --[(b)]
5. Temperature	NEG --[(b)]	NEG --[(b)]	NEG --[(b)]
Total Bias for Detailed Model[(a)]	**-0.00179 ± 0.00006**	**-0.00189 ± 0.00006**	**-0.00114 ± 0.00006**

(a) Bias is the arithmetic sum of Items 1 through 5; bias uncertainty is the square root of the sum of the squares of each uncertainty for items 1 through 5.
(b) The uncertainties in the measured corrections are already accounted for in evaluation of the total experimental uncertainty (see Section 2.1.4).

3.1.2.2 Biases for Simple Model

Additional simplifications were performed to facilitate the application of a simple model in place of the detailed model. Simplifications include the homogenization of uranium and graphite, and removal of impurities from the uranium annuli and graphite. MCNP5-1.60 and ENDF/B-VII.1 was utilized to estimate the biases, with a statistical uncertainty in Δk_{eff} of 0.00004.

The total bias for the simple benchmark model includes those for the detailed benchmark model as well as the model simplifications discussed earlier in this section for homogenization, impurity removal, and implementing standard material densities.

Homogenization of Graphite Cylinders

When homogenizing the graphite parts in each configuration, the mass is conserved and the total stack height of the graphite cylinder is retained, including the gaps between parts and the gap between the bottom of the upper section and the top of the lower section. After the height was slightly adjusted to the same height of the HEU simple model, the density is recalculated and the impurity contents for each element are averaged over the volume. Results for these simplifications are shown in Table 35.

Removal of Graphite Impurities

The impurity of each graphite was just simply removed from the configuration and the mass is reduced accordingly accounting for the removal of impurities (graphite weight fraction of 0.998606); otherwise the dimensions of each graphite parts and configurations are retained. Results for these simplifications are shown in Table 35.

Homogenization of HEU Annuli

For the HEU annuli in each configuration, all the annuli were converted into one annulus with the nominal ID and OD (see Table 39) and the height for the homogenization annulus is the averaged value of the height of all the annuli. The masses are conserved and the isotopic contents of uranium and the impurities content were averaged over the volume. Results for these simplifications are shown in Table 35.

Removal of HEU Impurities

The weight fraction of isotopes in the uranium annulus was obtained by taking the weight-averaged isotopic contents of the individual annuli. The mass of the uranium annulus was also reduced by replacing the impurities with void (uranium weight fraction of 0.999509). Results for these simplifications are shown in Table 35.

Table 35. Calculated Biases (Δk_{eff}) for Simple Benchmark Model Simplifications.

Bias/*Correction*	**Case 1**	**Case 2**	**Case 3**
1. Room Return and Air Effects	-0.00117 ± 0.00006	-0.00125 ± 0.00006	-0.00094 ± 0.00006
2. Removal of Stainless Steel Diaphragm	0.00068 --[(b)]	0.00108 --[(b)]	0.00077 --[(b)]
3. Removal of Diaphragm Support Ring	-0.00042 --[(b)]	-0.00038 --[(b)]	-0.00032 --[(b)]
4. Removal of Support Structure	-0.00088 --[(b)]	-0.00133 --[(b)]	-0.00065 --[(b)]
5. Temperature	NEG --[(b)]	NEG --[(b)]	NEG --[(b)]
6. Homogenization of Graphite Cylinder	-0.00002 ± 0.00006	-0.00024 ± 0.00006	-0.00002 ± 0.00006
7. Removal of Graphite Impurities	-0.00001 ± 0.00006	0.00005 ± 0.00006	-0.00005 ± 0.00006
8. Homogenization of HEU Annuli	0.00070 ± 0.00006	0.00043 ± 0.00006	0.00039 ± 0.00006
9. Removal of HEU Impurities	-0.00021 ± 0.00006	-0.00018 ± 0.00006	-0.00025 ± 0.00006
Total Bias for Simplified Model[(a)]	**-0.00133 ± 0.00013**	**-0.00183 ± 0.00013**	**-0.00107 ± 0.00013**

(a) Bias is the arithmetic sum of the total bias of the detailed model and the calculated simplification bias; bias uncertainty is the square root of the sum of the squares of the uncertainty in the bias for the detailed model and the uncertainty in the calculated simplification bias.

(b) The uncertainties in the measured corrections are already accounted for in evaluation of the total experimental uncertainty (see Section 2.1.4).

3.2 Dimensions

3.2.1 Detailed Benchmark Model

The detailed benchmark models for each case are shown in Figure 8, Figure 9, Figure 10, Figure 11, Figure 12 and Figure 13 for the part dimensions and gaps between HEU parts, respectively. They are labeled with part identifiers and dimensions. Part dimensions for the HEU annuli and the graphite cylinders are also summarized in Table 36, Table 37 and Table 38. The average gap heights are summarized in Table 5 and illustrated in Figure 9, Figure 11, and Figure 13.

Table 36. Properties of Detailed Benchmark Model for Case 1.

Annulus	Part Number	Mass (g)	Height (cm)	IR (cm)	OR (cm)	Density (g/cc)
center -9"						
upper	61	445	0.635000	-	11.428095	1.70800
	70	998	1.428750	-	11.428095	1.70246
	29	1763	2.540000	-	11.428095	1.69169
	42	2675	3.810000	-	11.428095	1.71120
lower	44	3533	5.080000	-	11.428095	1.69505
9"-11"						
upper	2778	2411	0.637540	11.432540	13.965555	18.71113
	2767	5410	1.427480	11.431270	13.964920	18.74827
	2748	14462	3.810000	11.433175	13.966825	18.77466
	2776	9644	2.543810	11.431905	13.965555	18.75360
lower	2742	3617	0.952754	11.431905	13.965936	18.77622
	2746	1238	0.326771	11.432223	13.965555	18.74297
	2747	14436	3.809746	11.432540	13.965936	18.74516
11"-13"						
upper	2782	2914	0.639445	13.974445	16.504412	18.81144
	2781	1449	0.318008	13.973175	16.505873	18.78861
	2749	4360	0.958596	13.973810	16.504285	18.77198
	2755	6514	1.431290	13.973810	16.504920	18.77852
	2753	5782	1.273302	13.973810	16.505873	18.72884
	2752	5811	1.278255	13.973175	16.504285	18.75827
	2757	11575	2.543937	13.973175	16.504920	18.76964
lower	2751	5822	1.279017	13.971905	16.504666	18.77088
	2754	5826	1.279144	13.975080	16.504031	18.80864
	2756	11567	2.540508	13.974572	16.505809	18.78435
13"-15"						
upper	2886	3384	0.638683	16.513175	19.045682	18.72818
	2885	3415	0.644271	16.514064	19.045301	18.74496
	2784	5039	0.946150	16.511905	19.043015	18.83748
	2786	6717	1.256411	16.513175	19.043650	18.91332
	2787	6788	1.281176	16.511905	19.043650	18.73504
	2760	6743	1.270000	16.512540	19.043650	18.77899
	2739	13461	2.526030	16.513429	19.044285	18.84893
lower	2761	1706	0.321310	16.511270	19.043333	18.77300
	2785	5043	0.951738	16.513620	19.044603	18.74094
	2848	6748	1.274826	16.513937	19.045428	18.71729
	2735	13409	2.536190	16.512540	19.041745	18.71491

Table 37. Properties of Detailed Benchmark Model for Case 2.

Annulus	Part Number	Mass (g)	Height (cm)	IR (cm)	OR (cm)	Density (g/cc)
center -7"						
upper	1	130	0.317500	-	8.888095	1.64980
	7	536	1.270000	-	8.888095	1.70056
	27	1618	3.810000	-	8.888095	1.71114
lower	36	2131	5.080000	-	8.888095	1.69025
7"-9"						
upper	2763	953	0.315722	8.894826	11.424666	18.69095
	2762	7703	2.538095	8.894763	11.425238	18.78778
	2738	7710	2.543048	8.894763	11.424603	18.77352
lower	2773	962	0.317500	8.891905	11.426190	18.73018
	2829	2895	0.955675	8.894001	11.425238	18.74767
	2740	11568	3.810000	8.893175	11.425238	18.78530
7"-9"						
upper	2744	1223	0.321945	11.438255	13.965936	18.83069
	2743	3621	0.949960	11.433175	13.965555	18.86390
	2767	5410	1.427480	11.431270	13.964920	18.74827
	2776	9644	2.543810	11.431905	13.965555	18.75360
lower	2742	3617	0.952754	11.431905	13.965936	18.77622
	2746	1238	0.326771	11.432223	13.965555	18.74297
	2748	14462	3.810000	11.433175	13.966825	18.77466
9"-11"						
upper	2755	6514	1.431290	13.973810	16.504920	18.77852
	2752	5811	1.278255	13.973175	16.504285	18.75827
	2757	11575	2.543937	13.973175	16.504920	18.76964
lower	2751	5822	1.279017	13.971905	16.504666	18.77088
	2754	5826	1.279144	13.975080	16.504031	18.80864
	2756	11567	2.540508	13.974572	16.505809	18.78435
11"-13"						
upper	2758	1685	0.316230	16.505555	19.045746	18.78124
	2760	6743	1.270000	16.512540	19.043650	18.77899
	2786	6717	1.256411	16.513175	19.043650	18.91332
	2739	13461	2.526030	16.513429	19.044285	18.84893
lower	2761	1706	0.321310	16.511270	19.043333	18.77300
	2785	5043	0.951738	16.513620	19.044603	18.74094
	2848	6748	1.274826	16.513937	19.045428	18.71729
	2735	13409	2.536190	16.512540	19.041745	18.71491

Table 38. Properties of Detailed Benchmark Model for Case 3.

Annulus	Part Number	Mass (g)	Height (cm)	IR (cm)	OR (cm)	Density (g/cc)
center -7"						
upper	3	266	0.635000	-	8.888095	1.68787
	7	536	1.270000	-	8.888095	1.70056
	27	1618	3.810000	-	8.888095	1.71114
lower	15	1065	2.540000	-	8.888095	1.68946
	36	2131	5.080000	-	8.888095	1.69025
7"-9"						
upper	2775	1917	0.631190	8.895080	11.425873	18.79795
	2738	7710	2.543048	8.894763	11.424603	18.77352
	2762	7703	2.538095	8.894763	11.425238	18.78778
lower	2740	11568	3.810000	8.893175	11.425238	18.78530
	2741	11568	3.810762	8.893175	11.425555	18.77890
9"-11"						
upper	2779	2417	0.637540	11.431905	13.966190	18.74829
	2745	9634	2.537460	11.431270	13.965555	18.77680
	2776	9644	2.543810	11.431905	13.965555	18.75360
lower	2747	14436	3.809746	11.432540	13.965936	18.74516
	2748	14462	3.810000	11.433175	13.966825	18.77466
11"-13"						
upper	2782	2914	0.639445	13.974445	16.504412	18.81144
	2749	4360	0.958596	13.973810	16.504285	18.77198
	2781	1449	0.318008	13.973175	16.505873	18.78861
	2754	5826	1.279144	13.975080	16.504031	18.80864
	2756	11567	2.540508	13.974572	16.505809	18.78435
lower	2780	1440	0.317119	13.972540	16.504984	18.72707
	2750	4336	0.953643	13.971905	16.503015	18.76286
	2753	5782	1.273302	13.973810	16.505873	18.72884
	2751	5822	1.279017	13.971905	16.504666	18.77088
	2752	5811	1.278255	13.973175	16.504285	18.75827
	2757	11575	2.543937	13.973175	16.504920	18.76964

Figure 8. Detailed Benchmark Model of Cases 1.

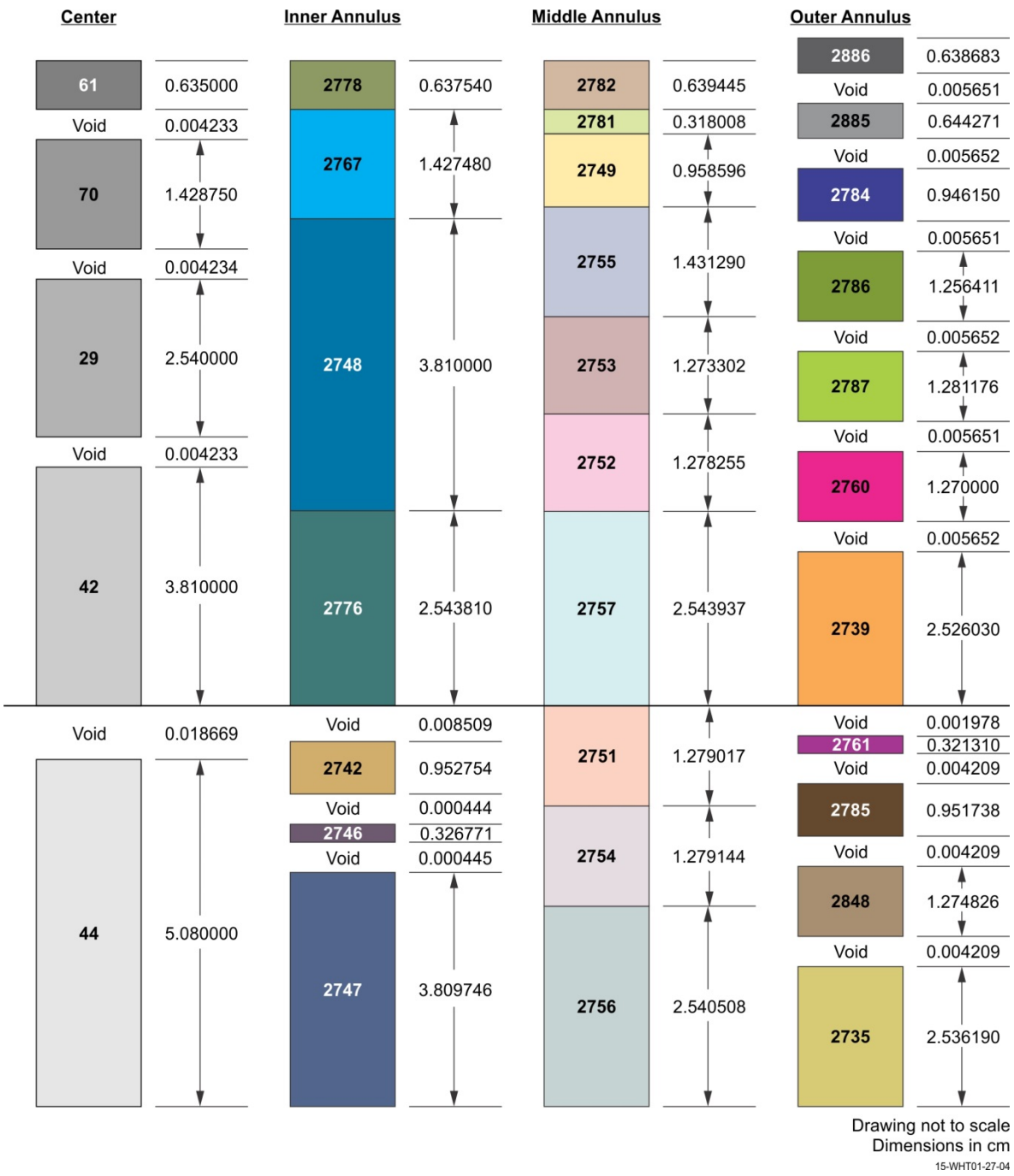


Figure 9. Gap Placement between HEU Annuli for Detailed Benchmark Model of Case 1.
(Note that gap heights are quite small and visually exaggerated for the benefit of the reader.)

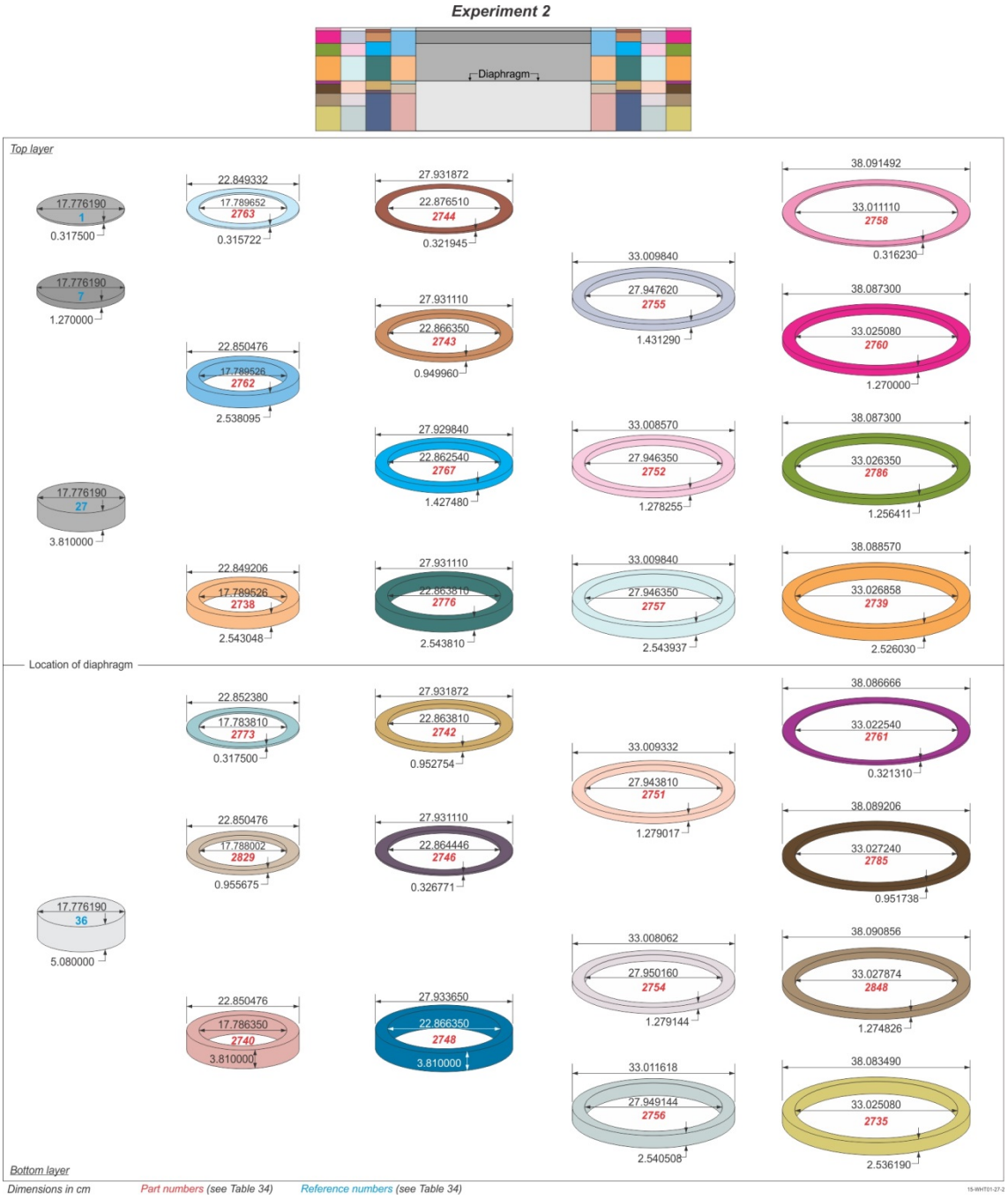


Figure 10. Detailed Benchmark Model of Cases 2.

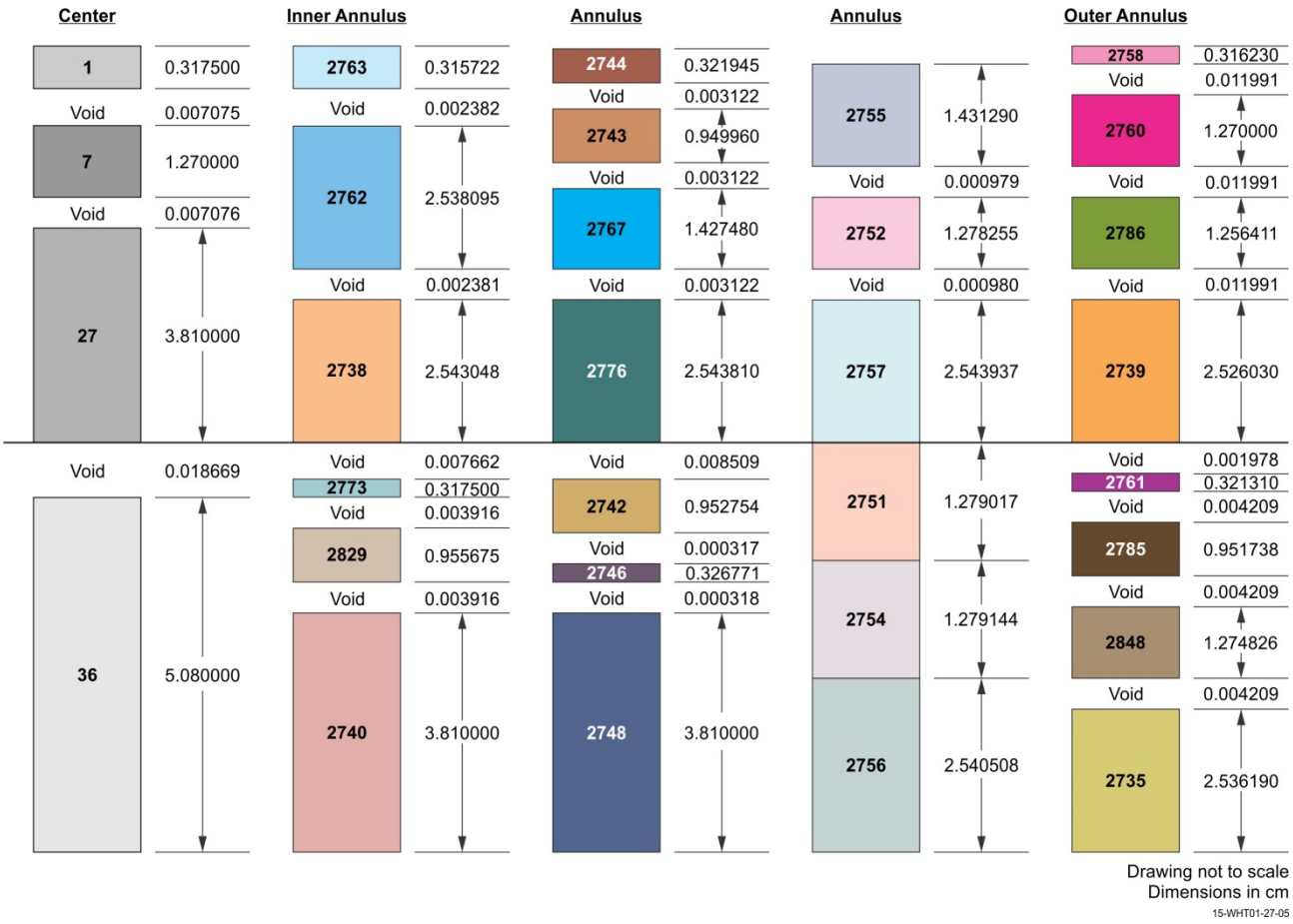


Figure 11. Gap Placement between HEU Annuli for Detailed Benchmark Model of Case 2.
(Note that gap heights are quite small and visually exaggerated for the benefit of the reader.)

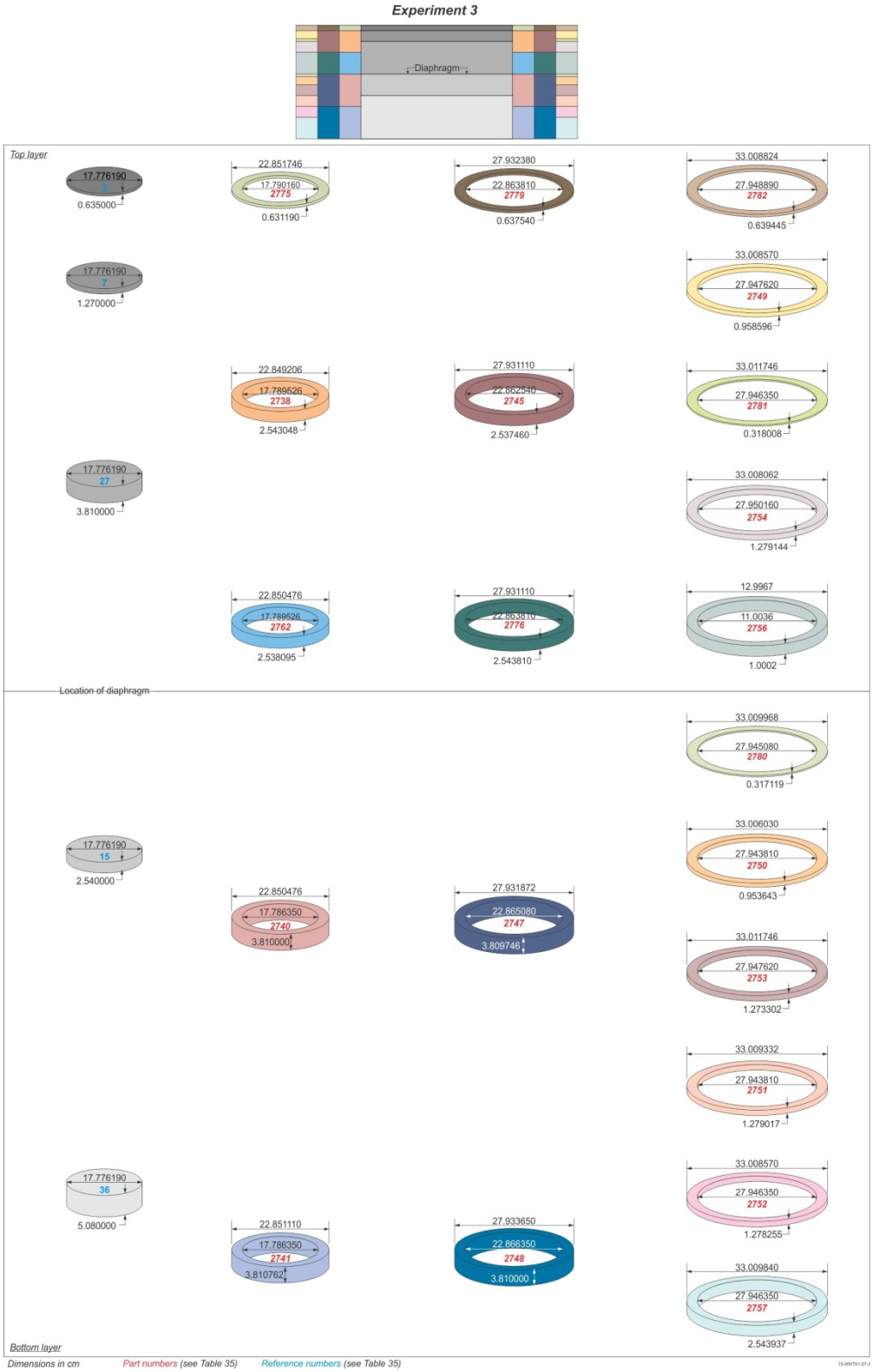


Figure 12. Detailed Benchmark Model of Cases 3.

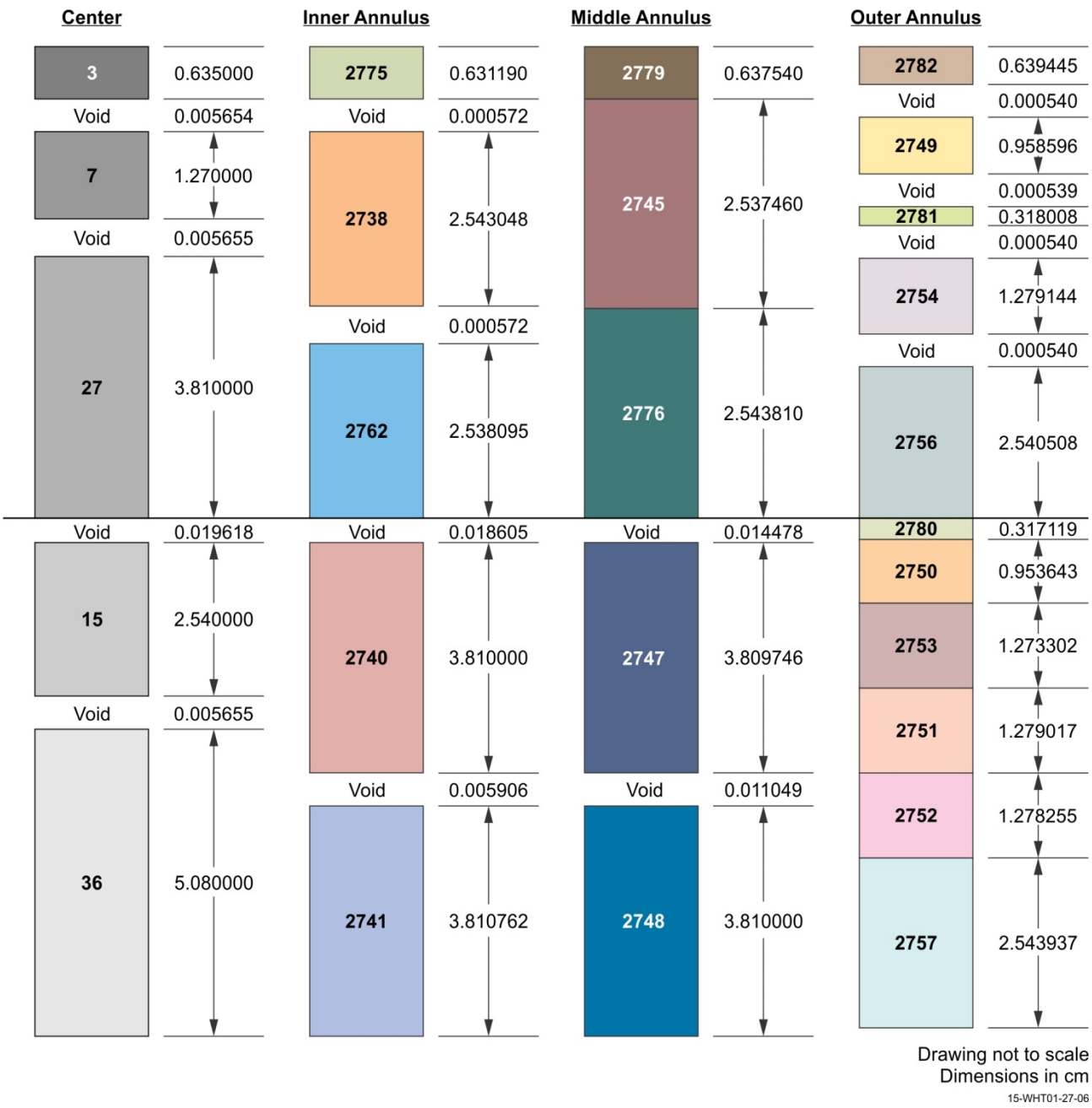


Figure 13. Gap Placement between HEU Annuli for Detailed Benchmark Model of Case 3.
(Note that gap heights are quite small and visually exaggerated for the benefit of the reader.)

3.2.2 Simple Benchmark Model

The dimensions for the simple models are listed in Table 39 and are shown in Figure 14, Figure 15 and Figure 16.

Table 39. Dimensions for Simple Models.

Case Number	Dimensions (cm)			
	Graphite Cylinder		HEU Annulus	
	OD	Height	OD	Height
1	22.860000	13.584767	38.100000	13.584767
2	17.780000	10.427237	38.100000	10.427237
3	17.780000	13.368655	33.020000	13.368655

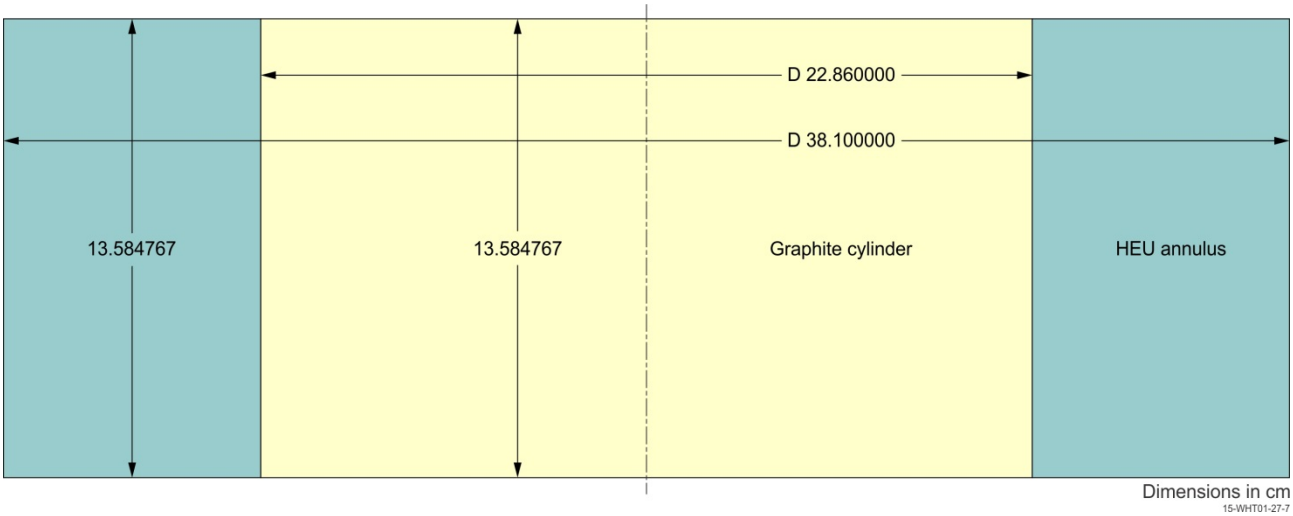


Figure 14. Simple Benchmark Model of Case 1.

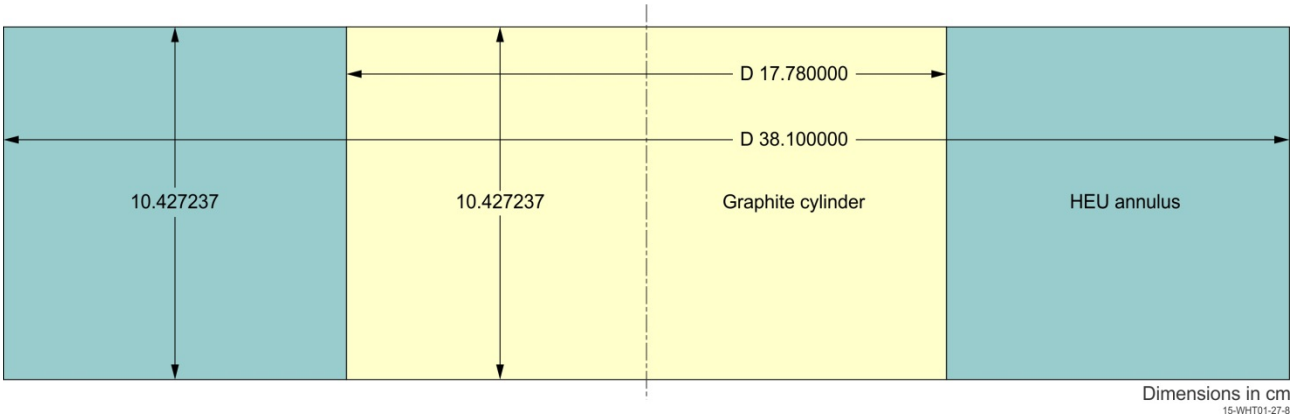


Figure 15. Simple Benchmark Model of Case 2.

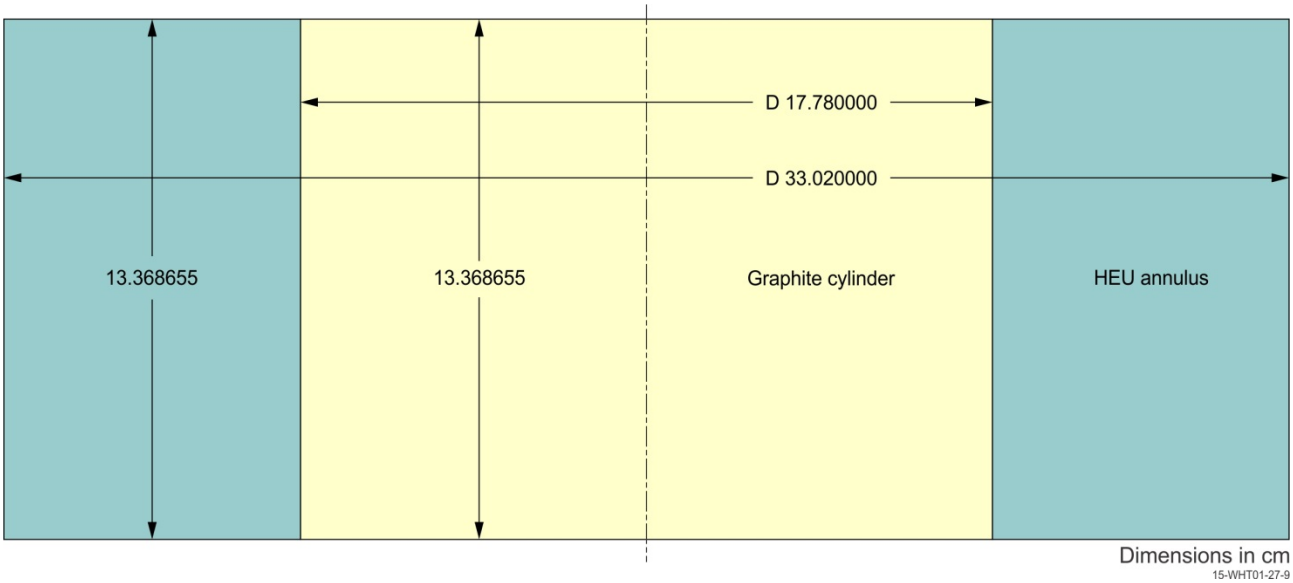


Figure 16. Simple Benchmark Model of Case 3.

3.3 Material Data

3.3.1 Detailed Benchmark Material Data

Material densities were obtained by taking the individual mass of the uranium, graphite components divided by the individual volume they occupy in the detailed benchmark model.

3.3.1.1 Uranium

The atom densities of the various uranium annuli are given in Table 40, where part identifiers match the identifiers shown in Figure 8, Figure 10 and Figure 12.

Table 40. HEU Atomic Densities (atoms/barns-cm) for the Detailed Benchmark Models.

Part Number	2735	2738	2739	2740	2741	2742
^{234}U	4.7169E-04	4.7317E-04	4.6537E-04	4.6863E-04	4.6364E-04	4.7323E-04
^{235}U	4.4629E-02	4.4783E-02	4.4968E-02	4.4821E-02	4.4810E-02	4.4785E-02
^{236}U	1.1931E-04	1.1489E-04	1.2016E-04	1.1497E-04	1.1971E-04	1.1012E-04
^{238}U	2.6736E-03	2.6725E-03	2.6832E-03	2.6694E-03	2.6638E-03	2.6824E-03
Ag	8.3584E-07	8.3846E-07	8.4183E-07	8.3899E-07	8.3870E-07	8.3858E-07
Ba	4.1034E-10	4.1162E-10	4.1328E-10	4.1188E-10	4.1174E-10	4.1168E-10
Bi	8.8445E-06	8.8722E-06	8.9079E-06	8.8778E-06	8.8748E-06	8.8735E-06
C	4.6921E-06	4.7067E-06	4.7257E-06	4.7097E-06	4.7081E-06	4.7074E-06
Ca	2.8120E-08	2.8208E-08	2.8321E-08	2.8225E-08	2.8216E-08	2.8212E-08
Cd	5.0130E-08	5.0287E-08	5.0489E-08	5.0319E-08	5.0302E-08	5.0295E-08
Co	9.5625E-07	9.5924E-07	9.6309E-07	9.5984E-07	9.5951E-07	9.5938E-07
Cr	1.5173E-06	1.5220E-06	1.5281E-06	1.5230E-06	1.5225E-06	1.5222E-06
Cu	4.4336E-06	4.4475E-06	4.4654E-06	4.4503E-06	4.4488E-06	4.4482E-06
K	2.8824E-08	2.8915E-08	2.9031E-08	2.8933E-08	2.8923E-08	2.8919E-08
Li	1.6240E-06	1.6290E-06	1.6356E-06	1.6301E-06	1.6295E-06	1.6293E-06
Mg	1.3908E-06	1.3952E-06	1.4008E-06	1.3961E-06	1.3956E-06	1.3954E-06
Mn	1.1488E-05	1.1524E-05	1.1570E-05	1.1531E-05	1.1527E-05	1.1525E-05
Mo	5.8736E-08	5.8920E-08	5.9157E-08	5.8957E-08	5.8937E-08	5.8929E-08
Na	1.3236E-05	1.3278E-05	1.3331E-05	1.3286E-05	1.3281E-05	1.3279E-05
Ni	1.9200E-05	1.9260E-05	1.9337E-05	1.9272E-05	1.9265E-05	1.9263E-05
Sb	3.5176E-06	3.5286E-06	3.5428E-06	3.5309E-06	3.5297E-06	3.5292E-06
Ti	2.3529E-07	2.3603E-07	2.3697E-07	2.3617E-07	2.3609E-07	2.3606E-07
O	1.4089E-05	1.4133E-05	1.4190E-05	1.4142E-05	1.4137E-05	1.4135E-05
N	2.4133E-05	2.4209E-05	2.4306E-05	2.4224E-05	2.4216E-05	2.4212E-05
Total	4.8004E-02	4.8154E-02	4.8348E-02	4.8185E-02	4.8168E-02	4.8161E-02
Density (g/cm^3)	18.7149	18.7735	18.8489	18.7853	18.7789	18.7762

Table 40 (cont'd.). HEU Atomic Densities (atoms/barns-cm) for the Detailed Benchmark Model.

Part Number	2743	2744	2745	2746	2747	2748
^{234}U	4.7544E-04	4.7461E-04	4.6359E-04	4.8204E-04	4.7245E-04	4.8285E-04
^{235}U	4.4994E-02	4.4915E-02	4.4815E-02	4.4681E-02	4.4720E-02	4.4757E-02
^{236}U	1.1064E-04	1.1044E-04	1.0534E-04	1.0515E-04	9.0820E-05	1.0533E-04
^{238}U	2.6949E-03	2.6902E-03	2.6682E-03	2.6966E-03	2.6874E-03	2.7012E-03
Ag	8.4250E-07	8.4101E-07	8.3861E-07	8.3710E-07	8.3719E-07	8.3851E-07
Ba	4.1360E-10	4.1288E-10	4.1169E-10	4.1095E-10	4.1100E-10	4.1165E-10
Bi	8.9149E-06	8.8992E-06	8.8738E-06	8.8578E-06	8.8588E-06	8.8728E-06
C	4.7294E-06	4.7211E-06	4.7076E-06	4.6991E-06	4.6996E-06	4.7070E-06
Ca	2.8343E-08	2.8293E-08	2.8213E-08	2.8162E-08	2.8165E-08	2.8209E-08
Cd	5.0529E-08	5.0440E-08	5.0296E-08	5.0206E-08	5.0211E-08	5.0290E-08
Co	9.6386E-07	9.6216E-07	9.5941E-07	9.5768E-07	9.5779E-07	9.5930E-07
Cr	1.5294E-06	1.5267E-06	1.5223E-06	1.5195E-06	1.5197E-06	1.5221E-06
Cu	4.4689E-06	4.4611E-06	4.4483E-06	4.4403E-06	4.4408E-06	4.4478E-06
K	2.9054E-08	2.9003E-08	2.8920E-08	2.8868E-08	2.8871E-08	2.8916E-08
Li	1.6369E-06	1.6340E-06	1.6293E-06	1.6264E-06	1.6266E-06	1.6291E-06
Mg	1.4019E-06	1.3994E-06	1.3954E-06	1.3929E-06	1.3931E-06	1.3953E-06
Mn	1.1579E-05	1.1559E-05	1.1526E-05	1.1505E-05	1.1506E-05	1.1524E-05
Mo	5.9204E-08	5.9100E-08	5.8930E-08	5.8824E-08	5.8831E-08	5.8924E-08
Na	1.3341E-05	1.3318E-05	1.3280E-05	1.3256E-05	1.3258E-05	1.3278E-05
Ni	1.9353E-05	1.9319E-05	1.9263E-05	1.9229E-05	1.9231E-05	1.9261E-05
Sb	3.5456E-06	3.5394E-06	3.5293E-06	3.5229E-06	3.5233E-06	3.5289E-06
Ti	2.3716E-07	2.3674E-07	2.3607E-07	2.3564E-07	2.3567E-07	2.3604E-07
O	1.4201E-05	1.4176E-05	1.4135E-05	1.4110E-05	1.4112E-05	1.4134E-05
N	2.4326E-05	2.4283E-05	2.4213E-05	2.4170E-05	2.4172E-05	2.4210E-05
Total	4.8386E-02	4.8301E-02	4.8163E-02	4.8076E-02	4.8081E-02	4.8157E-02
Density (g/cm^3)	18.8639	18.8307	18.7768	18.7430	18.7452	18.7747

Table 40 (cont'd.). HEU Atomic Densities (atoms/barns-cm) for the Detailed Benchmark Model.

Part Number	2749	2750	2751	2752	2753	2754
^{234}U	4.7313E-04	4.5842E-04	4.7310E-04	4.7278E-04	4.5759E-04	4.6438E-04
^{235}U	4.4799E-02	4.4743E-02	4.4767E-02	4.4737E-02	4.4662E-02	4.4843E-02
^{236}U	1.1967E-04	1.1961E-04	1.1488E-04	1.1480E-04	1.1940E-04	1.3429E-04
^{238}U	2.6486E-03	2.6947E-03	2.6816E-03	2.6798E-03	2.6898E-03	2.6918E-03
Ag	8.3839E-07	8.3798E-07	8.3834E-07	8.3778E-07	8.3647E-07	8.4003E-07
Ba	4.1159E-10	4.1139E-10	4.1156E-10	4.1129E-10	4.1064E-10	4.1239E-10
Bi	8.8715E-06	8.8672E-06	8.8710E-06	8.8650E-06	8.8511E-06	8.8888E-06
C	4.7064E-06	4.7041E-06	4.7061E-06	4.7029E-06	4.6955E-06	4.7156E-06
Ca	2.8205E-08	2.8192E-08	2.8204E-08	2.8185E-08	2.8140E-08	2.8260E-08
Cd	5.0283E-08	5.0259E-08	5.0280E-08	5.0246E-08	5.0168E-08	5.0381E-08
Co	9.5916E-07	9.5870E-07	9.5911E-07	9.5846E-07	9.5696E-07	9.6103E-07
Cr	1.5219E-06	1.5212E-06	1.5218E-06	1.5208E-06	1.5184E-06	1.5249E-06
Cu	4.4472E-06	4.4450E-06	4.4469E-06	4.4439E-06	4.4369E-06	4.4558E-06
K	2.8912E-08	2.8898E-08	2.8911E-08	2.8891E-08	2.8846E-08	2.8969E-08
Li	1.6289E-06	1.6281E-06	1.6288E-06	1.6277E-06	1.6252E-06	1.6321E-06
Mg	1.3951E-06	1.3944E-06	1.3950E-06	1.3940E-06	1.3919E-06	1.3978E-06
Mn	1.1523E-05	1.1517E-05	1.1522E-05	1.1514E-05	1.1496E-05	1.1545E-05
Mo	5.8915E-08	5.8887E-08	5.8912E-08	5.8872E-08	5.8780E-08	5.9030E-08
Na	1.3276E-05	1.3270E-05	1.3276E-05	1.3267E-05	1.3246E-05	1.3302E-05
Ni	1.9258E-05	1.9249E-05	1.9257E-05	1.9244E-05	1.9214E-05	1.9296E-05
Sb	3.5284E-06	3.5266E-06	3.5282E-06	3.5258E-06	3.5203E-06	3.5352E-06
Ti	2.3601E-07	2.3589E-07	2.3599E-07	2.3583E-07	2.3546E-07	2.3647E-07
O	1.4132E-05	1.4125E-05	1.4131E-05	1.4121E-05	1.4099E-05	1.4159E-05
N	2.4207E-05	2.4195E-05	2.4206E-05	2.4189E-05	2.4151E-05	2.4254E-05
Total	4.8151E-02	4.8127E-02	4.8147E-02	4.8115E-02	4.8039E-02	4.8244E-02
Density (g/cm^3)	18.7720	18.7629	18.7709	18.7583	18.7288	18.8086

Table 40 (cont'd.). HEU Atomic Densities (atoms/barns-cm) for the Detailed Benchmark Model.

Part Number	2755	2756	2757	2758	2760	2761
^{234}U	4.6363E-04	4.4928E-04	4.6341E-04	4.7336E-04	4.7813E-04	4.6350E-04
^{235}U	4.4771E-02	4.4823E-02	4.4798E-02	4.4806E-02	4.4787E-02	4.4767E-02
^{236}U	1.3408E-04	1.1975E-04	1.1008E-04	1.2931E-04	1.1493E-04	1.2925E-04
^{238}U	2.6875E-03	2.6788E-03	2.6625E-03	2.6546E-03	2.6780E-03	2.6819E-03
Ag	8.3868E-07	8.3894E-07	8.3829E-07	8.3881E-07	8.3871E-07	8.3844E-07
Ba	4.1173E-10	4.1186E-10	4.1154E-10	4.1179E-10	4.1174E-10	4.1161E-10
Bi	8.8746E-06	8.8773E-06	8.8704E-06	8.8759E-06	8.8748E-06	8.8720E-06
C	4.7080E-06	4.7095E-06	4.7058E-06	4.7087E-06	4.7081E-06	4.7066E-06
Ca	2.8215E-08	2.8224E-08	2.8202E-08	2.8219E-08	2.8216E-08	2.8207E-08
Cd	5.0301E-08	5.0316E-08	5.0277E-08	5.0308E-08	5.0302E-08	5.0286E-08
Co	9.5950E-07	9.5979E-07	9.5904E-07	9.5963E-07	9.5952E-07	9.5921E-07
Cr	1.5224E-06	1.5229E-06	1.5217E-06	1.5227E-06	1.5225E-06	1.5220E-06
Cu	4.4487E-06	4.4501E-06	4.4466E-06	4.4494E-06	4.4488E-06	4.4474E-06
K	2.8922E-08	2.8931E-08	2.8909E-08	2.8926E-08	2.8923E-08	2.8914E-08
Li	1.6295E-06	1.6300E-06	1.6287E-06	1.6297E-06	1.6295E-06	1.6290E-06
Mg	1.3956E-06	1.3960E-06	1.3949E-06	1.3958E-06	1.3956E-06	1.3951E-06
Mn	1.1527E-05	1.1530E-05	1.1521E-05	1.1528E-05	1.1527E-05	1.1523E-05
Mo	5.8936E-08	5.8954E-08	5.8908E-08	5.8944E-08	5.8937E-08	5.8919E-08
Na	1.3281E-05	1.3285E-05	1.3275E-05	1.3283E-05	1.3281E-05	1.3277E-05
Ni	1.9265E-05	1.9271E-05	1.9256E-05	1.9268E-05	1.9266E-05	1.9259E-05
Sb	3.5296E-06	3.5307E-06	3.5279E-06	3.5301E-06	3.5297E-06	3.5285E-06
Ti	2.3609E-07	2.3616E-07	2.3598E-07	2.3612E-07	2.3609E-07	2.3602E-07
O	1.4137E-05	1.4141E-05	1.4130E-05	1.4139E-05	1.4137E-05	1.4132E-05
N	2.4215E-05	2.4223E-05	2.4204E-05	2.4219E-05	2.4216E-05	2.4208E-05
Total	4.8167E-02	4.8182E-02	4.8145E-02	4.8174E-02	4.8168E-02	4.8153E-02
Density (g/cm^3)	18.7785	18.7844	18.7696	18.7812	18.7790	18.7730

Table 40 (cont'd.). HEU Atomic Densities (atoms/barns-cm) for the Detailed Benchmark Model.

Part Number	2762	2763	2767	2773	2775	2778
^{234}U	4.6869E-04	4.6147E-04	4.6289E-04	4.6726E-04	4.7378E-04	4.6197E-04
^{235}U	4.4807E-02	4.4600E-02	4.4718E-02	4.4689E-02	4.4841E-02	4.4639E-02
^{236}U	1.2935E-04	1.1915E-04	1.2430E-04	1.1463E-04	1.1504E-04	1.0974E-04
^{238}U	2.6745E-03	2.6513E-03	2.6737E-03	2.6616E-03	2.6760E-03	2.6731E-03
Ag	8.3910E-07	8.3477E-07	8.3733E-07	8.3653E-07	8.3955E-07	8.3567E-07
Ba	4.1193E-10	4.0981E-10	4.1107E-10	4.1067E-10	4.1216E-10	4.1025E-10
Bi	8.8790E-06	8.8332E-06	8.8603E-06	8.8517E-06	8.8838E-06	8.8427E-06
C	4.7103E-06	4.6860E-06	4.7004E-06	4.6959E-06	4.7129E-06	4.6911E-06
Ca	2.8229E-08	2.8084E-08	2.8170E-08	2.8142E-08	2.8244E-08	2.8114E-08
Cd	5.0326E-08	5.0066E-08	5.0220E-08	5.0171E-08	5.0353E-08	5.0120E-08
Co	9.5997E-07	9.5502E-07	9.5795E-07	9.5703E-07	9.6049E-07	9.5605E-07
Cr	1.5232E-06	1.5153E-06	1.5200E-06	1.5185E-06	1.5240E-06	1.5170E-06
Cu	4.4509E-06	4.4280E-06	4.4415E-06	4.4373E-06	4.4533E-06	4.4327E-06
K	2.8937E-08	2.8787E-08	2.8876E-08	2.8848E-08	2.8952E-08	2.8818E-08
Li	1.6303E-06	1.6219E-06	1.6269E-06	1.6253E-06	1.6312E-06	1.6236E-06
Mg	1.3962E-06	1.3890E-06	1.3933E-06	1.3920E-06	1.3970E-06	1.3905E-06
Mn	1.1532E-05	1.1473E-05	1.1508E-05	1.1497E-05	1.1539E-05	1.1485E-05
Mo	5.8965E-08	5.8661E-08	5.8841E-08	5.8784E-08	5.8997E-08	5.8724E-08
Na	1.3288E-05	1.3219E-05	1.3260E-05	1.3247E-05	1.3295E-05	1.3233E-05
Ni	1.9275E-05	1.9175E-05	1.9234E-05	1.9216E-05	1.9285E-05	1.9196E-05
Sb	3.5313E-06	3.5131E-06	3.5239E-06	3.5205E-06	3.5332E-06	3.5169E-06
Ti	2.3620E-07	2.3499E-07	2.3571E-07	2.3548E-07	2.3633E-07	2.3524E-07
O	1.4144E-05	1.4071E-05	1.4114E-05	1.4100E-05	1.4151E-05	1.4086E-05
N	2.4227E-05	2.4103E-05	2.4176E-05	2.4153E-05	2.4241E-05	2.4129E-05
Total	4.8191E-02	4.7943E-02	4.8089E-02	4.8043E-02	4.8217E-02	4.7994E-02
Density (g/cm^3)	18.7878	18.6910	18.7483	18.7302	18.7980	18.7111

Table 40 (cont'd.). HEU Atomic Densities (atoms/barns-cm) for the Detailed Benchmark Model.

Part Number	2779	2780	2781	2782	2784	2785
^{234}U	4.6289E-04	4.7200E-04	4.7355E-04	4.6445E-04	4.7962E-04	4.7235E-04
^{235}U	4.4728E-02	4.4663E-02	4.4838E-02	4.4898E-02	4.4916E-02	4.4701E-02
^{236}U	1.0996E-04	1.1938E-04	1.1978E-04	1.1033E-04	1.2489E-04	1.1469E-04
^{238}U	2.6784E-03	2.6706E-03	2.6509E-03	2.6684E-03	2.6864E-03	2.6726E-03
Ag	8.3733E-07	8.3639E-07	8.3914E-07	8.4015E-07	8.4132E-07	8.3701E-07
Ba	4.1107E-10	4.1060E-10	4.1195E-10	4.1245E-10	4.1302E-10	4.1091E-10
Bi	8.8603E-06	8.8503E-06	8.8794E-06	8.8901E-06	8.9025E-06	8.8568E-06
C	4.7004E-06	4.6951E-06	4.7105E-06	4.7163E-06	4.7228E-06	4.6986E-06
Ca	2.8170E-08	2.8138E-08	2.8230E-08	2.8265E-08	2.8304E-08	2.8159E-08
Cd	5.0220E-08	5.0163E-08	5.0328E-08	5.0389E-08	5.0459E-08	5.0200E-08
Co	9.5795E-07	9.5687E-07	9.6001E-07	9.6118E-07	9.6251E-07	9.5758E-07
Cr	1.5200E-06	1.5183E-06	1.5232E-06	1.5251E-06	1.5272E-06	1.5194E-06
Cu	4.4415E-06	4.4365E-06	4.4511E-06	4.4565E-06	4.4627E-06	4.4398E-06
K	2.8876E-08	2.8843E-08	2.8938E-08	2.8973E-08	2.9013E-08	2.8864E-08
Li	1.6269E-06	1.6250E-06	1.6304E-06	1.6323E-06	1.6346E-06	1.6262E-06
Mg	1.3933E-06	1.3917E-06	1.3963E-06	1.3980E-06	1.3999E-06	1.3928E-06
Mn	1.1508E-05	1.1495E-05	1.1533E-05	1.1547E-05	1.1563E-05	1.1504E-05
Mo	5.8841E-08	5.8774E-08	5.8968E-08	5.9039E-08	5.9121E-08	5.8818E-08
Na	1.3260E-05	1.3245E-05	1.3288E-05	1.3304E-05	1.3323E-05	1.3255E-05
Ni	1.9234E-05	1.9212E-05	1.9275E-05	1.9299E-05	1.9326E-05	1.9227E-05
Sb	3.5239E-06	3.5199E-06	3.5315E-06	3.5358E-06	3.5407E-06	3.5225E-06
Ti	2.3571E-07	2.3544E-07	2.3621E-07	2.3650E-07	2.3683E-07	2.3562E-07
O	1.4114E-05	1.4098E-05	1.4144E-05	1.4161E-05	1.4181E-05	1.4108E-05
N	2.4176E-05	2.4149E-05	2.4228E-05	2.4258E-05	2.4291E-05	2.4167E-05
Total	4.8090E-02	4.8035E-02	4.8193E-02	4.8252E-02	4.8318E-02	4.8071E-02
Density (g/cm^3)	18.7483	18.7271	18.7886	18.8114	18.8375	18.7410

Table 40 (cont'd.). HEU Atomic Densities (atoms/barns-cm) for the Detailed Benchmark Model.

Part Number	2786	2787	2829	2848	2885	2886
^{234}U	4.7669E-04	4.7220E-04	4.7734E-04	4.7656E-04	4.7727E-04	4.7684E-04
^{235}U	4.5112E-02	4.4687E-02	4.4697E-02	4.4663E-02	4.4696E-02	4.4656E-02
^{236}U	1.1575E-04	1.1466E-04	1.1474E-04	1.1455E-04	1.2428E-04	1.2417E-04
^{238}U	2.6972E-03	2.6718E-03	2.6878E-03	2.6456E-03	2.6732E-03	2.6708E-03
Ag	8.4470E-07	8.3674E-07	8.3731E-07	8.3595E-07	8.3719E-07	8.3644E-07
Ba	4.1469E-10	4.1078E-10	4.1105E-10	4.1039E-10	4.1100E-10	4.1063E-10
Bi	8.9383E-06	8.8540E-06	8.8600E-06	8.8457E-06	8.8587E-06	8.8508E-06
C	4.7418E-06	4.6971E-06	4.7003E-06	4.6926E-06	4.6996E-06	4.6954E-06
Ca	2.8418E-08	2.8150E-08	2.8169E-08	2.8123E-08	2.8165E-08	2.8139E-08
Cd	5.0662E-08	5.0184E-08	5.0218E-08	5.0137E-08	5.0211E-08	5.0166E-08
Co	9.6638E-07	9.5727E-07	9.5792E-07	9.5637E-07	9.5778E-07	9.5692E-07
Cr	1.5334E-06	1.5189E-06	1.5199E-06	1.5175E-06	1.5197E-06	1.5183E-06
Cu	4.4806E-06	4.4384E-06	4.4414E-06	4.4342E-06	4.4408E-06	4.4368E-06
K	2.9130E-08	2.8855E-08	2.8875E-08	2.8828E-08	2.8871E-08	2.8845E-08
Li	1.6412E-06	1.6257E-06	1.6268E-06	1.6242E-06	1.6266E-06	1.6251E-06
Mg	1.4056E-06	1.3923E-06	1.3933E-06	1.3910E-06	1.3931E-06	1.3918E-06
Mn	1.1610E-05	1.1500E-05	1.1508E-05	1.1489E-05	1.1506E-05	1.1496E-05
Mo	5.9359E-08	5.8799E-08	5.8839E-08	5.8744E-08	5.8831E-08	5.8778E-08
Na	1.3376E-05	1.3250E-05	1.3259E-05	1.3238E-05	1.3257E-05	1.3246E-05
Ni	1.9403E-05	1.9220E-05	1.9233E-05	1.9202E-05	1.9231E-05	1.9213E-05
Sb	3.5549E-06	3.5214E-06	3.5238E-06	3.5181E-06	3.5233E-06	3.5201E-06
Ti	2.3778E-07	2.3554E-07	2.3570E-07	2.3532E-07	2.3567E-07	2.3546E-07
O	1.4238E-05	1.4104E-05	1.4113E-05	1.4091E-05	1.4111E-05	1.4099E-05
N	2.4389E-05	2.4159E-05	2.4176E-05	2.4136E-05	2.4172E-05	2.4151E-05
Total	4.8513E-02	4.8056E-02	4.8088E-02	4.8010E-02	4.8081E-02	4.8038E-02
Density (g/cm^3)	18.9133	18.7350	18.7477	18.7173	18.7450	18.7282

3.3.1.2 Graphite

The composition of graphite is given in Table 41.

Table 41. Graphite Atomic Densities (atoms/barns-cm) for the Detailed Benchmark Models.

Part Number	1	3	7	15	27	29
C	8.2631E-02	8.4538E-02	8.5174E-02	8.4618E-02	8.5703E-02	8.4729E-02
Ag	4.6052E-09	4.7115E-09	4.7469E-09	4.7159E-09	4.7764E-09	4.7221E-09
Al	3.1301E-06	3.2023E-06	3.2264E-06	3.2053E-06	3.2465E-06	3.2096E-06
B	7.0769E-07	7.2402E-07	7.2947E-07	7.2470E-07	7.3400E-07	7.2566E-07
Ba	2.1704E-07	2.2205E-07	2.2372E-07	2.2225E-07	2.2511E-07	2.2255E-07
Be	5.5135E-08	5.6407E-08	5.6831E-08	5.6460E-08	5.7185E-08	5.6534E-08
Bi	7.1313E-09	7.2958E-09	7.3507E-09	7.3027E-09	7.3964E-09	7.3123E-09
Ca	1.2394E-05	1.2680E-05	1.2776E-05	1.2692E-05	1.2855E-05	1.2709E-05
Cd	4.4192E-08	4.5212E-08	4.5552E-08	4.5254E-08	4.5835E-08	4.5314E-08
Co	8.4297E-08	8.6242E-08	8.6891E-08	8.6324E-08	8.7431E-08	8.6437E-08
Cr	9.5539E-08	9.7743E-08	9.8478E-08	9.7835E-08	9.9091E-08	9.7964E-08
Cu	3.6427E-08	3.7267E-08	3.7548E-08	3.7302E-08	3.7781E-08	3.7352E-08
Fe	5.0343E-06	5.1505E-06	5.1892E-06	5.1554E-06	5.2215E-06	5.1622E-06
K	2.5410E-07	2.5996E-07	2.6192E-07	2.6021E-07	2.6355E-07	2.6055E-07
Li	7.1580E-08	7.3232E-08	7.3782E-08	7.3300E-08	7.4241E-08	7.3397E-08
Mg	1.7042E-06	1.7436E-06	1.7567E-06	1.7452E-06	1.7676E-06	1.7475E-06
Mn	1.8084E-08	1.8501E-08	1.8640E-08	1.8519E-08	1.8756E-08	1.8543E-08
Mo	5.1779E-09	5.2973E-09	5.3372E-09	5.3023E-09	5.3704E-09	5.3093E-09
Na	4.3216E-07	4.4213E-07	4.4545E-07	4.4254E-07	4.4822E-07	4.4313E-07
Nb	5.3467E-08	5.4701E-08	5.5112E-08	5.4752E-08	5.5455E-08	5.4825E-08
Ni	2.5388E-08	2.5974E-08	2.6169E-08	2.5999E-08	2.6332E-08	2.6033E-08
Pb	1.4386E-08	1.4718E-08	1.4828E-08	1.4732E-08	1.4921E-08	1.4751E-08
Rb	5.8121E-08	5.9463E-08	5.9910E-08	5.9518E-08	6.0282E-08	5.9597E-08
Sb	4.0802E-08	4.1743E-08	4.2057E-08	4.1783E-08	4.2319E-08	4.1838E-08
Si	9.0899E-06	9.2997E-06	9.3696E-06	9.3084E-06	9.4279E-06	9.3207E-06
Sn	1.2556E-08	1.2846E-08	1.2942E-08	1.2858E-08	1.3023E-08	1.2875E-08
Ta	1.6212E-07	1.6586E-07	1.6711E-07	1.6602E-07	1.6815E-07	1.6624E-07
Ti	2.4890E-07	2.5464E-07	2.5656E-07	2.5488E-07	2.5815E-07	2.5522E-07
V	7.8015E-07	7.9816E-07	8.0416E-07	7.9891E-07	8.0916E-07	7.9996E-07
W	8.1060E-08	8.2931E-08	8.3554E-08	8.3009E-08	8.4074E-08	8.3118E-08
Zn	3.7996E-07	3.8873E-07	3.9165E-07	3.8910E-07	3.9409E-07	3.8961E-07
Zr	5.4458E-08	5.5714E-08	5.6133E-08	5.5767E-08	5.6482E-08	5.5840E-08
Total	8.2657E-2	8.4565E-02	8.5201E-02	8.4644E-02	8.5731E-02	8.4756E-02
Density (g/cm^3)	1.6498	1.6879	1.7006	1.6895	1.7111	1.6917

Table 41 (cont'd.). Graphite Atomic Densities (atoms/barns-cm) for the Detailed Benchmark Model.

Part Number	36	42	44	61	70
C	8.4657E-02	8.5706E-02	8.4897E-02	8.5546E-02	8.5269E-02
Ag	4.7181E-09	4.7766E-09	4.7315E-09	4.7677E-09	4.7522E-09
Al	3.2068E-06	3.2466E-06	3.2159E-06	3.2405E-06	3.2300E-06
B	7.2504E-07	7.3403E-07	7.2710E-07	7.3266E-07	7.3028E-07
Ba	2.2236E-07	2.2511E-07	2.2299E-07	2.2469E-07	2.2396E-07
Be	5.6486E-08	5.7186E-08	5.6647E-08	5.7080E-08	5.6894E-08
Bi	7.3061E-09	7.3966E-09	7.3268E-09	7.3828E-09	7.3589E-09
Ca	1.2698E-05	1.2856E-05	1.2734E-05	1.2832E-05	1.2790E-05
Cd	4.5276E-08	4.5837E-08	4.5404E-08	4.5751E-08	4.5603E-08
Co	8.6364E-08	8.7434E-08	8.6609E-08	8.7271E-08	8.6988E-08
Cr	9.7881E-08	9.9094E-08	9.8159E-08	9.8909E-08	9.8588E-08
Cu	3.7320E-08	3.7782E-08	3.7426E-08	3.7712E-08	3.7589E-08
Fe	5.1578E-06	5.2217E-06	5.1724E-06	5.2119E-06	5.1950E-06
K	2.6033E-07	2.6356E-07	2.6107E-07	2.6306E-07	2.6221E-07
Li	7.3335E-08	7.4244E-08	7.3543E-08	7.4105E-08	7.3864E-08
Mg	1.7460E-06	1.7677E-06	1.7510E-06	1.7644E-06	1.7586E-06
Mn	1.8527E-08	1.8757E-08	1.8580E-08	1.8722E-08	1.8661E-08
Mo	5.3048E-09	5.3705E-09	5.3199E-09	5.3605E-09	5.3431E-09
Na	4.4275E-07	4.4824E-07	4.4401E-07	4.4740E-07	4.4595E-07
Nb	5.4778E-08	5.5457E-08	5.4933E-08	5.5353E-08	5.5174E-08
Ni	2.6011E-08	2.6333E-08	2.6084E-08	2.6284E-08	2.6199E-08
Pb	1.4738E-08	1.4921E-08	1.4780E-08	1.4893E-08	1.4845E-08
Rb	5.9546E-08	6.0284E-08	5.9715E-08	6.0172E-08	5.9976E-08
Sb	4.1802E-08	4.2320E-08	4.1921E-08	4.2241E-08	4.2104E-08
Si	9.3128E-06	9.4282E-06	9.3392E-06	9.4106E-06	9.3800E-06
Sn	1.2864E-08	1.3023E-08	1.2900E-08	1.2999E-08	1.2957E-08
Ta	1.6610E-07	1.6815E-07	1.6657E-07	1.6784E-07	1.6729E-07
Ti	2.5500E-07	2.5816E-07	2.5573E-07	2.5768E-07	2.5684E-07
V	7.9928E-07	8.0919E-07	8.0155E-07	8.0768E-07	8.0505E-07
W	8.3048E-08	8.4077E-08	8.3283E-08	8.3920E-08	8.3647E-08
Zn	3.8928E-07	3.9410E-07	3.9038E-07	3.9337E-07	3.9209E-07
Zr	5.5793E-08	5.6484E-08	5.5951E-08	5.6379E-08	5.6196E-08
Total	8.4684E-02	8.5734E-02	8.4924E-02	8.5573E-02	8.5296E-02
Density (g/cm^3)	1.6903	1.7112	1.6951	1.7080	1.7025

3.3.2 Simple Benchmark Material Data

Material densities were obtained by taking the total mass of the uranium and graphite components divided by the total volume they occupy in the simple benchmark model.

The density of the uranium annulus in the simple case is obtained by dividing the total uranium mass by the volume of the modeled annulus; the density of uranium is multiplied by the factor 0.999509 to account for the removal of impurities. The isotopic content of the simple cases is obtained by taking the weight-averaged isotopic content of the individual HEU parts.

The same approach is used for calculating the density of the graphite. The density of graphite is multiplied by the factor 0.998606 to account for the removal of impurities, but the element of carbon is 100%.

3.3.2.1 Uranium

The densities and isotopic mass weight of uranium annulus are list in Table 42. The atom densities of the uranium annulus are listed in Table 43. The masses are deducted by 0.999509 to account for the impurities.

Table 42. Density, Mass and Isotopic Contents of Uranium for Simple Benchmark Models.

Case	Mass (g)	Density (g/cc)	Isotopic Content (wt.%)				
			U-234	U-235	U-236	U-238	Total
1	185200.0	18.6839	0.972586	93.142461	0.240284	5.644669	100
2	173547.7	18.6629	0.971911	93.142629	0.244134	5.641327	100
3	151866.4	18.6825	0.967779	93.154941	0.236051	5.641229	100

Table 43. Atomic Density of Uranium for Simple Benchmark Models (atoms/barns-cm).

Case	U-234	U-235	U-236	U-238	Total
1	4.6758E-04	4.4588E-02	1.1454E-04	2.6680E-03	4.7838E-02
2	4.6672E-04	4.4538E-02	1.1624E-04	2.6634E-03	4.7784E-02
3	4.6523E-04	4.4590E-02	1.1251E-04	2.6662E-03	4.7834E-02

3.3.2.2 Graphite

The material data for graphite cylinder are listed in Table 44. The masses are deducted by 0.998606 to account for the impurities.

Table 44. Material Data of Graphite for Simple Benchmark Models.

Case	Mass (g)	Content of C (%)	Mass Density (g/cc)	Atomic Density of C (atoms/barns-cm)
1	9400.9	100	1.6861	8.4543E-02
2	4408.8	100	1.7029	8.5390E-02
3	5608.2	100	1.6896	8.4720E-02

3.4 Temperature Data

The temperature for both benchmark models is 293.6 K.

3.5 Experimental and Benchmark-Model k_{eff}

The experimental k_{eff} for Cases 1, 2 and 3 were given in Table 5, and the 1σ uncertainty for the three experiments was summarized in Section 2.4. The measured corrections and simplification biases, with their associated bias uncertainties, are discussed and summarized in Section 3.1.1 and Section 3.1.2 respectively and applied to the benchmark models. The uncertainty in the benchmark k_{eff} value is obtained by summing the quadrature of the total experimental uncertainty (Table 31, Table 32 and Table 33) and the total bias uncertainty (Table 34, Table 35).

3.5.1 Detailed Benchmark Model

The benchmark k_{eff} is provided in Table 45 for the detailed benchmark model.

Table 45. Experimental and Benchmark Eigenvalues, Biases, and Uncertainties for the Detailed Benchmark Models.

Case	HEU Nominal Diameter (inch)	Experimental[(a)]			Bias			Benchmark Experiment		
		k_{eff}	±	σ	Δk	±	σ	k_{eff}	±	σ
1	15-9	0.99986	±	0.00054	-0.00179	±	0.00006	0.9981	±	0.0006
2	15-7	0.99901	±	0.00055	-0.00189	±	0.00006	0.9971	±	0.0006
3	13-7	1.00123	±	0.00054	-0.00114	±	0.00006	1.0001	±	0.0006

(a) Since the correction for the support structure is included in the bias, these values are obtained from the third column of Table **6** by using a β_{eff} of 0.00660.

3.5.2 Simple Benchmark Model

The benchmark k_{eff} is provided in Table 46 for simple benchmark models.

Table 46. Experimental and Benchmark Eigenvalues, Biases, and Uncertainties for the Simple Benchmark Models.

Case	HEU Nominal Diameter (inch)	Experimental[(a)]			Bias			Benchmark Experiment		
		k_{eff}	±	σ	Δk	±	σ	k_{eff}	±	σ
1	15-9	0.99986	±	0.00054	-0.00133	±	0.00013	0.9985	±	0.0006
2	15-7	0.99901	±	0.00055	-0.00183	±	0.00013	0.9972	±	0.0006
3	13-7	1.00123	±	0.00054	-0.00107	±	0.00013	1.0002	±	0.0006

(a) Since the correction for the support structure is included in the bias, these values are obtained from the third column of Table **6**, by using a β_{eff} of 0.00660.

4.0 RESULTS OF SAMPLE CALCULATIONS

Results were calculated using MCNP6-1.0 with ENDF/B-VII.1, ENDF/B-VII.0, JEFF-3.1, and JENDL-3.3 neutron cross section libraries, and the input decks and specifications (with ENDF/B-VII.1 cross sections) for both detailed and simple model are provided in Appendix A. A comparison of the neutron spectral data between the detailed and simple models is provided in Appendix B. The cross section data for ^{16}O is used for ^{18}O in the input decks. Calculations were performed with 2150 generations with 100,000 neutrons per generation. The k_{eff} estimates did not include the first 150 generations. Isotopic abundances were taken from the 17th edition of the Chart of the Nuclides.[a]

Detailed Benchmark Model

The calculated results for the detailed benchmark model are reported in Table 47, Table 48 and Table 49 for the three cases, respectively. There are small differences between the calculated results for the different libraries with most libraries calculating the eigenvalue slightly smaller than the benchmark eigenvalue, but all results within ±0.5%.

Table 47. Comparison of Detailed Benchmark Model Experimental and Calculated Eigenvalues (Case 1).

Analysis Code	Neutron Cross Section Library	Calculated k_{eff} ± σ	Benchmark Experiment k_{eff} ± σ	$\frac{C-E}{E}$%
MCNP6-1.0	ENDF/B-VII.1	0.99723 ± 0.00004	0.9981 ± 0.0006	-0.08 ± 0.06
	ENDF/B-VII.0	0.99735 ± 0.00004		-0.07 ± 0.06
	JEFF-3.1[(a)]	0.99408 ± 0.00004		-0.40 ± 0.06
	JENDL-3.3[(a)]	1.00077 ± 0.00004		0.27 ± 0.06

(a) Results provided by John D. Bess from Idaho National Laboratory.

Table 48. Comparison of Detailed Benchmark Model Experimental and Calculated Eigenvalues (Case 2).

Analysis Code	Neutron Cross Section Library	Calculated k_{eff} ± σ	Benchmark Experiment k_{eff} ± σ	$\frac{C-E}{E}$%
MCNP6-1.0	ENDF/B-VII.1	0.99628 ± 0.00004	0.9971 ± 0.0006	-0.08 ± 0.06
	ENDF/B-VII.0	0.99640 ± 0.00004		-0.07 ± 0.06
	JEFF-3.1[(a)]	0.99312 ± 0.00004		-0.40 ± 0.06
	JENDL-3.3[(a)]	1.00005 ± 0.00004		0.29 ± 0.06

(a) Results provided by John D. Bess from Idaho National Laboratory.

[a] E. M. Baum, M. C. Ernesti, H. D. Knox, T. R. Miller, and A. M. Watson, *Nuclides and Isotopes, Chart of the Nuclides: 17th Edition*, Knolls Atomic Power Laboratory (2009).

Table 49. Comparison of Detailed Benchmark Model Experimental and Calculated Eigenvalues (Case 3).

Analysis Code	Neutron Cross Section Library	Calculated k_{eff} ± σ	Benchmark Experiment k_{eff} ± σ	$\frac{C-E}{E}$%
MCNP6-1.0	ENDF/B-VII.1	0.99886 ± 0.00004	1.0001 ± 0.0006	-0.12 ± 0.06
	ENDF/B-VII.0	0.99893 ± 0.00004		-0.12 ± 0.06
	JEFF-3.1[(a)]	0.99568 ± 0.00004		-0.44 ± 0.06
	JENDL-3.3[(a)]	1.00218 ± 0.00004		0.21 ± 0.06

(a) Results provided by John D. Bess from Idaho National Laboratory.

Simple Benchmark Model

The calculated results for the simple benchmark model are reported in Table 50, Table 51 and Table 52 respectively. Comments discussed in the previous section regarding calculations of the detailed benchmark model also apply to calculations of the simple benchmark model. The differences between the calculated results and the benchmark experiments are also within ±0.5%.

Table 50. Comparison of Simple Benchmark Model Experimental and Calculated Eigenvalues (Case 1).

Analysis Code	Neutron Cross Section Library	Calculated k_{eff} ± σ	Benchmark Experiment k_{eff} ± σ	$\frac{C-E}{E}$ %
MCNP6-1.0	ENDF/B-VII.1	0.99784 ± 0.00004	0.9985 ± 0.0006	-0.07 ± 0.06
	ENDF/B-VII.0	0.99775 ± 0.00004		-0.08 ± 0.06
	JEFF-3.1[(a)]	0.99459 ± 0.00004		-0.39 ± 0.06
	JENDL-3.3[(a)]	1.00125 ± 0.00004		0.27 ± 0.06

(a) Results provided by John D. Bess from Idaho National Laboratory.

Table 51. Comparison of Simple Benchmark Model Experimental and Calculated Eigenvalues (Case 2).

Analysis Code	Neutron Cross Section Library	Calculated k_{eff} ± σ	Benchmark Experiment k_{eff} ± σ	$\frac{C-E}{E}$ %
MCNP6-1.0	ENDF/B-VII.1	0.99619 ± 0.00004	0.9972 ± 0.0006	-0.10 ± 0.06
	ENDF/B-VII.0	0.99626 ± 0.00004		-0.09 ± 0.06
	JEFF-3.1[(a)]	0.99303 ± 0.00004		-0.42 ± 0.06
	JENDL-3.3[(a)]	1.00001 ± 0.00004		0.28 ± 0.06

(a) Results provided by John D. Bess from Idaho National Laboratory.

Table 52. Comparison of Simple Benchmark Model Experimental and Calculated Eigenvalues (Case 3).

Analysis Code	Neutron Cross Section Library	Calculated k_{eff} ± σ	Benchmark Experiment k_{eff} ± σ	$\frac{C-E}{E}$ %
MCNP6-1.0	ENDF/B-VII.1	0.99911 ± 0.00004	1.0002 ± 0.0006	-0.10 ± 0.06
	ENDF/B-VII.0	0.99922 ± 0.00004		-0.09 ± 0.06
	JEFF-3.1[(a)]	0.99589 ± 0.00004		-0.43 ± 0.06
	JENDL-3.3[(a)]	1.00244 ± 0.00004		0.23 ± 0.06

(a) Results provided by John D. Bess from Idaho National Laboratory.

5.0 REFERENCES

1. J. T. Mihalczo, "Graphite and Polyethylene Reflected Uranium Metal Cylinders and Annuli," Union Carbide Corporation, Nuclear Division Report Y-DR-81 (April, 1972).

APPENDIX A: TYPICAL INPUT LISTINGS

Models were created using Monte Carlo n-Particle, version 6.1.0, (MCNP6-1.0) and ENDF/B-VII.1 neutron cross section libraries. Isotopic abundances for all elements except uranium were taken from "Nuclides and Isotopes: Chart of the Nuclides," Sixteenth Edition, KAPL, 2002. MCNP5.1.60 models were run for 2150 active cycles (150 inactive cycles) with 100,000 histories per cycle.

A.1 MCNP Input Listings

Experiment 1 Configuration (Detailed Model), Table 47.

```
ORALLOY (93.15 235U) METAL ANNULI WHITH INTERNAL GRAPHITE CYLINDER
c Case "1", HEU Annuli 15-9 inches.
c
c LIU XIAOBO - Idaho National Laboratory & INPC
c Last Updated: March"20," 2015
c
c
c Cell Cards ****************************************************************
c ------ Graphite "Center-9""" ------
1061 1061 8.5560E-02 -1061 imp:n=1 $ Top/Upper
1070 1070 8.5283E-02 -1070 imp:n=1
1029 1029 8.4743E-02 -1029 imp:n=1
1042 1042 8.5721E-02 -1042 imp:n=1 $ Bottom/Upper
1044 1044 8.4911E-02 -1044 imp:n=1 $ Only one layer/Lower
c
c ------ "9""-11""" HEU Annulus ------
2778 2778 4.7994E-02 9778 -2778 imp:n=1 $ Top/Upper
2767 2767 4.8089E-02 9767 -2767 imp:n=1
2748 2748 4.8157E-02 9748 -2748 imp:n=1
2776 2776 4.8103E-02 9776 -2776 imp:n=1 $ Bottom/Upper
2742 2742 4.8161E-02 9742 -2742 imp:n=1 $ Top/Lower
2746 2746 4.8076E-02 9746 -2746 imp:n=1
2747 2747 4.8081E-02 9747 -2747 imp:n=1 $ Bottom/Lower
c
c ------ "11""-13""" HEU Annulus ------
2782 2782 4.8252E-02 9782 -2782 imp:n=1 $ Top/Upper
2781 2781 4.8193E-02 9781 -2781 imp:n=1
2749 2749 4.8151E-02 9749 -2749 imp:n=1
2755 2755 4.8167E-02 9755 -2755 imp:n=1
2753 2753 4.8039E-02 9753 -2753 imp:n=1
2752 2752 4.8115E-02 9752 -2752 imp:n=1
2757 2757 4.8145E-02 9757 -2757 imp:n=1 $ Bottom/Upper
2751 2751 4.8147E-02 9751 -2751 imp:n=1 $ Top/Lower
2754 2754 4.8244E-02 9754 -2754 imp:n=1
2756 2756 4.8182E-02 9756 -2756 imp:n=1 $ Bottom/Lower
c
c ------ "13""-15""" HEU Annulus ------
2886 2886 4.8038E-02 9886 -2886 imp:n=1 $ Top/Upper
2885 2885 4.8081E-02 9885 -2885 imp:n=1
2784 2784 4.8318E-02 9784 -2784 imp:n=1
2786 2786 4.8513E-02 9786 -2786 imp:n=1
2787 2787 4.8056E-02 9787 -2787 imp:n=1
2760 2760 4.8168E-02 9760 -2760 imp:n=1
2739 2739 4.8348E-02 9739 -2739 imp:n=1 $ Bottom/Upper
2761 2761 4.8153E-02 9761 -2761 imp:n=1 $ Top/Lower
2785 2785 4.8071E-02 9785 -2785 imp:n=1
2848 2848 4.8010E-02 9848 -2848 imp:n=1
2735 2735 4.8004E-02 9735 -2735 imp:n=1 $ Bottom/Lower
c
c ------ Void Spaces------
9990 0 #1061 #1070 #1029 #1042 #1044
      #2778 #2767 #2748 #2776 #2742 #2746 #2747
      #2782 #2781 #2749 #2755 #2753 #2752 #2757 #2751 #2754 #2756
      #2886 #2885 #2784 #2786 #2787 #2760 #2739 #2761 #2785 #2848 #2735
```

```
      -9999 imp:n=1 $ Gaps
9991 0 9999 imp:n=0 $ The Great Void

c Surface Cards ************************************************************
c ------ Graphite "Center-9""" ------
1061  rcc 0 0 7.791450 0 0 0.635000 11.428095 $ Top/Upper 8.426450
1070  rcc 0 0 6.358467 0 0 1.428750 11.428095
1029  rcc 0 0 3.814233 0 0 2.540000 11.428095
1042  rcc 0 0 0.000000 0 0 3.810000 11.428095 $ Bottom/Upper
1044 10 rcc 0 0 0.000000 0 0 5.080000 11.428095 $ One/Lower 5.080000
c
c ------ "9""-11""" HEU Annulus ------
c --------- Outer Surfaces ---------
2778  rcc 0 0 7.781290 0 0 0.637540 13.965555 $ Top/Upper 8.418830
2767  rcc 0 0 6.353810 0 0 1.427480 13.964920
2748  rcc 0 0 2.543810 0 0 3.810000 13.966825
2776  rcc 0 0 0.000000 0 0 2.543810 13.965555 $ Bottom/Upper
2742 10 rcc 0 0 4.137406 0 0 0.952754 13.965936 $ Top/Lower 5.090160
2746 10 rcc 0 0 3.810191 0 0 0.326771 13.965555
2747 10 rcc 0 0 0.000000 0 0 3.809746 13.965936 $ Bottom/Lower
c --------- Inner Surfaces ---------
9778 cz 11.432540
9767 cz 11.431270
9748 cz 11.433175
9776 cz 11.431905
9742 cz 11.431905
9746 cz 11.432223
9747 cz 11.432540
c
c ------ "11""-13""" HEU Annulus ------
c --------- Outer Surfaces ---------
2782  rcc 0 0 7.803388 0 0 0.639445 16.504412 $ Top/Upper 8.442833
2781  rcc 0 0 7.485380 0 0 0.318008 16.505873
2749  rcc 0 0 6.526784 0 0 0.958596 16.504285
2755  rcc 0 0 5.095494 0 0 1.431290 16.504920
2753  rcc 0 0 3.822192 0 0 1.273302 16.505873
2752  rcc 0 0 2.543937 0 0 1.278255 16.504285
2757  rcc 0 0 0.000000 0 0 2.543937 16.504920 $ Bottom/Upper
2751 10 rcc 0 0 3.819652 0 0 1.279017 16.504666 $ Top/Lower 5.098669
2754 10 rcc 0 0 2.540508 0 0 1.279144 16.504031
2756 10 rcc 0 0 0.000000 0 0 2.540508 16.505809 $ Bottom/Lower
c --------- Inner Surfaces ---------
9782 cz 13.974445
9781 cz 13.973175
9749 cz 13.973810
9755 cz 13.973810
9753 cz 13.973810
9752 cz 13.973175
9757 cz 13.973175
9751 cz 13.971905
9754 cz 13.975080
9756 cz 13.974572
c
c ------ "13""-15""" HEU Annulus ------
c --------- Outer Surfaces ---------
2886  rcc 0 0 7.957947 0 0 0.638683 19.045682 $ Top/Upper 8.596630
2885  rcc 0 0 7.308025 0 0 0.644271 19.045301
2784  rcc 0 0 6.356223 0 0 0.946150 19.043015
2786  rcc 0 0 5.094161 0 0 1.256411 19.043650
2787  rcc 0 0 3.807333 0 0 1.281176 19.043650
2760  rcc 0 0 2.531682 0 0 1.270000 19.043650
2739  rcc 0 0 0.000000 0 0 2.526030 19.044285 $ Bottom/Upper
2761 10 rcc 0 0 4.775381 0 0 0.321310 19.043333 $ Top/Lower 5.096691
2785 10 rcc 0 0 3.819434 0 0 0.951738 19.044603
2848 10 rcc 0 0 2.540399 0 0 1.274826 19.045428
2735 10 rcc 0 0 0.000000 0 0 2.536190 19.041745 $ Bottom/Lower
c --------- Inner Surfaces ---------
9886 cz 16.513175
9885 cz 16.514064
9784 cz 16.511905
9786 cz 16.513175
9787 cz 16.511905
9760 cz 16.512540
```

```
9739 cz 16.513429
9761 cz 16.511270
9785 cz 16.513620
9848 cz 16.513937
9735 cz 16.512540
c
c ------ Problem Boundary ------
9999 rcc 0 0 -8.000000 0 0 20.000000 20.000000
c

c Data Cards ************************************************************
tr10 0 0 -5.098669
c --- Material Cards ------------------------------------------------------
c ------ Graphite "Center-9""" ------
m1061
       6000.80c 8.5524E-02
      47107.80c 2.4715E-09
      47109.80c 2.2962E-09
      13027.80c 3.2405E-06
       5010.80c 1.4580E-07
       5011.80c 5.8686E-07
      56130.80c 2.3818E-10
      56132.80c 2.2694E-10
      56134.80c 5.4309E-09
      56135.80c 1.4812E-08
      56136.80c 1.7647E-08
      56137.80c 2.5238E-08
      56138.80c 1.6110E-07
       4009.80c 5.7080E-08
      83209.80c 7.3828E-09
      20040.80c 1.2439E-05
      20042.80c 8.3020E-08
      20043.80c 1.7323E-08
      20044.80c 2.6767E-07
      20046.80c 5.1326E-10
      20048.80c 2.3995E-08
      48106.80c 5.7189E-10
      48108.80c 4.0718E-10
      48110.80c 5.7143E-09
      48111.80c 5.8561E-09
      48112.80c 1.1040E-08
      48113.80c 5.5908E-09
      48114.80c 1.3144E-08
      48116.80c 3.4268E-09
      27059.80c 8.7271E-08
      24050.80c 4.2976E-09
      24052.80c 8.2875E-08
      24053.80c 9.3973E-09
      24054.80c 2.3392E-09
      29063.80c 2.6085E-08
      29065.80c 1.1627E-08
      26054.80c 3.0464E-07
      26056.80c 4.7822E-06
      26057.80c 1.1044E-07
      26058.80c 1.4698E-08
      19039.80c 2.4533E-07
      19040.80c 3.0778E-11
      19041.80c 1.7705E-08
       3006.80c 5.6246E-09
       3007.80c 6.8480E-08
      12024.80c 1.3937E-06
      12025.80c 1.7644E-07
      12026.80c 1.9426E-07
      25055.80c 1.8722E-08
      42092.80c 7.9550E-10
      42094.80c 4.9585E-10
      42095.80c 8.5339E-10
      42096.80c 8.9413E-10
      42097.80c 5.1193E-10
      42098.80c 1.2935E-09
      42100.80c 5.1622E-10
      11023.80c 4.4740E-07
      41093.80c 5.5353E-08
```

```
      28058.80c 1.7893E-08
      28060.80c 6.8924E-09
      28061.80c 2.9961E-10
      28062.80c 9.5529E-10
      28064.80c 2.4328E-10
      82204.80c 2.0850E-10
      82206.80c 3.5893E-09
      82207.80c 3.2914E-09
      82208.80c 7.8040E-09
      37085.80c 4.3426E-08
      37087.80c 1.6746E-08
      51121.80c 2.4166E-08
      51123.80c 1.8075E-08
      14028.80c 8.6787E-06
      14029.80c 4.4089E-07
      14030.80c 2.9098E-07
      50112.80c 1.2609E-10
      50114.80c 8.5794E-11
      50115.80c 4.4197E-11
      50116.80c 1.8901E-09
      50117.80c 9.9833E-10
      50118.80c 3.1484E-09
      50119.80c 1.1166E-09
      50120.80c 4.2351E-09
      50122.80c 6.0186E-10
      50124.80c 7.5265E-10
      73180.80c 2.0141E-11
      73181.80c 1.6782E-07
      22046.80c 2.1259E-08
      22047.80c 1.9171E-08
      22048.80c 1.8996E-07
      22049.80c 1.3941E-08
      22050.80c 1.3348E-08
      23050.80c 2.0192E-09
      23051.80c 8.0566E-07
      74180.80c 1.0070E-10
      74182.80c 2.2239E-08
      74183.80c 1.2009E-08
      74184.80c 2.5713E-08
      74186.80c 2.3858E-08
      30064.80c 1.9129E-07
      30066.80c 1.0975E-07
      30067.80c 1.6128E-08
      30068.80c 7.3756E-08
      30070.80c 2.4389E-09
      40090.80c 2.9007E-08
      40091.80c 6.3257E-09
      40092.80c 9.6690E-09
      40094.80c 9.7986E-09
      40096.80c 1.5786E-09
c Total 8.5560E-02
c Total 8.5560E-02 rho 1.70800
mt1061 grph.20t
c
m1070
       6000.80c 8.5246E-02
      47107.80c 2.4635E-09
      47109.80c 2.2887E-09
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       5011.80c 5.8495E-07
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      56132.80c 2.2620E-10
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      56136.80c 1.7590E-08
      56137.80c 2.5156E-08
      56138.80c 1.6058E-07
       4009.80c 5.6894E-08
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      20042.80c 8.2750E-08
      20043.80c 1.7266E-08
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19040.80c 3.0678E-11
19041.80c 1.7647E-08
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12025.80c 1.7586E-07
12026.80c 1.9363E-07
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14029.80c 4.3946E-07
14030.80c 2.9003E-07
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50117.80c 9.9509E-10
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50120.80c 4.2214E-09
50122.80c 5.9990E-10
50124.80c 7.5020E-10
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73181.80c 1.6727E-07
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      74184.80c 2.5629E-08
      74186.80c 2.3781E-08
      30064.80c 1.9067E-07
      30066.80c 1.0939E-07
      30067.80c 1.6076E-08
      30068.80c 7.3517E-08
      30070.80c 2.4310E-09
      40090.80c 2.8913E-08
      40091.80c 6.3052E-09
      40092.80c 9.6376E-09
      40094.80c 9.7668E-09
      40096.80c 1.5735E-09
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c Total 8.5283E-02 rho 1.70246
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      56132.80c 2.2477E-10
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      56138.80c 1.5956E-07
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      83209.80c 7.3123E-09
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      20042.80c 8.2227E-08
      20043.80c 1.7157E-08
      20044.80c 2.6511E-07
      20046.80c 5.0836E-10
      20048.80c 2.3766E-08
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      48108.80c 4.0330E-10
      48110.80c 5.6597E-09
      48111.80c 5.8002E-09
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      48116.80c 3.3940E-09
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      24050.80c 4.2566E-09
      24052.80c 8.2083E-08
      24053.80c 9.3076E-09
      24054.80c 2.3169E-09
      29063.80c 2.5836E-08
      29065.80c 1.1515E-08
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      26056.80c 4.7365E-06
      26057.80c 1.0939E-07
      26058.80c 1.4557E-08
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      19040.80c 3.0484E-11
      19041.80c 1.7536E-08
       3006.80c 5.5708E-09
       3007.80c 6.7826E-08
      12024.80c 1.3804E-06
      12025.80c 1.7475E-07
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      42094.80c 4.9111E-10
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      28064.80c 2.4096E-10
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      82207.80c 3.2600E-09
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      37085.80c 4.3011E-08
      37087.80c 1.6586E-08
      51121.80c 2.3935E-08
      51123.80c 1.7902E-08
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      14029.80c 4.3668E-07
      14030.80c 2.8820E-07
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      50118.80c 3.1183E-09
      50119.80c 1.1060E-09
      50120.80c 4.1947E-09
      50122.80c 5.9611E-10
      50124.80c 7.4546E-10
      73180.80c 1.9948E-11
      73181.80c 1.6622E-07
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      22047.80c 1.8988E-08
      22048.80c 1.8815E-07
      22049.80c 1.3807E-08
      22050.80c 1.3220E-08
      23050.80c 1.9999E-09
      23051.80c 7.9796E-07
      74180.80c 9.9742E-11
      74182.80c 2.2026E-08
      74183.80c 1.1894E-08
      74184.80c 2.5467E-08
      74186.80c 2.3630E-08
      30064.80c 1.8947E-07
      30066.80c 1.0870E-07
      30067.80c 1.5974E-08
      30068.80c 7.3052E-08
      30070.80c 2.4156E-09
      40090.80c 2.8730E-08
      40091.80c 6.2653E-09
      40092.80c 9.5766E-09
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c Total 8.4743E-02 rho 1.69169
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       5011.80c 5.8796E-07
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20046.80c 5.1422E-10
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48112.80c 1.1060E-08
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48114.80c 1.3169E-08
48116.80c 3.4332E-09
27059.80c 8.7434E-08
24050.80c 4.3056E-09
24052.80c 8.3030E-08
24053.80c 9.4149E-09
24054.80c 2.3436E-09
29063.80c 2.6134E-08
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26054.80c 3.0521E-07
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26058.80c 1.4725E-08
19039.80c 2.4579E-07
19040.80c 3.0836E-11
19041.80c 1.7738E-08
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12024.80c 1.3963E-06
12025.80c 1.7677E-07
12026.80c 1.9462E-07
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42096.80c 8.9581E-10
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51123.80c 1.8109E-08
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14029.80c 4.4171E-07
14030.80c 2.9152E-07
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      23051.80c 8.0716E-07
      74180.80c 1.0089E-10
      74182.80c 2.2280E-08
      74183.80c 1.2031E-08
      74184.80c 2.5761E-08
      74186.80c 2.3903E-08
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      30066.80c 1.0995E-07
      30067.80c 1.6158E-08
      30068.80c 7.3894E-08
      30070.80c 2.4434E-09
      40090.80c 2.9061E-08
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       5011.80c 5.8241E-07
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      56132.80c 2.2522E-10
      56134.80c 5.3897E-09
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      56136.80c 1.7514E-08
      56137.80c 2.5046E-08
      56138.80c 1.5988E-07
       4009.80c 5.6647E-08
      83209.80c 7.3268E-09
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      20042.80c 8.2390E-08
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      20044.80c 2.6564E-07
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      48110.80c 5.6710E-09
      48111.80c 5.8117E-09
      48112.80c 1.0956E-08
      48113.80c 5.5484E-09
      48114.80c 1.3045E-08
      48116.80c 3.4008E-09
      27059.80c 8.6609E-08
      24050.80c 4.2650E-09
      24052.80c 8.2246E-08
      24053.80c 9.3261E-09
      24054.80c 2.3215E-09
      29063.80c 2.5887E-08
      29065.80c 1.1538E-08
      26054.80c 3.0233E-07
      26056.80c 4.7459E-06
      26057.80c 1.0960E-07
      26058.80c 1.4586E-08
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      42096.80c 8.8735E-10
      42097.80c 5.0805E-10
      42098.80c 1.2837E-09
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      82206.80c 3.5620E-09
      82207.80c 3.2664E-09
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      14030.80c 2.8877E-07
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      50115.80c 4.3862E-11
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      50117.80c 9.9076E-10
      50118.80c 3.1245E-09
      50119.80c 1.1082E-09
      50120.80c 4.2030E-09
      50122.80c 5.9729E-10
      50124.80c 7.4694E-10
      73180.80c 1.9988E-11
      73181.80c 1.6655E-07
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      74183.80c 1.1918E-08
      74184.80c 2.5518E-08
      74186.80c 2.3677E-08
      30064.80c 1.8984E-07
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      30067.80c 1.6006E-08
      30068.80c 7.3197E-08
      30070.80c 2.4204E-09
      40090.80c 2.8787E-08
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      20043.80c 3.7954E-11
      20044.80c 5.8645E-10
      20046.80c 1.1246E-12
      20048.80c 5.2573E-11
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      48108.80c 4.4607E-10
      48110.80c 6.2600E-09
      48111.80c 6.4154E-09
      48112.80c 1.2094E-08
      48113.80c 6.1247E-09
      48114.80c 1.4400E-08
      48116.80c 3.7540E-09
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      24053.80c 1.4413E-07
      24054.80c 3.5876E-08
      29063.80c 3.0661E-06
      29065.80c 1.3666E-06
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      19040.80c 3.3718E-12
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      12025.80c 1.3905E-07
      12026.80c 1.5310E-07
      25055.80c 1.1485E-05
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      42095.80c 9.3489E-09
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      42097.80c 5.6082E-09
      42098.80c 1.4170E-08
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      51123.80c 1.5049E-06
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      22050.80c 1.2185E-08
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       8017.80c 5.3526E-09
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      29065.80c 1.3693E-06
      19039.80c 2.6929E-08
      19040.80c 3.3785E-12
      19041.80c 1.9434E-09
       3006.80c 1.2348E-07
       3007.80c 1.5034E-06
      12024.80c 1.1006E-06
      12025.80c 1.3933E-07
      12026.80c 1.5340E-07
      25055.80c 1.1508E-05
      42092.80c 8.7320E-09
      42094.80c 5.4428E-09
      42095.80c 9.3675E-09
      42096.80c 9.8147E-09
      42097.80c 5.6193E-09
      42098.80c 1.4198E-08
      42100.80c 5.6664E-09
      11023.80c 1.3260E-05
      28058.80c 1.3094E-05
      28060.80c 5.0438E-06
      28061.80c 2.1925E-07
      28062.80c 6.9906E-07
      28064.80c 1.7803E-07
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      51123.80c 1.5079E-06
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      22047.80c 1.7537E-08
      22048.80c 1.7376E-07
      22049.80c 1.2752E-08
      22050.80c 1.2210E-08
       8016.80c 1.4109E-05
       8017.80c 5.3633E-09
       7014.80c 2.4088E-05
       7015.80c 8.8002E-08
c Total 4.8089E-02
c Total 4.8089E-02 rho 18.74827
c
m2748
      92234.80c 4.8285E-04
      92235.80c 4.4757E-02
      92236.80c 1.0533E-04
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      47109.80c 4.0384E-07
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      56132.80c 4.1576E-13
      56134.80c 9.9495E-12
      56135.80c 2.7136E-11
      56136.80c 3.2331E-11
      56137.80c 4.6236E-11
      56138.80c 2.9514E-10
      83209.80c 8.8728E-06
       6000.80c 4.7070E-06
      20040.80c 2.7346E-08
      20042.80c 1.8251E-10
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      20044.80c 5.8845E-10
      20046.80c 1.1284E-12
      20048.80c 5.2751E-11
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      48108.80c 4.4758E-10
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      48112.80c 1.2135E-08
      48113.80c 6.1455E-09
      48114.80c 1.4448E-08
      48116.80c 3.7668E-09
      27059.80c 9.5930E-07
      24050.80c 6.6136E-08
      24052.80c 1.2754E-06
      24053.80c 1.4462E-07
      24054.80c 3.5998E-08
      29063.80c 3.0765E-06
      29065.80c 1.3713E-06
      19039.80c 2.6967E-08
      19040.80c 3.3832E-12
      19041.80c 1.9461E-09
       3006.80c 1.2365E-07
       3007.80c 1.5055E-06
      12024.80c 1.1021E-06
      12025.80c 1.3953E-07
      12026.80c 1.5362E-07
      25055.80c 1.1524E-05
      42092.80c 8.7443E-09
      42094.80c 5.4504E-09
      42095.80c 9.3807E-09
      42096.80c 9.8285E-09
      42097.80c 5.6272E-09
      42098.80c 1.4218E-08
      42100.80c 5.6744E-09
      11023.80c 1.3278E-05
      28058.80c 1.3112E-05
      28060.80c 5.0509E-06
      28061.80c 2.1956E-07
      28062.80c 7.0005E-07
      28064.80c 1.7828E-07
      51121.80c 2.0189E-06
      51123.80c 1.5100E-06
      22046.80c 1.9473E-08
      22047.80c 1.7561E-08
      22048.80c 1.7401E-07
      22049.80c 1.2770E-08
      22050.80c 1.2227E-08
       8016.80c 1.4128E-05
       8017.80c 5.3708E-09
       7014.80c 2.4122E-05
       7015.80c 8.8126E-08
c Total 4.8157E-02
c Total 4.8157E-02 rho 18.77466
c
m2776
      92234.80c 4.6302E-04
      92235.80c 4.4740E-02
      92236.80c 1.0999E-04
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      47109.80c 4.0338E-07
      56130.80c 4.3586E-13
      56132.80c 4.1530E-13
      56134.80c 9.9383E-12
      56135.80c 2.7105E-11
      56136.80c 3.2294E-11
      56137.80c 4.6184E-11
      56138.80c 2.9481E-10
      83209.80c 8.8628E-06
       6000.80c 4.7018E-06
      20040.80c 2.7316E-08
      20042.80c 1.8231E-10
      20043.80c 3.8040E-11
      20044.80c 5.8779E-10
      20046.80c 1.1271E-12
      20048.80c 5.2692E-11
      48106.80c 6.2792E-10
      48108.80c 4.4708E-10
      48110.80c 6.2742E-09
      48111.80c 6.4300E-09
      48112.80c 1.2121E-08
      48113.80c 6.1386E-09
      48114.80c 1.4432E-08
      48116.80c 3.7625E-09
      27059.80c 9.5822E-07
      24050.80c 6.6062E-08
      24052.80c 1.2739E-06
      24053.80c 1.4445E-07
      24054.80c 3.5958E-08
      29063.80c 3.0731E-06
      29065.80c 1.3697E-06
      19039.80c 2.6937E-08
      19040.80c 3.3794E-12
      19041.80c 1.9439E-09
       3006.80c 1.2351E-07
       3007.80c 1.5038E-06
      12024.80c 1.1009E-06
      12025.80c 1.3937E-07
      12026.80c 1.5345E-07
      25055.80c 1.1512E-05
      42092.80c 8.7345E-09
      42094.80c 5.4443E-09
      42095.80c 9.3701E-09
      42096.80c 9.8175E-09
      42097.80c 5.6209E-09
      42098.80c 1.4202E-08
      42100.80c 5.6680E-09
      11023.80c 1.3263E-05
      28058.80c 1.3098E-05
      28060.80c 5.0452E-06
      28061.80c 2.1931E-07
      28062.80c 6.9926E-07
      28064.80c 1.7808E-07
      51121.80c 2.0166E-06
      51123.80c 1.5083E-06
      22046.80c 1.9451E-08
      22047.80c 1.7542E-08
      22048.80c 1.7381E-07
      22049.80c 1.2755E-08
      22050.80c 1.2213E-08
       8016.80c 1.4113E-05
       8017.80c 5.3648E-09
       7014.80c 2.4095E-05
       7015.80c 8.8027E-08
c Total 4.8103E-02
c Total 4.8103E-02 rho 18.75360
c
m2742
      92234.80c 4.7323E-04
      92235.80c 4.4785E-02
      92236.80c 1.1012E-04
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      47109.80c 4.0387E-07
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      56132.80c 4.1580E-13
      56134.80c 9.9503E-12
      56135.80c 2.7138E-11
      56136.80c 3.2333E-11
      56137.80c 4.6240E-11
      56138.80c 2.9517E-10
      83209.80c 8.8735E-06
       6000.80c 4.7074E-06
      20040.80c 2.7349E-08
      20042.80c 1.8253E-10
      20043.80c 3.8086E-11
      20044.80c 5.8849E-10
      20046.80c 1.1285E-12
      20048.80c 5.2756E-11
      48106.80c 6.2868E-10
      48108.80c 4.4762E-10
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      48113.80c 6.1460E-09
      48114.80c 1.4450E-08
      48116.80c 3.7671E-09
      27059.80c 9.5938E-07
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      24053.80c 1.4463E-07
      24054.80c 3.6001E-08
      29063.80c 3.0768E-06
      29065.80c 1.3714E-06
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      19040.80c 3.3835E-12
      19041.80c 1.9463E-09
       3006.80c 1.2366E-07
       3007.80c 1.5056E-06
      12024.80c 1.1022E-06
      12025.80c 1.3954E-07
      12026.80c 1.5363E-07
      25055.80c 1.1525E-05
      42092.80c 8.7450E-09
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      42097.80c 5.6277E-09
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      42100.80c 5.6748E-09
      11023.80c 1.3279E-05
      28058.80c 1.3113E-05
      28060.80c 5.0513E-06
      28061.80c 2.1958E-07
      28062.80c 7.0010E-07
      28064.80c 1.7830E-07
      51121.80c 2.0190E-06
      51123.80c 1.5101E-06
      22046.80c 1.9475E-08
      22047.80c 1.7563E-08
      22048.80c 1.7402E-07
      22049.80c 1.2771E-08
      22050.80c 1.2228E-08
       8016.80c 1.4130E-05
       8017.80c 5.3713E-09
       7014.80c 2.4124E-05
       7015.80c 8.8133E-08
c Total 4.8161E-02
c Total 4.8161E-02 rho 18.77622
c
m2746
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      92235.80c 4.4681E-02
      92236.80c 1.0515E-04
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      92238.80c 2.6966E-03
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      47109.80c 4.0315E-07
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      56132.80c 4.1506E-13
      56134.80c 9.9327E-12
      56135.80c 2.7090E-11
      56136.80c 3.2276E-11
      56137.80c 4.6158E-11
      56138.80c 2.9464E-10
      83209.80c 8.8578E-06
       6000.80c 4.6991E-06
      20040.80c 2.7300E-08
      20042.80c 1.8221E-10
      20043.80c 3.8018E-11
      20044.80c 5.8745E-10
      20046.80c 1.1265E-12
      20048.80c 5.2662E-11
      48106.80c 6.2757E-10
      48108.80c 4.4683E-10
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      48113.80c 6.1351E-09
      48114.80c 1.4424E-08
      48116.80c 3.7604E-09
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      24053.80c 1.4437E-07
      24054.80c 3.5937E-08
      29063.80c 3.0713E-06
      29065.80c 1.3689E-06
      19039.80c 2.6921E-08
      19040.80c 3.3775E-12
      19041.80c 1.9428E-09
       3006.80c 1.2344E-07
       3007.80c 1.5030E-06
      12024.80c 1.1003E-06
      12025.80c 1.3929E-07
      12026.80c 1.5336E-07
      25055.80c 1.1505E-05
      42092.80c 8.7295E-09
      42094.80c 5.4412E-09
      42095.80c 9.3648E-09
      42096.80c 9.8119E-09
      42097.80c 5.6177E-09
      42098.80c 1.4194E-08
      42100.80c 5.6648E-09
      11023.80c 1.3256E-05
      28058.80c 1.3090E-05
      28060.80c 5.0423E-06
      28061.80c 2.1919E-07
      28062.80c 6.9886E-07
      28064.80c 1.7798E-07
      51121.80c 2.0155E-06
      51123.80c 1.5075E-06
      22046.80c 1.9440E-08
      22047.80c 1.7532E-08
      22048.80c 1.7371E-07
      22049.80c 1.2748E-08
      22050.80c 1.2206E-08
       8016.80c 1.4105E-05
       8017.80c 5.3618E-09
       7014.80c 2.4082E-05
       7015.80c 8.7977E-08
c Total 4.8076E-02
c Total 4.8076E-02 rho 18.74297
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m2747
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      92235.80c 4.4720E-02
      92236.80c 9.0820E-05
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      47109.80c 4.0320E-07
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      56132.80c 4.1511E-13
      56134.80c 9.9339E-12
      56135.80c 2.7093E-11
      56136.80c 3.2280E-11
      56137.80c 4.6164E-11
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      83209.80c 8.8588E-06
       6000.80c 4.6996E-06
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      20043.80c 3.8023E-11
      20044.80c 5.8752E-10
      20046.80c 1.1266E-12
      20048.80c 5.2669E-11
      48106.80c 6.2764E-10
      48108.80c 4.4688E-10
      48110.80c 6.2714E-09
      48111.80c 6.4271E-09
      48112.80c 1.2116E-08
      48113.80c 6.1358E-09
      48114.80c 1.4426E-08
      48116.80c 3.7608E-09
      27059.80c 9.5779E-07
      24050.80c 6.6032E-08
      24052.80c 1.2734E-06
      24053.80c 1.4439E-07
      24054.80c 3.5942E-08
      29063.80c 3.0717E-06
      29065.80c 1.3691E-06
      19039.80c 2.6924E-08
      19040.80c 3.3779E-12
      19041.80c 1.9431E-09
       3006.80c 1.2346E-07
       3007.80c 1.5031E-06
      12024.80c 1.1004E-06
      12025.80c 1.3931E-07
      12026.80c 1.5338E-07
      25055.80c 1.1506E-05
      42092.80c 8.7305E-09
      42094.80c 5.4419E-09
      42095.80c 9.3659E-09
      42096.80c 9.8130E-09
      42097.80c 5.6184E-09
      42098.80c 1.4196E-08
      42100.80c 5.6654E-09
      11023.80c 1.3258E-05
      28058.80c 1.3092E-05
      28060.80c 5.0429E-06
      28061.80c 2.1921E-07
      28062.80c 6.9895E-07
      28064.80c 1.7800E-07
      51121.80c 2.0157E-06
      51123.80c 1.5076E-06
      22046.80c 1.9443E-08
      22047.80c 1.7534E-08
      22048.80c 1.7373E-07
      22049.80c 1.2750E-08
      22050.80c 1.2208E-08
       8016.80c 1.4106E-05
       8017.80c 5.3624E-09
       7014.80c 2.4084E-05
       7015.80c 8.7988E-08
c Total 4.8081E-02
c Total 4.8081E-02 rho 18.74516
c
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m2782
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      92235.80c 4.4898E-02
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      56132.80c 4.1658E-13
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      56136.80c 3.2394E-11
      56137.80c 4.6327E-11
      56138.80c 2.9572E-10
      83209.80c 8.8901E-06
       6000.80c 4.7163E-06
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      20046.80c 1.1306E-12
      20048.80c 5.2855E-11
      48106.80c 6.2986E-10
      48108.80c 4.4846E-10
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      48111.80c 6.4498E-09
      48112.80c 1.2159E-08
      48113.80c 6.1575E-09
      48114.80c 1.4477E-08
      48116.80c 3.7741E-09
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      24050.80c 6.6266E-08
      24052.80c 1.2779E-06
      24053.80c 1.4490E-07
      24054.80c 3.6069E-08
      29063.80c 3.0826E-06
      29065.80c 1.3739E-06
      19039.80c 2.7020E-08
      19040.80c 3.3898E-12
      19041.80c 1.9499E-09
       3006.80c 1.2389E-07
       3007.80c 1.5084E-06
      12024.80c 1.1043E-06
      12025.80c 1.3980E-07
      12026.80c 1.5392E-07
      25055.80c 1.1547E-05
      42092.80c 8.7614E-09
      42094.80c 5.4611E-09
      42095.80c 9.3990E-09
      42096.80c 9.8477E-09
      42097.80c 5.6382E-09
      42098.80c 1.4246E-08
      42100.80c 5.6855E-09
      11023.80c 1.3304E-05
      28058.80c 1.3138E-05
      28060.80c 5.0608E-06
      28061.80c 2.1999E-07
      28062.80c 7.0142E-07
      28064.80c 1.7863E-07
      51121.80c 2.0228E-06
      51123.80c 1.5130E-06
      22046.80c 1.9511E-08
      22047.80c 1.7596E-08
      22048.80c 1.7435E-07
      22049.80c 1.2795E-08
      22050.80c 1.2251E-08
       8016.80c 1.4156E-05
       8017.80c 5.3813E-09
       7014.80c 2.4170E-05
       7015.80c 8.8299E-08
c Total 4.8252E-02
c Total 4.8252E-02 rho 18.81144
c
m2781
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      92235.80c 4.4838E-02
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      56134.80c 9.9569E-12
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      56136.80c 3.2355E-11
      56137.80c 4.6271E-11
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      83209.80c 8.8794E-06
       6000.80c 4.7105E-06
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      20044.80c 5.8888E-10
      20046.80c 1.1292E-12
      20048.80c 5.2791E-11
      48106.80c 6.2910E-10
      48108.80c 4.4792E-10
      48110.80c 6.2859E-09
      48111.80c 6.4420E-09
      48112.80c 1.2144E-08
      48113.80c 6.1501E-09
      48114.80c 1.4459E-08
      48116.80c 3.7696E-09
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      24050.80c 6.6185E-08
      24052.80c 1.2763E-06
      24053.80c 1.4472E-07
      24054.80c 3.6025E-08
      29063.80c 3.0788E-06
      29065.80c 1.3723E-06
      19039.80c 2.6987E-08
      19040.80c 3.3857E-12
      19041.80c 1.9476E-09
       3006.80c 1.2374E-07
       3007.80c 1.5066E-06
      12024.80c 1.1029E-06
      12025.80c 1.3963E-07
      12026.80c 1.5373E-07
      25055.80c 1.1533E-05
      42092.80c 8.7508E-09
      42094.80c 5.4545E-09
      42095.80c 9.3876E-09
      42096.80c 9.8358E-09
      42097.80c 5.6314E-09
      42098.80c 1.4229E-08
      42100.80c 5.6786E-09
      11023.80c 1.3288E-05
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      28060.80c 5.0546E-06
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      28062.80c 7.0057E-07
      28064.80c 1.7841E-07
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      51123.80c 1.5111E-06
      22046.80c 1.9488E-08
      22047.80c 1.7574E-08
      22048.80c 1.7414E-07
      22049.80c 1.2779E-08
      22050.80c 1.2236E-08
       8016.80c 1.4139E-05
       8017.80c 5.3748E-09
       7014.80c 2.4140E-05
       7015.80c 8.8192E-08
c Total 4.8193E-02
c Total 4.8193E-02 rho 18.78861
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m2749
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      92235.80c 4.4799E-02
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      24053.80c 1.4460E-07
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      19040.80c 3.3827E-12
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       3007.80c 1.5053E-06
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      12025.80c 1.3951E-07
      12026.80c 1.5360E-07
      25055.80c 1.1523E-05
      42092.80c 8.7430E-09
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       8017.80c 5.3701E-09
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       7015.80c 8.8114E-08
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      56137.80c 4.6246E-11
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       6000.80c 4.7080E-06
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      20046.80c 1.1286E-12
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      19041.80c 1.9465E-09
       3006.80c 1.2368E-07
       3007.80c 1.5058E-06
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      12025.80c 1.3956E-07
      12026.80c 1.5365E-07
      25055.80c 1.1527E-05
      42092.80c 8.7461E-09
      42094.80c 5.4516E-09
      42095.80c 9.3826E-09
      42096.80c 9.8305E-09
      42097.80c 5.6284E-09
      42098.80c 1.4221E-08
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      28058.80c 1.3115E-05
      28060.80c 5.0519E-06
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      28062.80c 7.0019E-07
      28064.80c 1.7832E-07
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      51123.80c 1.5103E-06
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      22047.80c 1.7565E-08
      22048.80c 1.7404E-07
      22049.80c 1.2772E-08
      22050.80c 1.2229E-08
       8016.80c 1.4131E-05
       8017.80c 5.3719E-09
       7014.80c 2.4127E-05
       7015.80c 8.8144E-08
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      83209.80c 8.8511E-06
       6000.80c 4.6955E-06
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      20044.80c 5.8701E-10
      20046.80c 1.1256E-12
      20048.80c 5.2623E-11
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      48108.80c 4.4649E-10
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      48111.80c 6.4215E-09
      48112.80c 1.2105E-08
      48113.80c 6.1305E-09
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      48116.80c 3.7576E-09
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      24050.80c 6.5975E-08
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      24053.80c 1.4426E-07
      24054.80c 3.5910E-08
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      25055.80c 1.1496E-05
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      42095.80c 9.3578E-09
      42096.80c 9.8045E-09
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      42098.80c 1.4184E-08
      42100.80c 5.6605E-09
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       6000.80c 4.7029E-06
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      20046.80c 1.1274E-12
      20048.80c 5.2705E-11
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      24053.80c 1.4449E-07
      24054.80c 3.5967E-08
      29063.80c 3.0739E-06
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      25055.80c 1.1514E-05
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      42096.80c 9.8199E-09
      42097.80c 5.6223E-09
      42098.80c 1.4206E-08
      42100.80c 5.6694E-09
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      28062.80c 6.9943E-07
      28064.80c 1.7813E-07
      51121.80c 2.0171E-06
      51123.80c 1.5087E-06
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      22047.80c 1.7546E-08
      22048.80c 1.7386E-07
      22049.80c 1.2759E-08
      22050.80c 1.2216E-08
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      20046.80c 1.1281E-12
      20048.80c 5.2737E-11
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      12026.80c 1.5358E-07
      25055.80c 1.1521E-05
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      42095.80c 9.3782E-09
      42096.80c 9.8259E-09
      42097.80c 5.6257E-09
      42098.80c 1.4214E-08
      42100.80c 5.6728E-09
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      28062.80c 6.9986E-07
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      51121.80c 2.0183E-06
      51123.80c 1.5096E-06
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      22047.80c 1.7557E-08
      22048.80c 1.7396E-07
      22049.80c 1.2766E-08
      22050.80c 1.2224E-08
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       8017.80c 5.3694E-09
       7014.80c 2.4116E-05
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      20044.80c 5.8833E-10
      20046.80c 1.1281E-12
      20048.80c 5.2741E-11
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       3007.80c 1.5052E-06
      12024.80c 1.1019E-06
      12025.80c 1.3950E-07
      12026.80c 1.5359E-07
      25055.80c 1.1522E-05
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      28062.80c 6.9991E-07
      28064.80c 1.7825E-07
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      51123.80c 1.5097E-06
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      22048.80c 1.7397E-07
      22049.80c 1.2767E-08
      22050.80c 1.2224E-08
       8016.80c 1.4126E-05
       8017.80c 5.3697E-09
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      22048.80c 1.7432E-07
      22049.80c 1.2793E-08
      22050.80c 1.2249E-08
       8016.80c 1.4154E-05
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      19040.80c 3.3850E-12
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      12025.80c 1.3960E-07
      12026.80c 1.5370E-07
      25055.80c 1.1530E-05
      42092.80c 8.7488E-09
      42094.80c 5.4533E-09
      42095.80c 9.3855E-09
      42096.80c 9.8336E-09
      42097.80c 5.6301E-09
      42098.80c 1.4226E-08
      42100.80c 5.6773E-09
      11023.80c 1.3285E-05
      28058.80c 1.3119E-05
      28060.80c 5.0535E-06
      28061.80c 2.1967E-07
      28062.80c 7.0041E-07
      28064.80c 1.7837E-07
      51121.80c 2.0199E-06
      51123.80c 1.5108E-06
      22046.80c 1.9483E-08
      22047.80c 1.7570E-08
      22048.80c 1.7410E-07
      22049.80c 1.2776E-08
      22050.80c 1.2233E-08
       8016.80c 1.4136E-05
       8017.80c 5.3736E-09
       7014.80c 2.4135E-05
       7015.80c 8.8172E-08
c Total 4.8182E-02
c Total 4.8182E-02 rho 18.78435
c
c ------ "13""-15""" HEU Annulus ------
m2886
      92234.80c 4.7684E-04
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      92236.80c 1.2417E-04
      92238.80c 2.6708E-03
      47107.80c 4.3360E-07
      47109.80c 4.0284E-07
      56130.80c 4.3527E-13
      56132.80c 4.1473E-13
      56134.80c 9.9249E-12
      56135.80c 2.7069E-11
      56136.80c 3.2251E-11
      56137.80c 4.6122E-11
      56138.80c 2.9441E-10
      83209.80c 8.8508E-06
       6000.80c 4.6954E-06
      20040.80c 2.7279E-08
      20042.80c 1.8206E-10
      20043.80c 3.7988E-11
      20044.80c 5.8699E-10
      20046.80c 1.1256E-12
      20048.80c 5.2621E-11
      48106.80c 6.2707E-10
      48108.80c 4.4648E-10
      48110.80c 6.2657E-09
      48111.80c 6.4212E-09
      48112.80c 1.2105E-08
      48113.80c 6.1303E-09
      48114.80c 1.4413E-08
      48116.80c 3.7574E-09
      27059.80c 9.5692E-07
      24050.80c 6.5972E-08
      24052.80c 1.2722E-06
      24053.80c 1.4426E-07
      24054.80c 3.5909E-08
      29063.80c 3.0689E-06
      29065.80c 1.3679E-06
      19039.80c 2.6900E-08
      19040.80c 3.3748E-12
      19041.80c 1.9413E-09
       3006.80c 1.2335E-07
       3007.80c 1.5018E-06
      12024.80c 1.0994E-06
      12025.80c 1.3918E-07
      12026.80c 1.5324E-07
      25055.80c 1.1496E-05
      42092.80c 8.7226E-09
      42094.80c 5.4370E-09
      42095.80c 9.3574E-09
      42096.80c 9.8042E-09
      42097.80c 5.6133E-09
      42098.80c 1.4183E-08
      42100.80c 5.6603E-09
      11023.80c 1.3246E-05
      28058.80c 1.3080E-05
      28060.80c 5.0384E-06
      28061.80c 2.1901E-07
      28062.80c 6.9831E-07
      28064.80c 1.7784E-07
      51121.80c 2.0139E-06
      51123.80c 1.5063E-06
      22046.80c 1.9425E-08
      22047.80c 1.7518E-08
      22048.80c 1.7358E-07
      22049.80c 1.2738E-08
      22050.80c 1.2197E-08
       8016.80c 1.4093E-05
       8017.80c 5.3575E-09
       7014.80c 2.4063E-05
       7015.80c 8.7908E-08
c Total 4.8038E-02
c Total 4.8038E-02 rho 18.72818
c
m2885
      92234.80c 4.7727E-04
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      92236.80c 1.2428E-04
      92238.80c 2.6732E-03
      47107.80c 4.3399E-07
      47109.80c 4.0320E-07
      56130.80c 4.3566E-13
      56132.80c 4.1511E-13
      56134.80c 9.9338E-12
      56135.80c 2.7093E-11
      56136.80c 3.2280E-11
      56137.80c 4.6163E-11
      56138.80c 2.9468E-10
      83209.80c 8.8587E-06
       6000.80c 4.6996E-06
      20040.80c 2.7303E-08
      20042.80c 1.8223E-10
      20043.80c 3.8022E-11
      20044.80c 5.8752E-10
      20046.80c 1.1266E-12
      20048.80c 5.2668E-11
      48106.80c 6.2764E-10
      48108.80c 4.4688E-10
      48110.80c 6.2713E-09
      48111.80c 6.4270E-09
      48112.80c 1.2116E-08
      48113.80c 6.1358E-09
      48114.80c 1.4426E-08
      48116.80c 3.7608E-09
      27059.80c 9.5778E-07
      24050.80c 6.6031E-08
      24052.80c 1.2733E-06
      24053.80c 1.4439E-07
      24054.80c 3.5941E-08
      29063.80c 3.0717E-06
      29065.80c 1.3691E-06
      19039.80c 2.6924E-08
      19040.80c 3.3779E-12
      19041.80c 1.9430E-09
       3006.80c 1.2346E-07
       3007.80c 1.5031E-06
      12024.80c 1.1004E-06
      12025.80c 1.3931E-07
      12026.80c 1.5338E-07
      25055.80c 1.1506E-05
      42092.80c 8.7304E-09
      42094.80c 5.4418E-09
      42095.80c 9.3658E-09
      42096.80c 9.8129E-09
      42097.80c 5.6183E-09
      42098.80c 1.4196E-08
      42100.80c 5.6654E-09
      11023.80c 1.3257E-05
      28058.80c 1.3092E-05
      28060.80c 5.0429E-06
      28061.80c 2.1921E-07
      28062.80c 6.9894E-07
      28064.80c 1.7800E-07
      51121.80c 2.0157E-06
      51123.80c 1.5076E-06
      22046.80c 1.9442E-08
      22047.80c 1.7534E-08
      22048.80c 1.7373E-07
      22049.80c 1.2750E-08
      22050.80c 1.2207E-08
       8016.80c 1.4106E-05
       8017.80c 5.3623E-09
       7014.80c 2.4084E-05
       7015.80c 8.7987E-08
c Total 4.8081E-02
c Total 4.8081E-02 rho 18.74496
c
m2784
      92234.80c 4.7962E-04
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      92238.80c 2.6864E-03
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      47109.80c 4.0519E-07
      56130.80c 4.3781E-13
      56132.80c 4.1715E-13
      56134.80c 9.9828E-12
      56135.80c 2.7227E-11
      56136.80c 3.2439E-11
      56137.80c 4.6391E-11
      56138.80c 2.9613E-10
      83209.80c 8.9025E-06
       6000.80c 4.7228E-06
      20040.80c 2.7438E-08
      20042.80c 1.8312E-10
      20043.80c 3.8210E-11
      20044.80c 5.9041E-10
      20046.80c 1.1321E-12
      20048.80c 5.2928E-11
      48106.80c 6.3073E-10
      48108.80c 4.4908E-10
      48110.80c 6.3023E-09
      48111.80c 6.4587E-09
      48112.80c 1.2176E-08
      48113.80c 6.1660E-09
      48114.80c 1.4497E-08
      48116.80c 3.7794E-09
      27059.80c 9.6251E-07
      24050.80c 6.6357E-08
      24052.80c 1.2796E-06
      24053.80c 1.4510E-07
      24054.80c 3.6119E-08
      29063.80c 3.0868E-06
      29065.80c 1.3758E-06
      19039.80c 2.7057E-08
      19040.80c 3.3945E-12
      19041.80c 1.9526E-09
       3006.80c 1.2407E-07
       3007.80c 1.5105E-06
      12024.80c 1.1058E-06
      12025.80c 1.3999E-07
      12026.80c 1.5413E-07
      25055.80c 1.1563E-05
      42092.80c 8.7735E-09
      42094.80c 5.4687E-09
      42095.80c 9.4120E-09
      42096.80c 9.8614E-09
      42097.80c 5.6460E-09
      42098.80c 1.4266E-08
      42100.80c 5.6933E-09
      11023.80c 1.3323E-05
      28058.80c 1.3156E-05
      28060.80c 5.0678E-06
      28061.80c 2.2029E-07
      28062.80c 7.0239E-07
      28064.80c 1.7888E-07
      51121.80c 2.0256E-06
      51123.80c 1.5151E-06
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      22047.80c 1.7620E-08
      22048.80c 1.7459E-07
      22049.80c 1.2812E-08
      22050.80c 1.2268E-08
       8016.80c 1.4176E-05
       8017.80c 5.3888E-09
       7014.80c 2.4203E-05
       7015.80c 8.8421E-08
c Total 4.8318E-02
c Total 4.8318E-02 rho 18.83748
c
m2786
      92234.80c 4.7669E-04
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      92236.80c 1.1575E-04
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      47109.80c 4.0682E-07
      56130.80c 4.3957E-13
      56132.80c 4.1883E-13
      56134.80c 1.0023E-11
      56135.80c 2.7336E-11
      56136.80c 3.2570E-11
      56137.80c 4.6578E-11
      56138.80c 2.9732E-10
      83209.80c 8.9383E-06
       6000.80c 4.7418E-06
      20040.80c 2.7548E-08
      20042.80c 1.8386E-10
      20043.80c 3.8364E-11
      20044.80c 5.9279E-10
      20046.80c 1.1367E-12
      20048.80c 5.3141E-11
      48106.80c 6.3327E-10
      48108.80c 4.5089E-10
      48110.80c 6.3277E-09
      48111.80c 6.4847E-09
      48112.80c 1.2225E-08
      48113.80c 6.1909E-09
      48114.80c 1.4555E-08
      48116.80c 3.7946E-09
      27059.80c 9.6638E-07
      24050.80c 6.6624E-08
      24052.80c 1.2848E-06
      24053.80c 1.4568E-07
      24054.80c 3.6264E-08
      29063.80c 3.0993E-06
      29065.80c 1.3814E-06
      19039.80c 2.7166E-08
      19040.80c 3.4082E-12
      19041.80c 1.9605E-09
       3006.80c 1.2457E-07
       3007.80c 1.5166E-06
      12024.80c 1.1103E-06
      12025.80c 1.4056E-07
      12026.80c 1.5475E-07
      25055.80c 1.1610E-05
      42092.80c 8.8089E-09
      42094.80c 5.4907E-09
      42095.80c 9.4499E-09
      42096.80c 9.9011E-09
      42097.80c 5.6688E-09
      42098.80c 1.4323E-08
      42100.80c 5.7163E-09
      11023.80c 1.3376E-05
      28058.80c 1.3209E-05
      28060.80c 5.0882E-06
      28061.80c 2.2118E-07
      28062.80c 7.0522E-07
      28064.80c 1.7960E-07
      51121.80c 2.0338E-06
      51123.80c 1.5212E-06
      22046.80c 1.9617E-08
      22047.80c 1.7691E-08
      22048.80c 1.7529E-07
      22049.80c 1.2864E-08
      22050.80c 1.2317E-08
       8016.80c 1.4233E-05
       8017.80c 5.4105E-09
       7014.80c 2.4300E-05
       7015.80c 8.8777E-08
c Total 4.8513E-02
c Total 4.8513E-02 rho 18.91332
c
m2787
      92234.80c 4.7220E-04
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      47107.80c 4.3376E-07
      47109.80c 4.0298E-07
      56130.80c 4.3542E-13
      56132.80c 4.1489E-13
      56134.80c 9.9285E-12
      56135.80c 2.7078E-11
      56136.80c 3.2263E-11
      56137.80c 4.6139E-11
      56138.80c 2.9452E-10
      83209.80c 8.8540E-06
       6000.80c 4.6971E-06
      20040.80c 2.7289E-08
      20042.80c 1.8213E-10
      20043.80c 3.8002E-11
      20044.80c 5.8720E-10
      20046.80c 1.1260E-12
      20048.80c 5.2640E-11
      48106.80c 6.2730E-10
      48108.80c 4.4664E-10
      48110.80c 6.2680E-09
      48111.80c 6.4236E-09
      48112.80c 1.2109E-08
      48113.80c 6.1325E-09
      48114.80c 1.4418E-08
      48116.80c 3.7588E-09
      27059.80c 9.5727E-07
      24050.80c 6.5996E-08
      24052.80c 1.2727E-06
      24053.80c 1.4431E-07
      24054.80c 3.5922E-08
      29063.80c 3.0700E-06
      29065.80c 1.3684E-06
      19039.80c 2.6910E-08
      19040.80c 3.3761E-12
      19041.80c 1.9420E-09
       3006.80c 1.2339E-07
       3007.80c 1.5023E-06
      12024.80c 1.0998E-06
      12025.80c 1.3923E-07
      12026.80c 1.5329E-07
      25055.80c 1.1500E-05
      42092.80c 8.7258E-09
      42094.80c 5.4389E-09
      42095.80c 9.3609E-09
      42096.80c 9.8077E-09
      42097.80c 5.6153E-09
      42098.80c 1.4188E-08
      42100.80c 5.6624E-09
      11023.80c 1.3250E-05
      28058.80c 1.3085E-05
      28060.80c 5.0402E-06
      28061.80c 2.1909E-07
      28062.80c 6.9857E-07
      28064.80c 1.7790E-07
      51121.80c 2.0146E-06
      51123.80c 1.5068E-06
      22046.80c 1.9432E-08
      22047.80c 1.7524E-08
      22048.80c 1.7364E-07
      22049.80c 1.2743E-08
      22050.80c 1.2201E-08
       8016.80c 1.4099E-05
       8017.80c 5.3595E-09
       7014.80c 2.4071E-05
       7015.80c 8.7940E-08
c Total 4.8056E-02
c Total 4.8056E-02 rho 18.73504
c
m2760
      92234.80c 4.7813E-04
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      92235.80c 4.4787E-02
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      92238.80c 2.6780E-03
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      47109.80c 4.0393E-07
      56130.80c 4.3645E-13
      56132.80c 4.1586E-13
      56134.80c 9.9518E-12
      56135.80c 2.7142E-11
      56136.80c 3.2338E-11
      56137.80c 4.6247E-11
      56138.80c 2.9521E-10
      83209.80c 8.8748E-06
       6000.80c 4.7081E-06
      20040.80c 2.7353E-08
      20042.80c 1.8256E-10
      20043.80c 3.8091E-11
      20044.80c 5.8858E-10
      20046.80c 1.1286E-12
      20048.80c 5.2764E-11
      48106.80c 6.2878E-10
      48108.80c 4.4769E-10
      48110.80c 6.2827E-09
      48111.80c 6.4387E-09
      48112.80c 1.2138E-08
      48113.80c 6.1469E-09
      48114.80c 1.4452E-08
      48116.80c 3.7676E-09
      27059.80c 9.5952E-07
      24050.80c 6.6151E-08
      24052.80c 1.2757E-06
      24053.80c 1.4465E-07
      24054.80c 3.6006E-08
      29063.80c 3.0772E-06
      29065.80c 1.3716E-06
      19039.80c 2.6973E-08
      19040.80c 3.3840E-12
      19041.80c 1.9466E-09
       3006.80c 1.2368E-07
       3007.80c 1.5058E-06
      12024.80c 1.1024E-06
      12025.80c 1.3956E-07
      12026.80c 1.5365E-07
      25055.80c 1.1527E-05
      42092.80c 8.7463E-09
      42094.80c 5.4517E-09
      42095.80c 9.3828E-09
      42096.80c 9.8307E-09
      42097.80c 5.6285E-09
      42098.80c 1.4222E-08
      42100.80c 5.6757E-09
      11023.80c 1.3281E-05
      28058.80c 1.3115E-05
      28060.80c 5.0520E-06
      28061.80c 2.1961E-07
      28062.80c 7.0021E-07
      28064.80c 1.7832E-07
      51121.80c 2.0193E-06
      51123.80c 1.5103E-06
      22046.80c 1.9478E-08
      22047.80c 1.7565E-08
      22048.80c 1.7405E-07
      22049.80c 1.2773E-08
      22050.80c 1.2230E-08
       8016.80c 1.4132E-05
       8017.80c 5.3721E-09
       7014.80c 2.4128E-05
       7015.80c 8.8146E-08
c Total 4.8168E-02
c Total 4.8168E-02 rho 18.77899
c
m2739
      92234.80c 4.6537E-04
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      92235.80c 4.4968E-02
      92236.80c 1.2016E-04
      92238.80c 2.6832E-03
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      47109.80c 4.0543E-07
      56130.80c 4.3807E-13
      56132.80c 4.1741E-13
      56134.80c 9.9889E-12
      56135.80c 2.7243E-11
      56136.80c 3.2459E-11
      56137.80c 4.6419E-11
      56138.80c 2.9631E-10
      83209.80c 8.9079E-06
       6000.80c 4.7257E-06
      20040.80c 2.7455E-08
      20042.80c 1.8324E-10
      20043.80c 3.8233E-11
      20044.80c 5.9077E-10
      20046.80c 1.1328E-12
      20048.80c 5.2960E-11
      48106.80c 6.3112E-10
      48108.80c 4.4936E-10
      48110.80c 6.3061E-09
      48111.80c 6.4626E-09
      48112.80c 1.2183E-08
      48113.80c 6.1698E-09
      48114.80c 1.4506E-08
      48116.80c 3.7817E-09
      27059.80c 9.6309E-07
      24050.80c 6.6398E-08
      24052.80c 1.2804E-06
      24053.80c 1.4519E-07
      24054.80c 3.6140E-08
      29063.80c 3.0887E-06
      29065.80c 1.3767E-06
      19039.80c 2.7074E-08
      19040.80c 3.3966E-12
      19041.80c 1.9538E-09
       3006.80c 1.2414E-07
       3007.80c 1.5115E-06
      12024.80c 1.1065E-06
      12025.80c 1.4008E-07
      12026.80c 1.5423E-07
      25055.80c 1.1570E-05
      42092.80c 8.7789E-09
      42094.80c 5.4720E-09
      42095.80c 9.4178E-09
      42096.80c 9.8674E-09
      42097.80c 5.6495E-09
      42098.80c 1.4275E-08
      42100.80c 5.6968E-09
      11023.80c 1.3331E-05
      28058.80c 1.3164E-05
      28060.80c 5.0708E-06
      28061.80c 2.2043E-07
      28062.80c 7.0282E-07
      28064.80c 1.7899E-07
      51121.80c 2.0268E-06
      51123.80c 1.5160E-06
      22046.80c 1.9550E-08
      22047.80c 1.7631E-08
      22048.80c 1.7470E-07
      22049.80c 1.2820E-08
      22050.80c 1.2275E-08
       8016.80c 1.4184E-05
       8017.80c 5.3921E-09
       7014.80c 2.4218E-05
       7015.80c 8.8475E-08
c Total 4.8348E-02
c Total 4.8348E-02 rho 18.84893
c
m2761
      92234.80c 4.6350E-04
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      92235.80c 4.4767E-02
      92236.80c 1.2925E-04
      92238.80c 2.6819E-03
      47107.80c 4.3464E-07
      47109.80c 4.0380E-07
      56130.80c 4.3631E-13
      56132.80c 4.1573E-13
      56134.80c 9.9486E-12
      56135.80c 2.7133E-11
      56136.80c 3.2328E-11
      56137.80c 4.6232E-11
      56138.80c 2.9512E-10
      83209.80c 8.8720E-06
       6000.80c 4.7066E-06
      20040.80c 2.7344E-08
      20042.80c 1.8250E-10
      20043.80c 3.8079E-11
      20044.80c 5.8839E-10
      20046.80c 1.1283E-12
      20048.80c 5.2747E-11
      48106.80c 6.2857E-10
      48108.80c 4.4754E-10
      48110.80c 6.2807E-09
      48111.80c 6.4366E-09
      48112.80c 1.2134E-08
      48113.80c 6.1449E-09
      48114.80c 1.4447E-08
      48116.80c 3.7664E-09
      27059.80c 9.5921E-07
      24050.80c 6.6130E-08
      24052.80c 1.2753E-06
      24053.80c 1.4460E-07
      24054.80c 3.5995E-08
      29063.80c 3.0763E-06
      29065.80c 1.3711E-06
      19039.80c 2.6964E-08
      19040.80c 3.3829E-12
      19041.80c 1.9460E-09
       3006.80c 1.2364E-07
       3007.80c 1.5054E-06
      12024.80c 1.1020E-06
      12025.80c 1.3951E-07
      12026.80c 1.5360E-07
      25055.80c 1.1523E-05
      42092.80c 8.7435E-09
      42094.80c 5.4500E-09
      42095.80c 9.3798E-09
      42096.80c 9.8276E-09
      42097.80c 5.6267E-09
      42098.80c 1.4217E-08
      42100.80c 5.6739E-09
      11023.80c 1.3277E-05
      28058.80c 1.3111E-05
      28060.80c 5.0504E-06
      28061.80c 2.1954E-07
      28062.80c 6.9998E-07
      28064.80c 1.7827E-07
      51121.80c 2.0187E-06
      51123.80c 1.5099E-06
      22046.80c 1.9472E-08
      22047.80c 1.7560E-08
      22048.80c 1.7399E-07
      22049.80c 1.2769E-08
      22050.80c 1.2226E-08
       8016.80c 1.4127E-05
       8017.80c 5.3703E-09
       7014.80c 2.4120E-05
       7015.80c 8.8118E-08
c Total 4.8153E-02
c Total 4.8153E-02 rho 18.77300
c
m2785
      92234.80c 4.7235E-04
```

```
      92235.80c 4.4701E-02
      92236.80c 1.1469E-04
      92238.80c 2.6726E-03
      47107.80c 4.3390E-07
      47109.80c 4.0311E-07
      56130.80c 4.3556E-13
      56132.80c 4.1502E-13
      56134.80c 9.9316E-12
      56135.80c 2.7087E-11
      56136.80c 3.2273E-11
      56137.80c 4.6153E-11
      56138.80c 2.9461E-10
      83209.80c 8.8568E-06
       6000.80c 4.6986E-06
      20040.80c 2.7297E-08
      20042.80c 1.8219E-10
      20043.80c 3.8014E-11
      20044.80c 5.8739E-10
      20046.80c 1.1263E-12
      20048.80c 5.2657E-11
      48106.80c 6.2750E-10
      48108.80c 4.4678E-10
      48110.80c 6.2700E-09
      48111.80c 6.4256E-09
      48112.80c 1.2113E-08
      48113.80c 6.1344E-09
      48114.80c 1.4422E-08
      48116.80c 3.7600E-09
      27059.80c 9.5758E-07
      24050.80c 6.6017E-08
      24052.80c 1.2731E-06
      24053.80c 1.4436E-07
      24054.80c 3.5933E-08
      29063.80c 3.0710E-06
      29065.80c 1.3688E-06
      19039.80c 2.6918E-08
      19040.80c 3.3771E-12
      19041.80c 1.9426E-09
       3006.80c 1.2343E-07
       3007.80c 1.5028E-06
      12024.80c 1.1001E-06
      12025.80c 1.3928E-07
      12026.80c 1.5334E-07
      25055.80c 1.1504E-05
      42092.80c 8.7286E-09
      42094.80c 5.4407E-09
      42095.80c 9.3638E-09
      42096.80c 9.8108E-09
      42097.80c 5.6171E-09
      42098.80c 1.4193E-08
      42100.80c 5.6642E-09
      11023.80c 1.3255E-05
      28058.80c 1.3089E-05
      28060.80c 5.0418E-06
      28061.80c 2.1916E-07
      28062.80c 6.9879E-07
      28064.80c 1.7796E-07
      51121.80c 2.0152E-06
      51123.80c 1.5073E-06
      22046.80c 1.9438E-08
      22047.80c 1.7530E-08
      22048.80c 1.7370E-07
      22049.80c 1.2747E-08
      22050.80c 1.2205E-08
       8016.80c 1.4103E-05
       8017.80c 5.3612E-09
       7014.80c 2.4079E-05
       7015.80c 8.7968E-08
c Total 4.8071E-02
c Total 4.8071E-02 rho 18.74094
c
m2848
      92234.80c 4.7656E-04
```

```
      92235.80c 4.4663E-02
      92236.80c 1.1455E-04
      92238.80c 2.6456E-03
      47107.80c 4.3335E-07
      47109.80c 4.0260E-07
      56130.80c 4.3501E-13
      56132.80c 4.1449E-13
      56134.80c 9.9191E-12
      56135.80c 2.7053E-11
      56136.80c 3.2232E-11
      56137.80c 4.6095E-11
      56138.80c 2.9424E-10
      83209.80c 8.8457E-06
       6000.80c 4.6926E-06
      20040.80c 2.7263E-08
      20042.80c 1.8196E-10
      20043.80c 3.7966E-11
      20044.80c 5.8665E-10
      20046.80c 1.1249E-12
      20048.80c 5.2590E-11
      48106.80c 6.2671E-10
      48108.80c 4.4622E-10
      48110.80c 6.2621E-09
      48111.80c 6.4175E-09
      48112.80c 1.2098E-08
      48113.80c 6.1267E-09
      48114.80c 1.4404E-08
      48116.80c 3.7552E-09
      27059.80c 9.5637E-07
      24050.80c 6.5934E-08
      24052.80c 1.2715E-06
      24053.80c 1.4417E-07
      24054.80c 3.5888E-08
      29063.80c 3.0671E-06
      29065.80c 1.3671E-06
      19039.80c 2.6884E-08
      19040.80c 3.3729E-12
      19041.80c 1.9402E-09
       3006.80c 1.2327E-07
       3007.80c 1.5009E-06
      12024.80c 1.0988E-06
      12025.80c 1.3910E-07
      12026.80c 1.5315E-07
      25055.80c 1.1489E-05
      42092.80c 8.7176E-09
      42094.80c 5.4338E-09
      42095.80c 9.3520E-09
      42096.80c 9.7984E-09
      42097.80c 5.6100E-09
      42098.80c 1.4175E-08
      42100.80c 5.6570E-09
      11023.80c 1.3238E-05
      28058.80c 1.3072E-05
      28060.80c 5.0354E-06
      28061.80c 2.1889E-07
      28062.80c 6.9791E-07
      28064.80c 1.7774E-07
      51121.80c 2.0127E-06
      51123.80c 1.5054E-06
      22046.80c 1.9414E-08
      22047.80c 1.7508E-08
      22048.80c 1.7348E-07
      22049.80c 1.2731E-08
      22050.80c 1.2189E-08
       8016.80c 1.4085E-05
       8017.80c 5.3544E-09
       7014.80c 2.4049E-05
       7015.80c 8.7857E-08
c Total 4.8010E-02
c Total 4.8010E-02 rho 18.71729
c
m2735
      92234.80c 4.7169E-04
```

```
      92235.80c 4.4629E-02
      92236.80c 1.1931E-04
      92238.80c 2.6736E-03
      47107.80c 4.3329E-07
      47109.80c 4.0255E-07
      56130.80c 4.3496E-13
      56132.80c 4.1444E-13
      56134.80c 9.9178E-12
      56135.80c 2.7049E-11
      56136.80c 3.2228E-11
      56137.80c 4.6089E-11
      56138.80c 2.9420E-10
      83209.80c 8.8445E-06
       6000.80c 4.6921E-06
      20040.80c 2.7259E-08
      20042.80c 1.8193E-10
      20043.80c 3.7961E-11
      20044.80c 5.8657E-10
      20046.80c 1.1248E-12
      20048.80c 5.2584E-11
      48106.80c 6.2663E-10
      48108.80c 4.4616E-10
      48110.80c 6.2613E-09
      48111.80c 6.4167E-09
      48112.80c 1.2096E-08
      48113.80c 6.1259E-09
      48114.80c 1.4402E-08
      48116.80c 3.7548E-09
      27059.80c 9.5625E-07
      24050.80c 6.5926E-08
      24052.80c 1.2713E-06
      24053.80c 1.4416E-07
      24054.80c 3.5884E-08
      29063.80c 3.0667E-06
      29065.80c 1.3669E-06
      19039.80c 2.6881E-08
      19040.80c 3.3724E-12
      19041.80c 1.9399E-09
       3006.80c 1.2326E-07
       3007.80c 1.5007E-06
      12024.80c 1.0986E-06
      12025.80c 1.3908E-07
      12026.80c 1.5313E-07
      25055.80c 1.1488E-05
      42092.80c 8.7165E-09
      42094.80c 5.4331E-09
      42095.80c 9.3508E-09
      42096.80c 9.7972E-09
      42097.80c 5.6093E-09
      42098.80c 1.4173E-08
      42100.80c 5.6563E-09
      11023.80c 1.3236E-05
      28058.80c 1.3071E-05
      28060.80c 5.0348E-06
      28061.80c 2.1886E-07
      28062.80c 6.9782E-07
      28064.80c 1.7771E-07
      51121.80c 2.0124E-06
      51123.80c 1.5052E-06
      22046.80c 1.9411E-08
      22047.80c 1.7505E-08
      22048.80c 1.7345E-07
      22049.80c 1.2729E-08
      22050.80c 1.2188E-08
       8016.80c 1.4083E-05
       8017.80c 5.3537E-09
       7014.80c 2.4046E-05
       7015.80c 8.7846E-08
c Total 4.8004E-02
c Total 4.8004E-02 rho 18.71491
c
c --- Control Cards ------------------------------------------------------
mode n
```

```
kcode 100000 1.00 150 2150
ksrc 12 0 0.1 -12 0 0.1
kopts blocksize=10 kinetics=yes precursor=yes
print
```

Experiment 2 Configuration (Detailed Model), Table 48.

```
ORALLOY (93.15 235U) METAL ANNULI WHITH INTERNAL GRAPHITE CYLINDER
c Case "2," HEU Annuli 15-7 inches.
c
c LIU XIAOBO - Idaho National Laboratory & INPC
c Last Updated: March"20," 2015
c
c
c Cell Cards ************************************************************
c ------ Graphite "Center-7""" ------
1001 1001 8.2645E-02 -1001 imp:n=1 $ Top/Upper
1007 1007 8.5188E-02 -1007 imp:n=1
1027 1027 8.5718E-02 -1027 imp:n=1 $ Bottom/Upper
1036 1036 8.4671E-02 -1036 imp:n=1 $ Only one layer/Lower
c
c ------ "7""-9""" HEU Annulus ------
2763 2763 4.7943E-02 9763 -2763 imp:n=1 $ Top/Upper
2762 2762 4.8191E-02 9762 -2762 imp:n=1
2738 2738 4.8154E-02 9738 -2738 imp:n=1 $ Bottom/Upper
2773 2773 4.8043E-02 9773 -2773 imp:n=1 $ Top/Lower
2829 2829 4.8088E-02 9829 -2829 imp:n=1
2740 2740 4.8185E-02 9740 -2740 imp:n=1 $ Bottom/Lower
c
c ------ "9""-11""" HEU Annulus ------
2744 2744 4.8301E-02 9744 -2744 imp:n=1 $ Top/Upper
2743 2743 4.8386E-02 9743 -2743 imp:n=1
2767 2767 4.8089E-02 9767 -2767 imp:n=1
2776 2776 4.8103E-02 9776 -2776 imp:n=1 $ Bottom/Upper
2742 2742 4.8161E-02 9742 -2742 imp:n=1 $ Top/Lower
2746 2746 4.8076E-02 9746 -2746 imp:n=1
2748 2748 4.8157E-02 9748 -2748 imp:n=1 $ Bottom/Lower
c
c ------ "11""-13""" HEU Annulus ------
2755 2755 4.8167E-02 9755 -2755 imp:n=1 $ Top/Upper
2752 2752 4.8115E-02 9752 -2752 imp:n=1
2757 2757 4.8145E-02 9757 -2757 imp:n=1 $ Bottom/Upper
2751 2751 4.8147E-02 9751 -2751 imp:n=1 $ Top/Lower
2754 2754 4.8244E-02 9754 -2754 imp:n=1
2756 2756 4.8182E-02 9756 -2756 imp:n=1 $ Bottom/Lower
c
c ------ "13""-15""" HEU Annulus ------
2758 2758 4.8174E-02 9758 -2758 imp:n=1 $ Top/Upper
2760 2760 4.8168E-02 9760 -2760 imp:n=1
2786 2786 4.8513E-02 9786 -2786 imp:n=1
2739 2739 4.8348E-02 9739 -2739 imp:n=1 $ Bottom/Upper
2761 2761 4.8153E-02 9761 -2761 imp:n=1 $ Top/Lower
2785 2785 4.8071E-02 9785 -2785 imp:n=1
2848 2848 4.8010E-02 9848 -2848 imp:n=1
2735 2735 4.8004E-02 9735 -2735 imp:n=1 $ Bottom/Lower
c
c ------ Void Spaces------
9990 0 #1001 #1007 #1027 #1036
      #2763 #2762 #2738 #2773 #2829 #2740
      #2744 #2743 #2767 #2776 #2742 #2746 #2748
      #2755 #2752 #2757 #2751 #2754 #2756
      #2758 #2760 #2786 #2739 #2761 #2785 #2848 #2735
      -9999 imp:n=1 $ Gaps
9991 0 9999 imp:n=0 $ The Great Void

c Surface Cards *********************************************************
c ------ Graphite "Center-7""" ------
1001  rcc 0 0 5.094151 0 0 0.317500 8.888095 $ Top/Upper 5.411651
1007  rcc 0 0 3.817076 0 0 1.270000 8.888095
1027  rcc 0 0 0.000000 0 0 3.810000 8.888095 $ Bottom/Upper
1036 10 rcc 0 0 0.000000 0 0 5.080000 8.888095 $ One/Lower 5.080000
c
c ------ "7""-9""" HEU Annulus ------
c --------- Outer Surfaces ---------
2763  rcc 0 0 5.085906 0 0 0.315722 11.424666 $ Top/Upper 5.401628
2762  rcc 0 0 2.545429 0 0 2.538095 11.425238
2738  rcc 0 0 0.000000 0 0 2.543048 11.424603 $ Bottom/Upper
2773 10 rcc 0 0 4.773507 0 0 0.317500 11.426190 $ Top/Lower 5.091007
```

```
2829 10 rcc 0 0 3.813916 0 0 0.955675 11.425238
2740 10 rcc 0 0 0.000000 0 0 3.810000 11.425238 $ Bottom/Lower
c --------- Inner Surfaces ---------
9763 cz 8.894826
9762 cz 8.894763
9738 cz 8.894763
9773 cz 8.891905
9829 cz 8.894001
9740 cz 8.893175
c
c ------ "9""-11""" HEU Annulus ------
c --------- Outer Surfaces ---------
2744  rcc 0 0 4.930616 0 0 0.321945 13.965936 $ Top/Upper 5.252561
2743  rcc 0 0 3.977534 0 0 0.949960 13.965555
2767  rcc 0 0 2.546932 0 0 1.427480 13.964920
2776  rcc 0 0 0.000000 0 0 2.543810 13.965555 $ Bottom/Upper
2742 10 rcc 0 0 4.137406 0 0 0.952754 13.965936 $ Top/Lower 5.090160
2746 10 rcc 0 0 3.810318 0 0 0.326771 13.965555
2748 10 rcc 0 0 0.000000 0 0 3.810000 13.966825 $ Bottom/Lower
c --------- Inner Surfaces ---------
9744 cz 11.438255
9743 cz 11.433175
9767 cz 11.431270
9776 cz 11.431905
9742 cz 11.431905
9746 cz 11.432223
9748 cz 11.433175
c
c ------ "11""-13""" HEU Annulus ------
c --------- Outer Surfaces ---------
2755  rcc 0 0 3.824151 0 0 1.431290 16.504920 $ Top/Upper 5.255441
2752  rcc 0 0 2.544917 0 0 1.278255 16.504285
2757  rcc 0 0 0.000000 0 0 2.543937 16.504920 $ Bottom/Upper
2751 10 rcc 0 0 3.819652 0 0 1.279017 16.504666 $ Top/Lower 5.098669
2754 10 rcc 0 0 2.540508 0 0 1.279144 16.504031
2756 10 rcc 0 0 0.000000 0 0 2.540508 16.505809 $ Bottom/Lower
c --------- Inner Surfaces ---------
9755 cz 13.973810
9752 cz 13.973175
9757 cz 13.973175
9751 cz 13.971905
9754 cz 13.975080
9756 cz 13.974572
c
c ------ "13""-15""" HEU Annulus ------
c --------- Outer Surfaces ---------
2758  rcc 0 0 5.088414 0 0 0.316230 19.045746 $ Top/Upper 5.404644
2760  rcc 0 0 3.806423 0 0 1.270000 19.043650
2786  rcc 0 0 2.538021 0 0 1.256411 19.043650
2739  rcc 0 0 0.000000 0 0 2.526030 19.044285 $ Bottom/Upper
2761 10 rcc 0 0 4.775381 0 0 0.321310 19.043333 $ Top/Lower 5.096691
2785 10 rcc 0 0 3.819434 0 0 0.951738 19.044603
2848 10 rcc 0 0 2.540399 0 0 1.274826 19.045428
2735 10 rcc 0 0 0.000000 0 0 2.536190 19.041745 $ Bottom/Lower
c --------- Inner Surfaces ---------
9758 cz 16.505555
9760 cz 16.512540
9786 cz 16.513175
9739 cz 16.513429
9761 cz 16.511270
9785 cz 16.513620
9848 cz 16.513937
9735 cz 16.512540
c
c ------ Problem Boundary ------
9999 rcc 0 0 -8.000000 0 0 20.000000 20.000000
c

c Data Cards ******************************************************************
tr10 0 0 -5.098669
c --- Material Cards ------------------------------------------------------
c ------ Graphite "Center-7""" ------
m1001
```

```
 6000.80c 8.2610E-02
47107.80c 2.3873E-09
47109.80c 2.2179E-09
13027.80c 3.1301E-06
 5010.80c 1.4083E-07
 5011.80c 5.6686E-07
56130.80c 2.3006E-10
56132.80c 2.1921E-10
56134.80c 5.2458E-09
56135.80c 1.4307E-08
56136.80c 1.7046E-08
56137.80c 2.4378E-08
56138.80c 1.5561E-07
 4009.80c 5.5135E-08
83209.80c 7.1313E-09
20040.80c 1.2015E-05
20042.80c 8.0191E-08
20043.80c 1.6732E-08
20044.80c 2.5854E-07
20046.80c 4.9577E-10
20048.80c 2.3177E-08
48106.80c 5.5240E-10
48108.80c 3.9331E-10
48110.80c 5.5196E-09
48111.80c 5.6566E-09
48112.80c 1.0664E-08
48113.80c 5.4003E-09
48114.80c 1.2696E-08
48116.80c 3.3100E-09
27059.80c 8.4297E-08
24050.80c 4.1512E-09
24052.80c 8.0051E-08
24053.80c 9.0771E-09
24054.80c 2.2595E-09
29063.80c 2.5196E-08
29065.80c 1.1230E-08
26054.80c 2.9426E-07
26056.80c 4.6192E-06
26057.80c 1.0668E-07
26058.80c 1.4197E-08
19039.80c 2.3697E-07
19040.80c 2.9730E-11
19041.80c 1.7101E-08
 3006.80c 5.4329E-09
 3007.80c 6.6147E-08
12024.80c 1.3462E-06
12025.80c 1.7042E-07
12026.80c 1.8764E-07
25055.80c 1.8084E-08
42092.80c 7.6839E-10
42094.80c 4.7895E-10
42095.80c 8.2431E-10
42096.80c 8.6367E-10
42097.80c 4.9448E-10
42098.80c 1.2494E-09
42100.80c 4.9863E-10
11023.80c 4.3216E-07
41093.80c 5.3467E-08
28058.80c 1.7284E-08
28060.80c 6.6576E-09
28061.80c 2.8940E-10
28062.80c 9.2274E-10
28064.80c 2.3499E-10
82204.80c 2.0140E-10
82206.80c 3.4670E-09
82207.80c 3.1792E-09
82208.80c 7.5381E-09
37085.80c 4.1946E-08
37087.80c 1.6175E-08
51121.80c 2.3343E-08
51123.80c 1.7459E-08
14028.80c 8.3830E-06
14029.80c 4.2586E-07
```

```
      14030.80c 2.8106E-07
      50112.80c 1.2179E-10
      50114.80c 8.2871E-11
      50115.80c 4.2691E-11
      50116.80c 1.8257E-09
      50117.80c 9.6431E-10
      50118.80c 3.0411E-09
      50119.80c 1.0786E-09
      50120.80c 4.0908E-09
      50122.80c 5.8135E-10
      50124.80c 7.2700E-10
      73180.80c 1.9454E-11
      73181.80c 1.6210E-07
      22046.80c 2.0534E-08
      22047.80c 1.8518E-08
      22048.80c 1.8349E-07
      22049.80c 1.3465E-08
      22050.80c 1.2893E-08
      23050.80c 1.9504E-09
      23051.80c 7.7820E-07
      74180.80c 9.7272E-11
      74182.80c 2.1481E-08
      74183.80c 1.1600E-08
      74184.80c 2.4837E-08
      74186.80c 2.3045E-08
      30064.80c 1.8478E-07
      30066.80c 1.0601E-07
      30067.80c 1.5578E-08
      30068.80c 7.1243E-08
      30070.80c 2.3558E-09
      40090.80c 2.8018E-08
      40091.80c 6.1102E-09
      40092.80c 9.3395E-09
      40094.80c 9.4647E-09
      40096.80c 1.5248E-09
c Total 8.2645E-02
c Total 8.2645E-02 rho 1.64980
mt1001 grph.20t
c
m1007
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      47107.80c 2.4607E-09
      47109.80c 2.2862E-09
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       5010.80c 1.4516E-07
       5011.80c 5.8430E-07
      56130.80c 2.3714E-10
      56132.80c 2.2595E-10
      56134.80c 5.4072E-09
      56135.80c 1.4747E-08
      56136.80c 1.7571E-08
      56137.80c 2.5128E-08
      56138.80c 1.6040E-07
       4009.80c 5.6831E-08
      83209.80c 7.3507E-09
      20040.80c 1.2385E-05
      20042.80c 8.2658E-08
      20043.80c 1.7247E-08
      20044.80c 2.6650E-07
      20046.80c 5.1103E-10
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      48106.80c 5.6940E-10
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      48111.80c 5.8306E-09
      48112.80c 1.0992E-08
      48113.80c 5.5664E-09
      48114.80c 1.3087E-08
      48116.80c 3.4118E-09
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      24050.80c 4.2789E-09
      24052.80c 8.2514E-08
      24053.80c 9.3564E-09
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26057.80c 1.0996E-07
26058.80c 1.4634E-08
19039.80c 2.4426E-07
19040.80c 3.0644E-11
19041.80c 1.7628E-08
 3006.80c 5.6001E-09
 3007.80c 6.8182E-08
12024.80c 1.3876E-06
12025.80c 1.7567E-07
12026.80c 1.9341E-07
25055.80c 1.8640E-08
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42096.80c 8.9024E-10
42097.80c 5.0970E-10
42098.80c 1.2879E-09
42100.80c 5.1397E-10
11023.80c 4.4545E-07
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37087.80c 1.6673E-08
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51123.80c 1.7996E-08
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50115.80c 4.4004E-11
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50117.80c 9.9398E-10
50118.80c 3.1347E-09
50119.80c 1.1118E-09
50120.80c 4.2167E-09
50122.80c 5.9924E-10
50124.80c 7.4937E-10
73180.80c 2.0053E-11
73181.80c 1.6709E-07
22046.80c 2.1166E-08
22047.80c 1.9088E-08
22048.80c 1.8913E-07
22049.80c 1.3880E-08
22050.80c 1.3290E-08
23050.80c 2.0104E-09
23051.80c 8.0215E-07
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74182.80c 2.2142E-08
74183.80c 1.1957E-08
74184.80c 2.5601E-08
74186.80c 2.3754E-08
30064.80c 1.9046E-07
30066.80c 1.0927E-07
30067.80c 1.6058E-08
30068.80c 7.3435E-08
30070.80c 2.4283E-09
40090.80c 2.8881E-08
40091.80c 6.2982E-09
40092.80c 9.6269E-09
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c Total 8.5188E-02 rho 1.70056
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      47109.80c 2.3004E-09
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       5011.80c 5.8794E-07
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      56132.80c 2.2736E-10
      56134.80c 5.4408E-09
      56135.80c 1.4839E-08
      56136.80c 1.7680E-08
      56137.80c 2.5284E-08
      56138.80c 1.6140E-07
       4009.80c 5.7185E-08
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      20042.80c 8.3173E-08
      20043.80c 1.7354E-08
      20044.80c 2.6816E-07
      20046.80c 5.1420E-10
      20048.80c 2.4039E-08
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      48108.80c 4.0793E-10
      48110.80c 5.7248E-09
      48111.80c 5.8669E-09
      48112.80c 1.1060E-08
      48113.80c 5.6011E-09
      48114.80c 1.3168E-08
      48116.80c 3.4330E-09
      27059.80c 8.7431E-08
      24050.80c 4.3055E-09
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      24053.80c 9.4146E-09
      24054.80c 2.3435E-09
      29063.80c 2.6133E-08
      29065.80c 1.1648E-08
      26054.80c 3.0520E-07
      26056.80c 4.7909E-06
      26057.80c 1.1064E-07
      26058.80c 1.4725E-08
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      19040.80c 3.0835E-11
      19041.80c 1.7737E-08
       3006.80c 5.6349E-09
       3007.80c 6.8606E-08
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      12025.80c 1.7676E-07
      12026.80c 1.9461E-07
      25055.80c 1.8756E-08
      42092.80c 7.9696E-10
      42094.80c 4.9676E-10
      42095.80c 8.5496E-10
      42096.80c 8.9578E-10
      42097.80c 5.1287E-10
      42098.80c 1.2959E-09
      42100.80c 5.1717E-10
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      41093.80c 5.5455E-08
      28058.80c 1.7926E-08
      28060.80c 6.9051E-09
      28061.80c 3.0016E-10
      28062.80c 9.5704E-10
      28064.80c 2.4373E-10
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      82206.80c 3.5959E-09
      82207.80c 3.2974E-09
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      51123.80c 1.8108E-08
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      14029.80c 4.4170E-07
      14030.80c 2.9151E-07
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      50115.80c 4.4278E-11
      50116.80c 1.8935E-09
      50117.80c 1.0002E-09
      50118.80c 3.1542E-09
      50119.80c 1.1187E-09
      50120.80c 4.2429E-09
      50122.80c 6.0296E-10
      50124.80c 7.5403E-10
      73180.80c 2.0178E-11
      73181.80c 1.6813E-07
      22046.80c 2.1298E-08
      22047.80c 1.9207E-08
      22048.80c 1.9031E-07
      22049.80c 1.3966E-08
      22050.80c 1.3372E-08
      23050.80c 2.0229E-09
      23051.80c 8.0714E-07
      74180.80c 1.0089E-10
      74182.80c 2.2280E-08
      74183.80c 1.2031E-08
      74184.80c 2.5760E-08
      74186.80c 2.3902E-08
      30064.80c 1.9165E-07
      30066.80c 1.0995E-07
      30067.80c 1.6158E-08
      30068.80c 7.3892E-08
      30070.80c 2.4434E-09
      40090.80c 2.9060E-08
      40091.80c 6.3373E-09
      40092.80c 9.6867E-09
      40094.80c 9.8166E-09
      40096.80c 1.5815E-09
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c Total 8.5718E-02 rho 1.71114
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      56132.80c 2.2458E-10
      56134.80c 5.3744E-09
      56135.80c 1.4658E-08
      56136.80c 1.7464E-08
      56137.80c 2.4975E-08
      56138.80c 1.5943E-07
       4009.80c 5.6486E-08
      83209.80c 7.3061E-09
      20040.80c 1.2310E-05
      20042.80c 8.2157E-08
      20043.80c 1.7143E-08
      20044.80c 2.6488E-07
      20046.80c 5.0793E-10
      20048.80c 2.3746E-08
      48106.80c 5.6595E-10
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      48112.80c 1.0925E-08
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24050.80c 4.2529E-09
24052.80c 8.2014E-08
24053.80c 9.2997E-09
24054.80c 2.3149E-09
29063.80c 2.5814E-08
29065.80c 1.1506E-08
26054.80c 3.0147E-07
26056.80c 4.7325E-06
26057.80c 1.0929E-07
26058.80c 1.4545E-08
19039.80c 2.4278E-07
19040.80c 3.0459E-11
19041.80c 1.7521E-08
 3006.80c 5.5661E-09
 3007.80c 6.7769E-08
12024.80c 1.3792E-06
12025.80c 1.7460E-07
12026.80c 1.9224E-07
25055.80c 1.8527E-08
42092.80c 7.8723E-10
42094.80c 4.9069E-10
42095.80c 8.4453E-10
42096.80c 8.8484E-10
42097.80c 5.0661E-10
42098.80c 1.2801E-09
42100.80c 5.1085E-10
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28060.80c 6.8208E-09
28061.80c 2.9650E-10
28062.80c 9.4536E-10
28064.80c 2.4076E-10
82204.80c 2.0634E-10
82206.80c 3.5520E-09
82207.80c 3.2572E-09
82208.80c 7.7229E-09
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37087.80c 1.6572E-08
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14029.80c 4.3631E-07
14030.80c 2.8795E-07
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50114.80c 8.4903E-11
50115.80c 4.3738E-11
50116.80c 1.8704E-09
50117.80c 9.8796E-10
50118.80c 3.1157E-09
50119.80c 1.1050E-09
50120.80c 4.1911E-09
50122.80c 5.9560E-10
50124.80c 7.4483E-10
73180.80c 1.9931E-11
73181.80c 1.6608E-07
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22047.80c 1.8972E-08
22048.80c 1.8799E-07
22049.80c 1.3796E-08
22050.80c 1.3209E-08
23050.80c 1.9982E-09
23051.80c 7.9728E-07
74180.80c 9.9657E-11
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      40096.80c 1.5622E-09
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c Total 8.4671E-02 rho 1.69025
mt1036 grph.20t
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      92238.80c 2.6513E-03
      47107.80c 4.3274E-07
      47109.80c 4.0204E-07
      56130.80c 4.3440E-13
      56132.80c 4.1391E-13
      56134.80c 9.9051E-12
      56135.80c 2.7015E-11
      56136.80c 3.2187E-11
      56137.80c 4.6030E-11
      56138.80c 2.9383E-10
      83209.80c 8.8332E-06
       6000.80c 4.6860E-06
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      20042.80c 1.8170E-10
      20043.80c 3.7913E-11
      20044.80c 5.8582E-10
      20046.80c 1.1233E-12
      20048.80c 5.2516E-11
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      48108.80c 4.4559E-10
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      48111.80c 6.4085E-09
      48112.80c 1.2081E-08
      48113.80c 6.1181E-09
      48114.80c 1.4384E-08
      48116.80c 3.7500E-09
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      24053.80c 1.4397E-07
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      29065.80c 1.3651E-06
      19039.80c 2.6847E-08
      19040.80c 3.3681E-12
      19041.80c 1.9374E-09
       3006.80c 1.2310E-07
       3007.80c 1.4988E-06
      12024.80c 1.0972E-06
      12025.80c 1.3890E-07
      12026.80c 1.5293E-07
      25055.80c 1.1473E-05
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      42095.80c 9.3388E-09
      42096.80c 9.7847E-09
      42097.80c 5.6021E-09
      42098.80c 1.4155E-08
      42100.80c 5.6491E-09
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      28058.80c 1.3054E-05
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      22050.80c 1.2172E-08
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c Total 4.7943E-02
c Total 4.7943E-02 rho 18.69095
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      92238.80c 2.6745E-03
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      47109.80c 4.0412E-07
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      56132.80c 4.1605E-13
      56134.80c 9.9565E-12
      56135.80c 2.7155E-11
      56136.80c 3.2353E-11
      56137.80c 4.6268E-11
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      20044.80c 5.8886E-10
      20046.80c 1.1292E-12
      20048.80c 5.2788E-11
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      48111.80c 6.4417E-09
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      48113.80c 6.1498E-09
      48114.80c 1.4459E-08
      48116.80c 3.7694E-09
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      12025.80c 1.3962E-07
      12026.80c 1.5373E-07
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      42098.80c 1.4228E-08
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      22049.80c 1.2779E-08
      22050.80c 1.2235E-08
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       7015.80c 8.8188E-08
c Total 4.8191E-02
c Total 4.8191E-02 rho 18.78778
c
m2738
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      92238.80c 2.6725E-03
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      47109.80c 4.0381E-07
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      56132.80c 4.1574E-13
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      12024.80c 1.1021E-06
      12025.80c 1.3952E-07
      12026.80c 1.5361E-07
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      22050.80c 1.2226E-08
       8016.80c 1.4128E-05
       8017.80c 5.3705E-09
       7014.80c 2.4121E-05
       7015.80c 8.8121E-08
c Total 4.8154E-02
c Total 4.8154E-02 rho 18.77352
c
m2773
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      92235.80c 4.4689E-02
      92236.80c 1.1463E-04
      92238.80c 2.6616E-03
      47107.80c 4.3365E-07
      47109.80c 4.0288E-07
      56130.80c 4.3531E-13
      56132.80c 4.1478E-13
      56134.80c 9.9259E-12
      56135.80c 2.7071E-11
      56136.80c 3.2254E-11
      56137.80c 4.6127E-11
      56138.80c 2.9444E-10
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       6000.80c 4.6959E-06
      20040.80c 2.7282E-08
      20042.80c 1.8208E-10
      20043.80c 3.7992E-11
      20044.80c 5.8705E-10
      20046.80c 1.1257E-12
      20048.80c 5.2626E-11
      48106.80c 6.2714E-10
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      48114.80c 1.4414E-08
      48116.80c 3.7578E-09
      27059.80c 9.5703E-07
      24050.80c 6.5979E-08
      24052.80c 1.2723E-06
      24053.80c 1.4427E-07
      24054.80c 3.5913E-08
      29063.80c 3.0692E-06
      29065.80c 1.3680E-06
      19039.80c 2.6903E-08
      19040.80c 3.3752E-12
      19041.80c 1.9415E-09
       3006.80c 1.2336E-07
       3007.80c 1.5019E-06
      12024.80c 1.0995E-06
      12025.80c 1.3920E-07
      12026.80c 1.5325E-07
      25055.80c 1.1497E-05
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      42094.80c 5.4375E-09
      42095.80c 9.3584E-09
      42096.80c 9.8052E-09
      42097.80c 5.6139E-09
      42098.80c 1.4185E-08
      42100.80c 5.6609E-09
      11023.80c 1.3247E-05
      28058.80c 1.3081E-05
      28060.80c 5.0389E-06
      28061.80c 2.1904E-07
      28062.80c 6.9839E-07
      28064.80c 1.7786E-07
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      22048.80c 1.7360E-07
      22049.80c 1.2739E-08
      22050.80c 1.2198E-08
       8016.80c 1.4095E-05
       8017.80c 5.3581E-09
       7014.80c 2.4065E-05
       7015.80c 8.7917E-08
c Total 4.8043E-02
c Total 4.8043E-02 rho 18.73018
c
m2829
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      92235.80c 4.4697E-02
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      92238.80c 2.6878E-03
      47107.80c 4.3405E-07
      47109.80c 4.0326E-07
      56130.80c 4.3572E-13
      56132.80c 4.1517E-13
      56134.80c 9.9352E-12
      56135.80c 2.7097E-11
      56136.80c 3.2284E-11
      56137.80c 4.6170E-11
      56138.80c 2.9472E-10
      83209.80c 8.8600E-06
       6000.80c 4.7003E-06
      20040.80c 2.7307E-08
      20042.80c 1.8225E-10
      20043.80c 3.8028E-11
      20044.80c 5.8760E-10
      20046.80c 1.1267E-12
      20048.80c 5.2676E-11
      48106.80c 6.2773E-10
      48108.80c 4.4694E-10
      48110.80c 6.2722E-09
      48111.80c 6.4279E-09
      48112.80c 1.2118E-08
      48113.80c 6.1367E-09
      48114.80c 1.4428E-08
      48116.80c 3.7613E-09
      27059.80c 9.5792E-07
      24050.80c 6.6041E-08
      24052.80c 1.2735E-06
      24053.80c 1.4441E-07
      24054.80c 3.5946E-08
      29063.80c 3.0721E-06
      29065.80c 1.3693E-06
      19039.80c 2.6928E-08
      19040.80c 3.3783E-12
      19041.80c 1.9433E-09
       3006.80c 1.2347E-07
       3007.80c 1.5033E-06
      12024.80c 1.1005E-06
      12025.80c 1.3933E-07
      12026.80c 1.5340E-07
      25055.80c 1.1508E-05
      42092.80c 8.7317E-09
      42094.80c 5.4426E-09
      42095.80c 9.3672E-09
      42096.80c 9.8143E-09
      42097.80c 5.6191E-09
      42098.80c 1.4198E-08
      42100.80c 5.6662E-09
      11023.80c 1.3259E-05
      28058.80c 1.3094E-05
      28060.80c 5.0436E-06
      28061.80c 2.1924E-07
      28062.80c 6.9904E-07
      28064.80c 1.7802E-07
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      22047.80c 1.7536E-08
      22048.80c 1.7376E-07
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      22050.80c 1.2209E-08
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       8017.80c 5.3631E-09
       7014.80c 2.4088E-05
       7015.80c 8.7999E-08
c Total 4.8088E-02
c Total 4.8088E-02 rho 18.74767
c
m2740
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      92235.80c 4.4821E-02
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      92238.80c 2.6694E-03
      47107.80c 4.3492E-07
      47109.80c 4.0406E-07
      56130.80c 4.3659E-13
      56132.80c 4.1600E-13
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      56136.80c 3.2349E-11
      56137.80c 4.6262E-11
      56138.80c 2.9531E-10
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       6000.80c 4.7097E-06
      20040.80c 2.7362E-08
      20042.80c 1.8262E-10
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      20044.80c 5.8878E-10
      20046.80c 1.1290E-12
      20048.80c 5.2781E-11
      48106.80c 6.2899E-10
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      48113.80c 6.1490E-09
      48114.80c 1.4457E-08
      48116.80c 3.7689E-09
      27059.80c 9.5984E-07
      24050.80c 6.6173E-08
      24052.80c 1.2761E-06
      24053.80c 1.4470E-07
      24054.80c 3.6018E-08
      29063.80c 3.0783E-06
      29065.80c 1.3720E-06
      19039.80c 2.6982E-08
      19040.80c 3.3851E-12
      19041.80c 1.9472E-09
       3006.80c 1.2372E-07
       3007.80c 1.5063E-06
      12024.80c 1.1027E-06
      12025.80c 1.3961E-07
      12026.80c 1.5371E-07
      25055.80c 1.1531E-05
      42092.80c 8.7492E-09
      42094.80c 5.4535E-09
      42095.80c 9.3860E-09
      42096.80c 9.8341E-09
      42097.80c 5.6304E-09
      42098.80c 1.4226E-08
      42100.80c 5.6776E-09
      11023.80c 1.3286E-05
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      28060.80c 5.0537E-06
      28061.80c 2.1968E-07
      28062.80c 7.0044E-07
      28064.80c 1.7838E-07
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      51123.80c 1.5109E-06
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      22047.80c 1.7571E-08
      22048.80c 1.7411E-07
      22049.80c 1.2777E-08
      22050.80c 1.2234E-08
       8016.80c 1.4136E-05
       8017.80c 5.3739E-09
       7014.80c 2.4136E-05
       7015.80c 8.8176E-08
c Total 4.8185E-02
c Total 4.8185E-02 rho 18.78530
c
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      92236.80c 1.1044E-04
      92238.80c 2.6902E-03
      47107.80c 4.3597E-07
      47109.80c 4.0504E-07
      56130.80c 4.3765E-13
      56132.80c 4.1700E-13
      56134.80c 9.9792E-12
      56135.80c 2.7217E-11
      56136.80c 3.2427E-11
      56137.80c 4.6374E-11
      56138.80c 2.9602E-10
      83209.80c 8.8992E-06
       6000.80c 4.7211E-06
      20040.80c 2.7428E-08
      20042.80c 1.8306E-10
      20043.80c 3.8196E-11
      20044.80c 5.9020E-10
      20046.80c 1.1317E-12
      20048.80c 5.2909E-11
      48106.80c 6.3051E-10
      48108.80c 4.4892E-10
      48110.80c 6.3000E-09
      48111.80c 6.4564E-09
      48112.80c 1.2171E-08
      48113.80c 6.1638E-09
      48114.80c 1.4492E-08
      48116.80c 3.7780E-09
      27059.80c 9.6216E-07
      24050.80c 6.6333E-08
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      24053.80c 1.4505E-07
      24054.80c 3.6106E-08
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      29065.80c 1.3753E-06
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      19040.80c 3.3933E-12
      19041.80c 1.9519E-09
       3006.80c 1.2402E-07
       3007.80c 1.5100E-06
      12024.80c 1.1054E-06
      12025.80c 1.3994E-07
      12026.80c 1.5408E-07
      25055.80c 1.1559E-05
      42092.80c 8.7704E-09
      42094.80c 5.4667E-09
      42095.80c 9.4087E-09
      42096.80c 9.8578E-09
      42097.80c 5.6440E-09
      42098.80c 1.4261E-08
      42100.80c 5.6913E-09
      11023.80c 1.3318E-05
      28058.80c 1.3152E-05
      28060.80c 5.0659E-06
      28061.80c 2.2021E-07
      28062.80c 7.0214E-07
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      22047.80c 1.7614E-08
      22048.80c 1.7453E-07
      22049.80c 1.2808E-08
      22050.80c 1.2263E-08
       8016.80c 1.4171E-05
       8017.80c 5.3869E-09
       7014.80c 2.4194E-05
       7015.80c 8.8389E-08
c Total 4.8301E-02
c Total 4.8301E-02 rho 18.83069
c
m2743
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      92238.80c 2.6949E-03
      47107.80c 4.3674E-07
      47109.80c 4.0576E-07
      56130.80c 4.3842E-13
      56132.80c 4.1774E-13
      56134.80c 9.9968E-12
      56135.80c 2.7265E-11
      56136.80c 3.2484E-11
      56137.80c 4.6456E-11
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      83209.80c 8.9149E-06
       6000.80c 4.7294E-06
      20040.80c 2.7476E-08
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      20046.80c 1.1337E-12
      20048.80c 5.3002E-11
      48106.80c 6.3162E-10
      48108.80c 4.4971E-10
      48110.80c 6.3111E-09
      48111.80c 6.4678E-09
      48112.80c 1.2193E-08
      48113.80c 6.1747E-09
      48114.80c 1.4517E-08
      48116.80c 3.7847E-09
      27059.80c 9.6386E-07
      24050.80c 6.6450E-08
      24052.80c 1.2814E-06
      24053.80c 1.4530E-07
      24054.80c 3.6169E-08
      29063.80c 3.0912E-06
      29065.80c 1.3778E-06
      19039.80c 2.7095E-08
      19040.80c 3.3993E-12
      19041.80c 1.9554E-09
       3006.80c 1.2424E-07
       3007.80c 1.5127E-06
      12024.80c 1.1074E-06
      12025.80c 1.4019E-07
      12026.80c 1.5435E-07
      25055.80c 1.1579E-05
      42092.80c 8.7858E-09
      42094.80c 5.4764E-09
      42095.80c 9.4252E-09
      42096.80c 9.8752E-09
      42097.80c 5.6540E-09
      42098.80c 1.4286E-08
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      11023.80c 1.3341E-05
      28058.80c 1.3175E-05
      28060.80c 5.0749E-06
      28061.80c 2.2060E-07
      28062.80c 7.0337E-07
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      22048.80c 1.7484E-07
      22049.80c 1.2830E-08
      22050.80c 1.2285E-08
       8016.80c 1.4196E-05
       8017.80c 5.3964E-09
       7014.80c 2.4237E-05
       7015.80c 8.8545E-08
c Total 4.8386E-02
c Total 4.8386E-02 rho 18.86390
c
m2767
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      92235.80c 4.4718E-02
      92236.80c 1.2430E-04
      92238.80c 2.6737E-03
      47107.80c 4.3407E-07
      47109.80c 4.0327E-07
      56130.80c 4.3573E-13
      56132.80c 4.1518E-13
      56134.80c 9.9355E-12
      56135.80c 2.7098E-11
      56136.80c 3.2285E-11
      56137.80c 4.6171E-11
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      83209.80c 8.8603E-06
       6000.80c 4.7004E-06
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      20046.80c 1.1268E-12
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      48111.80c 6.4281E-09
      48112.80c 1.2118E-08
      48113.80c 6.1368E-09
      48114.80c 1.4428E-08
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      19040.80c 3.3785E-12
      19041.80c 1.9434E-09
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      12024.80c 1.1006E-06
      12025.80c 1.3933E-07
      12026.80c 1.5340E-07
      25055.80c 1.1508E-05
      42092.80c 8.7320E-09
      42094.80c 5.4428E-09
      42095.80c 9.3675E-09
      42096.80c 9.8147E-09
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      42098.80c 1.4198E-08
      42100.80c 5.6664E-09
      11023.80c 1.3260E-05
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      28061.80c 2.1925E-07
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      22048.80c 1.7376E-07
      22049.80c 1.2752E-08
      22050.80c 1.2210E-08
       8016.80c 1.4109E-05
       8017.80c 5.3633E-09
       7014.80c 2.4088E-05
       7015.80c 8.8002E-08
c Total 4.8089E-02
c Total 4.8089E-02 rho 18.74827
c
m2776
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      92238.80c 2.6792E-03
      47107.80c 4.3419E-07
      47109.80c 4.0338E-07
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      19041.80c 1.9439E-09
       3006.80c 1.2351E-07
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      12024.80c 1.1009E-06
      12025.80c 1.3937E-07
      12026.80c 1.5345E-07
      25055.80c 1.1512E-05
      42092.80c 8.7345E-09
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      42095.80c 9.3701E-09
      42096.80c 9.8175E-09
      42097.80c 5.6209E-09
      42098.80c 1.4202E-08
      42100.80c 5.6680E-09
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      28060.80c 5.0452E-06
      28061.80c 2.1931E-07
      28062.80c 6.9926E-07
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      22048.80c 1.7381E-07
      22049.80c 1.2755E-08
      22050.80c 1.2213E-08
       8016.80c 1.4113E-05
       8017.80c 5.3648E-09
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       7015.80c 8.8027E-08
c Total 4.8103E-02
c Total 4.8103E-02 rho 18.75360
c
m2742
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      92236.80c 1.1012E-04
      92238.80c 2.6824E-03
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      47109.80c 4.0387E-07
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      24050.80c 6.6141E-08
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      24053.80c 1.4463E-07
      24054.80c 3.6001E-08
      29063.80c 3.0768E-06
      29065.80c 1.3714E-06
      19039.80c 2.6969E-08
      19040.80c 3.3835E-12
      19041.80c 1.9463E-09
       3006.80c 1.2366E-07
       3007.80c 1.5056E-06
      12024.80c 1.1022E-06
      12025.80c 1.3954E-07
      12026.80c 1.5363E-07
      25055.80c 1.1525E-05
      42092.80c 8.7450E-09
      42094.80c 5.4509E-09
      42095.80c 9.3814E-09
      42096.80c 9.8293E-09
      42097.80c 5.6277E-09
      42098.80c 1.4219E-08
      42100.80c 5.6748E-09
      11023.80c 1.3279E-05
      28058.80c 1.3113E-05
      28060.80c 5.0513E-06
      28061.80c 2.1958E-07
      28062.80c 7.0010E-07
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      22048.80c 1.7402E-07
      22049.80c 1.2771E-08
      22050.80c 1.2228E-08
       8016.80c 1.4130E-05
       8017.80c 5.3713E-09
       7014.80c 2.4124E-05
       7015.80c 8.8133E-08
c Total 4.8161E-02
c Total 4.8161E-02 rho 18.77622
c
m2746
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      92235.80c 4.4681E-02
      92236.80c 1.0515E-04
      92238.80c 2.6966E-03
      47107.80c 4.3394E-07
      47109.80c 4.0315E-07
      56130.80c 4.3561E-13
      56132.80c 4.1506E-13
      56134.80c 9.9327E-12
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      56136.80c 3.2276E-11
      56137.80c 4.6158E-11
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      83209.80c 8.8578E-06
       6000.80c 4.6991E-06
      20040.80c 2.7300E-08
      20042.80c 1.8221E-10
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      20044.80c 5.8745E-10
      20046.80c 1.1265E-12
      20048.80c 5.2662E-11
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      48108.80c 4.4683E-10
      48110.80c 6.2707E-09
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      48112.80c 1.2115E-08
      48113.80c 6.1351E-09
      48114.80c 1.4424E-08
      48116.80c 3.7604E-09
      27059.80c 9.5768E-07
      24050.80c 6.6024E-08
      24052.80c 1.2732E-06
      24053.80c 1.4437E-07
      24054.80c 3.5937E-08
      29063.80c 3.0713E-06
      29065.80c 1.3689E-06
      19039.80c 2.6921E-08
      19040.80c 3.3775E-12
      19041.80c 1.9428E-09
       3006.80c 1.2344E-07
       3007.80c 1.5030E-06
      12024.80c 1.1003E-06
      12025.80c 1.3929E-07
      12026.80c 1.5336E-07
      25055.80c 1.1505E-05
      42092.80c 8.7295E-09
      42094.80c 5.4412E-09
      42095.80c 9.3648E-09
      42096.80c 9.8119E-09
      42097.80c 5.6177E-09
      42098.80c 1.4194E-08
      42100.80c 5.6648E-09
      11023.80c 1.3256E-05
      28058.80c 1.3090E-05
      28060.80c 5.0423E-06
      28061.80c 2.1919E-07
      28062.80c 6.9886E-07
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      22047.80c 1.7532E-08
      22048.80c 1.7371E-07
      22049.80c 1.2748E-08
      22050.80c 1.2206E-08
       8016.80c 1.4105E-05
       8017.80c 5.3618E-09
       7014.80c 2.4082E-05
       7015.80c 8.7977E-08
c Total 4.8076E-02
c Total 4.8076E-02 rho 18.74297
c
m2748
      92234.80c 4.8285E-04
      92235.80c 4.4757E-02
      92236.80c 1.0533E-04
      92238.80c 2.7012E-03
      47107.80c 4.3468E-07
      47109.80c 4.0384E-07
      56130.80c 4.3635E-13
      56132.80c 4.1576E-13
      56134.80c 9.9495E-12
      56135.80c 2.7136E-11
      56136.80c 3.2331E-11
      56137.80c 4.6236E-11
      56138.80c 2.9514E-10
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       6000.80c 4.7070E-06
      20040.80c 2.7346E-08
      20042.80c 1.8251E-10
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      20046.80c 1.1284E-12
      20048.80c 5.2751E-11
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      48108.80c 4.4758E-10
      48110.80c 6.2813E-09
      48111.80c 6.4372E-09
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      48113.80c 6.1455E-09
      48114.80c 1.4448E-08
      48116.80c 3.7668E-09
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      24050.80c 6.6136E-08
      24052.80c 1.2754E-06
      24053.80c 1.4462E-07
      24054.80c 3.5998E-08
      29063.80c 3.0765E-06
      29065.80c 1.3713E-06
      19039.80c 2.6967E-08
      19040.80c 3.3832E-12
      19041.80c 1.9461E-09
       3006.80c 1.2365E-07
       3007.80c 1.5055E-06
      12024.80c 1.1021E-06
      12025.80c 1.3953E-07
      12026.80c 1.5362E-07
      25055.80c 1.1524E-05
      42092.80c 8.7443E-09
      42094.80c 5.4504E-09
      42095.80c 9.3807E-09
      42096.80c 9.8285E-09
      42097.80c 5.6272E-09
      42098.80c 1.4218E-08
      42100.80c 5.6744E-09
      11023.80c 1.3278E-05
      28058.80c 1.3112E-05
      28060.80c 5.0509E-06
      28061.80c 2.1956E-07
      28062.80c 7.0005E-07
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      51123.80c 1.5100E-06
      22046.80c 1.9473E-08
      22047.80c 1.7561E-08
      22048.80c 1.7401E-07
      22049.80c 1.2770E-08
      22050.80c 1.2227E-08
       8016.80c 1.4128E-05
       8017.80c 5.3708E-09
       7014.80c 2.4122E-05
       7015.80c 8.8126E-08
c Total 4.8157E-02
c Total 4.8157E-02 rho 18.77466
c
c ------ "11""-13""" HEU Annulus ------
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      92235.80c 4.4771E-02
      92236.80c 1.3408E-04
      92238.80c 2.6875E-03
      47107.80c 4.3477E-07
      47109.80c 4.0392E-07
      56130.80c 4.3644E-13
      56132.80c 4.1585E-13
      56134.80c 9.9515E-12
      56135.80c 2.7141E-11
      56136.80c 3.2337E-11
      56137.80c 4.6246E-11
      56138.80c 2.9520E-10
      83209.80c 8.8746E-06
       6000.80c 4.7080E-06
      20040.80c 2.7352E-08
      20042.80c 1.8255E-10
      20043.80c 3.8090E-11
      20044.80c 5.8857E-10
      20046.80c 1.1286E-12
      20048.80c 5.2762E-11
      48106.80c 6.2876E-10
      48108.80c 4.4768E-10
      48110.80c 6.2826E-09
      48111.80c 6.4385E-09
      48112.80c 1.2138E-08
      48113.80c 6.1468E-09
      48114.80c 1.4451E-08
      48116.80c 3.7675E-09
      27059.80c 9.5950E-07
      24050.80c 6.6150E-08
      24052.80c 1.2756E-06
      24053.80c 1.4465E-07
      24054.80c 3.6005E-08
      29063.80c 3.0772E-06
      29065.80c 1.3715E-06
      19039.80c 2.6972E-08
      19040.80c 3.3839E-12
      19041.80c 1.9465E-09
       3006.80c 1.2368E-07
       3007.80c 1.5058E-06
      12024.80c 1.1023E-06
      12025.80c 1.3956E-07
      12026.80c 1.5365E-07
      25055.80c 1.1527E-05
      42092.80c 8.7461E-09
      42094.80c 5.4516E-09
      42095.80c 9.3826E-09
      42096.80c 9.8305E-09
      42097.80c 5.6284E-09
      42098.80c 1.4221E-08
      42100.80c 5.6755E-09
      11023.80c 1.3281E-05
      28058.80c 1.3115E-05
      28060.80c 5.0519E-06
      28061.80c 2.1960E-07
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      28062.80c 7.0019E-07
      28064.80c 1.7832E-07
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      51123.80c 1.5103E-06
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      22047.80c 1.7565E-08
      22048.80c 1.7404E-07
      22049.80c 1.2772E-08
      22050.80c 1.2229E-08
       8016.80c 1.4131E-05
       8017.80c 5.3719E-09
       7014.80c 2.4127E-05
       7015.80c 8.8144E-08
c Total 4.8167E-02
c Total 4.8167E-02 rho 18.77852
c
m2752
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      92235.80c 4.4737E-02
      92236.80c 1.1480E-04
      92238.80c 2.6798E-03
      47107.80c 4.3430E-07
      47109.80c 4.0348E-07
      56130.80c 4.3596E-13
      56132.80c 4.1540E-13
      56134.80c 9.9408E-12
      56135.80c 2.7112E-11
      56136.80c 3.2303E-11
      56137.80c 4.6196E-11
      56138.80c 2.9488E-10
      83209.80c 8.8650E-06
       6000.80c 4.7029E-06
      20040.80c 2.7323E-08
      20042.80c 1.8235E-10
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      20044.80c 5.8793E-10
      20046.80c 1.1274E-12
      20048.80c 5.2705E-11
      48106.80c 6.2808E-10
      48108.80c 4.4719E-10
      48110.80c 6.2758E-09
      48111.80c 6.4316E-09
      48112.80c 1.2124E-08
      48113.80c 6.1401E-09
      48114.80c 1.4436E-08
      48116.80c 3.7635E-09
      27059.80c 9.5846E-07
      24050.80c 6.6078E-08
      24052.80c 1.2743E-06
      24053.80c 1.4449E-07
      24054.80c 3.5967E-08
      29063.80c 3.0739E-06
      29065.80c 1.3701E-06
      19039.80c 2.6943E-08
      19040.80c 3.3803E-12
      19041.80c 1.9444E-09
       3006.80c 1.2354E-07
       3007.80c 1.5042E-06
      12024.80c 1.1012E-06
      12025.80c 1.3940E-07
      12026.80c 1.5348E-07
      25055.80c 1.1514E-05
      42092.80c 8.7366E-09
      42094.80c 5.4457E-09
      42095.80c 9.3725E-09
      42096.80c 9.8199E-09
      42097.80c 5.6223E-09
      42098.80c 1.4206E-08
      42100.80c 5.6694E-09
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      28058.80c 1.3101E-05
      28060.80c 5.0465E-06
      28061.80c 2.1937E-07
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      51123.80c 1.5087E-06
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      22047.80c 1.7546E-08
      22048.80c 1.7386E-07
      22049.80c 1.2759E-08
      22050.80c 1.2216E-08
       8016.80c 1.4116E-05
       8017.80c 5.3661E-09
       7014.80c 2.4101E-05
       7015.80c 8.8049E-08
c Total 4.8115E-02
c Total 4.8147E-02 rho 18.75827
c
m2757
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      92235.80c 4.4798E-02
      92236.80c 1.1008E-04
      92238.80c 2.6625E-03
      47107.80c 4.3456E-07
      47109.80c 4.0373E-07
      56130.80c 4.3623E-13
      56132.80c 4.1565E-13
      56134.80c 9.9468E-12
      56135.80c 2.7128E-11
      56136.80c 3.2322E-11
      56137.80c 4.6224E-11
      56138.80c 2.9506E-10
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       6000.80c 4.7058E-06
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      20044.80c 5.8829E-10
      20046.80c 1.1281E-12
      20048.80c 5.2737E-11
      48106.80c 6.2846E-10
      48108.80c 4.4746E-10
      48110.80c 6.2796E-09
      48111.80c 6.4355E-09
      48112.80c 1.2132E-08
      48113.80c 6.1438E-09
      48114.80c 1.4445E-08
      48116.80c 3.7657E-09
      27059.80c 9.5904E-07
      24050.80c 6.6118E-08
      24052.80c 1.2750E-06
      24053.80c 1.4458E-07
      24054.80c 3.5988E-08
      29063.80c 3.0757E-06
      29065.80c 1.3709E-06
      19039.80c 2.6960E-08
      19040.80c 3.3823E-12
      19041.80c 1.9456E-09
       3006.80c 1.2362E-07
       3007.80c 1.5051E-06
      12024.80c 1.1018E-06
      12025.80c 1.3949E-07
      12026.80c 1.5358E-07
      25055.80c 1.1521E-05
      42092.80c 8.7419E-09
      42094.80c 5.4490E-09
      42095.80c 9.3782E-09
      42096.80c 9.8259E-09
      42097.80c 5.6257E-09
      42098.80c 1.4214E-08
      42100.80c 5.6728E-09
      11023.80c 1.3275E-05
      28058.80c 1.3109E-05
      28060.80c 5.0495E-06
      28061.80c 2.1950E-07
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      22047.80c 1.7557E-08
      22048.80c 1.7396E-07
      22049.80c 1.2766E-08
      22050.80c 1.2224E-08
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       8017.80c 5.3694E-09
       7014.80c 2.4116E-05
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c Total 4.8145E-02 rho 18.76964
c
m2751
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      92235.80c 4.4767E-02
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      92238.80c 2.6816E-03
      47107.80c 4.3459E-07
      47109.80c 4.0375E-07
      56130.80c 4.3626E-13
      56132.80c 4.1568E-13
      56134.80c 9.9475E-12
      56135.80c 2.7130E-11
      56136.80c 3.2324E-11
      56137.80c 4.6227E-11
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      83209.80c 8.8710E-06
       6000.80c 4.7061E-06
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      20044.80c 5.8833E-10
      20046.80c 1.1281E-12
      20048.80c 5.2741E-11
      48106.80c 6.2850E-10
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      48114.80c 1.4446E-08
      48116.80c 3.7660E-09
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      24053.80c 1.4459E-07
      24054.80c 3.5991E-08
      29063.80c 3.0759E-06
      29065.80c 1.3710E-06
      19039.80c 2.6961E-08
      19040.80c 3.3825E-12
      19041.80c 1.9457E-09
       3006.80c 1.2363E-07
       3007.80c 1.5052E-06
      12024.80c 1.1019E-06
      12025.80c 1.3950E-07
      12026.80c 1.5359E-07
      25055.80c 1.1522E-05
      42092.80c 8.7425E-09
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      42095.80c 9.3788E-09
      42096.80c 9.8265E-09
      42097.80c 5.6261E-09
      42098.80c 1.4215E-08
      42100.80c 5.6732E-09
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      28060.80c 5.0499E-06
      28061.80c 2.1951E-07
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      22047.80c 1.7558E-08
      22048.80c 1.7397E-07
      22049.80c 1.2767E-08
      22050.80c 1.2224E-08
       8016.80c 1.4126E-05
       8017.80c 5.3697E-09
       7014.80c 2.4117E-05
       7015.80c 8.8108E-08
c Total 4.8147E-02
c Total 4.8147E-02 rho 18.77088
c
m2754
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      92235.80c 4.4843E-02
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      92238.80c 2.6918E-03
      47107.80c 4.3546E-07
      47109.80c 4.0457E-07
      56130.80c 4.3714E-13
      56132.80c 4.1652E-13
      56134.80c 9.9675E-12
      56135.80c 2.7185E-11
      56136.80c 3.2389E-11
      56137.80c 4.6320E-11
      56138.80c 2.9568E-10
      83209.80c 8.8888E-06
       6000.80c 4.7156E-06
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      20042.80c 1.8284E-10
      20043.80c 3.8151E-11
      20044.80c 5.8951E-10
      20046.80c 1.1304E-12
      20048.80c 5.2847E-11
      48106.80c 6.2977E-10
      48108.80c 4.4839E-10
      48110.80c 6.2926E-09
      48111.80c 6.4488E-09
      48112.80c 1.2157E-08
      48113.80c 6.1566E-09
      48114.80c 1.4475E-08
      48116.80c 3.7736E-09
      27059.80c 9.6103E-07
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      24054.80c 3.6063E-08
      29063.80c 3.0821E-06
      29065.80c 1.3737E-06
      19039.80c 2.7016E-08
      19040.80c 3.3893E-12
      19041.80c 1.9496E-09
       3006.80c 1.2388E-07
       3007.80c 1.5082E-06
      12024.80c 1.1041E-06
      12025.80c 1.3978E-07
      12026.80c 1.5390E-07
      25055.80c 1.1545E-05
      42092.80c 8.7601E-09
      42094.80c 5.4603E-09
      42095.80c 9.3976E-09
      42096.80c 9.8463E-09
      42097.80c 5.6374E-09
      42098.80c 1.4244E-08
      42100.80c 5.6846E-09
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      22049.80c 1.2793E-08
      22050.80c 1.2249E-08
       8016.80c 1.4154E-05
       8017.80c 5.3805E-09
       7014.80c 2.4166E-05
       7015.80c 8.8286E-08
c Total 4.8244E-02
c Total 4.8244E-02 rho 18.80864
c
m2756
      92234.80c 4.4928E-04
      92235.80c 4.4823E-02
      92236.80c 1.1975E-04
      92238.80c 2.6788E-03
      47107.80c 4.3490E-07
      47109.80c 4.0404E-07
      56130.80c 4.3657E-13
      56132.80c 4.1598E-13
      56134.80c 9.9546E-12
      56135.80c 2.7150E-11
      56136.80c 3.2347E-11
      56137.80c 4.6260E-11
      56138.80c 2.9529E-10
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       6000.80c 4.7095E-06
      20040.80c 2.7360E-08
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      20043.80c 3.8102E-11
      20044.80c 5.8875E-10
      20046.80c 1.1290E-12
      20048.80c 5.2779E-11
      48106.80c 6.2895E-10
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      48110.80c 6.2845E-09
      48111.80c 6.4405E-09
      48112.80c 1.2141E-08
      48113.80c 6.1487E-09
      48114.80c 1.4456E-08
      48116.80c 3.7687E-09
      27059.80c 9.5979E-07
      24050.80c 6.6170E-08
      24052.80c 1.2760E-06
      24053.80c 1.4469E-07
      24054.80c 3.6017E-08
      29063.80c 3.0781E-06
      29065.80c 1.3720E-06
      19039.80c 2.6981E-08
      19040.80c 3.3850E-12
      19041.80c 1.9471E-09
       3006.80c 1.2372E-07
       3007.80c 1.5063E-06
      12024.80c 1.1027E-06
      12025.80c 1.3960E-07
      12026.80c 1.5370E-07
      25055.80c 1.1530E-05
      42092.80c 8.7488E-09
      42094.80c 5.4533E-09
      42095.80c 9.3855E-09
      42096.80c 9.8336E-09
      42097.80c 5.6301E-09
      42098.80c 1.4226E-08
      42100.80c 5.6773E-09
      11023.80c 1.3285E-05
      28058.80c 1.3119E-05
      28060.80c 5.0535E-06
      28061.80c 2.1967E-07
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      28064.80c 1.7837E-07
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      51123.80c 1.5108E-06
      22046.80c 1.9483E-08
      22047.80c 1.7570E-08
      22048.80c 1.7410E-07
      22049.80c 1.2776E-08
      22050.80c 1.2233E-08
       8016.80c 1.4136E-05
       8017.80c 5.3736E-09
       7014.80c 2.4135E-05
       7015.80c 8.8172E-08
c Total 4.8182E-02
c Total 4.8182E-02 rho 18.78435
c
c ------ "13""-15""" HEU Annulus ------
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      92235.80c 4.4806E-02
      92236.80c 1.2931E-04
      92238.80c 2.6546E-03
      47107.80c 4.3483E-07
      47109.80c 4.0398E-07
      56130.80c 4.3650E-13
      56132.80c 4.1591E-13
      56134.80c 9.9530E-12
      56135.80c 2.7145E-11
      56136.80c 3.2342E-11
      56137.80c 4.6252E-11
      56138.80c 2.9525E-10
      83209.80c 8.8759E-06
       6000.80c 4.7087E-06
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      20042.80c 1.8258E-10
      20043.80c 3.8096E-11
      20044.80c 5.8865E-10
      20046.80c 1.1288E-12
      20048.80c 5.2770E-11
      48106.80c 6.2885E-10
      48108.80c 4.4774E-10
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      48111.80c 6.4394E-09
      48112.80c 1.2139E-08
      48113.80c 6.1476E-09
      48114.80c 1.4453E-08
      48116.80c 3.7681E-09
      27059.80c 9.5963E-07
      24050.80c 6.6159E-08
      24052.80c 1.2758E-06
      24053.80c 1.4467E-07
      24054.80c 3.6011E-08
      29063.80c 3.0776E-06
      29065.80c 1.3717E-06
      19039.80c 2.6976E-08
      19040.80c 3.3844E-12
      19041.80c 1.9468E-09
       3006.80c 1.2370E-07
       3007.80c 1.5060E-06
      12024.80c 1.1025E-06
      12025.80c 1.3958E-07
      12026.80c 1.5367E-07
      25055.80c 1.1528E-05
      42092.80c 8.7473E-09
      42094.80c 5.4524E-09
      42095.80c 9.3839E-09
      42096.80c 9.8319E-09
      42097.80c 5.6292E-09
      42098.80c 1.4223E-08
      42100.80c 5.6763E-09
      11023.80c 1.3283E-05
      28058.80c 1.3117E-05
      28060.80c 5.0526E-06
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      28062.80c 7.0029E-07
      28064.80c 1.7834E-07
      51121.80c 2.0196E-06
      51123.80c 1.5105E-06
      22046.80c 1.9480E-08
      22047.80c 1.7567E-08
      22048.80c 1.7407E-07
      22049.80c 1.2774E-08
      22050.80c 1.2231E-08
       8016.80c 1.4133E-05
       8017.80c 5.3727E-09
       7014.80c 2.4131E-05
       7015.80c 8.8157E-08
c Total 4.8174E-02
c Total 4.8174E-02 rho 18.78124
c
m2760
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      92235.80c 4.4787E-02
      92236.80c 1.1493E-04
      92238.80c 2.6780E-03
      47107.80c 4.3478E-07
      47109.80c 4.0393E-07
      56130.80c 4.3645E-13
      56132.80c 4.1586E-13
      56134.80c 9.9518E-12
      56135.80c 2.7142E-11
      56136.80c 3.2338E-11
      56137.80c 4.6247E-11
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      83209.80c 8.8748E-06
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      20044.80c 5.8858E-10
      20046.80c 1.1286E-12
      20048.80c 5.2764E-11
      48106.80c 6.2878E-10
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      48111.80c 6.4387E-09
      48112.80c 1.2138E-08
      48113.80c 6.1469E-09
      48114.80c 1.4452E-08
      48116.80c 3.7676E-09
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      24053.80c 1.4465E-07
      24054.80c 3.6006E-08
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      29065.80c 1.3716E-06
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      19040.80c 3.3840E-12
      19041.80c 1.9466E-09
       3006.80c 1.2368E-07
       3007.80c 1.5058E-06
      12024.80c 1.1024E-06
      12025.80c 1.3956E-07
      12026.80c 1.5365E-07
      25055.80c 1.1527E-05
      42092.80c 8.7463E-09
      42094.80c 5.4517E-09
      42095.80c 9.3828E-09
      42096.80c 9.8307E-09
      42097.80c 5.6285E-09
      42098.80c 1.4222E-08
      42100.80c 5.6757E-09
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      28058.80c 1.3115E-05
      28060.80c 5.0520E-06
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      51121.80c 2.0193E-06
      51123.80c 1.5103E-06
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      22047.80c 1.7565E-08
      22048.80c 1.7405E-07
      22049.80c 1.2773E-08
      22050.80c 1.2230E-08
       8016.80c 1.4132E-05
       8017.80c 5.3721E-09
       7014.80c 2.4128E-05
       7015.80c 8.8146E-08
c Total 4.8168E-02
c Total 4.8168E-02 rho 18.77899
c
m2786
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      92235.80c 4.5112E-02
      92236.80c 1.1575E-04
      92238.80c 2.6972E-03
      47107.80c 4.3789E-07
      47109.80c 4.0682E-07
      56130.80c 4.3957E-13
      56132.80c 4.1883E-13
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      56135.80c 2.7336E-11
      56136.80c 3.2570E-11
      56137.80c 4.6578E-11
      56138.80c 2.9732E-10
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      20046.80c 1.1367E-12
      20048.80c 5.3141E-11
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      48108.80c 4.5089E-10
      48110.80c 6.3277E-09
      48111.80c 6.4847E-09
      48112.80c 1.2225E-08
      48113.80c 6.1909E-09
      48114.80c 1.4555E-08
      48116.80c 3.7946E-09
      27059.80c 9.6638E-07
      24050.80c 6.6624E-08
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      24053.80c 1.4568E-07
      24054.80c 3.6264E-08
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      29065.80c 1.3814E-06
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      19041.80c 1.9605E-09
       3006.80c 1.2457E-07
       3007.80c 1.5166E-06
      12024.80c 1.1103E-06
      12025.80c 1.4056E-07
      12026.80c 1.5475E-07
      25055.80c 1.1610E-05
      42092.80c 8.8089E-09
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      42096.80c 9.9011E-09
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      42098.80c 1.4323E-08
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      28058.80c 1.3209E-05
      28060.80c 5.0882E-06
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      28062.80c 7.0522E-07
      28064.80c 1.7960E-07
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      51123.80c 1.5212E-06
      22046.80c 1.9617E-08
      22047.80c 1.7691E-08
      22048.80c 1.7529E-07
      22049.80c 1.2864E-08
      22050.80c 1.2317E-08
       8016.80c 1.4233E-05
       8017.80c 5.4105E-09
       7014.80c 2.4300E-05
       7015.80c 8.8777E-08
c Total 4.8513E-02
c Total 4.8513E-02 rho 18.91332
c
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      92235.80c 4.4968E-02
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      92238.80c 2.6832E-03
      47107.80c 4.3640E-07
      47109.80c 4.0543E-07
      56130.80c 4.3807E-13
      56132.80c 4.1741E-13
      56134.80c 9.9889E-12
      56135.80c 2.7243E-11
      56136.80c 3.2459E-11
      56137.80c 4.6419E-11
      56138.80c 2.9631E-10
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      20044.80c 5.9077E-10
      20046.80c 1.1328E-12
      20048.80c 5.2960E-11
      48106.80c 6.3112E-10
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      48111.80c 6.4626E-09
      48112.80c 1.2183E-08
      48113.80c 6.1698E-09
      48114.80c 1.4506E-08
      48116.80c 3.7817E-09
      27059.80c 9.6309E-07
      24050.80c 6.6398E-08
      24052.80c 1.2804E-06
      24053.80c 1.4519E-07
      24054.80c 3.6140E-08
      29063.80c 3.0887E-06
      29065.80c 1.3767E-06
      19039.80c 2.7074E-08
      19040.80c 3.3966E-12
      19041.80c 1.9538E-09
       3006.80c 1.2414E-07
       3007.80c 1.5115E-06
      12024.80c 1.1065E-06
      12025.80c 1.4008E-07
      12026.80c 1.5423E-07
      25055.80c 1.1570E-05
      42092.80c 8.7789E-09
      42094.80c 5.4720E-09
      42095.80c 9.4178E-09
      42096.80c 9.8674E-09
      42097.80c 5.6495E-09
      42098.80c 1.4275E-08
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      28058.80c 1.3164E-05
      28060.80c 5.0708E-06
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      51123.80c 1.5160E-06
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      22047.80c 1.7631E-08
      22048.80c 1.7470E-07
      22049.80c 1.2820E-08
      22050.80c 1.2275E-08
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       8017.80c 5.3921E-09
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c Total 4.8348E-02 rho 18.84893
c
m2761
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      92235.80c 4.4767E-02
      92236.80c 1.2925E-04
      92238.80c 2.6819E-03
      47107.80c 4.3464E-07
      47109.80c 4.0380E-07
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      56132.80c 4.1573E-13
      56134.80c 9.9486E-12
      56135.80c 2.7133E-11
      56136.80c 3.2328E-11
      56137.80c 4.6232E-11
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      83209.80c 8.8720E-06
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      20044.80c 5.8839E-10
      20046.80c 1.1283E-12
      20048.80c 5.2747E-11
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      48113.80c 6.1449E-09
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      24053.80c 1.4460E-07
      24054.80c 3.5995E-08
      29063.80c 3.0763E-06
      29065.80c 1.3711E-06
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      19041.80c 1.9460E-09
       3006.80c 1.2364E-07
       3007.80c 1.5054E-06
      12024.80c 1.1020E-06
      12025.80c 1.3951E-07
      12026.80c 1.5360E-07
      25055.80c 1.1523E-05
      42092.80c 8.7435E-09
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      42095.80c 9.3798E-09
      42096.80c 9.8276E-09
      42097.80c 5.6267E-09
      42098.80c 1.4217E-08
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      22048.80c 1.7399E-07
      22049.80c 1.2769E-08
      22050.80c 1.2226E-08
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c Total 4.8153E-02 rho 18.77300
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      92238.80c 2.6726E-03
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      47109.80c 4.0311E-07
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      56137.80c 4.6153E-11
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      48116.80c 3.7600E-09
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      24054.80c 3.5933E-08
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      12024.80c 1.1001E-06
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      42096.80c 9.8108E-09
      42097.80c 5.6171E-09
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      22048.80c 1.7370E-07
      22049.80c 1.2747E-08
      22050.80c 1.2205E-08
       8016.80c 1.4103E-05
       8017.80c 5.3612E-09
       7014.80c 2.4079E-05
       7015.80c 8.7968E-08
c Total 4.8071E-02
c Total 4.8071E-02 rho 18.74094
c
m2848
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      92235.80c 4.4663E-02
      92236.80c 1.1455E-04
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      47109.80c 4.0260E-07
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      56137.80c 4.6095E-11
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      83209.80c 8.8457E-06
       6000.80c 4.6926E-06
      20040.80c 2.7263E-08
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      20044.80c 5.8665E-10
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      48110.80c 6.2621E-09
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      48112.80c 1.2098E-08
      48113.80c 6.1267E-09
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      24052.80c 1.2715E-06
      24053.80c 1.4417E-07
      24054.80c 3.5888E-08
      29063.80c 3.0671E-06
      29065.80c 1.3671E-06
      19039.80c 2.6884E-08
      19040.80c 3.3729E-12
      19041.80c 1.9402E-09
       3006.80c 1.2327E-07
       3007.80c 1.5009E-06
      12024.80c 1.0988E-06
      12025.80c 1.3910E-07
      12026.80c 1.5315E-07
      25055.80c 1.1489E-05
      42092.80c 8.7176E-09
      42094.80c 5.4338E-09
      42095.80c 9.3520E-09
      42096.80c 9.7984E-09
      42097.80c 5.6100E-09
      42098.80c 1.4175E-08
      42100.80c 5.6570E-09
      11023.80c 1.3238E-05
      28058.80c 1.3072E-05
      28060.80c 5.0354E-06
```

```
      28061.80c 2.1889E-07
      28062.80c 6.9791E-07
      28064.80c 1.7774E-07
      51121.80c 2.0127E-06
      51123.80c 1.5054E-06
      22046.80c 1.9414E-08
      22047.80c 1.7508E-08
      22048.80c 1.7348E-07
      22049.80c 1.2731E-08
      22050.80c 1.2189E-08
       8016.80c 1.4085E-05
       8017.80c 5.3544E-09
       7014.80c 2.4049E-05
       7015.80c 8.7857E-08
c Total 4.8010E-02
c Total 4.8010E-02 rho 18.71729
c
m2735
      92234.80c 4.7169E-04
      92235.80c 4.4629E-02
      92236.80c 1.1931E-04
      92238.80c 2.6736E-03
      47107.80c 4.3329E-07
      47109.80c 4.0255E-07
      56130.80c 4.3496E-13
      56132.80c 4.1444E-13
      56134.80c 9.9178E-12
      56135.80c 2.7049E-11
      56136.80c 3.2228E-11
      56137.80c 4.6089E-11
      56138.80c 2.9420E-10
      83209.80c 8.8445E-06
       6000.80c 4.6921E-06
      20040.80c 2.7259E-08
      20042.80c 1.8193E-10
      20043.80c 3.7961E-11
      20044.80c 5.8657E-10
      20046.80c 1.1248E-12
      20048.80c 5.2584E-11
      48106.80c 6.2663E-10
      48108.80c 4.4616E-10
      48110.80c 6.2613E-09
      48111.80c 6.4167E-09
      48112.80c 1.2096E-08
      48113.80c 6.1259E-09
      48114.80c 1.4402E-08
      48116.80c 3.7548E-09
      27059.80c 9.5625E-07
      24050.80c 6.5926E-08
      24052.80c 1.2713E-06
      24053.80c 1.4416E-07
      24054.80c 3.5884E-08
      29063.80c 3.0667E-06
      29065.80c 1.3669E-06
      19039.80c 2.6881E-08
      19040.80c 3.3724E-12
      19041.80c 1.9399E-09
       3006.80c 1.2326E-07
       3007.80c 1.5007E-06
      12024.80c 1.0986E-06
      12025.80c 1.3908E-07
      12026.80c 1.5313E-07
      25055.80c 1.1488E-05
      42092.80c 8.7165E-09
      42094.80c 5.4331E-09
      42095.80c 9.3508E-09
      42096.80c 9.7972E-09
      42097.80c 5.6093E-09
      42098.80c 1.4173E-08
      42100.80c 5.6563E-09
      11023.80c 1.3236E-05
      28058.80c 1.3071E-05
      28060.80c 5.0348E-06
```

```
      28061.80c 2.1886E-07
      28062.80c 6.9782E-07
      28064.80c 1.7771E-07
      51121.80c 2.0124E-06
      51123.80c 1.5052E-06
      22046.80c 1.9411E-08
      22047.80c 1.7505E-08
      22048.80c 1.7345E-07
      22049.80c 1.2729E-08
      22050.80c 1.2188E-08
       8016.80c 1.4083E-05
       8017.80c 5.3537E-09
       7014.80c 2.4046E-05
       7015.80c 8.7846E-08
c Total 4.8004E-02
c Total 4.8004E-02 rho 18.71491
c
c --- Control Cards ------------------------------------------------------
mode n
kcode 100000 1.00 150 2150
ksrc 12 0 0.1 -12 0 0.1
kopts blocksize=10 kinetics=yes precursor=yes
print
```

Experiment 3 Configuration (Detailed Model), Table 49.

```
ORALLOY (93.15 235U) METAL ANNULI WHITH INTERNAL GRAPHITE CYLINDER
c Case "3," HEU Annuli 13-7 inches.
c
c LIU XIAOBO - Idaho National Laboratory & INPC
c Last Updated: March"20," 2015
c
c
c Cell Cards ************************************************************
c ------ Graphite "Center-7""" ------
1003 1003 8.4552E-02 -1003 imp:n=1 $ Top/Upper
1007 1007 8.5188E-02 -1007 imp:n=1
1027 1027 8.5718E-02 -1027 imp:n=1 $ Bottom/Upper
1015 1015 8.4632E-02 -1015 imp:n=1 $ Top/Lower
1036 1036 8.4671E-02 -1036 imp:n=1 $ Bottom/Lower
c
c ------ "7""-9""" HEU Annulus ------
2775 2775 4.8217E-02 9775 -2775 imp:n=1 $ Top/Upper
2738 2738 4.8154E-02 9738 -2738 imp:n=1
2762 2762 4.8191E-02 9762 -2762 imp:n=1 $ Bottom/Upper
2740 2740 4.8185E-02 9740 -2740 imp:n=1 $ Top/Lower
2741 2741 4.8168E-02 9741 -2741 imp:n=1 $ Bottom/Lower
c
c ------ "9""-11""" HEU Annulus ------
2779 2779 4.8090E-02 9779 -2779 imp:n=1 $ Top/Upper
2745 2745 4.8163E-02 9745 -2745 imp:n=1
2776 2776 4.8103E-02 9776 -2776 imp:n=1 $ Bottom/Upper
2747 2747 4.8081E-02 9747 -2747 imp:n=1 $ Top/Lower
2748 2748 4.8157E-02 9748 -2748 imp:n=1 $ Bottom/Lower
c
c ------ "11""-13""" HEU Annulus ------
2782 2782 4.8252E-02 9782 -2782 imp:n=1 $ Top/Upper
2749 2749 4.8151E-02 9749 -2749 imp:n=1
2781 2781 4.8193E-02 9781 -2781 imp:n=1
2754 2754 4.8244E-02 9754 -2754 imp:n=1
2756 2756 4.8182E-02 9756 -2756 imp:n=1 $ Bottom/Upper
2780 2780 4.8035E-02 9780 -2780 imp:n=1 $ Top/Lower
2750 2750 4.8127E-02 9750 -2750 imp:n=1
2753 2753 4.8039E-02 9753 -2753 imp:n=1
2751 2751 4.8147E-02 9751 -2751 imp:n=1
2752 2752 4.8115E-02 9752 -2752 imp:n=1
2757 2757 4.8145E-02 9757 -2757 imp:n=1 $ Bottom/Lower
c
c ------ Void Spaces------
9990 0 #1003 #1007 #1027 #1015 #1036
      #2775 #2738 #2762 #2740 #2741
      #2779 #2745 #2776 #2747 #2748
      #2782 #2749 #2781 #2754 #2756 #2780 #2750 #2753 #2751 #2752 #2757
      -9999 imp:n=1 $ Gaps
9991 0 9999 imp:n=0 $ The Great Void

c Surface Cards *********************************************************
c ------ Graphite "Center-7""" ------
1003  rcc 0 0 5.091309  0 0 0.635000  8.888095  $ Top/Upper 5.726309
1007  rcc 0 0 3.815655  0 0 1.270000  8.888095
1027  rcc 0 0 0.000000  0 0 3.810000  8.888095  $ Bottom/Upper
1015 10 rcc 0 0 5.085655  0 0 2.540000  8.888095  $ Top/Lower 7.625655
1036 10 rcc 0 0 0.000000  0 0 5.080000  8.888095  $ Bottom/Lower
c
c ------ "7""-9""" HEU Annulus ------
c --------- Outer Surfaces ---------
2775  rcc 0 0 5.082286  0 0 0.631190  11.425873  $ Top/Upper 5.713476
2738  rcc 0 0 2.538667  0 0 2.543048  11.424603
2762  rcc 0 0 0.000000  0 0 2.538095  11.425238  $ Bottom/Upper
2740 10 rcc 0 0 3.816668  0 0 3.810000  11.425238  $ Top/Lower 7.626668
2741 10 rcc 0 0 0.000000  0 0 3.810762  11.425555  $ Bottom/Lower
c --------- Inner Surfaces ---------
9775 cz 8.895080
9738 cz 8.894763
9762 cz 8.894763
9740 cz 8.893175
9741 cz 8.893175
```

```
c
c ------ "9""-11""" HEU Annulus ------
c --------- Outer Surfaces ---------
2779  rcc 0 0 5.081270  0 0 0.637540  13.966190  $ Top/Upper 5.718810
2745  rcc 0 0 2.543810  0 0 2.537460  13.965555
2776  rcc 0 0 0.000000  0 0 2.543810  13.965555  $ Bottom/Upper
2747 10 rcc 0 0 3.821049  0 0 3.809746  13.965936  $ Top/Lower 7.630795
2748 10 rcc 0 0 0.000000  0 0 3.810000  13.966825  $ Bottom/Lower
c --------- Inner Surfaces ---------
9779 cz 11.431905
9745 cz 11.431270
9776 cz 11.431905
9747 cz 11.432540
9748 cz 11.433175
c
c ------ "11""-13""" HEU Annulus ------
c --------- Outer Surfaces ---------
2782  rcc 0 0 5.098415  0 0 0.639445  16.504412  $ Top/Upper 5.737860
2749  rcc 0 0 4.139279  0 0 0.958596  16.504285
2781  rcc 0 0 3.820732  0 0 0.318008  16.505873
2754  rcc 0 0 2.541048  0 0 1.279144  16.504031
2756  rcc 0 0 0.000000  0 0 2.540508  16.505809  $ Bottom/Upper
2780 10 rcc 0 0 7.328154  0 0 0.317119  16.504984  $ Top/Lower 7.645273
2750 10 rcc 0 0 6.374511  0 0 0.953643  16.503015
2753 10 rcc 0 0 5.101209  0 0 1.273302  16.505873
2751 10 rcc 0 0 3.822192  0 0 1.279017  16.504666
2752 10 rcc 0 0 2.543937  0 0 1.278255  16.504285
2757 10 rcc 0 0 0.000000  0 0 2.543937  16.504920  $ Bottom/Lower
c --------- Inner Surfaces ---------
9782 cz 13.974445
9749 cz 13.973810
9781 cz 13.973175
9754 cz 13.975080
9756 cz 13.974572
9780 cz 13.972540
9750 cz 13.971905
9753 cz 13.973810
9751 cz 13.971905
9752 cz 13.973175
9757 cz 13.973175
c
c ------ Problem Boundary ------
9999 rcc 0 0 -8.000000 0.000000  0 20.000000  20.000000
c

c Data Cards ******************************************************************
tr10 0 0 -7.645273
c --- Material Cards ------------------------------------------------------
c ------ Graphite "Center-7""" ------
m1003
       6000.80c 8.4516E-02
      47107.80c 2.4424E-09
      47109.80c 2.2691E-09
      13027.80c 3.2023E-06
       5010.80c 1.4408E-07
       5011.80c 5.7994E-07
      56130.80c 2.3537E-10
      56132.80c 2.2427E-10
      56134.80c 5.3669E-09
      56135.80c 1.4637E-08
      56136.80c 1.7440E-08
      56137.80c 2.4940E-08
      56138.80c 1.5920E-07
       4009.80c 5.6407E-08
      83209.80c 7.2958E-09
      20040.80c 1.2292E-05
      20042.80c 8.2042E-08
      20043.80c 1.7118E-08
      20044.80c 2.6451E-07
      20046.80c 5.0721E-10
      20048.80c 2.3712E-08
      48106.80c 5.6515E-10
      48108.80c 4.0239E-10
```

```
48110.80c 5.6470E-09
48111.80c 5.7871E-09
48112.80c 1.0910E-08
48113.80c 5.5249E-09
48114.80c 1.2989E-08
48116.80c 3.3864E-09
27059.80c 8.6242E-08
24050.80c 4.2470E-09
24052.80c 8.1898E-08
24053.80c 9.2866E-09
24054.80c 2.3116E-09
29063.80c 2.5778E-08
29065.80c 1.1490E-08
26054.80c 3.0105E-07
26056.80c 4.7258E-06
26057.80c 1.0914E-07
26058.80c 1.4524E-08
19039.80c 2.4244E-07
19040.80c 3.0416E-11
19041.80c 1.7496E-08
 3006.80c 5.5583E-09
 3007.80c 6.7673E-08
12024.80c 1.3772E-06
12025.80c 1.7436E-07
12026.80c 1.9197E-07
25055.80c 1.8501E-08
42092.80c 7.8613E-10
42094.80c 4.9000E-10
42095.80c 8.4334E-10
42096.80c 8.8360E-10
42097.80c 5.0590E-10
42098.80c 1.2782E-09
42100.80c 5.1013E-10
11023.80c 4.4213E-07
41093.80c 5.4701E-08
28058.80c 1.7682E-08
28060.80c 6.8112E-09
28061.80c 2.9608E-10
28062.80c 9.4403E-10
28064.80c 2.4042E-10
82204.80c 2.0605E-10
82206.80c 3.5470E-09
82207.80c 3.2526E-09
82208.80c 7.7121E-09
37085.80c 4.2914E-08
37087.80c 1.6548E-08
51121.80c 2.3881E-08
51123.80c 1.7862E-08
14028.80c 8.5765E-06
14029.80c 4.3569E-07
14030.80c 2.8755E-07
50112.80c 1.2461E-10
50114.80c 8.4783E-11
50115.80c 4.3676E-11
50116.80c 1.8678E-09
50117.80c 9.8657E-10
50118.80c 3.1113E-09
50119.80c 1.1035E-09
50120.80c 4.1852E-09
50122.80c 5.9477E-10
50124.80c 7.4378E-10
73180.80c 1.9903E-11
73181.80c 1.6584E-07
22046.80c 2.1008E-08
22047.80c 1.8946E-08
22048.80c 1.8772E-07
22049.80c 1.3776E-08
22050.80c 1.3191E-08
23050.80c 1.9954E-09
23051.80c 7.9616E-07
74180.80c 9.9517E-11
74182.80c 2.1977E-08
74183.80c 1.1867E-08
```

```
      74184.80c 2.5410E-08
      74186.80c 2.3577E-08
      30064.80c 1.8904E-07
      30066.80c 1.0846E-07
      30067.80c 1.5938E-08
      30068.80c 7.2887E-08
      30070.80c 2.4101E-09
      40090.80c 2.8665E-08
      40091.80c 6.2512E-09
      40092.80c 9.5550E-09
      40094.80c 9.6832E-09
      40096.80c 1.5600E-09
c Total 8.4552E-02
c Total 8.4552E-02 rho 1.687873
mt1003 grph.20t
c
m1007
       6000.80c 8.5151E-02
      47107.80c 2.4607E-09
      47109.80c 2.2862E-09
      13027.80c 3.2264E-06
       5010.80c 1.4516E-07
       5011.80c 5.8430E-07
      56130.80c 2.3714E-10
      56132.80c 2.2595E-10
      56134.80c 5.4072E-09
      56135.80c 1.4747E-08
      56136.80c 1.7571E-08
      56137.80c 2.5128E-08
      56138.80c 1.6040E-07
       4009.80c 5.6831E-08
      83209.80c 7.3507E-09
      20040.80c 1.2385E-05
      20042.80c 8.2658E-08
      20043.80c 1.7247E-08
      20044.80c 2.6650E-07
      20046.80c 5.1103E-10
      20048.80c 2.3890E-08
      48106.80c 5.6940E-10
      48108.80c 4.0541E-10
      48110.80c 5.6894E-09
      48111.80c 5.8306E-09
      48112.80c 1.0992E-08
      48113.80c 5.5664E-09
      48114.80c 1.3087E-08
      48116.80c 3.4118E-09
      27059.80c 8.6891E-08
      24050.80c 4.2789E-09
      24052.80c 8.2514E-08
      24053.80c 9.3564E-09
      24054.80c 2.3290E-09
      29063.80c 2.5972E-08
      29065.80c 1.1576E-08
      26054.80c 3.0331E-07
      26056.80c 4.7613E-06
      26057.80c 1.0996E-07
      26058.80c 1.4634E-08
      19039.80c 2.4426E-07
      19040.80c 3.0644E-11
      19041.80c 1.7628E-08
       3006.80c 5.6001E-09
       3007.80c 6.8182E-08
      12024.80c 1.3876E-06
      12025.80c 1.7567E-07
      12026.80c 1.9341E-07
      25055.80c 1.8640E-08
      42092.80c 7.9204E-10
      42094.80c 4.9369E-10
      42095.80c 8.4968E-10
      42096.80c 8.9024E-10
      42097.80c 5.0970E-10
      42098.80c 1.2879E-09
      42100.80c 5.1397E-10
```

```
      11023.80c 4.4545E-07
      41093.80c 5.5112E-08
      28058.80c 1.7815E-08
      28060.80c 6.8624E-09
      28061.80c 2.9831E-10
      28062.80c 9.5113E-10
      28064.80c 2.4222E-10
      82204.80c 2.0760E-10
      82206.80c 3.5736E-09
      82207.80c 3.2771E-09
      82208.80c 7.7701E-09
      37085.80c 4.3237E-08
      37087.80c 1.6673E-08
      51121.80c 2.4061E-08
      51123.80c 1.7996E-08
      14028.80c 8.6409E-06
      14029.80c 4.3897E-07
      14030.80c 2.8971E-07
      50112.80c 1.2554E-10
      50114.80c 8.5420E-11
      50115.80c 4.4004E-11
      50116.80c 1.8818E-09
      50117.80c 9.9398E-10
      50118.80c 3.1347E-09
      50119.80c 1.1118E-09
      50120.80c 4.2167E-09
      50122.80c 5.9924E-10
      50124.80c 7.4937E-10
      73180.80c 2.0053E-11
      73181.80c 1.6709E-07
      22046.80c 2.1166E-08
      22047.80c 1.9088E-08
      22048.80c 1.8913E-07
      22049.80c 1.3880E-08
      22050.80c 1.3290E-08
      23050.80c 2.0104E-09
      23051.80c 8.0215E-07
      74180.80c 1.0027E-10
      74182.80c 2.2142E-08
      74183.80c 1.1957E-08
      74184.80c 2.5601E-08
      74186.80c 2.3754E-08
      30064.80c 1.9046E-07
      30066.80c 1.0927E-07
      30067.80c 1.6058E-08
      30068.80c 7.3435E-08
      30070.80c 2.4283E-09
      40090.80c 2.8881E-08
      40091.80c 6.2982E-09
      40092.80c 9.6269E-09
      40094.80c 9.7560E-09
      40096.80c 1.5717E-09
c Total 8.5188E-02
c Total 8.5188E-02 rho 1.70056
mt1007 grph.20t
c
m1027
       6000.80c 8.5681E-02
      47107.80c 2.4760E-09
      47109.80c 2.3004E-09
      13027.80c 3.2465E-06
       5010.80c 1.4607E-07
       5011.80c 5.8794E-07
      56130.80c 2.3861E-10
      56132.80c 2.2736E-10
      56134.80c 5.4408E-09
      56135.80c 1.4839E-08
      56136.80c 1.7680E-08
      56137.80c 2.5284E-08
      56138.80c 1.6140E-07
       4009.80c 5.7185E-08
      83209.80c 7.3964E-09
      20040.80c 1.2462E-05
```

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20042.80c 8.3173E-08
20043.80c 1.7354E-08
20044.80c 2.6816E-07
20046.80c 5.1420E-10
20048.80c 2.4039E-08
48106.80c 5.7294E-10
48108.80c 4.0793E-10
48110.80c 5.7248E-09
48111.80c 5.8669E-09
48112.80c 1.1060E-08
48113.80c 5.6011E-09
48114.80c 1.3168E-08
48116.80c 3.4330E-09
27059.80c 8.7431E-08
24050.80c 4.3055E-09
24052.80c 8.3027E-08
24053.80c 9.4146E-09
24054.80c 2.3435E-09
29063.80c 2.6133E-08
29065.80c 1.1648E-08
26054.80c 3.0520E-07
26056.80c 4.7909E-06
26057.80c 1.1064E-07
26058.80c 1.4725E-08
19039.80c 2.4578E-07
19040.80c 3.0835E-11
19041.80c 1.7737E-08
 3006.80c 5.6349E-09
 3007.80c 6.8606E-08
12024.80c 1.3962E-06
12025.80c 1.7676E-07
12026.80c 1.9461E-07
25055.80c 1.8756E-08
42092.80c 7.9696E-10
42094.80c 4.9676E-10
42095.80c 8.5496E-10
42096.80c 8.9578E-10
42097.80c 5.1287E-10
42098.80c 1.2959E-09
42100.80c 5.1717E-10
11023.80c 4.4822E-07
41093.80c 5.5455E-08
28058.80c 1.7926E-08
28060.80c 6.9051E-09
28061.80c 3.0016E-10
28062.80c 9.5704E-10
28064.80c 2.4373E-10
82204.80c 2.0889E-10
82206.80c 3.5959E-09
82207.80c 3.2974E-09
82208.80c 7.8184E-09
37085.80c 4.3506E-08
37087.80c 1.6777E-08
51121.80c 2.4211E-08
51123.80c 1.8108E-08
14028.80c 8.6947E-06
14029.80c 4.4170E-07
14030.80c 2.9151E-07
50112.80c 1.2632E-10
50114.80c 8.5952E-11
50115.80c 4.4278E-11
50116.80c 1.8935E-09
50117.80c 1.0002E-09
50118.80c 3.1542E-09
50119.80c 1.1187E-09
50120.80c 4.2429E-09
50122.80c 6.0296E-10
50124.80c 7.5403E-10
73180.80c 2.0178E-11
73181.80c 1.6813E-07
22046.80c 2.1298E-08
22047.80c 1.9207E-08
22048.80c 1.9031E-07
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      22050.80c 1.3372E-08
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      23051.80c 8.0714E-07
      74180.80c 1.0089E-10
      74182.80c 2.2280E-08
      74183.80c 1.2031E-08
      74184.80c 2.5760E-08
      74186.80c 2.3902E-08
      30064.80c 1.9165E-07
      30066.80c 1.0995E-07
      30067.80c 1.6158E-08
      30068.80c 7.3892E-08
      30070.80c 2.4434E-09
      40090.80c 2.9060E-08
      40091.80c 6.3373E-09
      40092.80c 9.6867E-09
      40094.80c 9.8166E-09
      40096.80c 1.5815E-09
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c Total 8.5718E-02 rho 1.71114
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      47109.80c 2.2712E-09
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       5011.80c 5.8049E-07
      56130.80c 2.3559E-10
      56132.80c 2.2448E-10
      56134.80c 5.3719E-09
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      56136.80c 1.7456E-08
      56137.80c 2.4964E-08
      56138.80c 1.5935E-07
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      20043.80c 1.7135E-08
      20044.80c 2.6476E-07
      20046.80c 5.0769E-10
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      48108.80c 4.0276E-10
      48110.80c 5.6523E-09
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      48112.80c 1.0920E-08
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      48114.80c 1.3002E-08
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      24053.80c 9.2953E-09
      24054.80c 2.3138E-09
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      26056.80c 4.7302E-06
      26057.80c 1.0924E-07
      26058.80c 1.4538E-08
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      19040.80c 3.0444E-11
      19041.80c 1.7512E-08
       3006.80c 5.5635E-09
       3007.80c 6.7737E-08
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      12025.80c 1.7452E-07
      12026.80c 1.9215E-07
      25055.80c 1.8519E-08
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      42097.80c 5.0637E-10
      42098.80c 1.2794E-09
      42100.80c 5.1061E-10
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      41093.80c 5.4752E-08
      28058.80c 1.7699E-08
      28060.80c 6.8176E-09
      28061.80c 2.9636E-10
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      28064.80c 2.4064E-10
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      82206.80c 3.5503E-09
      82207.80c 3.2557E-09
      82208.80c 7.7193E-09
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      37087.80c 1.6564E-08
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      51123.80c 1.7879E-08
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      14029.80c 4.3610E-07
      14030.80c 2.8782E-07
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      50114.80c 8.4863E-11
      50115.80c 4.3717E-11
      50116.80c 1.8696E-09
      50117.80c 9.8749E-10
      50118.80c 3.1142E-09
      50119.80c 1.1045E-09
      50120.80c 4.1891E-09
      50122.80c 5.9532E-10
      50124.80c 7.4448E-10
      73180.80c 1.9922E-11
      73181.80c 1.6600E-07
      22046.80c 2.1028E-08
      22047.80c 1.8963E-08
      22048.80c 1.8790E-07
      22049.80c 1.3789E-08
      22050.80c 1.3203E-08
      23050.80c 1.9973E-09
      23051.80c 7.9691E-07
      74180.80c 9.9610E-11
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      74183.80c 1.1879E-08
      74184.80c 2.5434E-08
      74186.80c 2.3599E-08
      30064.80c 1.8922E-07
      30066.80c 1.0856E-07
      30067.80c 1.5953E-08
      30068.80c 7.2956E-08
      30070.80c 2.4124E-09
      40090.80c 2.8692E-08
      40091.80c 6.2570E-09
      40092.80c 9.5640E-09
      40094.80c 9.6923E-09
      40096.80c 1.5615E-09
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c Total 8.4632E-02 rho 1.68946
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      47109.80c 2.2723E-09
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      56132.80c 2.2458E-10
      56134.80c 5.3744E-09
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20042.80c 8.2157E-08
20043.80c 1.7143E-08
20044.80c 2.6488E-07
20046.80c 5.0793E-10
20048.80c 2.3746E-08
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48108.80c 4.0295E-10
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24054.80c 2.3149E-09
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29065.80c 1.1506E-08
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26056.80c 4.7325E-06
26057.80c 1.0929E-07
26058.80c 1.4545E-08
19039.80c 2.4278E-07
19040.80c 3.0459E-11
19041.80c 1.7521E-08
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 3007.80c 6.7769E-08
12024.80c 1.3792E-06
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12026.80c 1.9224E-07
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42096.80c 8.8484E-10
42097.80c 5.0661E-10
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11023.80c 4.4275E-07
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28060.80c 6.8208E-09
28061.80c 2.9650E-10
28062.80c 9.4536E-10
28064.80c 2.4076E-10
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82207.80c 3.2572E-09
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51123.80c 1.7887E-08
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14029.80c 4.3631E-07
14030.80c 2.8795E-07
50112.80c 1.2478E-10
50114.80c 8.4903E-11
50115.80c 4.3738E-11
50116.80c 1.8704E-09
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50118.80c 3.1157E-09
50119.80c 1.1050E-09
50120.80c 4.1911E-09
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      22047.80c 1.8972E-08
      22048.80c 1.8799E-07
      22049.80c 1.3796E-08
      22050.80c 1.3209E-08
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      23051.80c 7.9728E-07
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      74182.80c 2.2008E-08
      74183.80c 1.1884E-08
      74184.80c 2.5446E-08
      74186.80c 2.3610E-08
      30064.80c 1.8931E-07
      30066.80c 1.0861E-07
      30067.80c 1.5960E-08
      30068.80c 7.2990E-08
      30070.80c 2.4135E-09
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c Total 8.4671E-02 rho 1.69025
mt1036 grph.20t
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      92236.80c 1.1504E-04
      92238.80c 2.6760E-03
      47107.80c 4.3522E-07
      47109.80c 4.0434E-07
      56130.80c 4.3689E-13
      56132.80c 4.1628E-13
      56134.80c 9.9618E-12
      56135.80c 2.7169E-11
      56136.80c 3.2371E-11
      56137.80c 4.6294E-11
      56138.80c 2.9551E-10
      83209.80c 8.8838E-06
       6000.80c 4.7129E-06
      20040.80c 2.7380E-08
      20042.80c 1.8274E-10
      20043.80c 3.8130E-11
      20044.80c 5.8918E-10
      20046.80c 1.1298E-12
      20048.80c 5.2817E-11
      48106.80c 6.2941E-10
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      48114.80c 1.4466E-08
      48116.80c 3.7714E-09
      27059.80c 9.6049E-07
      24050.80c 6.6218E-08
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      24053.80c 1.4480E-07
      24054.80c 3.6043E-08
      29063.80c 3.0804E-06
      29065.80c 1.3730E-06
      19039.80c 2.7000E-08
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       3006.80c 1.2381E-07
       3007.80c 1.5074E-06
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      42095.80c 9.3923E-09
      42096.80c 9.8407E-09
      42097.80c 5.6342E-09
      42098.80c 1.4236E-08
      42100.80c 5.6814E-09
      11023.80c 1.3295E-05
      28058.80c 1.3129E-05
      28060.80c 5.0571E-06
      28061.80c 2.1983E-07
      28062.80c 7.0091E-07
      28064.80c 1.7850E-07
      51121.80c 2.0214E-06
      51123.80c 1.5119E-06
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      22048.80c 1.7422E-07
      22049.80c 1.2786E-08
      22050.80c 1.2242E-08
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c Total 4.8217E-02
c Total 4.8217E-02 rho 18.79795
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m2762
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      92238.80c 2.6745E-03
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      47109.80c 4.0412E-07
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      56132.80c 4.1605E-13
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      56135.80c 2.7155E-11
      56136.80c 3.2353E-11
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      20044.80c 5.8886E-10
      20046.80c 1.1292E-12
      20048.80c 5.2788E-11
      48106.80c 6.2907E-10
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      48113.80c 6.1498E-09
      48114.80c 1.4459E-08
      48116.80c 3.7694E-09
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      24054.80c 3.6023E-08
      29063.80c 3.0787E-06
      29065.80c 1.3722E-06
      19039.80c 2.6986E-08
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      42096.80c 9.8353E-09
      42097.80c 5.6311E-09
      42098.80c 1.4228E-08
      42100.80c 5.6783E-09
      11023.80c 1.3288E-05
      28058.80c 1.3122E-05
      28060.80c 5.0544E-06
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      28062.80c 7.0054E-07
      28064.80c 1.7841E-07
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      51123.80c 1.5111E-06
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      22048.80c 1.7413E-07
      22049.80c 1.2779E-08
      22050.80c 1.2235E-08
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       7015.80c 8.8188E-08
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c Total 4.8191E-02 rho 18.78778
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      47109.80c 4.0381E-07
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      29065.80c 1.3712E-06
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      28064.80c 1.7827E-07
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      51123.80c 1.5099E-06
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      22047.80c 1.7560E-08
      22048.80c 1.7400E-07
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      22050.80c 1.2226E-08
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c Total 4.8134E-02 rho 18.77352
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m2740
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      92238.80c 2.6694E-03
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      47109.80c 4.0406E-07
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      20046.80c 1.1290E-12
      20048.80c 5.2781E-11
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      48112.80c 1.2142E-08
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      48114.80c 1.4457E-08
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      24053.80c 1.4470E-07
      24054.80c 3.6018E-08
      29063.80c 3.0783E-06
      29065.80c 1.3720E-06
      19039.80c 2.6982E-08
      19040.80c 3.3851E-12
      19041.80c 1.9472E-09
       3006.80c 1.2372E-07
       3007.80c 1.5063E-06
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      42097.80c 5.6304E-09
      42098.80c 1.4226E-08
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      28062.80c 7.0044E-07
      28064.80c 1.7838E-07
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      51123.80c 1.5109E-06
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      22047.80c 1.7571E-08
      22048.80c 1.7411E-07
      22049.80c 1.2777E-08
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       7015.80c 8.8176E-08
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c Total 4.8185E-02 rho 18.78530
c
m2741
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      92235.80c 4.4810E-02
      92236.80c 1.1971E-04
      92238.80c 2.6638E-03
      47107.80c 4.3477E-07
      47109.80c 4.0393E-07
      56130.80c 4.3644E-13
      56132.80c 4.1586E-13
      56134.80c 9.9517E-12
      56135.80c 2.7142E-11
      56136.80c 3.2338E-11
      56137.80c 4.6247E-11
      56138.80c 2.9521E-10
      83209.80c 8.8748E-06
       6000.80c 4.7081E-06
      20040.80c 2.7353E-08
      20042.80c 1.8256E-10
      20043.80c 3.8091E-11
      20044.80c 5.8858E-10
      20046.80c 1.1286E-12
      20048.80c 5.2763E-11
      48106.80c 6.2877E-10
      48108.80c 4.4769E-10
      48110.80c 6.2827E-09
      48111.80c 6.4386E-09
      48112.80c 1.2138E-08
      48113.80c 6.1469E-09
      48114.80c 1.4452E-08
      48116.80c 3.7676E-09
      27059.80c 9.5951E-07
      24050.80c 6.6151E-08
      24052.80c 1.2757E-06
      24053.80c 1.4465E-07
      24054.80c 3.6006E-08
      29063.80c 3.0772E-06
      29065.80c 1.3716E-06
      19039.80c 2.6973E-08
      19040.80c 3.3840E-12
      19041.80c 1.9466E-09
       3006.80c 1.2368E-07
       3007.80c 1.5058E-06
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      12024.80c 1.1024E-06
      12025.80c 1.3956E-07
      12026.80c 1.5365E-07
      25055.80c 1.1527E-05
      42092.80c 8.7463E-09
      42094.80c 5.4517E-09
      42095.80c 9.3828E-09
      42096.80c 9.8307E-09
      42097.80c 5.6285E-09
      42098.80c 1.4222E-08
      42100.80c 5.6756E-09
      11023.80c 1.3281E-05
      28058.80c 1.3115E-05
      28060.80c 5.0520E-06
      28061.80c 2.1961E-07
      28062.80c 7.0020E-07
      28064.80c 1.7832E-07
      51121.80c 2.0193E-06
      51123.80c 1.5103E-06
      22046.80c 1.9478E-08
      22047.80c 1.7565E-08
      22048.80c 1.7405E-07
      22049.80c 1.2773E-08
      22050.80c 1.2230E-08
       8016.80c 1.4132E-05
       8017.80c 5.3720E-09
       7014.80c 2.4128E-05
       7015.80c 8.8146E-08
c Total 4.8168E-02
c Total 4.8168E-02 rho 18.77890
c
c ------ "9""-11""" HEU Annulus ------
m2779
      92234.80c 4.6289E-04
      92235.80c 4.4728E-02
      92236.80c 1.0996E-04
      92238.80c 2.6784E-03
      47107.80c 4.3407E-07
      47109.80c 4.0327E-07
      56130.80c 4.3573E-13
      56132.80c 4.1518E-13
      56134.80c 9.9355E-12
      56135.80c 2.7098E-11
      56136.80c 3.2285E-11
      56137.80c 4.6171E-11
      56138.80c 2.9473E-10
      83209.80c 8.8603E-06
       6000.80c 4.7004E-06
      20040.80c 2.7308E-08
      20042.80c 1.8226E-10
      20043.80c 3.8029E-11
      20044.80c 5.8762E-10
      20046.80c 1.1268E-12
      20048.80c 5.2677E-11
      48106.80c 6.2775E-10
      48108.80c 4.4696E-10
      48110.80c 6.2724E-09
      48111.80c 6.4281E-09
      48112.80c 1.2118E-08
      48113.80c 6.1369E-09
      48114.80c 1.4428E-08
      48116.80c 3.7615E-09
      27059.80c 9.5795E-07
      24050.80c 6.6043E-08
      24052.80c 1.2736E-06
      24053.80c 1.4441E-07
      24054.80c 3.5948E-08
      29063.80c 3.0722E-06
      29065.80c 1.3693E-06
      19039.80c 2.6929E-08
      19040.80c 3.3785E-12
      19041.80c 1.9434E-09
       3006.80c 1.2348E-07
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       3007.80c 1.5034E-06
      12024.80c 1.1006E-06
      12025.80c 1.3933E-07
      12026.80c 1.5340E-07
      25055.80c 1.1508E-05
      42092.80c 8.7320E-09
      42094.80c 5.4428E-09
      42095.80c 9.3675E-09
      42096.80c 9.8147E-09
      42097.80c 5.6193E-09
      42098.80c 1.4198E-08
      42100.80c 5.6664E-09
      11023.80c 1.3260E-05
      28058.80c 1.3094E-05
      28060.80c 5.0438E-06
      28061.80c 2.1925E-07
      28062.80c 6.9906E-07
      28064.80c 1.7803E-07
      51121.80c 2.0160E-06
      51123.80c 1.5079E-06
      22046.80c 1.9446E-08
      22047.80c 1.7537E-08
      22048.80c 1.7376E-07
      22049.80c 1.2752E-08
      22050.80c 1.2210E-08
       8016.80c 1.4109E-05
       8017.80c 5.3633E-09
       7014.80c 2.4088E-05
       7015.80c 8.8002E-08
c Total 4.8090E-02
c Total 4.8090E-02 rho 18.74829
c
m2745
      92234.80c 4.6359E-04
      92235.80c 4.4815E-02
      92236.80c 1.0534E-04
      92238.80c 2.6682E-03
      47107.80c 4.3473E-07
      47109.80c 4.0388E-07
      56130.80c 4.3640E-13
      56132.80c 4.1581E-13
      56134.80c 9.9506E-12
      56135.80c 2.7139E-11
      56136.80c 3.2334E-11
      56137.80c 4.6241E-11
      56138.80c 2.9518E-10
      83209.80c 8.8738E-06
       6000.80c 4.7076E-06
      20040.80c 2.7350E-08
      20042.80c 1.8254E-10
      20043.80c 3.8087E-11
      20044.80c 5.8851E-10
      20046.80c 1.1285E-12
      20048.80c 5.2757E-11
      48106.80c 6.2870E-10
      48108.80c 4.4764E-10
      48110.80c 6.2820E-09
      48111.80c 6.4379E-09
      48112.80c 1.2136E-08
      48113.80c 6.1462E-09
      48114.80c 1.4450E-08
      48116.80c 3.7672E-09
      27059.80c 9.5941E-07
      24050.80c 6.6144E-08
      24052.80c 1.2755E-06
      24053.80c 1.4463E-07
      24054.80c 3.6002E-08
      29063.80c 3.0769E-06
      29065.80c 1.3714E-06
      19039.80c 2.6970E-08
      19040.80c 3.3836E-12
      19041.80c 1.9463E-09
       3006.80c 1.2367E-07
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       3007.80c 1.5057E-06
      12024.80c 1.1022E-06
      12025.80c 1.3954E-07
      12026.80c 1.5364E-07
      25055.80c 1.1526E-05
      42092.80c 8.7453E-09
      42094.80c 5.4511E-09
      42095.80c 9.3817E-09
      42096.80c 9.8296E-09
      42097.80c 5.6279E-09
      42098.80c 1.4220E-08
      42100.80c 5.6750E-09
      11023.80c 1.3280E-05
      28058.80c 1.3114E-05
      28060.80c 5.0514E-06
      28061.80c 2.1958E-07
      28062.80c 7.0013E-07
      28064.80c 1.7830E-07
      51121.80c 2.0191E-06
      51123.80c 1.5102E-06
      22046.80c 1.9475E-08
      22047.80c 1.7563E-08
      22048.80c 1.7403E-07
      22049.80c 1.2771E-08
      22050.80c 1.2228E-08
       8016.80c 1.4130E-05
       8017.80c 5.3714E-09
       7014.80c 2.4125E-05
       7015.80c 8.8136E-08
c Total 4.8163E-02
c Total 4.8163E-02 rho 18.77680
c
m2776
      92234.80c 4.6302E-04
      92235.80c 4.4740E-02
      92236.80c 1.0999E-04
      92238.80c 2.6792E-03
      47107.80c 4.3419E-07
      47109.80c 4.0338E-07
      56130.80c 4.3586E-13
      56132.80c 4.1530E-13
      56134.80c 9.9383E-12
      56135.80c 2.7105E-11
      56136.80c 3.2294E-11
      56137.80c 4.6184E-11
      56138.80c 2.9481E-10
      83209.80c 8.8628E-06
       6000.80c 4.7018E-06
      20040.80c 2.7316E-08
      20042.80c 1.8231E-10
      20043.80c 3.8040E-11
      20044.80c 5.8779E-10
      20046.80c 1.1271E-12
      20048.80c 5.2692E-11
      48106.80c 6.2792E-10
      48108.80c 4.4708E-10
      48110.80c 6.2742E-09
      48111.80c 6.4300E-09
      48112.80c 1.2121E-08
      48113.80c 6.1386E-09
      48114.80c 1.4432E-08
      48116.80c 3.7625E-09
      27059.80c 9.5822E-07
      24050.80c 6.6062E-08
      24052.80c 1.2739E-06
      24053.80c 1.4445E-07
      24054.80c 3.5958E-08
      29063.80c 3.0731E-06
      29065.80c 1.3697E-06
      19039.80c 2.6937E-08
      19040.80c 3.3794E-12
      19041.80c 1.9439E-09
       3006.80c 1.2351E-07
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       3007.80c 1.5038E-06
      12024.80c 1.1009E-06
      12025.80c 1.3937E-07
      12026.80c 1.5345E-07
      25055.80c 1.1512E-05
      42092.80c 8.7345E-09
      42094.80c 5.4443E-09
      42095.80c 9.3701E-09
      42096.80c 9.8175E-09
      42097.80c 5.6209E-09
      42098.80c 1.4202E-08
      42100.80c 5.6680E-09
      11023.80c 1.3263E-05
      28058.80c 1.3098E-05
      28060.80c 5.0452E-06
      28061.80c 2.1931E-07
      28062.80c 6.9926E-07
      28064.80c 1.7808E-07
      51121.80c 2.0166E-06
      51123.80c 1.5083E-06
      22046.80c 1.9451E-08
      22047.80c 1.7542E-08
      22048.80c 1.7381E-07
      22049.80c 1.2755E-08
      22050.80c 1.2213E-08
       8016.80c 1.4113E-05
       8017.80c 5.3648E-09
       7014.80c 2.4095E-05
       7015.80c 8.8027E-08
c Total 4.8103E-02
c Total 4.8103E-02 rho 18.75360
c
m2747
      92234.80c 4.7245E-04
      92235.80c 4.4720E-02
      92236.80c 9.0820E-05
      92238.80c 2.6874E-03
      47107.80c 4.3399E-07
      47109.80c 4.0320E-07
      56130.80c 4.3566E-13
      56132.80c 4.1511E-13
      56134.80c 9.9339E-12
      56135.80c 2.7093E-11
      56136.80c 3.2280E-11
      56137.80c 4.6164E-11
      56138.80c 2.9468E-10
      83209.80c 8.8588E-06
       6000.80c 4.6996E-06
      20040.80c 2.7303E-08
      20042.80c 1.8223E-10
      20043.80c 3.8023E-11
      20044.80c 5.8752E-10
      20046.80c 1.1266E-12
      20048.80c 5.2669E-11
      48106.80c 6.2764E-10
      48108.80c 4.4688E-10
      48110.80c 6.2714E-09
      48111.80c 6.4271E-09
      48112.80c 1.2116E-08
      48113.80c 6.1358E-09
      48114.80c 1.4426E-08
      48116.80c 3.7608E-09
      27059.80c 9.5779E-07
      24050.80c 6.6032E-08
      24052.80c 1.2734E-06
      24053.80c 1.4439E-07
      24054.80c 3.5942E-08
      29063.80c 3.0717E-06
      29065.80c 1.3691E-06
      19039.80c 2.6924E-08
      19040.80c 3.3779E-12
      19041.80c 1.9431E-09
       3006.80c 1.2346E-07
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       3007.80c 1.5031E-06
      12024.80c 1.1004E-06
      12025.80c 1.3931E-07
      12026.80c 1.5338E-07
      25055.80c 1.1506E-05
      42092.80c 8.7305E-09
      42094.80c 5.4419E-09
      42095.80c 9.3659E-09
      42096.80c 9.8130E-09
      42097.80c 5.6184E-09
      42098.80c 1.4196E-08
      42100.80c 5.6654E-09
      11023.80c 1.3258E-05
      28058.80c 1.3092E-05
      28060.80c 5.0429E-06
      28061.80c 2.1921E-07
      28062.80c 6.9895E-07
      28064.80c 1.7800E-07
      51121.80c 2.0157E-06
      51123.80c 1.5076E-06
      22046.80c 1.9443E-08
      22047.80c 1.7534E-08
      22048.80c 1.7373E-07
      22049.80c 1.2750E-08
      22050.80c 1.2208E-08
       8016.80c 1.4106E-05
       8017.80c 5.3624E-09
       7014.80c 2.4084E-05
       7015.80c 8.7988E-08
c Total 4.8081E-02
c Total 4.8081E-02 rho 18.74516
c
m2748
      92234.80c 4.8285E-04
      92235.80c 4.4757E-02
      92236.80c 1.0533E-04
      92238.80c 2.7012E-03
      47107.80c 4.3468E-07
      47109.80c 4.0384E-07
      56130.80c 4.3635E-13
      56132.80c 4.1576E-13
      56134.80c 9.9495E-12
      56135.80c 2.7136E-11
      56136.80c 3.2331E-11
      56137.80c 4.6236E-11
      56138.80c 2.9514E-10
      83209.80c 8.8728E-06
       6000.80c 4.7070E-06
      20040.80c 2.7346E-08
      20042.80c 1.8251E-10
      20043.80c 3.8083E-11
      20044.80c 5.8845E-10
      20046.80c 1.1284E-12
      20048.80c 5.2751E-11
      48106.80c 6.2863E-10
      48108.80c 4.4758E-10
      48110.80c 6.2813E-09
      48111.80c 6.4372E-09
      48112.80c 1.2135E-08
      48113.80c 6.1455E-09
      48114.80c 1.4448E-08
      48116.80c 3.7668E-09
      27059.80c 9.5930E-07
      24050.80c 6.6136E-08
      24052.80c 1.2754E-06
      24053.80c 1.4462E-07
      24054.80c 3.5998E-08
      29063.80c 3.0765E-06
      29065.80c 1.3713E-06
      19039.80c 2.6967E-08
      19040.80c 3.3832E-12
      19041.80c 1.9461E-09
       3006.80c 1.2365E-07
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       3007.80c 1.5055E-06
      12024.80c 1.1021E-06
      12025.80c 1.3953E-07
      12026.80c 1.5362E-07
      25055.80c 1.1524E-05
      42092.80c 8.7443E-09
      42094.80c 5.4504E-09
      42095.80c 9.3807E-09
      42096.80c 9.8285E-09
      42097.80c 5.6272E-09
      42098.80c 1.4218E-08
      42100.80c 5.6744E-09
      11023.80c 1.3278E-05
      28058.80c 1.3112E-05
      28060.80c 5.0509E-06
      28061.80c 2.1956E-07
      28062.80c 7.0005E-07
      28064.80c 1.7828E-07
      51121.80c 2.0189E-06
      51123.80c 1.5100E-06
      22046.80c 1.9473E-08
      22047.80c 1.7561E-08
      22048.80c 1.7401E-07
      22049.80c 1.2770E-08
      22050.80c 1.2227E-08
       8016.80c 1.4128E-05
       8017.80c 5.3708E-09
       7014.80c 2.4122E-05
       7015.80c 8.8126E-08
c Total 4.8157E-02
c Total 4.8157E-02 rho 18.77466
c
c ------ "11""-13""" HEU Annulus ------
m2782
      92234.80c 4.6445E-04
      92235.80c 4.4898E-02
      92236.80c 1.1033E-04
      92238.80c 2.6684E-03
      47107.80c 4.3553E-07
      47109.80c 4.0463E-07
      56130.80c 4.3720E-13
      56132.80c 4.1658E-13
      56134.80c 9.9690E-12
      56135.80c 2.7189E-11
      56136.80c 3.2394E-11
      56137.80c 4.6327E-11
      56138.80c 2.9572E-10
      83209.80c 8.8901E-06
       6000.80c 4.7163E-06
      20040.80c 2.7400E-08
      20042.80c 1.8287E-10
      20043.80c 3.8157E-11
      20044.80c 5.8960E-10
      20046.80c 1.1306E-12
      20048.80c 5.2855E-11
      48106.80c 6.2986E-10
      48108.80c 4.4846E-10
      48110.80c 6.2936E-09
      48111.80c 6.4498E-09
      48112.80c 1.2159E-08
      48113.80c 6.1575E-09
      48114.80c 1.4477E-08
      48116.80c 3.7741E-09
      27059.80c 9.6118E-07
      24050.80c 6.6266E-08
      24052.80c 1.2779E-06
      24053.80c 1.4490E-07
      24054.80c 3.6069E-08
      29063.80c 3.0826E-06
      29065.80c 1.3739E-06
      19039.80c 2.7020E-08
      19040.80c 3.3898E-12
      19041.80c 1.9499E-09
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        3006.80c 1.2389E-07
        3007.80c 1.5084E-06
       12024.80c 1.1043E-06
       12025.80c 1.3980E-07
       12026.80c 1.5392E-07
       25055.80c 1.1547E-05
       42092.80c 8.7614E-09
       42094.80c 5.4611E-09
       42095.80c 9.3990E-09
       42096.80c 9.8477E-09
       42097.80c 5.6382E-09
       42098.80c 1.4246E-08
       42100.80c 5.6855E-09
       11023.80c 1.3304E-05
       28058.80c 1.3138E-05
       28060.80c 5.0608E-06
       28061.80c 2.1999E-07
       28062.80c 7.0142E-07
       28064.80c 1.7863E-07
       51121.80c 2.0228E-06
       51123.80c 1.5130E-06
       22046.80c 1.9511E-08
       22047.80c 1.7596E-08
       22048.80c 1.7435E-07
       22049.80c 1.2795E-08
       22050.80c 1.2251E-08
        8016.80c 1.4156E-05
        8017.80c 5.3813E-09
        7014.80c 2.4170E-05
        7015.80c 8.8299E-08
c Total 4.8252E-02
c Total 4.8252E-02 rho 18.81144
c
m2749
       92234.80c 4.7313E-04
       92235.80c 4.4799E-02
       92236.80c 1.1967E-04
       92238.80c 2.6486E-03
       47107.80c 4.3461E-07
       47109.80c 4.0378E-07
       56130.80c 4.3628E-13
       56132.80c 4.1570E-13
       56134.80c 9.9481E-12
       56135.80c 2.7132E-11
       56136.80c 3.2326E-11
       56137.80c 4.6230E-11
       56138.80c 2.9510E-10
       83209.80c 8.8715E-06
        6000.80c 4.7064E-06
       20040.80c 2.7342E-08
       20042.80c 1.8249E-10
       20043.80c 3.8077E-11
       20044.80c 5.8836E-10
       20046.80c 1.1282E-12
       20048.80c 5.2744E-11
       48106.80c 6.2854E-10
       48108.80c 4.4752E-10
       48110.80c 6.2804E-09
       48111.80c 6.4363E-09
       48112.80c 1.2133E-08
       48113.80c 6.1446E-09
       48114.80c 1.4446E-08
       48116.80c 3.7662E-09
       27059.80c 9.5916E-07
       24050.80c 6.6127E-08
       24052.80c 1.2752E-06
       24053.80c 1.4460E-07
       24054.80c 3.5993E-08
       29063.80c 3.0761E-06
       29065.80c 1.3711E-06
       19039.80c 2.6963E-08
       19040.80c 3.3827E-12
       19041.80c 1.9458E-09
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        3006.80c 1.2363E-07
        3007.80c 1.5053E-06
       12024.80c 1.1020E-06
       12025.80c 1.3951E-07
       12026.80c 1.5360E-07
       25055.80c 1.1523E-05
       42092.80c 8.7430E-09
       42094.80c 5.4497E-09
       42095.80c 9.3793E-09
       42096.80c 9.8271E-09
       42097.80c 5.6264E-09
       42098.80c 1.4216E-08
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       28058.80c 1.3111E-05
       28060.80c 5.0501E-06
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       28062.80c 6.9995E-07
       28064.80c 1.7826E-07
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       51123.80c 1.5098E-06
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       22050.80c 1.2225E-08
        8016.80c 1.4126E-05
        8017.80c 5.3701E-09
        7014.80c 2.4119E-05
        7015.80c 8.8114E-08
c Total 4.8151E-02
c Total 4.8151E-02 rho 18.77198
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m2781
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       92235.80c 4.4838E-02
       92236.80c 1.1978E-04
       92238.80c 2.6509E-03
       47107.80c 4.3500E-07
       47109.80c 4.0414E-07
       56130.80c 4.3667E-13
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       56134.80c 9.9569E-12
       56135.80c 2.7156E-11
       56136.80c 3.2355E-11
       56137.80c 4.6271E-11
       56138.80c 2.9536E-10
       83209.80c 8.8794E-06
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       48114.80c 1.4459E-08
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       24053.80c 1.4472E-07
       24054.80c 3.6025E-08
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       42095.80c 9.3876E-09
       42096.80c 9.8358E-09
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       28058.80c 1.3122E-05
       28060.80c 5.0546E-06
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       28062.80c 7.0057E-07
       28064.80c 1.7841E-07
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       22047.80c 1.7574E-08
       22048.80c 1.7414E-07
       22049.80c 1.2779E-08
       22050.80c 1.2236E-08
        8016.80c 1.4139E-05
        8017.80c 5.3748E-09
        7014.80c 2.4140E-05
        7015.80c 8.8192E-08
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c Total 4.8193E-02 rho 18.78861
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m2754
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       92235.80c 4.4843E-02
       92236.80c 1.3429E-04
       92238.80c 2.6918E-03
       47107.80c 4.3546E-07
       47109.80c 4.0457E-07
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       56136.80c 3.2389E-11
       56137.80c 4.6320E-11
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       20048.80c 5.2847E-11
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       48111.80c 6.4488E-09
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       48114.80c 1.4475E-08
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       24053.80c 1.4488E-07
       24054.80c 3.6063E-08
       29063.80c 3.0821E-06
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       19040.80c 3.3893E-12
       19041.80c 1.9496E-09
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      12026.80c 1.5390E-07
      25055.80c 1.1545E-05
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      42094.80c 5.4603E-09
      42095.80c 9.3976E-09
      42096.80c 9.8463E-09
      42097.80c 5.6374E-09
      42098.80c 1.4244E-08
      42100.80c 5.6846E-09
      11023.80c 1.3302E-05
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      28060.80c 5.0600E-06
      28061.80c 2.1996E-07
      28062.80c 7.0131E-07
      28064.80c 1.7860E-07
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      51123.80c 1.5127E-06
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      22047.80c 1.7593E-08
      22048.80c 1.7432E-07
      22049.80c 1.2793E-08
      22050.80c 1.2249E-08
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       8017.80c 5.3805E-09
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c Total 4.8244E-02 rho 18.80864
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      47109.80c 4.0404E-07
      56130.80c 4.3657E-13
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      56134.80c 9.9546E-12
      56135.80c 2.7150E-11
      56136.80c 3.2347E-11
      56137.80c 4.6260E-11
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      20044.80c 5.8875E-10
      20046.80c 1.1290E-12
      20048.80c 5.2779E-11
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      48110.80c 6.2845E-09
      48111.80c 6.4405E-09
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      48116.80c 3.7687E-09
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      24053.80c 1.4469E-07
      24054.80c 3.6017E-08
      29063.80c 3.0781E-06
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       12026.80c 1.5370E-07
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       42092.80c 8.7488E-09
       42094.80c 5.4533E-09
       42095.80c 9.3855E-09
       42096.80c 9.8336E-09
       42097.80c 5.6301E-09
       42098.80c 1.4226E-08
       42100.80c 5.6773E-09
       11023.80c 1.3285E-05
       28058.80c 1.3119E-05
       28060.80c 5.0535E-06
       28061.80c 2.1967E-07
       28062.80c 7.0041E-07
       28064.80c 1.7837E-07
       51121.80c 2.0199E-06
       51123.80c 1.5108E-06
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       22047.80c 1.7570E-08
       22048.80c 1.7410E-07
       22049.80c 1.2776E-08
       22050.80c 1.2233E-08
        8016.80c 1.4136E-05
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c Total 4.8182E-02 rho 18.78435
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       47109.80c 4.0281E-07
       56130.80c 4.3524E-13
       56132.80c 4.1471E-13
       56134.80c 9.9243E-12
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       56136.80c 3.2249E-11
       56137.80c 4.6119E-11
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       83209.80c 8.8503E-06
        6000.80c 4.6951E-06
       20040.80c 2.7277E-08
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       20046.80c 1.1255E-12
       20048.80c 5.2618E-11
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       48108.80c 4.4645E-10
       48110.80c 6.2654E-09
       48111.80c 6.4209E-09
       48112.80c 1.2104E-08
       48113.80c 6.1299E-09
       48114.80c 1.4412E-08
       48116.80c 3.7572E-09
       27059.80c 9.5687E-07
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       19040.80c 3.3746E-12
       19041.80c 1.9412E-09
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       12026.80c 1.5323E-07
       25055.80c 1.1495E-05
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       42094.80c 5.4366E-09
       42095.80c 9.3569E-09
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       42098.80c 1.4182E-08
       42100.80c 5.6600E-09
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       28058.80c 1.3079E-05
       28060.80c 5.0381E-06
       28061.80c 2.1900E-07
       28062.80c 6.9827E-07
       28064.80c 1.7783E-07
       51121.80c 2.0137E-06
       51123.80c 1.5062E-06
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       22047.80c 1.7517E-08
       22048.80c 1.7357E-07
       22049.80c 1.2737E-08
       22050.80c 1.2196E-08
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        8017.80c 5.3572E-09
        7014.80c 2.4061E-05
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c Total 4.8035E-02 rho 18.72707
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       56136.80c 3.2310E-11
       56137.80c 4.6207E-11
       56138.80c 2.9496E-10
       83209.80c 8.8672E-06
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       20046.80c 1.1277E-12
       20048.80c 5.2718E-11
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       48108.80c 4.4730E-10
       48110.80c 6.2773E-09
       48111.80c 6.4331E-09
       48112.80c 1.2127E-08
       48113.80c 6.1416E-09
       48114.80c 1.4439E-08
       48116.80c 3.7644E-09
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       24053.80c 1.4453E-07
       24054.80c 3.5975E-08
       29063.80c 3.0746E-06
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       19040.80c 3.3811E-12
       19041.80c 1.9449E-09
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       42095.80c 9.3748E-09
       42096.80c 9.8223E-09
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       42100.80c 5.6708E-09
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       28058.80c 1.3104E-05
       28060.80c 5.0477E-06
       28061.80c 2.1942E-07
       28062.80c 6.9961E-07
       28064.80c 1.7817E-07
       51121.80c 2.0176E-06
       51123.80c 1.5091E-06
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       22047.80c 1.7550E-08
       22048.80c 1.7390E-07
       22049.80c 1.2762E-08
       22050.80c 1.2219E-08
        8016.80c 1.4119E-05
        8017.80c 5.3674E-09
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c Total 4.8127E-02 rho 18.76286
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m2753
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       47109.80c 4.0285E-07
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       20046.80c 1.1256E-12
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       48111.80c 6.4215E-09
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       48113.80c 6.1305E-09
       48114.80c 1.4413E-08
       48116.80c 3.7576E-09
       27059.80c 9.5696E-07
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       24054.80c 3.5910E-08
       29063.80c 3.0690E-06
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       42098.80c 1.4184E-08
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       28062.80c 6.9834E-07
       28064.80c 1.7785E-07
       51121.80c 2.0139E-06
       51123.80c 1.5063E-06
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       22048.80c 1.7358E-07
       22049.80c 1.2739E-08
       22050.80c 1.2197E-08
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m2751
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       47109.80c 4.0375E-07
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       48114.80c 1.4446E-08
       48116.80c 3.7660E-09
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       24053.80c 1.4459E-07
       24054.80c 3.5991E-08
       29063.80c 3.0759E-06
       29065.80c 1.3710E-06
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      28062.80c 6.9991E-07
      28064.80c 1.7825E-07
      51121.80c 2.0185E-06
      51123.80c 1.5097E-06
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      22047.80c 1.7558E-08
      22048.80c 1.7397E-07
      22049.80c 1.2767E-08
      22050.80c 1.2224E-08
       8016.80c 1.4126E-05
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       7015.80c 8.8108E-08
c Total 4.8147E-02 rho 18.77088
c
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      56137.80c 4.6196E-11
      56138.80c 2.9488E-10
      83209.80c 8.8650E-06
       6000.80c 4.7029E-06
      20040.80c 2.7323E-08
      20042.80c 1.8235E-10
      20043.80c 3.8049E-11
      20044.80c 5.8793E-10
      20046.80c 1.1274E-12
      20048.80c 5.2705E-11
      48106.80c 6.2808E-10
      48108.80c 4.4719E-10
      48110.80c 6.2758E-09
      48111.80c 6.4316E-09
      48112.80c 1.2124E-08
      48113.80c 6.1401E-09
      48114.80c 1.4436E-08
      48116.80c 3.7635E-09
      27059.80c 9.5846E-07
      24050.80c 6.6078E-08
      24052.80c 1.2743E-06
      24053.80c 1.4449E-07
      24054.80c 3.5967E-08
      29063.80c 3.0739E-06
      29065.80c 1.3701E-06
      19039.80c 2.6943E-08
      19040.80c 3.3803E-12
      19041.80c 1.9444E-09
       3006.80c 1.2354E-07
       3007.80c 1.5042E-06
```

```
      12024.80c 1.1012E-06
      12025.80c 1.3940E-07
      12026.80c 1.5348E-07
      25055.80c 1.1514E-05
      42092.80c 8.7366E-09
      42094.80c 5.4457E-09
      42095.80c 9.3725E-09
      42096.80c 9.8199E-09
      42097.80c 5.6223E-09
      42098.80c 1.4206E-08
      42100.80c 5.6694E-09
      11023.80c 1.3267E-05
      28058.80c 1.3101E-05
      28060.80c 5.0465E-06
      28061.80c 2.1937E-07
      28062.80c 6.9943E-07
      28064.80c 1.7813E-07
      51121.80c 2.0171E-06
      51123.80c 1.5087E-06
      22046.80c 1.9456E-08
      22047.80c 1.7546E-08
      22048.80c 1.7386E-07
      22049.80c 1.2759E-08
      22050.80c 1.2216E-08
       8016.80c 1.4116E-05
       8017.80c 5.3661E-09
       7014.80c 2.4101E-05
       7015.80c 8.8049E-08
c Total 4.8115E-02 rho 18.75827
c
m2757
      92234.80c 4.6341E-04
      92235.80c 4.4798E-02
      92236.80c 1.1008E-04
      92238.80c 2.6625E-03
      47107.80c 4.3456E-07
      47109.80c 4.0373E-07
      56130.80c 4.3623E-13
      56132.80c 4.1565E-13
      56134.80c 9.9468E-12
      56135.80c 2.7128E-11
      56136.80c 3.2322E-11
      56137.80c 4.6224E-11
      56138.80c 2.9506E-10
      83209.80c 8.8704E-06
       6000.80c 4.7058E-06
      20040.80c 2.7339E-08
      20042.80c 1.8247E-10
      20043.80c 3.8072E-11
      20044.80c 5.8829E-10
      20046.80c 1.1281E-12
      20048.80c 5.2737E-11
      48106.80c 6.2846E-10
      48108.80c 4.4746E-10
      48110.80c 6.2796E-09
      48111.80c 6.4355E-09
      48112.80c 1.2132E-08
      48113.80c 6.1438E-09
      48114.80c 1.4445E-08
      48116.80c 3.7657E-09
      27059.80c 9.5904E-07
      24050.80c 6.6118E-08
      24052.80c 1.2750E-06
      24053.80c 1.4458E-07
      24054.80c 3.5988E-08
      29063.80c 3.0757E-06
      29065.80c 1.3709E-06
      19039.80c 2.6960E-08
      19040.80c 3.3823E-12
      19041.80c 1.9456E-09
       3006.80c 1.2362E-07
       3007.80c 1.5051E-06
      12024.80c 1.1018E-06
```

```
      12025.80c 1.3949E-07
      12026.80c 1.5358E-07
      25055.80c 1.1521E-05
      42092.80c 8.7419E-09
      42094.80c 5.4490E-09
      42095.80c 9.3782E-09
      42096.80c 9.8259E-09
      42097.80c 5.6257E-09
      42098.80c 1.4214E-08
      42100.80c 5.6728E-09
      11023.80c 1.3275E-05
      28058.80c 1.3109E-05
      28060.80c 5.0495E-06
      28061.80c 2.1950E-07
      28062.80c 6.9986E-07
      28064.80c 1.7823E-07
      51121.80c 2.0183E-06
      51123.80c 1.5096E-06
      22046.80c 1.9468E-08
      22047.80c 1.7557E-08
      22048.80c 1.7396E-07
      22049.80c 1.2766E-08
      22050.80c 1.2224E-08
       8016.80c 1.4125E-05
       8017.80c 5.3694E-09
       7014.80c 2.4116E-05
       7015.80c 8.8103E-08
c Total 4.8145E-02 rho 18.76964
c
c --- Control Cards ------------------------------------------------------
mode n
kcode 100000 1 150 2150
ksrc 12 0 0.1 -12 0 0.1
kopts blocksize=10 kinetics=yes precursor=yes
print
```

Experiment 1 Configuration (Simple Model), Table 50.

```
ORALLOY (93.15 235U) METAL ANNULI WHITH INTERNAL GRAPHITE CYLINDER
c Case "1," HEU Annuli 15-9 inches.
c
c LIU XIAOBO - Idaho National Laboratory & INPC
c Last Updated: March"20," 2015
c
c
c Cell Cards ***************************************************************
6 6 8.4543E-02 -6 imp:n=1 $ Graphite "Center-9"""
92 92 4.7838E-02 6.1 -92 imp:n=1 $ "9""-15""" HEU Annulus
c
c ------ Void Spaces------
9990 0 #6 #92 -9999 imp:n=1 $ Boundary
9991 0 9999 imp:n=0 $ The Great Void

c Surface Cards ************************************************************
6 rcc 0 0 0 0 0 13.58476667 11.43 $ Graphite "Center-9"""
92 rcc 0 0 0 0 0 13.58476667 19.05 $ "9""-15""" HEU Annulus
9999 rcc 0 0 -2.00 0 0 17.00 20.00 $ Problem Boundary
c

c Data Cards ***************************************************************
c --- Material Cards -----------------------------------------------------
c ------ Graphite ------
m6
      6000.80c 8.4543E-02
c Total 8.4543E-02 rho 1.6861
mt6 grph.20t
c
c ------ HEU annulus ------
m92
      92234.80c 4.6758E-04
      92235.80c 4.4588E-02
      92236.80c 1.1454E-04
      92238.80c 2.6680E-03
c Total 4.7838E-02 rho 18.6839
c
c --- Control Cards ------------------------------------------------------
mode n
kcode 100000 1 150 2150
ksrc 12 0 0.1 -12 0 0.1
print
```

Experiment 2 Configuration (Simple Model), Table 51.

```
ORALLOY (93.15 235U) METAL ANNULI WHITH INTERNAL GRAPHITE CYLINDER
c Case "2," HEU Annuli 15-7 inches.
c
c LIU XIAOBO - Idaho National Laboratory & INPC
c Last Updated: March"20," 2015
c
c
c Cell Cards ***************************************************************
6 6 8.5390E-02 -6 imp:n=1 $ Graphite "Center-9"""
92 92 4.7784E-02 6.1 -92 imp:n=1 $ "9""-15""" HEU Annulus
c
c ------ Void Spaces------
9990 0 #6 #92 -9999 imp:n=1 $ Boundary
9991 0 9999 imp:n=0 $ The Great Void

c Surface Cards ************************************************************
6 rcc 0 0 0 0 0 10.427237 8.89 $ Graphite "Center-9"""
92 rcc 0 0 0 0 0 10.427237 19.05 $ "9""-15""" HEU Annulus
9999 rcc 0 0 -2.00 0 0 17.00 20.00 $ Problem Boundary
c

c Data Cards ***************************************************************
c --- Material Cards ---------------------------------------------------------
c ------ Graphite ------
m6
      6000.80c  8.5390E-02
c Total 8.5390E-02 rho 1.7029
mt6 grph.20t
c
c ------ HEU annulus ------
m92
      92234.80c  4.6672E-04
      92235.80c  4.4538E-02
      92236.80c  1.1624E-04
      92238.80c  2.6634E-03
c Total 4.7784E-02 rho 18.6629
c
c --- Control Cards ----------------------------------------------------------
mode n
kcode 100000 1 150 2150
ksrc 12 0 0.1 -12 0 0.1
print
```

Experiment 3 Configuration (Simple Model), Table 52.

```
ORALLOY (93.15 235U) METAL ANNULI WHITH INTERNAL GRAPHITE CYLINDER
c Case "3," HEU Annuli 13-7 inches.
c
c LIU XIAOBO - Idaho National Laboratory & INPC
c Last Updated: March"20," 2015
c
c
c Cell Cards ***************************************************************
6 6 8.4720E-02 -6 imp:n=1 $ Graphite "Center-9"""
92 92 4.7834E-02 6.1 -92 imp:n=1 $ "9""-15""" HEU Annulus
c
c ------ Void Spaces------
9990 0 #6 #92 -9999 imp:n=1 $ Boundary
9991 0 9999 imp:n=0 $ The Great Void

c Surface Cards ************************************************************
6 rcc 0 0 0 0 0 13.368655 8.89 $ Graphite "Center-9"""
92 rcc 0 0 0 0 0 13.368655 16.51 $ "9""-15""" HEU Annulus
9999 rcc 0 0 -2 0 0 17 20 $ Problem Boundary
c

c Data Cards ***************************************************************
c --- Material Cards ---------------------------------------------------------
c ------ Graphite ------
m6
      6000.80c  8.4723E-02
c Total 8.4723E-02 rho 1.6896
mt6 grph.20t
c
c ------ HEU annulus ------
m92
      92234.80c  4.6523E-04
      92235.80c  4.4590E-02
      92236.80c  1.1251E-04
      92238.80c  2.6662E-03
c Total 4.7834E-02 rho 18.6825
c
c --- Control Cards ----------------------------------------------------------
mode n
kcode 100000 1 150 2150
ksrc 12 0 0.1 -12 0 0.1
print
```

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.1 neutron cross section library is provided here for the MCNP6-1.0 analysis.

MCNP-Calculated Spectral Data

A summary of the computed neutron spectral data using MCNP6 for the benchmark model is provided in Tables B.1-1, B.1-2 and B.1-3 for Configurations 1, 2 and 3, respectively.

Table B.1-1. Neutron Spectral Data for Benchmark Model for Configuration 1.

Model		**Detailed**	**Simple**
Neutron Cross Section Library		ENDF/B-VII.1	ENDF/B-VII.1
$\mathbf{k_{eff}}$		0.99723	0.99784
$\mathbf{\pm\sigma_k}$		0.00004	0.00004
Neutron Leakage (%)[(a)]		56.82	56.79
Neutron Capture (%)		4.68	4.69
Neutron (x, xn) Reactions (%)		0.24	0.24
Neutron Fission (%)		38.26	38.28
Fission Fraction, by Energy (%)	**Thermal (<0.625 eV)**	0.00	0.00
	Intermediate	6.80	6.81
	Fast (>100 keV)	93.20	93.19
Average Number of Neutrons Produced per Fission		2.594	2.594
Energy of Average Neutron Lethargy Causing Fission (MeV)		0.76205	0.76174
Neutron Generation Time, Λ (nsec)		10.246	10.292
Rossi-α ($nsec^{-1}$)		-6.334E-04	-6.305E-04
$\mathbf{\beta_{eff}}$		0.00649	0.00649

(a) The neutron leakage is calculated using the neutron balance tables provided in the MCNP output file. Similar calculations are performed to evaluate neutron capture, (n, xn), and fission percentages. The sum of neutron balances originally is 100.49% in MCNP output file, but was scaled to 100%.

Table B.1-2. Neutron Spectral Data for Benchmark Model for Configuration 2.

Model		Detailed	Simple
Neutron Cross Section Library		ENDF/B-VII.1	ENDF/B-VII.1
$\mathbf{k_{eff}}$		0.99628	0.99619
$\mathbf{\pm\sigma_k}$		0.00004	0.00004
Neutron Leakage (%)[(a)]		57.03	57.03
Neutron Capture (%)		4.55	4.55
Neutron (x, xn) Reactions (%)		0.25	0.25
Neutron Fission (%)		38.17	38.17
Fission Fraction, by Energy (%)	**Thermal (<0.625 eV)**	0.00	0.00
	Intermediate	5.88	5.87
	Fast (>100 keV)	94.12	94.13
Average Number of Neutrons Produced per Fission		2.597	2.597
Energy of Average Neutron Lethargy Causing Fission (MeV)		0.79860	0.79900
Neutron Generation Time, Λ (nsec)		7.191	7.185
Rossi-α ($nsec^{-1}$)		-9.076E-04	-9.084E-04
$\mathbf{\beta_{eff}}$		0.00653	0.00653

(a) The neutron leakage is calculated using the neutron balance tables provided in the MCNP output file. Similar calculations are performed to evaluate neutron capture, (n, xn), and fission percentages. The sum of neutron balances originally is 100.49% in MCNP output file, but was scaled to 100%.

Table B.1-3. Neutron Spectral Data for Benchmark Model for Configuration 3.

Model		Detailed	Simple
Neutron Cross Section Library		ENDF/B-VII.1	ENDF/B-VII.1
k_{eff}		0.99886	0.99911
$\pm\sigma_k$		0.00004	0.00004
Neutron Leakage (%)[(a)]		56.76	56.76
Neutron Capture (%)		4.68	4.67
Neutron (x, xn) Reactions (%)		0.24	0.24
Neutron Fission (%)		38.32	38.32
Fission Fraction, by Energy (%)	**Thermal (<0.625 eV)**	0.00	0.00
	Intermediate	6.70	6.69
	Fast (>100 keV)	93.30	93.31
Average Number of Neutrons Produced per Fission		2.594	2.594
Energy of Average Neutron Lethargy Causing Fission (MeV)		0.76692	0.76700
Neutron Generation Time, Λ (nsec)		9.261	9.256
Rossi-α ($nsec^{-1}$)		-6.968E-04	-7.024E-04
β_{eff}		0.00645	0.00650

(a) The neutron leakage is calculated using the neutron balance tables provided in the MCNP output file. Similar calculations are performed to evaluate neutron capture, (n, xn), and fission percentages. The sum of neutron balances originally is 100.49% in MCNP output file, but was scaled to 100%.

APPENDIX C: Support Structure Assembly Schematics

Drawings of Diaphragm and Low-Mass Support Structures

Additional drawings were provided by the experimenter[a] to preserve the dimensions of the support structure immediately surrounding the experiment. Figure C-1 represents the diaphragm and rings with its support structure. Figure C-2 represents the low-mass support structure. Both of these structures can be seen in Figure 3. These support structures were used in many other critical experiments with oralloy at ORCEF (see Section 1.0).

[a] Personal communication with John T. Mihalczo, February 2010.

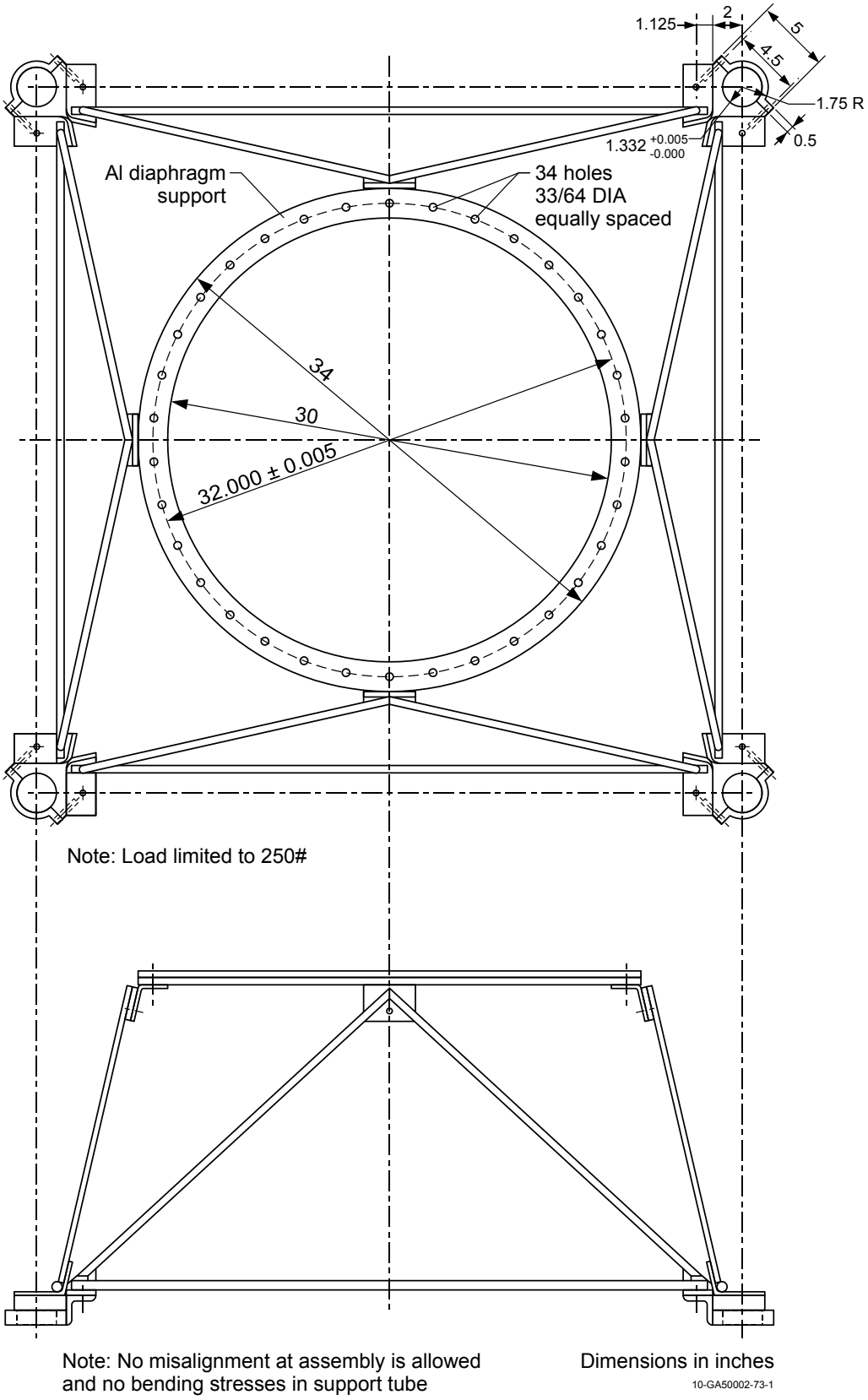

Figure C-1. Diaphragm Support Structure.

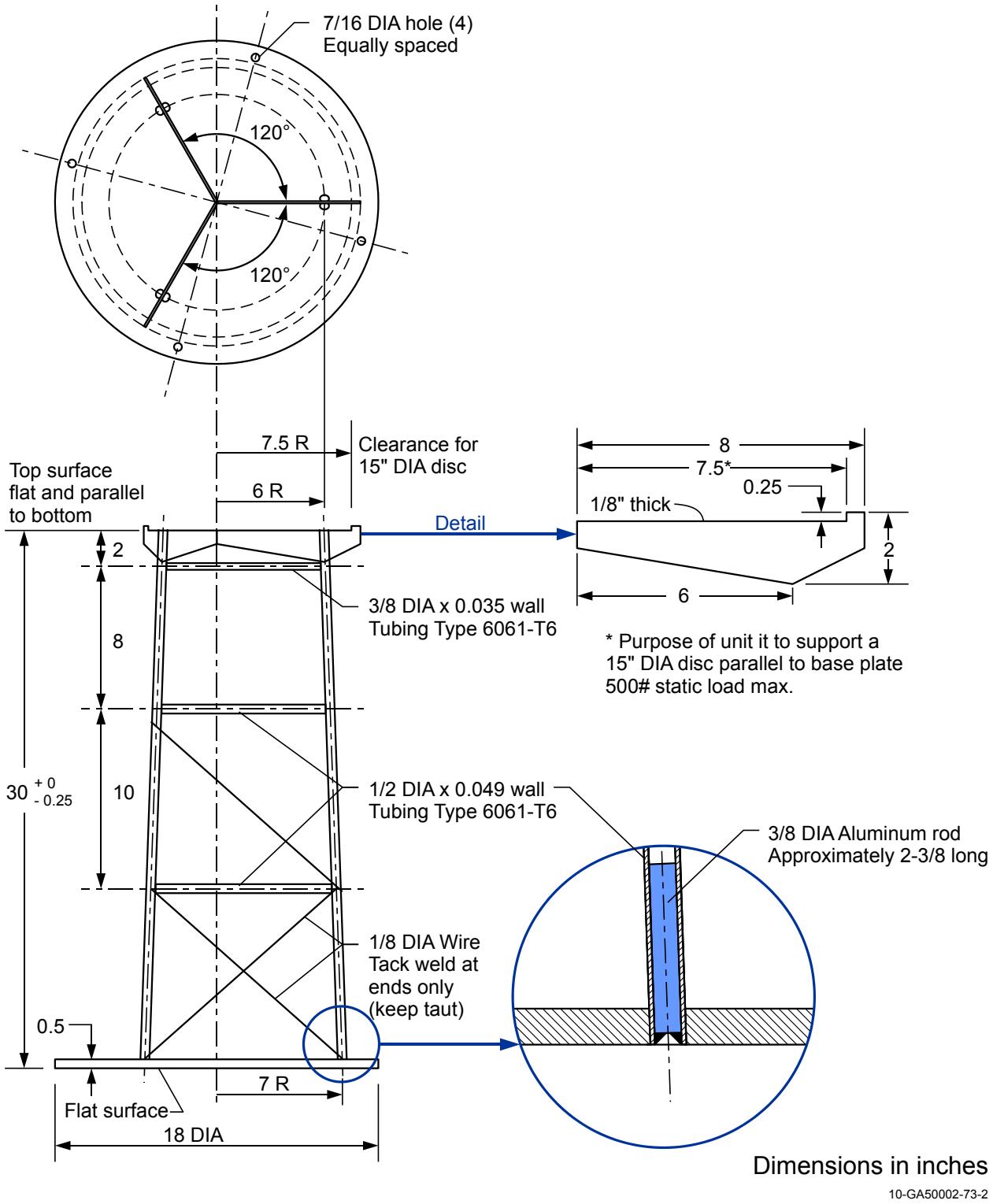

Figure C-2. Low-Mass Support Structure.