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HEU-MET-FAST-10X

CERBERUS: A ZEUS CONFIGURATION WITH HEU AND COPPER REFLECTED BY COPPER.

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CERBERUS: A ZEUS CONFIGURATION WITH HEU AND COPPER REFLECTED BY COPPER.

IDENTIFICATION NUMBER: HEU-MET-FAST-10X SPECTRA

KEY WORDS: Aluminum (Al), Copper (Cu), Highly Enriched Uranium (HEU), Comet, Zeus, Critical Experiment

1.0 DETAILED DESCRIPTION

1.1 Overview of Experiment

The Critical Experiment Reflected By copper to bEtteR Understand Scattering (CERBERUS) experiment is a a series of measurements performed at the National Criticality Experiments Research Center (NCERC) on the Comet critical assembly machine with a thick copper (Cu) reflector around alternating layers of Cu plates and highly enriched uranium (HEU) pancake plates. The measurements were performed by personnel from Los Alamos National Laboratory (LANL): T. Cutler, K. Amundson, N. Thompson, T. Grove, K. Stolte, and Z. Lemke, along with the multiple people who supported additional measurements and material handling (N. Whitman, R. Weldon, C. Kostelac, K. Valdez, C. Kiehne, A. Harper, S. Garger, E. Quarshie, and N. Rench). The purpose of this experiment was to investigate the impact of Cu scattering cross-sections in an integral experiment using the Comet critical assembly machine. Three configurations, which differed in the amount of Cu between each HEU layer, were evaluated as benchmarks. The three configurations are $^3/_{16}$ inch, $^5/_{16}$ inch, and $^7/_{16}$ inch, which represent the amount of Cu above and below each HEU layer. Throughout the rest of the document the units associated with the configuration will be removed from the configuration name.

The CERBERUS experiment was performed in August and September 2023. Information on this experiment was obtained from data sheets, engineering drawings, discussions with personnel at LANL, certification reports, and logbooks. Previous benchmark evaluations with Zeus configurations also served as a source of information because they also used the same Comet assembly, HEU pancake plates (also known as Jemima plates), and Cu reflectors. These benchmarks include HEU-MET-FAST-072, HEU-MET-FAST-073, HEU-MET-FAST-102, IEU-MET-FAST-025, HEU-MET-INTER-006, and HEU-MET-INTER-011.

All three configurations evaluated herein are judged to be acceptable for use as criticality-safety benchmark experiments.

1.2 Description of Experimental Configuration

All experiment configurations were assembled on the general-purpose Comet vertical assembly machine at NCERC at the Nevada National Security Site (NNSS) in August and September 2023. The Comet assembly has a load cell to determine when the lower core fully closes against the steel diaphragm and the uncertainty of the load cell value is ± 4 lb (1.81437 kg). The experimenters determined that the lower core was fully inserted when the load cell reading had a change in weight (ΔW) of $\sim$20 lb. A ΔW of 20 lbs was chosen for consistency among all configurations and due to the maximum allowable load for the platen. Table 1 shows the date and the associated reactor period measurement (which can be converted to reactivity) taken for each configuration using the local systems available in the Comet control room. Each of the reported reactor period measurements is from one of three compensated ion chambers (referred to as "linears" because they display data on a linear scale), which are each located at least 3 m from the assembly.

The experiment assembly included a cylindrical core region surrounded by metallic Cu reflectors as shown in Figure 1. Within the core, HEU pancake plates were interleaved with Cu plates, creating units. A unit consists of a single HEU layer, which includes a nested disk and an outer ring, with Cu layers (varying in number depending on the configuration) above and below. In all configurations some Cu plates were removed from units within the assembly to adjust the reactivity. A unit within a stack of multiple units is shown in Figure 2.

Table 1. Reactivity Measurements.[a]

Config.	Date	Period [s]
$^3/_{16}$	September 13, 2023	92.20, 92.67, 92.07
$^5/_{16}$	August 10, 2023	17.85, 18.00, 17.81
$^7/_{16}$	September 20, 2023	45.28, 45.59, 45.08

(a) From Comet Logbook (August 7 - September 20, 2023).

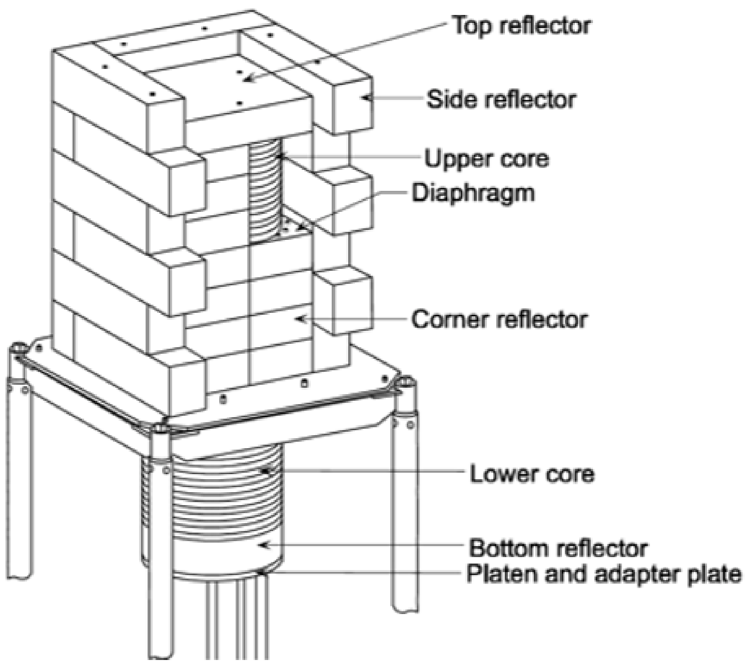

Figure 1. Schematic of a Zeus Configuration on the Comet Critical Assembly Machine. This includes CERBERUS.

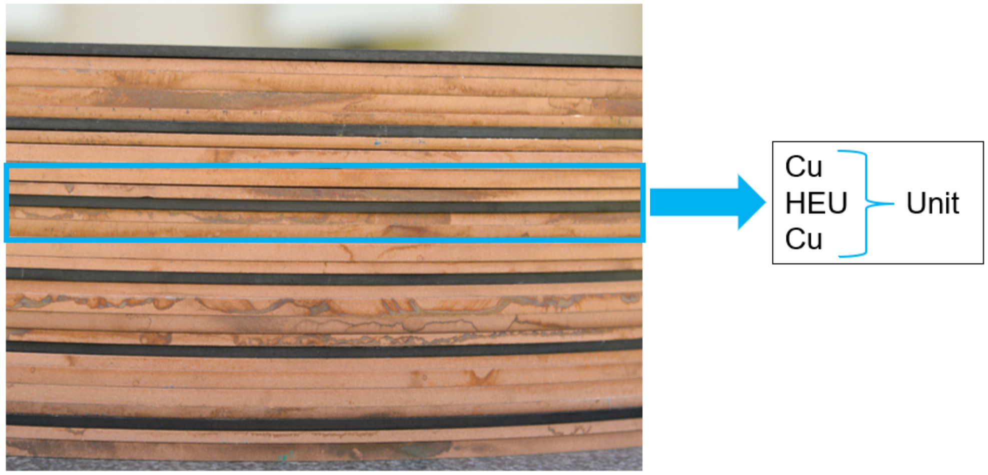

Figure 2. Example of a Unit Within Multiple Units (6). A unit consists of one HEU layer and varying number (1, 2, or 3 depending on the configuration) of Cu plates above and below the HEU layer.

The assembly is divided into a top and a bottom portion. The top portion includes the top, corner, and side reflectors that rest on an Al top plate attached to the Comet machine. In addition, the top portion includes the upper core stack that rests on a stainless steel plate, called the diaphragm, which is attached to the corner reflectors. The bottom portion includes the lower core stack, the bottom reflector (also referred to as the penny), and the lower support pieces (the platen, the platen adapter plate, and an Al alignment tube). All the plates in the lower core are centered using a hollow Al alignment tube.

1.2.1 Configuration Loadings

Three configurations were evaluated: $^{3}/_{16}$, $^{5}/_{16}$, and $^{7}/_{16}$, with the primary variation being the amount of Cu between each HEU layer. Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7 show a cross-section of the component arrangements (e.g., the HEU and Cu plate numbers) within the core for each configuration. Given the height of the $^{5}/_{16}$ and $^{7}/_{16}$ configurations, the upper and lower core are shown in separate figures. The HEU and interstitial Cu are labeled with their ID numbers. The Cu reflectors are labeled with their part type because the exact location of a specific part was not recorded. The Al components (alignment tube, shims, adapters, platen adapter plate, and platen) are labeled by the part type or in the case of the adapter by its dimensions (Al 6/2.5).

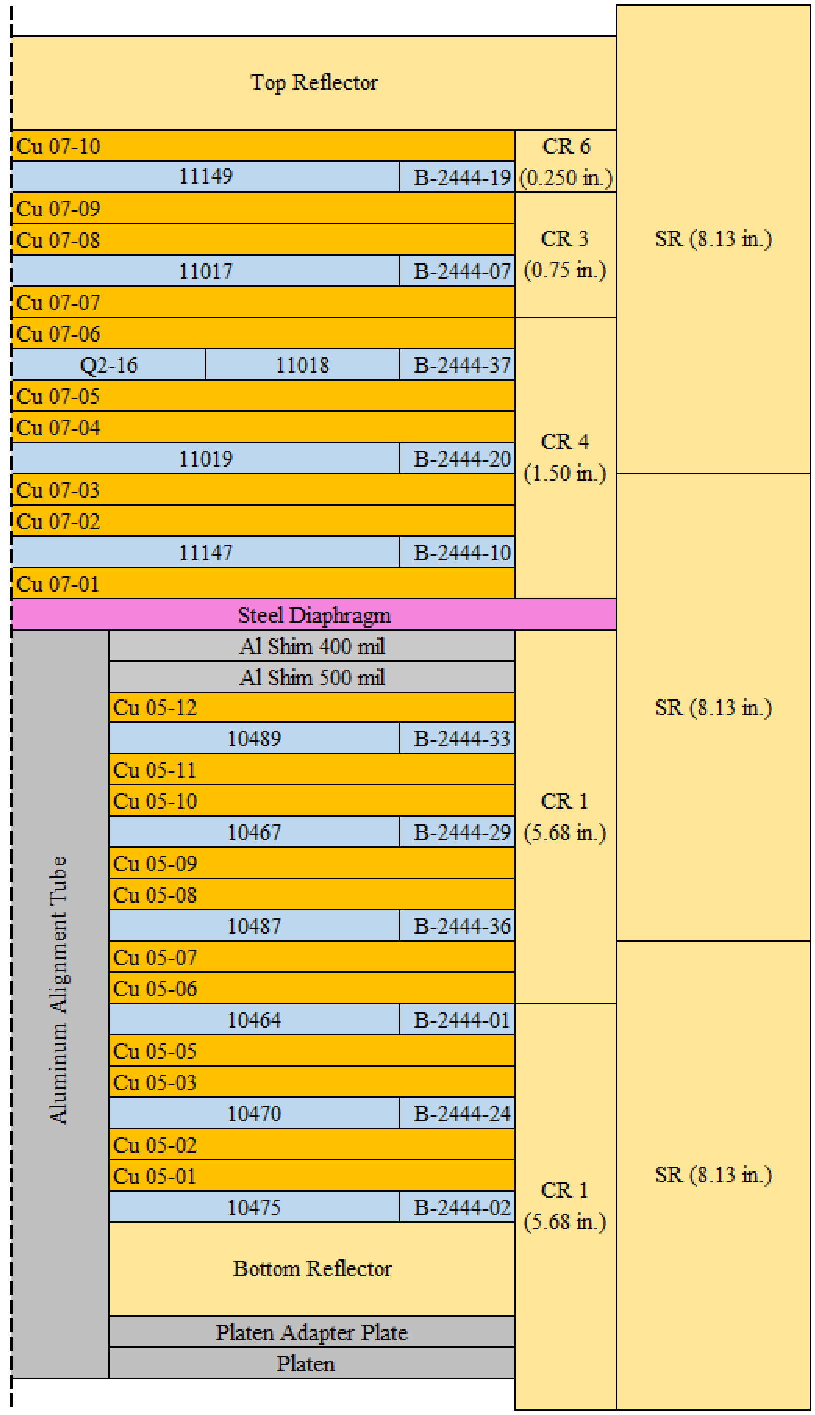

Figure 3. Cross-Section Component Arrangement for the $^{3}/_{16}$ Configuration. CR stands for corner reflector and SR stands for side reflector. For the CR and SR components, there are four pieces that make up each layer. This image is not to scale.

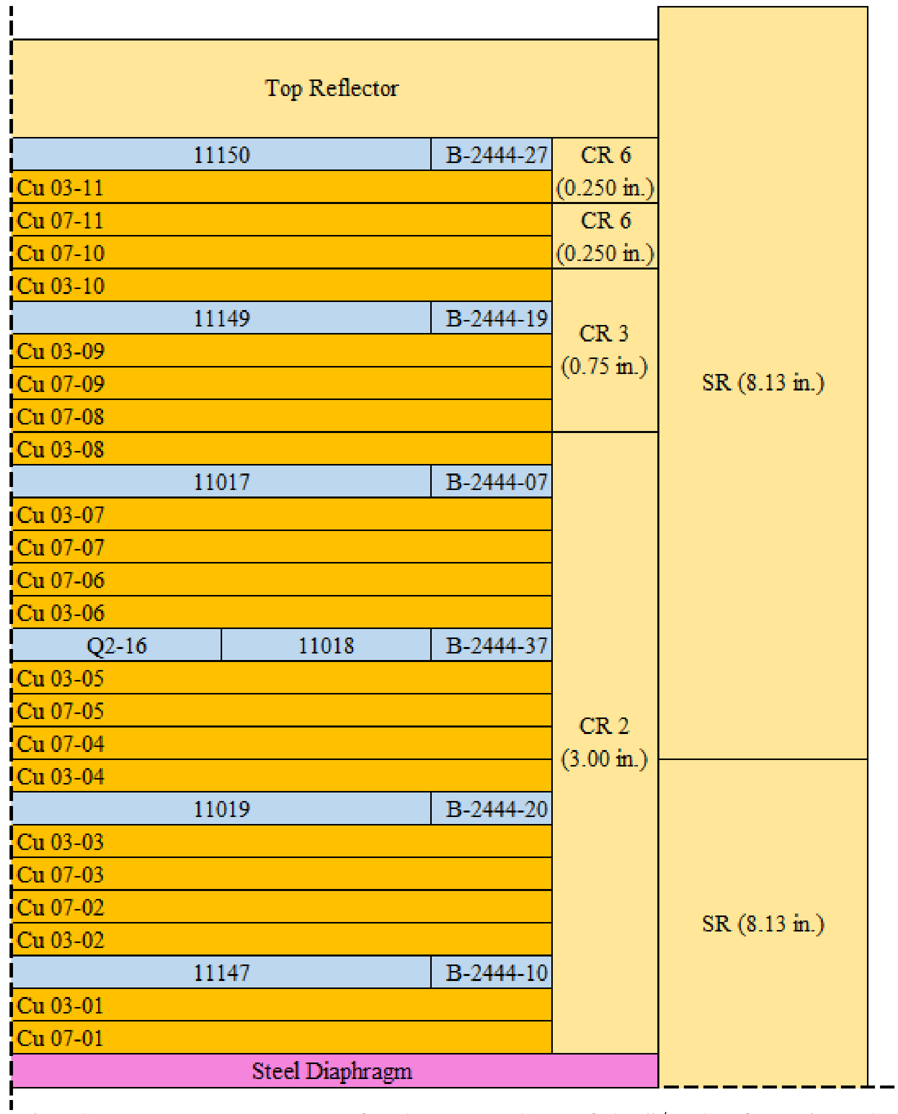

Figure 4. Cross-Section Component Arrangement for the Upper Core of the $^{5}/_{16}$ Configuration. CR stands for corner reflector and SR stands for side reflector. For the CR and SR components, there are four pieces that make up each layer. This image is not to scale.

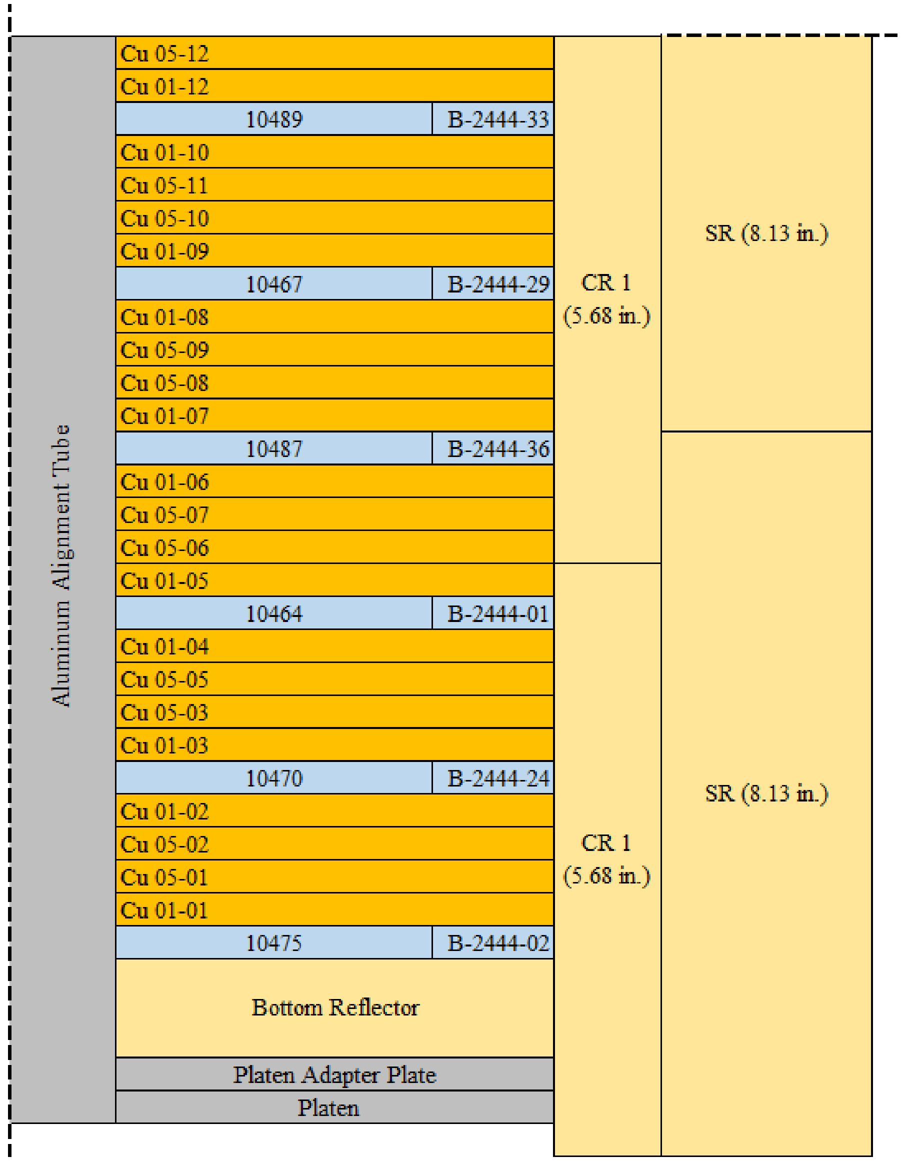

Figure 5. Cross-Section Component Arrangement for the Lower Core of the $^{5}/_{16}$ Configuration. CR stands for corner reflector and SR stands for side reflector. For the CR and SR components, there are four pieces that make up each layer. This image is not to scale.

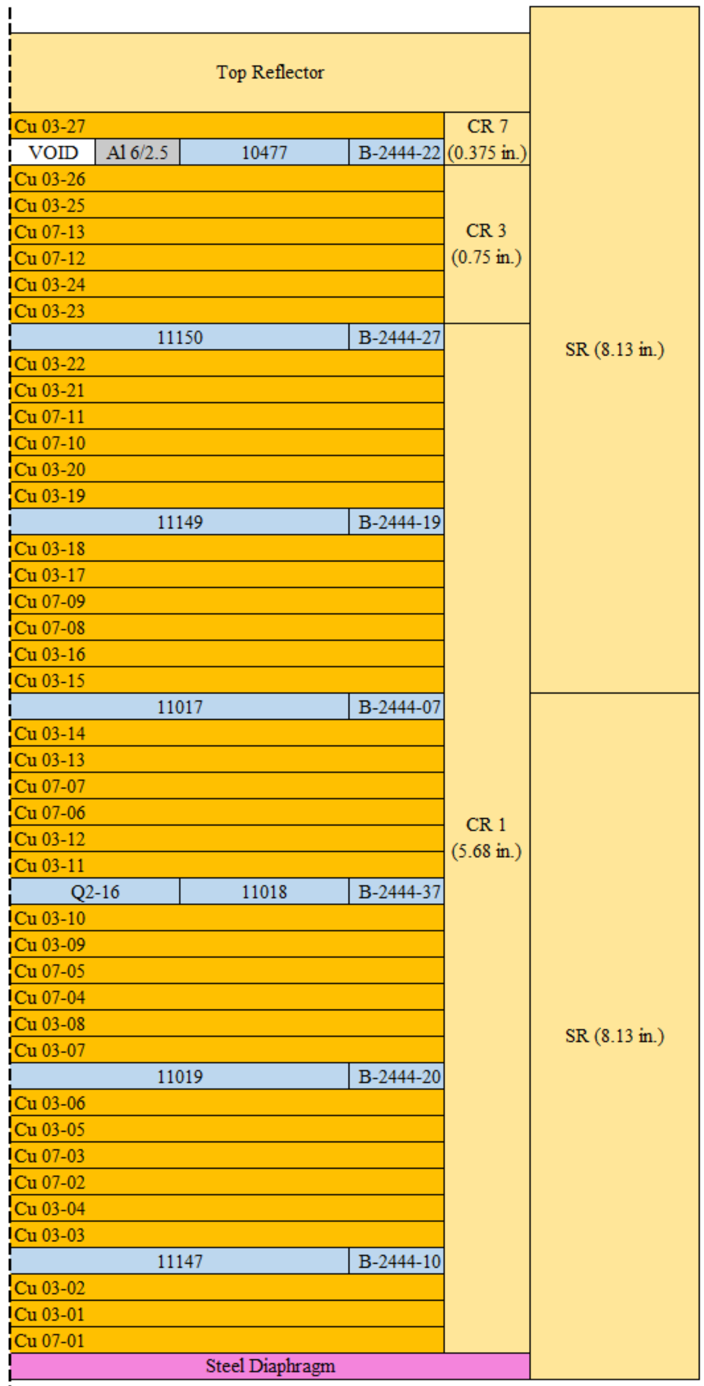

Figure 6. Cross-Section Component Arrangement for the Upper Core of the $^{7}/_{16}$ Configuration. CR stands for corner reflector and SR stands for side reflector. For the CR and SR components, there are four pieces that make up each layer. This image is not to scale.

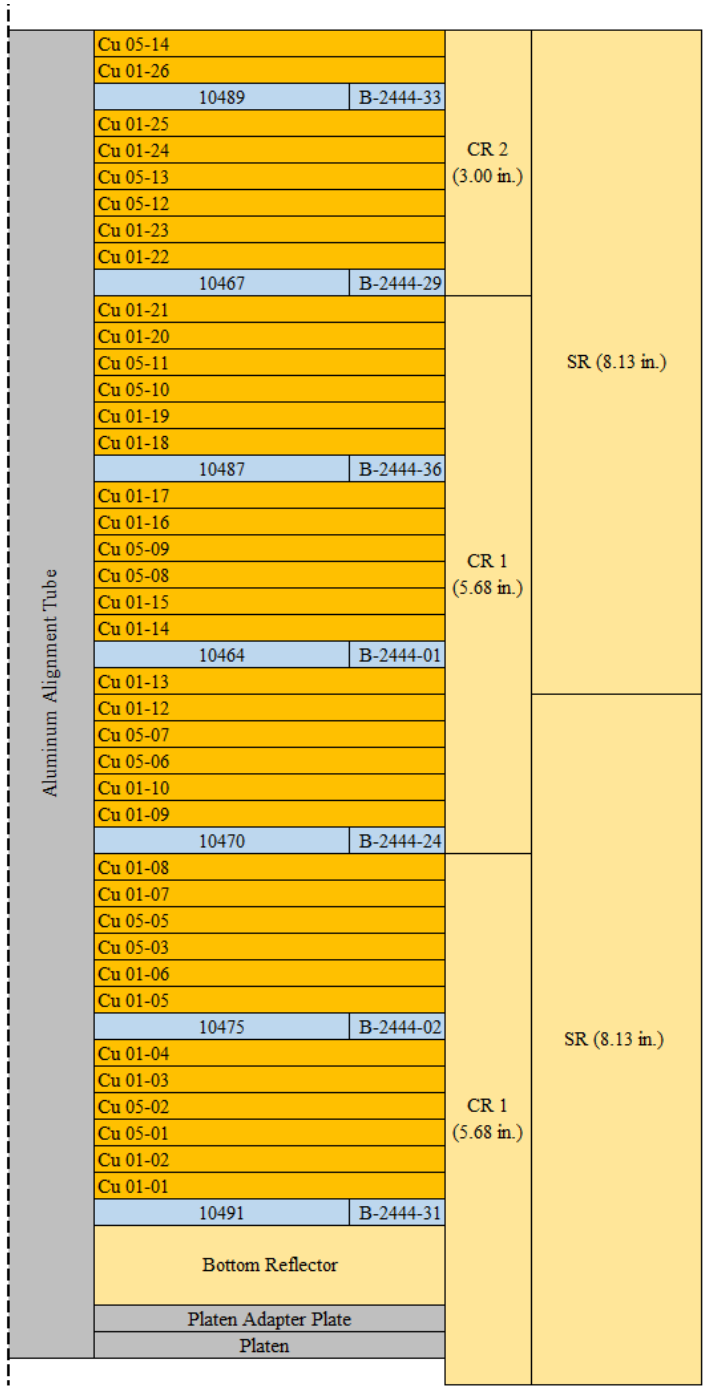

Figure 7. Cross-Section Component Arrangement for Lower Core of the $^{7}/_{16}$ Configuration. CR stands for corner reflector and SR stands for side reflector. For the CR and SR components, there are four pieces that make up each layer. This image is not to scale.

1.2.2 Stack Height Measurements

Stack heights were measured for the upper and lower cores for all three configurations using a calibrated Hexagon Absolute Arm V2P, 8525, 7-Axis coordinate measuring machine (CMM). The measurements were performed on a calibrated granite surface plate. In order to perform these measurements, each stack (upper and lower for each configuration) was removed from Comet and stacked (in the same order as it was on Comet) onto the granite surface plate. Figure 8 shows the upper stack of the $^{5}/_{16}$ configuration on the granite surface plate in preparation for CMM stack height measurements. The CMM measures the height by subtracting one plane, that was created by multiple point measurements of the top of the stack, from another plane, created by multiple point measurements of the granite surface plate, to calculate the distance. Four different heights were calculated for each stack with respect to the granite surface plate: a plane that covers the entire top surface of the stack (Stack Height 100%) and three separate measurements that cover $^{1}/_{3}$ of the top of the stack (Stack Height $^{1}/_{3}$). The CMM has an accuracy of $\pm$0.001 in. ($\pm$0.00254 cm). Table 2 summarizes the stack height measurements performed.

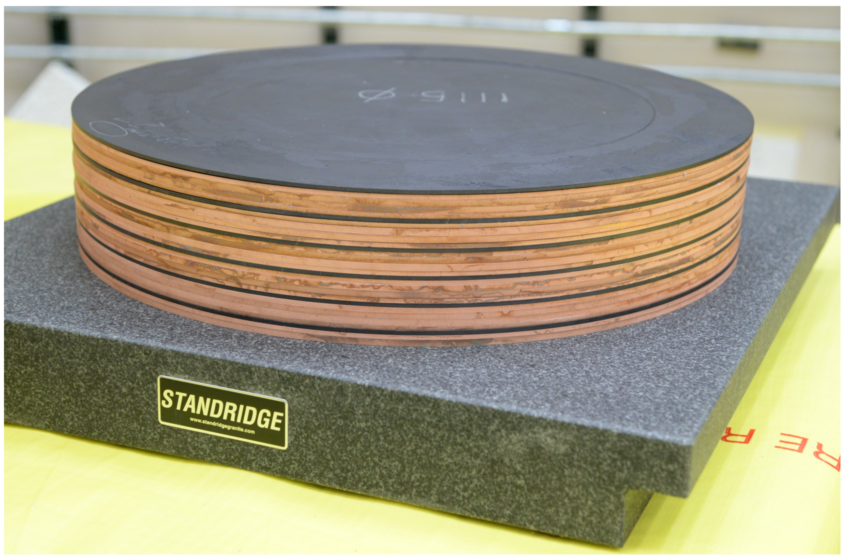

Figure 8. Example of a Stack Placed on the Granite Surface Plate in Preparation for a Measurements.

Table 2. Stack Height Measurements.

Config.	Stack	Stack Height 100% [cm]	Stack Height 1/3 [cm]
3/16	Top	6.402	6.419, 6.394, 6.398
	Bottom	9.526	9.521, 9.531, 9.529
	Bottom (without Al)	7.235	7.227, 7.248, 7.237
5/16	Top	10.722 (outer HEU) — 10.710 (inner HEU)[a]	10.713, 10.713, 10.718
	Bottom	10.812	10.809, 10.818, 10.821
7/16	Top	17.109	17.110, 17.130, 17.099
	Bottom	16.513	16.519, 16.501, 16.517

(a) Since the top layer of the top stack for the 5/16 is HEU, there is an inner and outer plate. Therefore, the Stack Height 100% has separate measurements for each plate. Cu is the top layer for all other stacks, so the measurement covers the entire plate.

1.2.3 Highly Enriched Uranium Disks and Rings

The HEU layers include solid disks (HEU 15/0 and HEU 6/0), disks with alignment holes (HEU 15/2.5), and rings (HEU 21/15 and HEU 15/6). The naming convention for the HEU pancake plates is to identify the material, in this case HEU, with the nominal outer diameter / nominal inner diameter in inches. Two sets of HEU plate orders were used in this experiment. The first order, which includes the HEU 15/0, 6/0, and 15/2.5, were manufactured by Los Alamos Scientific Laboratory (now LANL) in the mid-1950's. The second order, which includes the HEU 21/15 and 15/6, were manufactured by Oak Ridge at a later date. The HEU pancake plates were manufactured such that a disk inside an annular ring would fit tightly together (see Figure 9). Some of the same HEU disks and rings from HEU-MET-FAST-072, HEU-MET-FAST-073, HEU-MET-FAST-102, IEU-MET-FAST-025, HEU-MET-INTER-006, and HEU-MET-INTER-011 were used in this experiment. Figure 10, Figure 11, and Figure 12 show the engineering drawings for the HEU disks and rings (also known as the Jemima plates in referenced documents) used in the assembly. Oralloy and OY mentioned in the engineering drawings refers to HEU. Table 3 shows the part type, number of pieces used in each configuration, nominal dimensions, and dimension tolerances of HEU.

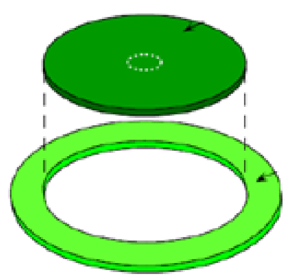

Figure 9. HEU Disks Are Nested Tightly Within HEU Rings in Each Unit of the Assemblies.

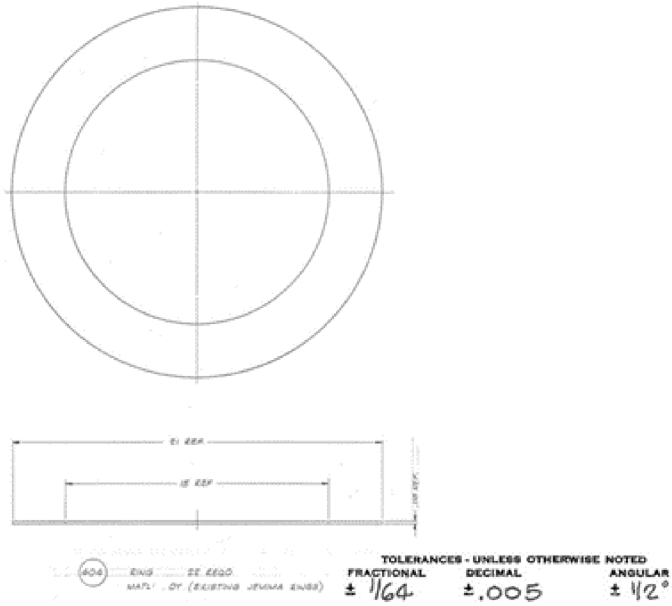

Figure 10. Engineering Drawing (19Y-29621-30A) of the HEU Outer Ring: HEU 21/15 (Dimensions in Inches).

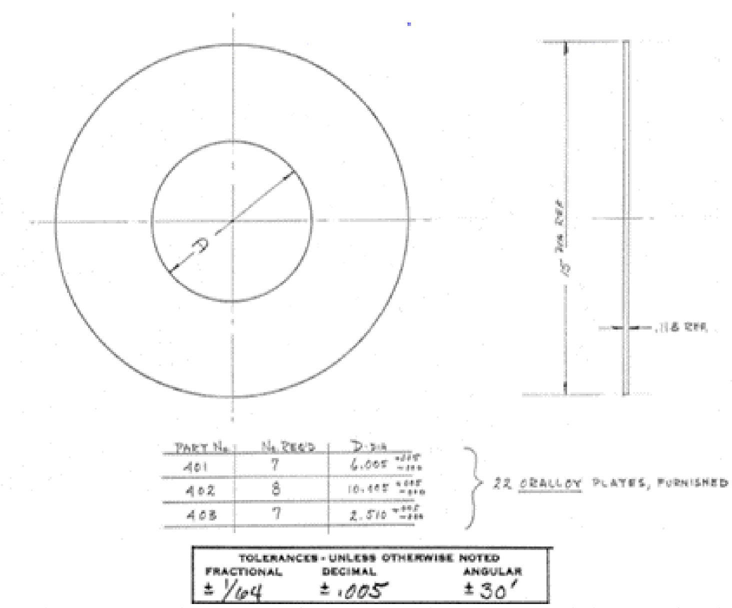

Figure 11. Engineering Drawing (19Y-29621-D27) of the HEU Rings: HEU 15/6, and 15/2.5 (Dimensions in Inches).

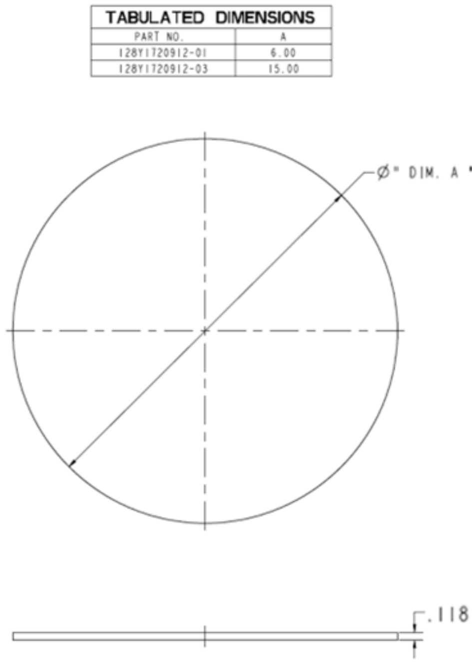

Figure 12. Engineering Drawing (128Y-1720912) of the Following HEU Plates: HEU 15/0 and 6/0 (Dimensions in Inches). Not an original drawing.

Table 3. Part Types, Number Used in Each Configuration and Dimensions and Tolerances Shown in the Engineering Drawings of HEU Components. Engineering drawings are in inches; cm values are provided in parentheses.

Part Type	**Number in Config.**			**Nominal Dimensions [in. (cm)]**			**Tolerances [in. (cm)]**		
	$^{3}/_{16}$	$^{5}/_{16}$	$^{7}/_{16}$	**Height**	**Inner Diameter**	**Outer Diameter**	**Height**	**Inner Diameter**	**Outer Diameter**
HEU 15/0	4	5	5	0.118 (0.29972)	—	15.00 (38.1)	Unknown	—	Unknown
HEU 6/0	1	1	1	0.118 (0.29972)	—	6.00 (15.24)	Unknown	—	Unknown
HEU 21/15	11	12	14	0.118 (0.29972)	15.00 (38.1)	21 (53.34)	± 0.005 (± 0.0127)	± 0.005 (± 0.0127)	± 0.005 (± 0.0127)
HEU 15/2.5	6	6	7	0.118 (0.29972)	2.510 (6.3754)	15 (38.1)	± 0.005 (± 0.0127)	+0.005/ -0.000 (+0.0127/ -0.000)	± 0.005 (± 0.0127)
HEU 15/6	1	1	2	0.118 (0.29972)	6.005 (15.2527)	15 (38.1)	± 0.005 (± 0.0127)	+0.005/ -0.000 (+0.0127/ -0.000)	± 0.005 (± 0.0127)

Mass, diameter, and thickness measurements of the HEU components used in this experiment were performed as part of this experiment campaign in July 2023. Therefore, the HEU masses may be different from previous benchmarks that use this fuel. Table 4 lists the height and masses for the different HEU components in the assembly. The height measurements were performed at three arbitrary points that were roughly 120° apart using a calibrated Brown & Sharpe IP67 caliper that has an accuracy of ±0.001 in. (0.00254 cm); but measurements can be performed in mm or in. When possible, height measurements were performed along the inner diameter as well as the outer diameter. Mass measurements were taken using a calibrated 16-kg Mettler Toledo scale (MS16001L), which has an accuracy of ±0.2 g on the direct readout and a repeatability of ±0.1 g. Mass measurements of the HEU components were performed with the HEU inside a plastic bag; therefore, measurements of the bag were performed prior to the measurement of the bag and HEU component. A CMM was used to measure the applicable diameters and the results are reported in Table 5. These measurements took place in August 2023.

Table 4. Dimensions and Masses of the HEU Plates.

Part Type	**ID**[a]	**Bag Mass [g]**	**HEU + Bag Mass [g]**	**Height Outer [mm]**	**Height Inner [mm]**
HEU 21/15	-01	99.4, 99.3, 99.3	6210.1, 6209.9, 6210.1	3.00, 3.04, 3.03	3.04, 3.03, 3.00
HEU 21/15	-02	97.3, 97.3, 97.3	6206.2, 6206.4, 6206.4	2.97, 2.98, 2.95	3.04, 3.04, 3.04
HEU 21/15	-07	105.2, 105.2, 105.2	6212.7, 6212.4, 6212.4	3.04, 3.04, 3.05	3.01, 3.02, 3.02
HEU 21/15	-10	98.0, 97.9, 97.9	6226.8, 6226.9, 6227.1	3.03, 3.06, 3.06	3.04, 3.06, 3.04
HEU 21/15	-19	97.6, 97.6, 97.6	6218.7, 6218.7, 6218.8	2.99, 2.99, 3.01	3.00, 2.99, 3.02
HEU 21/15	-20	104.7, 104.6, 104.6	6257.3, 6257.3, 6257.4	3.02, 3.03, 3.04	3.02, 3.02, 3.00
HEU 21/15	-22	104.3, 104.3, 104.3	6128.3, 6127.7, 6127.8	2.95, 2.95, 2.94	2.85, 2.86, 2.93
HEU 21/15	-24	97.5, 97.5, 97.5	6186.5, 6186.6, 6186.6	3.02, 3.03, 3.04	3.00, 3.00, 3.00
HEU 21/15	-27	103.2, 103.2, 103.2	6168.3, 6169.0, 6168.6	2.99, 2.97, 2.98	2.98, 2.98, 2.99
HEU 21/15	-29	97.9, 97.9, 97.9	6224.8, 6224.8, 6224.8	3.05, 3.04, 3.05	3.05, 3.05, 3.05
HEU 21/15	-31	101.3, 101.3, 101.4	6266.5, 6266.5, 6266.4	3.04, 3.04, 3.05	3.04, 3.03, 3.04
HEU 21/15	-33	98.9, 98.8, 98.8	6254.4, 6254.4, 6254.6	3.01, 3.03, 3.03	3.01, 3.01, 3.03
HEU 21/15	-36	99.0, 99.1, 99.1	6223.5, 6223.8, 6223.6	3.03, 3.03, 3.02	3.03, 3.01, 3.02
HEU 21/15	-37	104.0, 104.1, 104.1	6226.1, 6226.1, 6226.2	3.01, 3.01, 3.03	3.00, 3.01, 2.99
HEU 6/0	Q2-16	38.1, 38.1, 38.0	1112.9, 1112.9, 1113.0	3.27, 3.22, 3.24	—
HEU 15/2.5	10464	100.1, 100.1, 100.0	6358.4, 6358.3, 6358.3	3.07, 3.04, 3.06	3.05, 3.04, 3.02
HEU 15/2.5	10467	98.2, 98.2, 98.2	6434.0, 6434.0, 6434.0	3.07, 3.07, 3.08	3.04, 3.08, 3.08
HEU 15/2.5	10470	99.0, 99.0, 99.0	6377.5, 6377.2, 6377.3	3.06, 3.06, 3.08	3.04, 3.00, 3.00
HEU 15/2.5	10475	99.1, 99.1, 99.2	6327.1, 6327.2, 6327.2	3.04, 3.03, 3.03	2.99, 3.00, 3.02
HEU 15/6	10477	103.1, 103.1, 103.1	5601.6, 5601.5, 5601.8	3.12, 3.09, 3.11	3.12, 3.07, 3.03
HEU 15/2.5	10487	100.4, 100.3, 100.4	6375.1, 6375.3, 6375.2	3.05, 3.06, 3.06	3.01, 3.03, 3.01
HEU 15/2.5	10489	97.8, 97.9, 97.9	6441.4, 6441.3, 6441.4	3.10, 3.09, 3.05	3.04, 3.04, 3.06
HEU 15/2.5	10491	100.5, 100.5, 100.5	6492.1, 6492.2, 6492.2	3.14, 3.13, 3.14	3.06, 3.15, 3.15
HEU 15/0	11017	102.4, 102.3, 102.3	6599.3, 6599.3, 6599.4	3.02, 3.03, 3.02	—
HEU 15/6	11018	103.7, 103.8, 103.7	5472.7, 5472.7, 5472.8	3.06, 3.06, 3.06	3.00, 2.99, 2.97
HEU 15/0	11019	98.7, 98.8, 98.8	6567.3, 6567.4, 6567.4	3.01, 3.01, 3.00	—
HEU 15/0	11147	98.6, 98.6, 98.6	6610.5, 6610.5, 6610.5	3.07, 3.09, 3.09	—
HEU 15/0	11149	98.8, 98.9, 98.8	6481.1, 6481.3, 6481.4	3.00, 3.02, 3.02	—
HEU 15/0	11150	103.1, 103.1, 103.0	6507.4, 6507.4, 6507.5	3.00, 2.99, 3.01	—

(a) The HEU 21/15 plates are numbered B-2444-XX, and this is the value for XX.

Table 5. Diameter Measurements Performed Using the CMM.

Part Type	ID[a]	Outer Diameter [cm]	Inner Diameter [cm]
HEU 21/15	-01	53.356	38.136
HEU 21/15	-02	53.354	38.135
HEU 21/15	-07	53.365	38.132
HEU 21/15	-10	53.359	38.142
HEU 21/15	-19	53.355	38.140
HEU 21/15	-20	53.361	38.150
HEU 21/15	-22	53.374	38.130
HEU 21/15	-24	53.290	38.127
HEU 21/15	-27	53.359	38.130
HEU 21/15	-29	53.354	38.123
HEU 21/15	-31	53.353	38.117
HEU 21/15	-33	53.357	38.123
HEU 21/15	-36	53.359	38.124
HEU 21/15	-37	53.350	38.126
HEU 6/0	Q2-16	15.214	—
HEU 15/2.5	10464	38.088	6.378
HEU 15/2.5	10467	38.085	6.381
HEU 15/2.5	10470	38.093	6.338
HEU 15/2.5	10475	38.085	6.370
HEU 15/6	10477	38.086	15.262
HEU 15/2.5	10487	38.088	6.380
HEU 15/2.5	10489	38.091	6.379
HEU 15/2.5	10491	38.084	6.372
HEU 15/0	11017	38.096	—
HEU 15/6	11018	38.096	15.258
HEU 15/0	11019	38.097	—
HEU 15/0	11147	38.101	—
HEU 15/0	11149	38.092	—
HEU 15/0	11150	38.088	—

(a) The HEU 21/15 plates are numbered B-2444-XX, and this is the value for XX.

1.2.4 Non-Fissile Core Components

All configurations contained Cu plates within the core and some configurations required Al shims and Al adapter plates.

1.2.4.1 Interstitial Copper Plates

The Cu interstitial plates were manufactured by JR Metal Works and arrived at LANL in June 2023. The plates are identified with a 01, 03, 05, or 07 to identify the height and whether or not there was a central hole as well as an identification number. Two different heights ($\approx 2/16$ in. (0.3175 cm) and $\approx 3/16$ in. (0.47625)) of Cu interstitial plates were procured for this experiment to make the components easy to handle. Plates with a central hole (Cu 01 and Cu 05) are needed for the lower core due to having an Al alignment tube; solid plates (Cu 03 and Cu 07) can be used in the upper core. A drawing of the Cu interstitial plates is shown in Figure 13. Table 6 lists the the dimensions and tolerances of the Cu interstitial plates used in the CERBERUS experiments. Two samples from different Cu interstitial plates with central holes (05-04 and 01-11) were sent for chemical analysis and were not used in the experiment. Therefore, the dimension and mass measurements for those plates are not included.

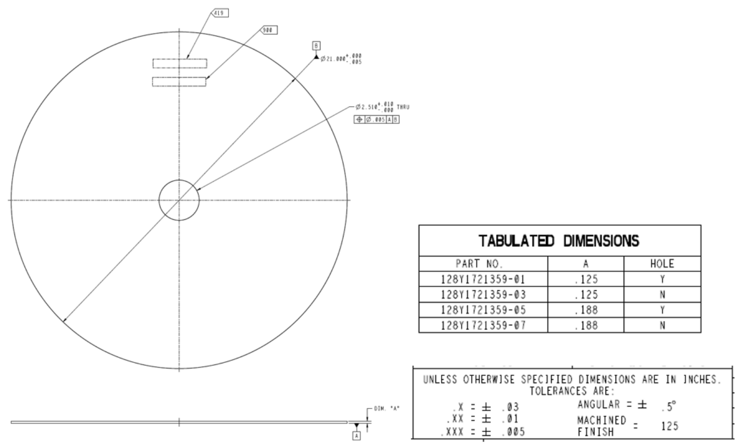

Figure 13. Engineering Drawing (128Y-1721359-D1) of the Cu Interstitial Plates (Dimensions in Inches).

Table 6. Part Types, Number Used in Each Configuration and Dimensions and Tolerances Shown in the Engineering Drawings of the Cu Interstitial Plates. Engineering drawings are in inches; cm values are provided in parentheses.

Part Type	Number in Config.			Nominal Dimensions [in. (cm)]			Tolerances [in. (cm)]		
	$^3/_{16}$	$^5/_{16}$	$^7/_{16}$	Height	Inner Diameter	Outer Diameter	Height	Inner Diameter	Outer Diameter
Cu 03	0	11	27	0.125 (0.3175)	N/A	21.000 (53.34)	±0.005 (± 0.0127)	N/A	+0.000/ -0.005 (+0.000/ -0.0127)
Cu 07	10	11	13	0.188 (0.47752)	N/A	21.000 (53.34)	±0.005 (± 0.0127)	N/A	+0.000/ -0.005 (+0.000/ -0.0127)
Cu 01	0	11	25	0.125 (0.3175)	2.510 (6.3754)	21.000 (53.34)	±0.005 (± 0.0127)	+0.010/ -0.000 (+0.0254/ -0.000)	+0.000/ -0.005 (+0.000/ -0.0127)
Cu 05	11	11	13	0.188 (0.47752)	2.510 (6.3754)	21.000 (53.34)	±0.005 (± 0.0127)	+0.010/ -0.000 (+0.0254/ -0.000)	+0.000/ -0.005 (+0.000/ -0.0127)

The mass of the Cu interstitial plates were measured with a calibrated 16-kg Mettler Toledo scale (MS16001L) in July 2023, which has an accuracy of ±0.2 g on the direct readout and a repeatability of ±0.1 g. The mass measurements are summarized in Table 7. The height of each Cu interstitial plate were measured using a calibrated L. S. Starrett Company micrometer in June 2023, which has an accuracy of ±0.00010 in (0.000254 cm). Three height measurements were performed along the outside of each plate approximately 120°apart; and when applicable, height measurements were performed similarly along the inner diameter. The micrometer has a reading of five digits after the decimal, but the last digit is either a 0 or 5. Inner (when applicable) and outer diameters were measured with calibrated Mitutoyo calipers (8 in. (20.32 cm) for the inner diameter and 24 in. (60.96 cm) for outer diameter) for each Cu interstitial plate. The 8 in. caliper has an accuracy of ±0.001 in. (0.00254 cm) and the 24 in. caliper has an accuracy of ±0.002 in (0.00508 cm). The caliper has a reading of four digits after the decimal, but the last digit is either a 0 or 5. All digits for the caliper and micrometer are included in Table 7.

Table 7. Mass, Height, and Diameter Measurements of Cu Interstitial Plates.

Part Type	ID	Mass [g]	Height [in.]	Outer Diameter [in.]	Inner Diameter [in.]
Cu 03	-01	6372.6, 6372.7, 6372.7	0.12560, 0.12620, 0.12600	20.9900, 20.9985, 20.9955	—
	-02	6345.8, 6345.8, 6345.8	0.12520, 0.12520, 0.12570	20.9930, 20.9945, 20.9995	—
	-03	6369.1, 6369.1, 6369.1	0.12580, 0.12570, 0.12590	20.9890, 20.9850, 20.9890	—
	-04	6362.6, 6362.7, 6362.6	0.12555, 0.12600, 0.12570	20.9995, 20.9970, 20.9910	—
	-05	6347.4, 6347.5, 6347.4	0.12515, 0.12530, 0.12540	20.9940, 21.0010, 20.9980	—
	-06	6379.4, 6379.3, 6379.3	0.12600, 0.12620, 0.12575	20.9985, 21.0000, 20.9965	—
	-07	6366.3, 6366.2, 6366.2	0.12560, 0.12595, 0.12565	20.9950, 20.9980, 20.9965	—
	-08	6340.8, 6340.9, 6340.8	0.12510, 0.12510, 0.12470	20.9990, 21.0010, 20.9995	—
	-09	6331.5, 6331.5, 6331.6	0.12510, 0.12500, 0.12490	20.9945, 20.9990, 20.9975	—
	-10	6346.6, 6346.6, 6346.6	0.12475, 0.12565, 0.12540	20.9955, 21.0020, 21.0040	—
	-11	6381.4, 6381.5, 6381.5	0.12570, 0.12585, 0.12650	20.9940, 20.9970, 20.9960	—
	-12	6376.2, 6376.3, 6376.3	0.12585, 0.12550, 0.12590	20.9975, 21.0000, 20.9950	—
	-13	6380.7, 6380.7, 6380.7	0.12560, 0.12620, 0.12600	20.9935, 20.9985, 20.9945	—
	-14	6375.2, 6375.1, 6375.2	0.12545, 0.12575, 0.12560	20.9970, 20.9990, 21.0005	—
	-15	6373.0, 6373.0, 6373.0	0.12585, 0.12565, 0.12535	20.9980, 20.9990, 20.9980	—

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Table 7 – *Continued from previous page*

Part Type	ID	Mass [g]	Height [in.]	Outer Diameter [in.]	Inner Diameter [in.]
	-16	6377.6, 6377.6, 6377.6	0.12590, 0.12575, 0.12575	20.9980, 20.9990, 20.9980	—
	-17	6385.7, 6385.8, 6385.8	0.12570, 0.12560, 0.12610	21.0000, 20.9985, 20.9985	—
	-18	6389.7, 6389.7, 6389.6	0.12615, 0.12640, 0.12655	20.9990, 20.9990, 21.0000	—
	-19	6366.2, 6366.1, 6366.2	0.12565, 0.12600, 0.12565	21.0010, 20.9980, 20.9990	—
	-20	6375.3, 6375.3, 6375.4	0.12575, 0.12615, 0.12590	20.9980, 20.9980, 20.9965	—
	-21	6379.1, 6379.1, 6379.1	0.12590, 0.12630, 0.12610	21.0005, 20.9990, 20.9995	—
	-22	6381.9, 6382.0, 6381.9	0.12625, 0.12595, 0.12595	20.9985, 20.9985, 20.9995	—
	-23	6385.6, 6385.7, 6385.6	0.12620, 0.12660, 0.12600	21.0000, 20.9950, 21.0000	—
	-24	6361.1, 6361.3, 6361.3	0.12535, 0.12565, 0.12535	20.9970, 21.0010, 20.9990	—
	-25	6339.5, 6339.6, 6339.7	0.12540, 0.12530, 0.12560	20.9990, 20.9960, 20.9980	—
	-26	6379.1, 6379.1, 6379.2	0.12610, 0.12620, 0.12595	20.9955, 20.9960, 20.9970	—
	-27	6382.9, 6382.9, 6382.9	0.12610, 0.12595, 0.12580	21.0030, 21.0035, 21.0030	—
Cu 07	-01	9488.4, 9488.6, 9488.6	0.18805, 0.18785, 0.18810	20.9915, 20.9890, 20.9930	—
	-02	9506.7, 9506.7, 9506.6	0.18800, 0.18850, 0.18785	20.9960, 20.9970, 20.9980	—
	-03	9513.4, 9513.5, 9513.5	0.18850, 0.18880, 0.18875	20.9985, 20.9965, 20.9990	—
	-04	9489.3, 9489.3, 9489.4	0.18795, 0.18755, 0.18765	20.9970, 20.9945, 20.9980	—
	-05	9505.6, 9505.7, 9505.7	0.18800, 0.18800, 0.18845	20.9945, 20.9965, 20.9950	—
	-06	9529.6, 9529.7, 9529.8	0.18895, 0.18840, 0.18890	21.0015, 20.9955, 20.9970	—
	-07	9507.6, 9507.7, 9507.6	0.18790, 0.18835, 0.18825	20.9975, 20.9980, 20.9985	—
	-08	9474.0, 9473.9, 9474.0	0.18800, 0.18780, 0.18715	20.9965, 20.9950, 20.9915	—

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Table 7 – *Continued from previous page*

Part Type	ID	Mass [g]	Height [in.]	Outer Diameter [in.]	Inner Diameter [in.]
	-09	9511.8, 9511.8, 9511.8	0.18820, 0.18850, 0.18825	20.9990, 20.9985, 20.9945	—
	-10	9504.7, 9504.8, 9504.8	0.18805, 0.18850, 0.18805	20.9985, 20.9965, 20.9935	—
	-11	9491.6, 9491.6, 9491.6	0.18790, 0.18815, 0.18805	20.9905, 20.9925, 20.9900	—
	-12	9461.7, 9461.7, 9461.8	0.18740, 0.18740, 0.18715	21.0000, 20.9955, 20.9980	—
	-13	9493.7, 9493.6, 9493.7	0.18835, 0.18780, 0.18785	20.9960, 20.9970, 20.9930	—
Cu 01	-01	6273.1, 6273.2, 6273.1	0.12540, 0.12590, 0.12570 0.12580, 0.12570, 0.12570	20.9930, 20.9900, 20.9910	2.5165, 2.5180, 2.5170
	-02	6290.4, 6290.4, 6290.5	0.12580, 0.12600, 0.12590 0.12590, 0.12600, 0.12620	20.9965, 20.9945, 20.9955	2.5120, 2.5080, 2.5140
	-03	6270.6, 6270.5, 6270.6	0.12570, 0.12540, 0.12560 0.12580, 0.12580, 0.12570	20.9955, 20.9900, 20.9990	2.5145, 2.5125, 2.5185
	-04	6251.3, 6251.4, 6251.4	0.12540, 0.12520, 0.12540 0.12510, 0.12500, 0.12500	20.9915, 20.9975, 20.9960	2.5120, 2.5130, 2.5115
	-05	6251.4, 6251.6, 6251.5	0.12540, 0.12560, 0.12540 0.12520, 0.12520, 0.12530	20.9900, 20.9950, 20.9960	2.5120, 2.5150, 2.5100
	-06	6266.7, 6266.7, 6266.8	0.12600, 0.12530, 0.12550 0.12500, 0.12550, 0.12520	20.9985, 20.9990, 20.9955	2.5105, 2.5140, 2.5080
	-07	6258.0, 6257.9, 6257.8	0.12520, 0.12550, 0.12590 0.12540, 0.12520, 0.12540	21.0005, 21.0000, 21.0000	2.5100, 2.5120, 2.5125
	-08	6289.6, 6289.8, 6289.7	0.12580, 0.12610, 0.12570 0.12590, 0.12600, 0.12590	20.9945, 21.0030, 20.9980	2.5125, 2.5140, 2.5115
	-09	6267.3, 6267.3, 6267.3	0.12600, 0.12540, 0.12580 0.12560, 0.12550, 0.12540	20.9985, 20.9985, 21.0000	2.5085, 2.5100, 2.5115
	-10	6250.7, 6250.8, 6250.8	0.12500, 0.12450, 0.12530 0.12520, 0.12490, 0.12490	20.9940, 20.9935, 20.9995	2.5100, 2.5100, 2.5120
	-12	6255.1, 6255.1, 6255.1	0.12530, 0.12590, 0.12550 0.12520, 0.12530, 0.12510	20.9960, 20.9970, 20.9980	2.5125, 2.5130, 2.5120
	-13	6259.2, 6259.3, 6259.2	0.12570, 0.12490, 0.12560 0.12490, 0.12510, 0.12510	20.9985, 20.9970, 21.0015	2.5115, 2.5145, 2.5515
	-14	6260.5, 6260.6, 6260.6	0.12510, 0.12490, 0.12530 0.12510, 0.12500, 0.12500	20.9995, 20.9980, 20.9970	2.5160, 2.5130, 2.5130
	-15	6263.1, 6263.2, 6263.2	0.12490, 0.12590, 0.12510 0.12540, 0.12540, 0.12530	20.9955, 20.9960, 20.9965	2.5130, 2.5130, 2.5130
	-16	6244.1, 6244.1, 6244.1	0.12570, 0.12500, 0.12510 0.12500, 0.12510, 0.12490	20.9970, 20.9970, 20.9955	2.5110, 2.5105, 2.5115

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Table 7 – *Continued from previous page*

Part Type	ID	Mass [g]	Height [in.]	Outer Diameter [in.]	Inner Diameter [in.]
	-17	6258.8, 6258.9, 6258.9	0.12560, 0.12570, 0.12490 0.12520, 0.12520, 0.12490	20.9890, 20.9990, 20.9950	2.5130, 2.5120, 2.5150
	-18	6283.7, 6283.7, 6283.7	0.12570, 0.12590, 0.12600 0.12570, 0.12550, 0.12570	20.9930, 20.9965, 21.0005	2.5120, 2.5165, 2.5150
	-19	6243.9, 6243.9, 6243.9	0.12580, 0.12540, 0.12530 0.12490, 0.12480, 0.12480	20.9970, 20.9985, 20.9935	2.5115, 2.5105, 2.5160
	-20	6252.9, 6253.0, 6253.0	0.12520, 0.12550, 0.12530 0.12540, 0.12550, 0.12580	20.9940, 20.9955, 20.9935	2.5150, 2.5145, 2.5135
	-21	6274.4, 6274.5, 6274.5	0.12560, 0.12550, 0.12550 0.12550, 0.12580, 0.12570	20.9965, 20.9985, 20.9980	2.5110, 2.5150, 2.5120
	-22	6247.4, 6247.4, 6247.4	0.12550, 0.12510, 0.12510 0.12510, 0.12510, 0.12540	20.9920, 20.9950, 20.9980	2.5150, 2.5120, 2.5135
	-23	6258.6, 6258.6, 6258.7	0.12560, 0.12560, 0.12530 0.12560, 0.12550, 0.12540	20.9930, 20.9965, 20.9950	2.5160, 2.5150, 2.5120
	-24	6259.7, 6259.7, 6259.8	0.12570, 0.12580, 0.12550 0.12540, 0.12560, 0.12530	20.9900, 20.9915, 20.9950	2.5100, 2.5145, 2.5150
	-25	6238.6, 6238.5, 6238.6	0.12480, 0.12510, 0.12470 0.12480, 0.12490, 0.12490	20.9965, 20.9950, 20.9950	2.5145, 2.5145, 2.5125
	-26	6267.4, 6267.4, 6267.3	0.12580, 0.12550, 0.12510 0.12540, 0.12530, 0.12540	20.9905, 20.9980, 20.9900	2.5135, 2.5155, 2.5145
	-27	6264.7, 6264.6, 6264.7	0.12520, 0.12580, 0.12600 0.12540, 0.12540, 0.12560	20.9875, 20.9965, 20.9965	2.5125, 2.5155, 2.5165
	-28	6265.4, 6265.5, 6265.4	0.12560, 0.12550, 0.12590 0.12550, 0.12550, 0.12560	20.9925, 20.9940, 20.9990	2.5145, 2.5125, 2.5130
	-29	6280.9, 6281.0, 6281.0	0.12580, 0.12600, 0.12600 0.12580, 0.12570, 0.12580	20.9955, 20.9850, 20.9920	2.5125, 2.5125, 2.5140
	-30	6259.3, 6259.4, 6259.4	0.12600, 0.12530, 0.12510 0.12530, 0.12560, 0.12530	20.9940, 21.0250, 20.9995	2.5130, 2.5140, 2.5130
	-31	6279.7, 6279.7, 6279.7	0.12570, 0.12590, 0.12580 0.12580, 0.12590, 0.12560	20.9945, 20.9975, 20.9950	2.5125, 2.5155, 2.5125
Cu 05	-01	9360.3, 9360.2, 9360.3	0.18850, 0.18820, 0.18810 0.18780, 0.18810, 0.18840	20.9865, 20.9885, 20.9845	2.5145, 2.5200, 2.5170
	-02	9355.7, 9355.6, 9355.7	0.18750, 0.18750, 0.18810 0.18760, 0.18760, 0.18760	20.9900, 20.9900, 20.9925	2.5170, 2.5155, 2.5150
	-03	9373.5, 9373.6, 9373.6	0.18790, 0.18820, 0.18840 0.18800, 0.18800, 0.18810	20.9965, 20.9935, 20.9935	2.5175, 2.5145, 2.5150
	-05	9336.1, 9336.1, 9336.1	0.18850, 0.18790, 0.18770 0.18750, 0.18740, 0.18720	20.9915, 20.9905, 20.9915	2.5155, 2.5180, 2.5160
	-06	9368.5, 9368.5, 9368.5	0.18790, 0.18860, 0.18870 0.18820, 0.18810, 0.18800	20.9870, 20.9915, 20.9915	2.5180, 2.5190, 2.5175

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Table 7 – *Continued from previous page*

Part Type	ID	Mass [g]	Height [in.]	Outer Diameter [in.]	Inner Diameter [in.]
	-07	9347.3, 9347.3, 9347.3	0.18780, 0.18750, 0.18760 0.18760, 0.18770, 0.18770	20.9990, 20.9845, 20.9890	2.5195, 2.5090, 2.5180
	-08	9365.4, 9365.5, 9365.6	0.18800, 0.18840, 0.18850 0.18790, 0.18790, 0.18800	20.9810, 20.9925, 20.9860	2.5135, 2.5185, 2.5170
	-09	9393.1, 9393.0, 9393.0	0.18850, 0.18840, 0.18890 0.18860, 0.18870, 0.18870	20.9910, 20.9945, 20.9965	2.5150, 2.5180, 2.5165
	-10	9365.8, 9365.9, 9365.9	0.18800, 0.18810, 0.18810 0.18820, 0.18820, 0.18830	20.9940, 20.9915, 20.9900	2.5180, 2.5180, 2.5190
	-11	9353.0, 9353.0, 9353.1	0.18810, 0.18790, 0.18820 0.18770, 0.18770, 0.18770	20.9910, 20.9870, 20.9915	2.5185, 2.5115, 2.5110
	-12	9361.0, 9361.1, 9361.1	0.18790, 0.18820, 0.18790 0.18780, 0.18760, 0.18780	20.9935, 20.9925, 20.9960	2.5175, 2.5150, 2.5135
	-13	9367.9, 9367.8, 9367.8	0.18800, 0.18800, 0.18800 0.18790, 0.18810, 0.18800	20.9905, 20.9990, 20.9920	2.5145, 2.5140, 2.5125
	-14	9382.2, 9382.3, 9382.3	0.18820, 0.18810, 0.18820 0.18850, 0.18840, 0.18830	20.9880, 20.9945, 20.9945	2.5120, 2.5130, 2.5185
	-15	9352.4, 9352.4, 9352.5	0.18820, 0.18780, 0.18760 0.18800, 0.18790, 0.18800	20.9805, 20.9940, 20.9850	2.5175, 2.5510, 2.5120
	-16	9375.0, 9375.1, 9375.0	0.18810, 0.18810, 0.18840 0.18820, 0.18820, 0.18800	20.9965, 20.9915, 20.9905	2.5140, 2.5155, 2.5175
	-17	9381.6, 9381.7, 9381.6	0.18840, 0.18830, 0.18830 0.18830, 0.18820, 0.18830	20.9890, 20.9890, 20.9905	2.5155, 2.5180, 2.5125

1.2.4.2 Aluminum Shims

The Al shims were manufactured by Hand Precision Machining Inc. in Los Alamos, NM and were received in 2020 (they were originally procured for HEU-MET-INTER-011). The Al shims were used to adjust the excess reactivity of the $^{3}/_{16}$ configuration. A drawing of the shims is shown in Figure 14. Table 8 lists the dimensions and tolerances of the Al shims used the series of experiments. The Al shim masses were measured with a calibrated Mettler Toledo MS16001L scale in June 2020. Calibration reports show that the scale has a systematic uncertainty of ± 0.2 g. The scale reports masses to the tenth of a gram (0.1 g). The height measurements were performed using a calibrated Brown & Sharpe TWIN CAL IP76 caliper with an uncertainty of ± 0.001 inches (0.00254 cm). The caliper has a reading of four digits after the decimal, but the last digit is either a 0 or 5. All digits are included in Table 9.

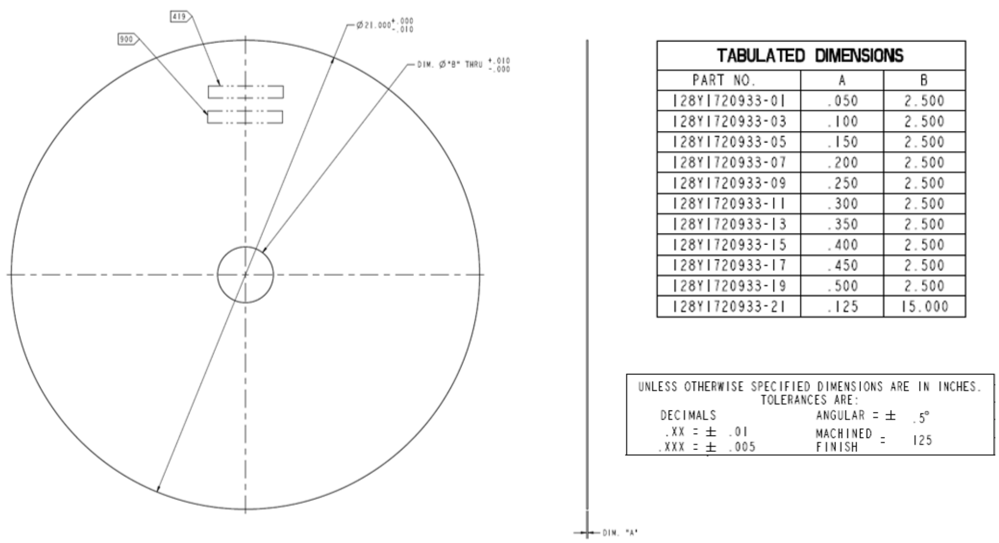

Figure 14. Engineering Drawing (128Y-1720933-D1) of the Al Shims (Dimensions in Inches).

Table 8. Part Types, Number Used in Each Configuration and Dimensions and Tolerances Shown in the Engineering Drawings of the Al Shims. Engineering drawings are in inches; cm values are provided in parentheses.

Part Type	**Number in Config.**			**Nominal Dimensions [in. (cm)]**			**Tolerances [in. (cm)]**		
	$^3/_{16}$	$^5/_{16}$	$^7/_{16}$	**Height**	**Inner Diameter**	**Outer Diameter**	**Height**	**Inner Diameter**	**Outer Diameter**
AS	2	0	0	0.400 or 0.500 (1.016 or 1.27)	2.500 (6.35)	21.000 (53.34)	±0.005 (± 0.0127)	+0.010/ -0.000 (+0.0254/ -0.000)	+0.000/ -0.010 (+0.000/ -0.0254)

Table 9. Height and Masses of Al Shims.[(a)]

Component Name	**Height [in. (cm)]**	**Mass [g]**
400 mil Al Shim	0.3990 (1.01346)	6023.0
500 mil Al Shim	0.5015 (1.27381)	7538.6

(a) Al shims were only used in the $^3/_{16}$ configuration.

1.2.4.3 Aluminum Adapter Plates

Al adapter plates (Figure 15) were only used in the $^7/_{16}$ configuration of the experiment and were the same height as the HEU pancake plates. The Al adapter plates were fabricated at LANL in February 2016. The Al adapter plates are used to fill layers of HEU due to limitations in the amount of HEU pancake plates available. The Al adapter plates used were designed to have an outer diameter of 5.995 in. (15.2273 cm), an inner diameter of 2.50 in. (6.35 cm), and a thickness of 0.118 in. (0.29972 cm). However, no mass or dimension measurements were taken of the adapter plates used in the experiment. Table 10 shows the part type, number of pieces used in each configuration, nominal dimensions, and dimension tolerances of the Al adapter plate.

Table 10. Part Types, Number Used in Each Configuration and Dimensions and Tolerances Shown in the Engineering Drawings of the Al Adapters. Engineering drawings are in inches; cm values are provided in parentheses.

Part Type	Number in Config.			Nominal Dimensions [in. (cm)]			Tolerances [in. (cm)]		
	$^3/_{16}$	$^5/_{16}$	$^7/_{16}$	Height	Inner Diameter	Outer Diameter	Height	Inner Diameter	Outer Diameter
AD	0	0	1	0.118 (0.29972)	2.50 (6.35)	5.995 (15.2273)	±0.002 (± 0.00508)	±0.01 (±0.0254)	+0.000/-0.005 (+0.000/-0.0127)

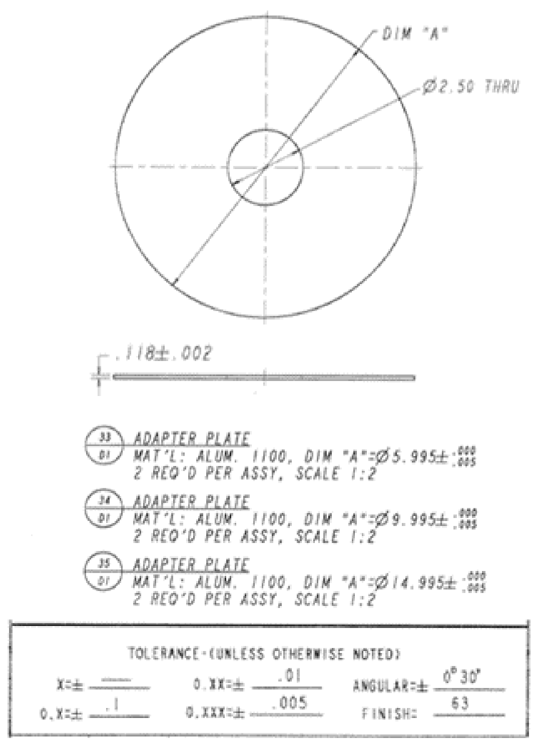

Figure 15. Engineering Drawing (128Y-270955-D5) of the Al Adapters That Are the Same Height as the HEU Plates and Are Used in the HEU Layers (Dimensions in Inches). These are labeled as item 33 in the drawing.

1.2.5 Copper Reflectors

The Cu reflectors used in the experiment were manufactured at ASARCO and arrived at LANL over multiple years. The Cu components include the top (TR), bottom (BR), corner (CR), and side (SR) reflectors. The top, bottom, and some corner reflectors arrived in 1996 (CR1, CR2, CR3, CR4, and CR7). The remaining corner reflectors (CR5 and CR6) arrived in 2001. Note, no CR5 corner reflectors were used in any CERBERUS configuration. The square top reflector rests on top of the four uppermost corner reflector pieces. The corner reflectors closely surround the circular core plates. The cylindrical bottom reflector rests on top of the platen adapter plate, which is secured to the platen of the Comet vertical drive assembly. It also supports the lower core plates. The core and corner reflectors create a square that is surrounded by the side reflectors. There are two types of Cu side reflectors that differ only in the locations of the screw holes. There is a set of side reflectors located on the bottom layer, and the other set is placed on the remaining upper layers. The side reflectors are offset to minimize large gaps. Figure 16 shows an arrangement of the side reflectors, whereas Figure 17 shows an image of four corner reflectors. Figure 18, Figure 19, Figure 20, Figure 21, and Figure 22 are the engineering drawings for the corner, side, top, and bottom reflectors, respectively. Table 11 shows the part type, number of pieces used in each configuration, nominal dimensions, and dimension tolerances of the Cu reflectors.

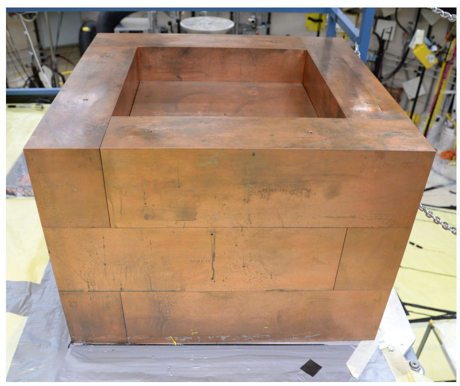

Figure 16. Example Arrangement of the Cu Side Reflectors for the $^3/_{16}$ and $^5/_{16}$ Configurations. The $^7/_{16}$ Configuration has a Fourth Layer.

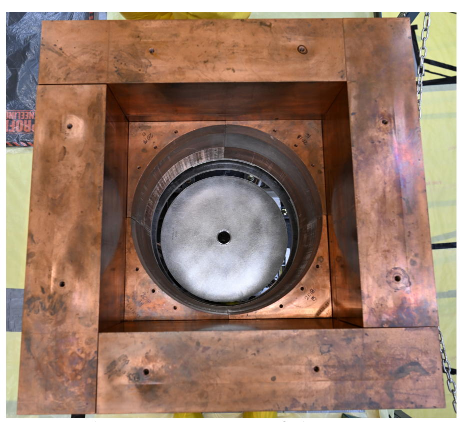

Figure 17. Example Arrangement of the Cu Corner Reflectors.

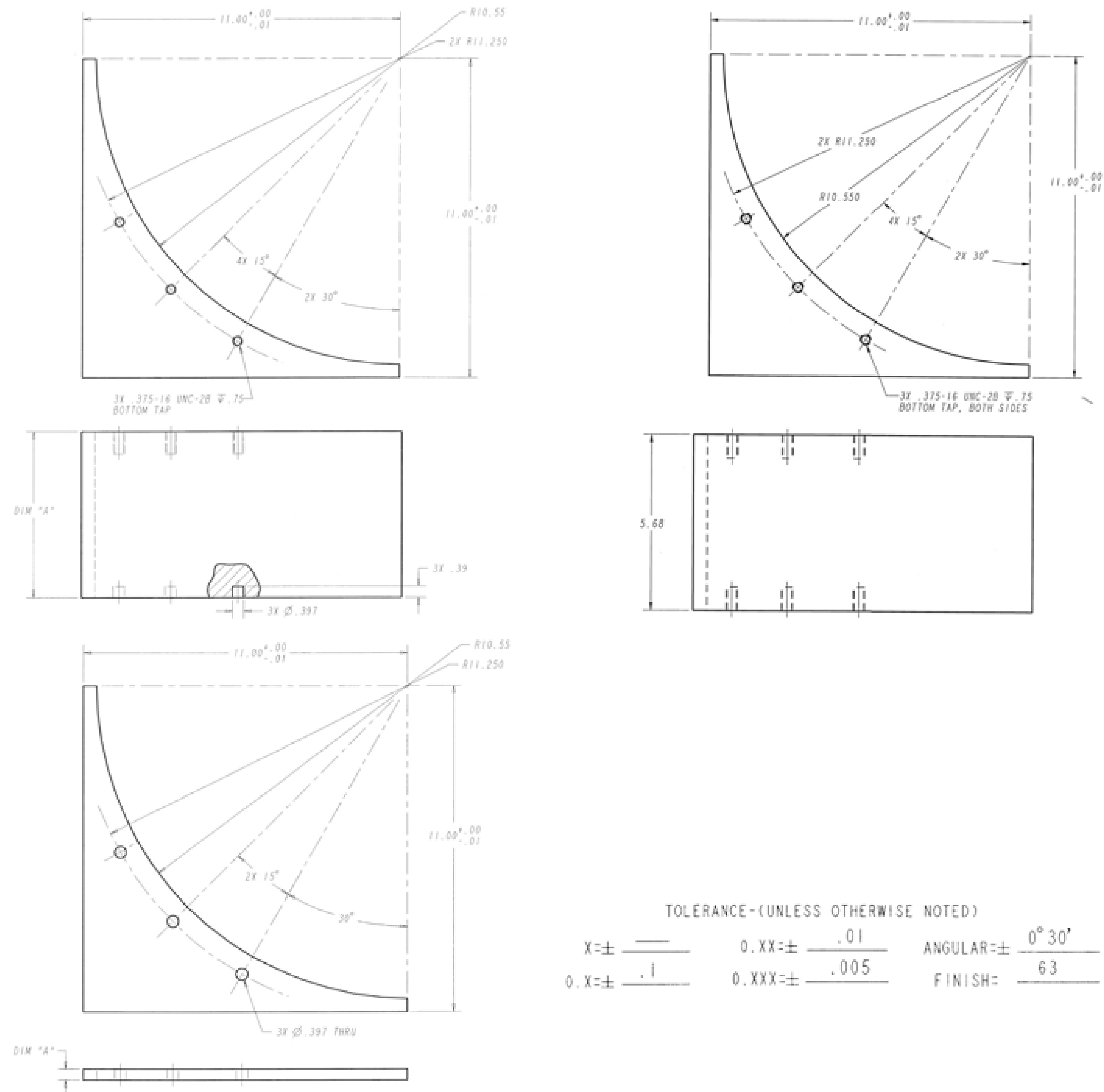

Figure 18. Engineering Drawing (128Y-270955-D2) of the Corner Reflectors (Dimensions in Inches). The drawing on the top left is for CR1, 2, and 4, whereas the drawing on the bottom left is for CR3, 5, 6, and 7. The drawing on the top right is for the bottom CR1 (128Y-270955-D3). See Table 11 for the values of Dim “A”, which originate from their associated engineering drawings.

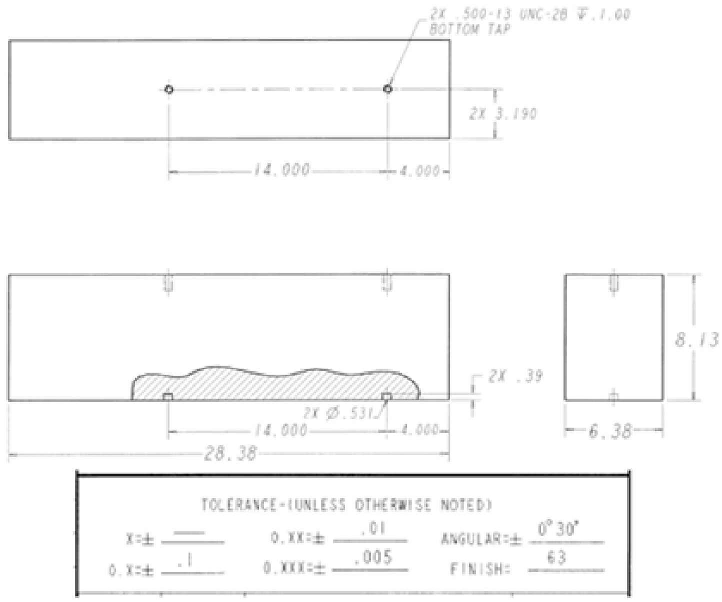

Figure 19. Engineering Drawing (128Y-270955-D2) of a Side Reflector (Dimensions in Inches).

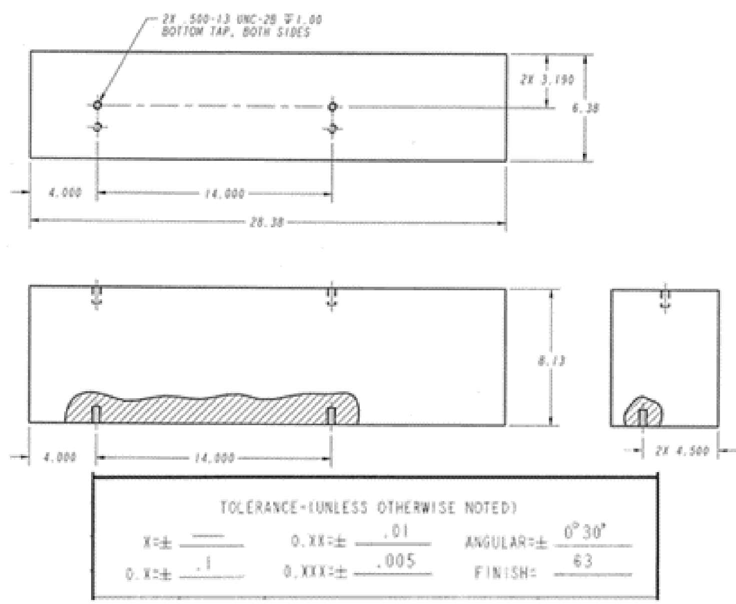

Figure 20. Engineering Drawing (128Y-270955-D3) of the Bottom Layer of Side Reflectors (Dimensions in Inches).

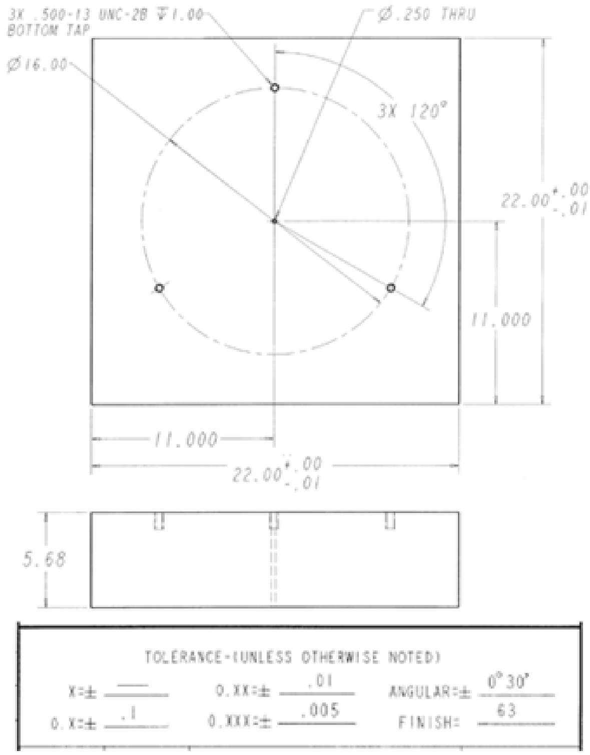

Figure 21. Engineering Drawing (128Y-270955-D2) of the Top Reflector (Dimensions in Inches).

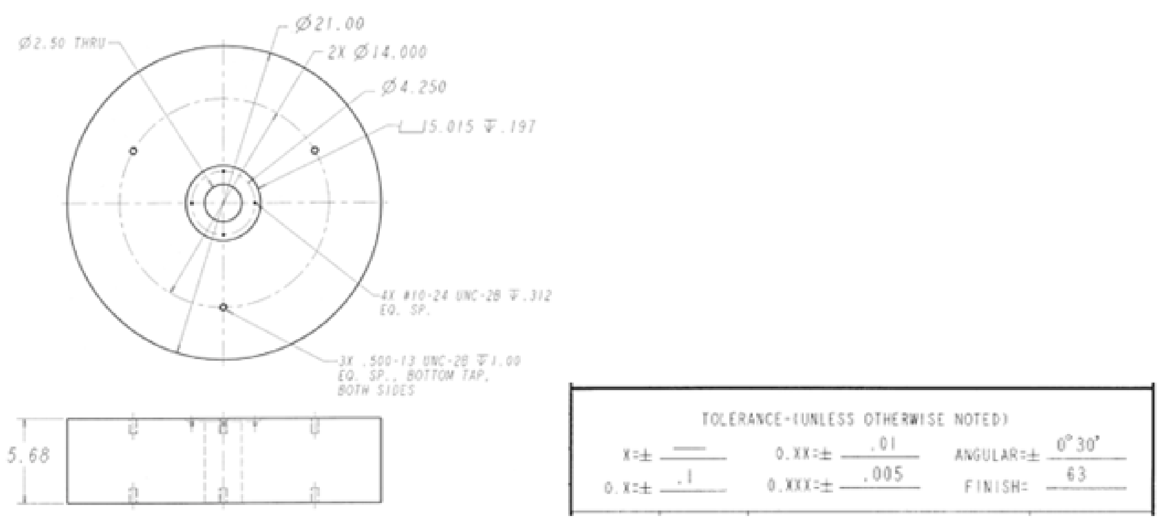

Figure 22. Engineering Drawing (128Y-270955-D2) of the Bottom Reflector (Dimensions in Inches).

Table 11. Part Types, Number in Each Configuration, and Dimensions/Tolerances Shown in the Engineering Drawings of the Cu Reflectors. Minor Details Like Screw Fastening and Positioning Holes Are Ignored. Engineering drawings are in inches; cm values are provided in parentheses.

Part Type	**Number in Config.**			**Nominal Dimensions [in. (cm)]**			**Tolerances [in. (cm)]**		
	3/16	5/16	7/16	**Height**	**Inner Dimension**	**Outer Dimension**	**Height**	**Inner Dimension**	**Outer Dimension**
TR	1	1	1	5.68 (14.4272)	0.250 (0.635)	22.00 (55.88)	±0.01 (±0.0254)	±0.005 (±0.0127)	+0.00/-0.01 (+0.00/-0.0254)
BR	1	1	1	5.68 (14.4272)	2.50 (6.35)	21.00 (53.34)	±0.01 (±0.0254)	±0.01 (±0.0254)	±0.01 (±0.0254)
SR	12	12	16	8.13 (20.6502)	6.38 × 28.38 (16.2052 × 72.0852)		±0.01 (±0.0254)	±0.01 (±0.0254)	±0.01 (±0.0254)
Corner Cu Reflectors[a]									
CR1	8	8	12	5.68 (14.4272)	10.55 (26.797)	22.00 (55.88)	±0.01 (±0.0254)	±0.01 (±0.0254)	+0.00/-0.01 (+0.00/-0.0254)
CR2	0	4	4	3.00 (7.62)	10.55 (26.797)	22.00 (55.88)	±0.01 (±0.0254)	±0.01 (±0.0254)	+0.00/-0.01 (+0.00/-0.0254)
CR3	4	4	4	0.75 (1.905)	10.55 (26.797)	22.00 (55.88)	±0.01 (±0.0254)	±0.01 (±0.0254)	+0.00/-0.01 (+0.00/-0.0254)
CR4	4	0	0	1.50 (3.81)	10.55 (26.797)	22.00 (55.88)	±0.01 (±0.0254)	±0.01 (±0.0254)	+0.00/-0.01 (+0.00/-0.0254)
CR6	4	8	0	0.250 (0.635)	10.55 (26.797)	22.00 (55.88)	± 0.005 (± 0.0127)	±0.01 (±0.0254)	+0.00/-0.01 (+0.00/-0.0254)
CR7	0	0	4	0.375 (0.9525)	10.55 (26.797)	22.00 (55.88)	± 0.005 (± 0.0127)	±0.01 (±0.0254)	+0.00/-0.01 (+0.00/-0.0254)

(a) The corner reflectors fit within a 22.00 in. × 22.00 in. (55.88 × 55.88 cm) square with a radius of 10.55 in. (26.797 cm)

Table 12 includes all the latest measured masses and heights for the Cu reflector components: top (TR), bottom (BR), side (SR), and corner reflectors (CR1 through 7, excluding CR5). These Cu reflectors were used in previous Zeus benchmarks (HEU-MET-FAST-072, HEU-MET-FAST-073, HEU-MET-FAST-102, IEU-MET-FAST-025, HEU-MET-INTER-006, and HEU-MET-INTER-011). Some of the components were reweighed because the initial measurements had a large uncertainty for the smaller corner reflector pieces (CR2 through 7) and these are the only components that have height measurements. Mass measurements for CR2 through 7 were performed in 2019 using a calibrated 16 kg Mettler Toledo scale (MS16001L), which has an accuracy of ±0.2 g on the reading, and the height measurements were performed with a calibrated Mitutoyo CD-24 in. caliper that has an accuracy of ±0.002 in. The caliper reports four digits after the decimal, and all digits are included in Table 12. Three height measurements were performed on each corner reflector. The top reflector, bottom reflector, side reflector, and CR1 do not have height measurements and no new mass measurements. The Cu top reflector mass was measured with a calibrated Mettler Toledo Panther Plus PTHK scale. Calibration reports show that the scale has a systematic uncertainty of ±0.5 lb. The scale reports masses to a tenth of a kilogram (100 g). The mass measurements for the bottom reflector, side reflector, and CR1 are the same as in previous Zeus benchmarks, which stated the measurements were performed using a calibrated ED-2000 electric dynamometer manufactured by the Dillion Company. Dillon advertises its accuracy and repeatability as 0.1% of full rated capacity, which in this case, was 2000 lb. In a telephone conversation, a Dillon technical representative confirmed that this meant an absolute 2 lb error anywhere along the scale, but he described the uncertainty as a limiting value as opposed to a standard deviation (1σ). These components were used in all experiment configurations. The location of each side reflector and the radial location of each corner reflector was not recorded.

Table 12. Heights and Masses of Cu Reflector Components.[(a)]

Part Type	Measured Heights [in.]	Masses of Components
TR	—	395.6 kg[(b)]
BR	—	616 lb[(c)]
CR1	—	61, 60, 60, 61, 60, 60.5, 60, 60, 60, 60, 60, 61, 60, 60, 60, 61, 60, 60, 60, 60, 60, 60, 60, 60, 60, 61, 60, 60 lb[(d)]
CR2	2.9955, 2.9980, 2.9960, 2.9955, 2.9995, 2.9990, 3.0005, 3.0010, 2.9970, 2.9965, 2.9955, 2.9960	14414.6, 14401.2, 14405.6, 14340.5 g
CR3	0.7475, 0.7445, 0.7475, 0.7445, 0.7450, 0.7500, 0.7485, 0.7475, 0.7575, 0.7520, 0.7500, 0.7500	3540.5, 3538.4, 3585.7, 3577.6 g
CR4	1.4985, 1.4965, 1.4955, 1.4945, 1.4990, 1.4965, 1.4975, 1.5000, 1.4985, 1.4975, 1.4965, 1.4965	7124.6, 7167.6, 7098.6, 7184.7 g
CR6	0.2495, 0.2495, 0.2485, 0.2490, 0.2500, 0.2495, 0.2475, 0.2495, 0.2485, 0.2495, 0.2495, 0.2490, 0.2500, 0.2490, 0.2485, 0.2500, 0.2510, 0.2510, 0.2485, 0.2505, 0.2495, 0.2515, 0.2505, 0.2505	1181.1, 1190.9, 1201.4, 1176.9, 1196.2, 1182.9, 1178.6, 1178.8 g
CR7	0.3760, 0.3790, 0.3760, 0.3755, 0.3775, 0.3785, 0.3765, 0.3770, 0.3770, 0.3740, 0.3730, 0.3720	1802.6, 1801.2, 1797.3, 1790.3 g
SR	—	465, 465, 464, 465, 465.5, 466, 464, 463, 466, 467, 466, 462, 464, 465, 464, 463, 467, 465, 464, 462, 462, 463, 464, 464 lb[(e)]

(a) K. M. Amundson, “Zeus Copper Information,” Los Alamos National Laboratory report LA-UR-21-29726, September 2021.
(b) 395.6 kg = 395,600 g
(c) 616 lb = 279,413 g
(d) 60 lb = 27,215.5 g, 60.5 lb = 27,442.34 g, 61 lb = 27,669.1 g
(e) 462 lb = 209,560 g, 463 lb = 210,013 g, 464 lb = 210,467 g, 465 lb = 210,920 g, 465.5 lb = 211,147.25 g, 466 lb = 211,374 g, 467 lb = 211,828 g

1.2.6 Comet Hardware

The Comet hardware was used in all configurations and includes the steel diaphragm, top plate, alignment tube, platen, and platen adapter plate.

1.2.6.1 Steel Diaphragm

A 304 stainless steel diaphragm was used to support the upper core of the Comet assembly, and was attached to the corner reflectors. The diaphragm used in this experiment was obtained from Ta Chen International Corporation and was reviewed for quality control by Jona Machining Co. in 2009. Table 13 shows the part type, number of pieces used in each configuration, nominal dimensions, and dimension tolerances of the diaphragm. The diaphragm is a 22.00 in. (55.88 cm) square plate that is 0.187 in. (0.47498 cm) thick and has a mass of 11,570.1 g. The mass measurements were taken using a calibrated 16-kg Mettler Toledo scale (MS16001L), which has an accuracy of ±0.2 g on the reading and a repeatability of ±0.1 g. An engineering drawing of the steel diaphragm is shown in Figure 23.

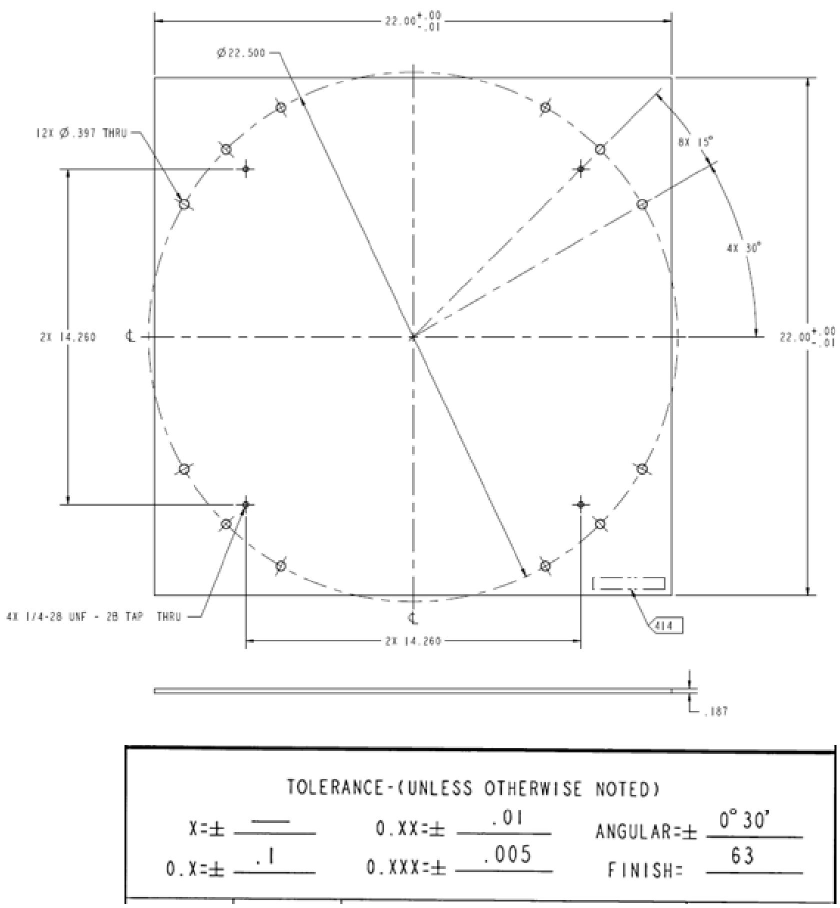

Figure 23. Engineering Drawing (128Y-270955-D3) of the Steel Diaphragm Plate (Dimensions in Inches).

Table 13. Part Types, Number Used in Each Configuration and Dimensions and Tolerances Shown in the Engineering Drawing of the Steel Diaphragm. Minor Details Like Screw Fastening and Positioning Holes Are Ignored. The engineering drawing is in inches; cm values are provided in parentheses.

Part Type	Number in Config.			Nominal Dimensions [in. (cm)]		Tolerances [in. (cm)]	
	$^{3}/_{16}$	$^{5}/_{16}$	$^{7}/_{16}$	Height	Length & Width	Height	Length & Width
Steel Diaphragm	1	1	1	0.187 (0.47498)	22.00 (55.88)	±0.005 (± 0.0127)	+0.00/-0.01 (+0.00/-0.0254)

1.2.6.2 Top Plate

The Al top plate is used to support the Cu reflectors and contains a central hole that allows the lower core to be raised into contact with the steel diaphragm that supports the upper core. No information on the mass of the top plate exists, but it is a 45.00 in. (114.3 cm) square plate that is 1.00 in. (2.54 cm) thick and has a central hole of 21.100 in. (53.594 cm) in diameter. Table 14 shows the part type, number of pieces used in each configuration, nominal dimensions, and dimension tolerances of the top plate. Figure 24 shows an engineering drawing of the top plate.

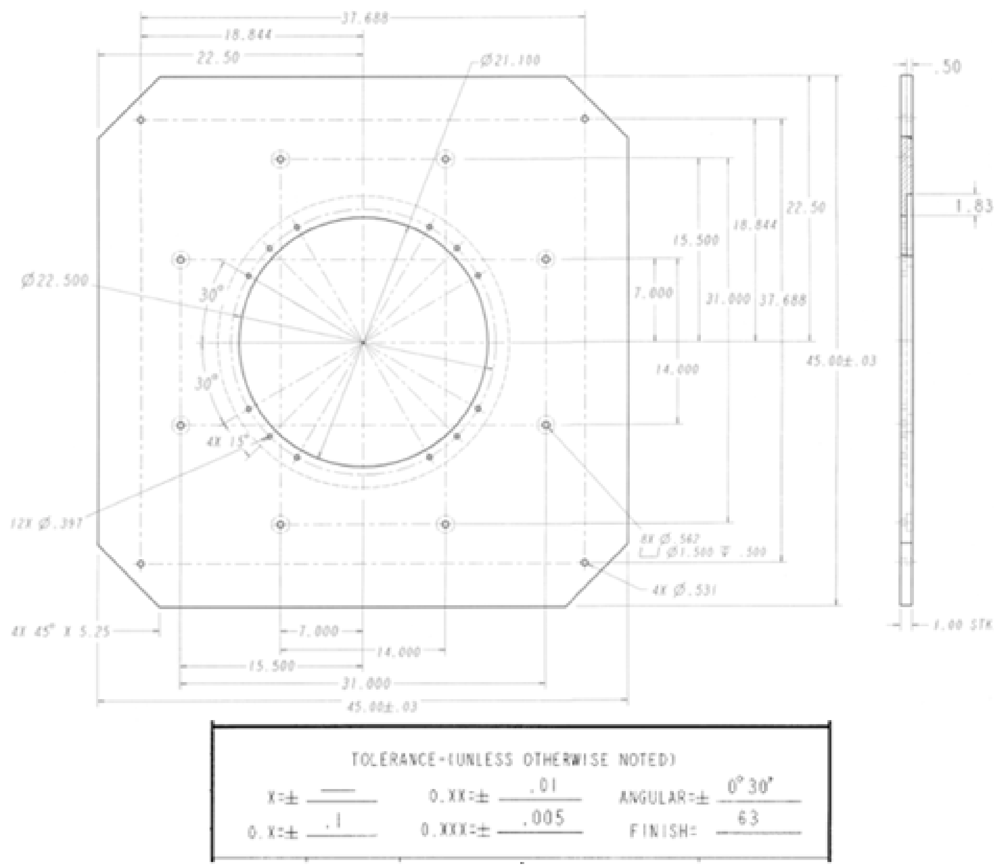

Figure 24. Engineering Drawing (128Y-270955-D4) of the Top Plate (Dimensions in Inches).

Table 14. Part Types, Number Used in Each Configuration and Dimensions and Tolerances Shown in the Engineering Drawing of the Top Plate. Minor Details Like Screw Fastening and Positioning Holes Are Ignored. The engineering drawing is in inches; cm values are provided in parentheses.

Part Type	**Number in Config.**			**Nominal Dimensions [in. (cm)]**			**Tolerances [in. (cm)]**		
	$^{3}/_{16}$	$^{5}/_{16}$	$^{7}/_{16}$	**Height**	**Inner Diameter**	**Length & Width**	**Height**	**Inner Diameter**	**Length & Width**
Top Plate	1	1	1	1.00 (2.54)	21.100 (53.594)	45.00 (114.3)	±0.01 (± 0.0254)	±0.005 (±0.0127)	±0.03 (±0.0762)

1.2.6.3 Alignment Tube

The alignment tube is used to align the plates in the lower core of the assembly. In the experiment, the alignment tube is not flush with the top of the lower core. Instead, the alignment tube is rotated down a quarter of a turn with an uncertainty of a quarter of a turn, which corresponds to 0.03125 in. ± 0.03125 in. (0.079375 cm ± 0.079375 cm). Table 15 shows the part type, number of pieces used in each configuration, nominal dimensions, and dimension tolerances of the alignment tube. The alignment tube has an inner diameter of 2.00 in. (5.08 cm), an outer diameter of 2.480 in. (6.2992 cm), and a height of 18.50 in. (46.99 cm). The mass of the alignment tube was not measured. The alignment tube has internal threads on both ends. Figure 25 shows the engineering drawing of the alignment tube.

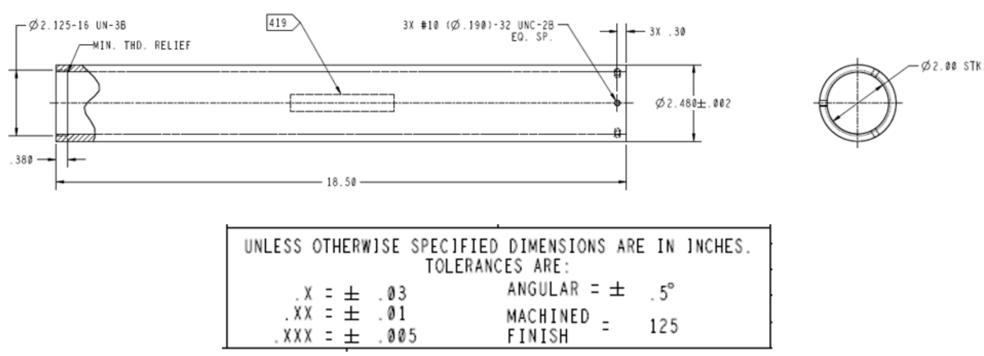

Figure 25. Engineering Drawing (128Y-1721373-D1) of the Al Alignment Tube (Dimensions in Inches).

Table 15. Part Types, Number Used in Each Configuration and Dimensions and Tolerances Shown in the Engineering Drawings of the Alignment Tube. Minor Details Like Screw Fastening and Positioning Holes Are Ignored. The engineering drawing is in inches; cm values are provided in parentheses.

Part Type	Number in Config.			Nominal Dimensions [in. (cm)]			Tolerances [in. (cm)]		
	$^3/_{16}$	$^5/_{16}$	$^7/_{16}$	Height	Inner Diameter	Outer Diameter	Height	Inner Diameter	Outer Diameter
AT	1	1	1	18.50 (46.99)	2.00 (5.08)	2.480 (6.2992)	±0.01 (±0.0254)	STK.[a]	±0.002 (±0.00508)

(a) STK. means nominal dimension of stock material.

1.2.6.4 Platen and Platen Adapter Plate

The platen and platen adapter plate rest below the bottom reflector, where the platen is connected to the vertical drive of the Comet machine. There is no information on the mass of either the platen adapter plate or the platen. The platen adapter plate and platen have an inner diameter of 3.75 in. (9.525 cm) and an outer diameter of 21.00 in. (53.34 cm). The platen adapter plate has an axial height of 1.5 in. (3.81 cm), and the platen has a height of 1.0 in. (2.54 cm). None of the dimensions have been measured. Table 16 shows the part type, number of pieces used in each configuration, nominal dimensions, and dimension tolerances of the platen and platen adapter plate. Figure 26 and Figure 27 show the engineering drawings of the platen adapter plate and the platen, respectively.

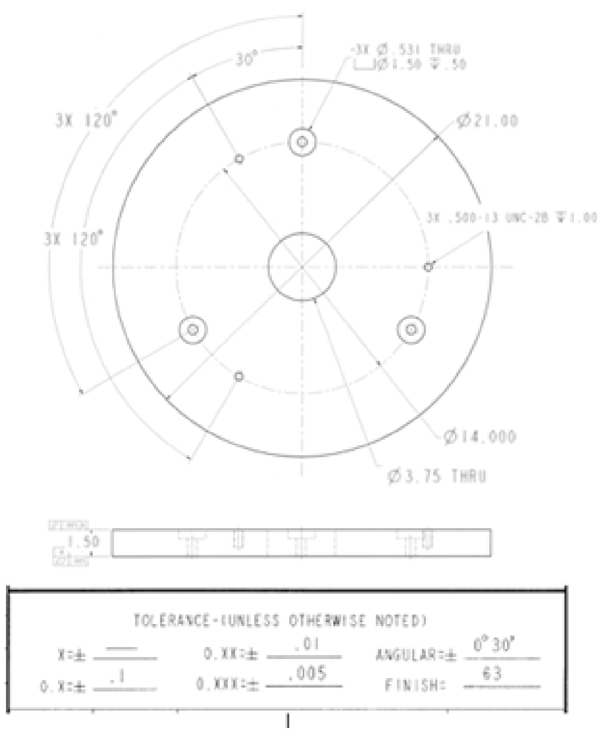

Figure 26. Engineering Drawing (128Y-270955-D6) of the Platen Adapter Plate (Dimensions in Inches).

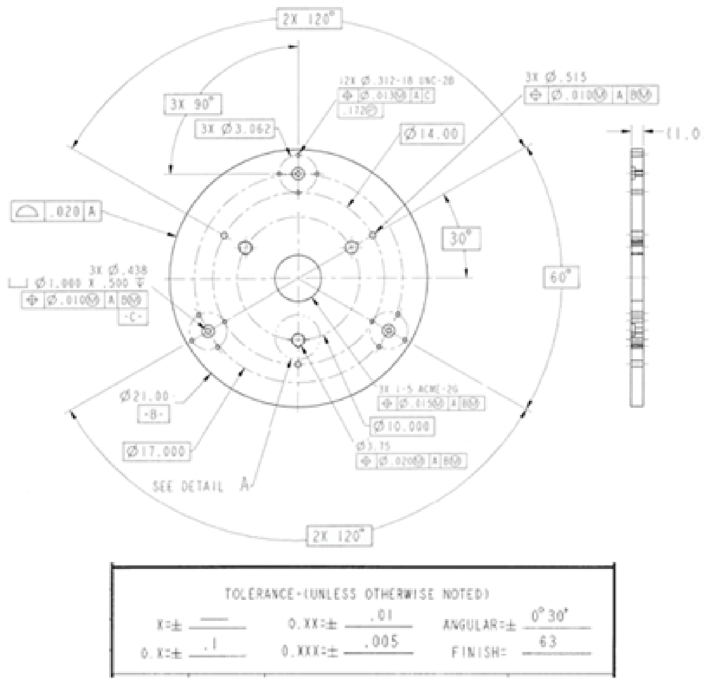

Figure 27. Engineering Drawing (128Y-270958-D2) of the Platen (Dimensions in Inches).

Table 16. Part Types, Number Used in Each Configuration and Dimensions and Tolerances Shown in the Engineering Drawings of the Platen and Platen Adapter Plate. Minor Details Like Screw Fastening and Positioning Holes Are Ignored. Engineering drawings are in inches; cm values are provided in parentheses.

Part Type	Number in Config.			Nominal Dimensions [in. (cm)]			Tolerances [in. (cm)]		
	$^3/_{16}$	$^5/_{16}$	$^7/_{16}$	Height	Inner Diameter	Outer Diameter	Height	Inner Diameter	Outer Diameter
Platen Adapter Plate	1	1	1	1.50 (3.81)	3.75 (9.525)	21.00 (53.34)	±0.01 (± 0.0254)	±0.01 (±0.0254)	±0.01 (±0.0254)
Platen	1	1	1	1.00 (2.54)	3.75 (9.525)	21.00 (53.34)	±0.01 (± 0.0254)	±0.01 (±0.0254)	±0.01 (±0.0254)

1.2.7 Facility Description

NCERC is located inside the Device Assembly Facility (DAF) at the NNSS. The entire facility is covered by compacted earth with a thick gravel overlaying roof. The experiments were performed in one of the buildings at NCERC that can be neutronically approximated using the following information. The room is cylindrical with an inner radius of ∼17 ft (5.1816 m) and a wall thickness of ∼1 ft (30.48 cm). There is an opening to the room that has a width of 8 ft (2.4384 m). All major features are shown in Figure 28.

Also shown in Figure 28 is the second critical assembly machine located in the building, Godiva-IV (HEU-MET-FAST-086). Three sets of detectors were also present in the room. The four startup detectors consist of helium-3 (He-3) tubes in polyethylene and were located more than 30 in. from the center of the assembly. The other two sets of detectors (seven total) are compensated ion chambers, which are all located more than 3 m from the assembly. This building also has a crane that is more than 2 m above the top of the assembly. The building has various equipment present that is not located near the assembly.

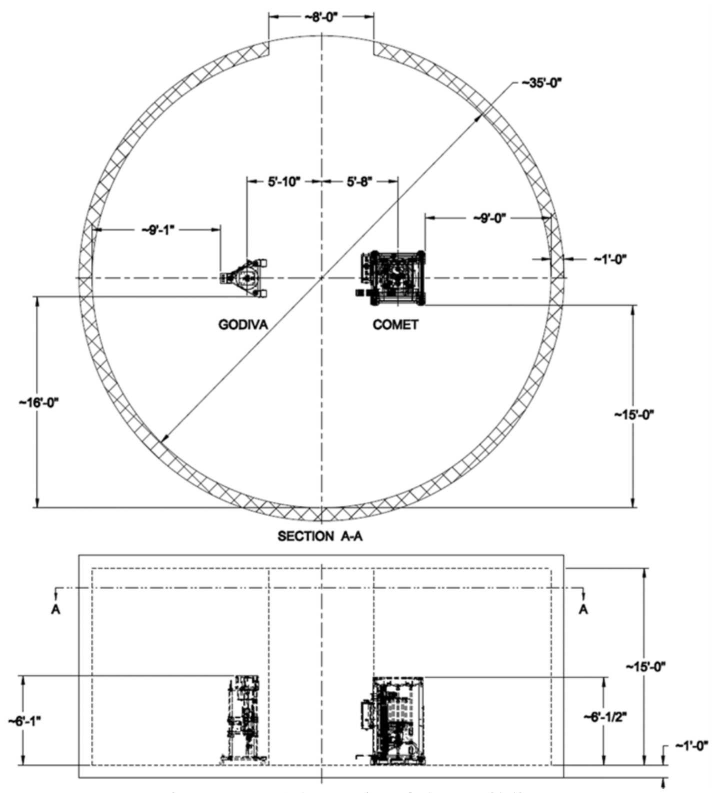

Figure 28. Schematic of the Building.

1.3 Description of Material Data (Excluding Source and Detector Materials)

1.3.1 Highly Enriched Uranium Disks and Rings

Uranium (U) isotopic measurements were performed using the AVCO mass spectrometer in May 1974. U isotopic measurements were only performed on a subset of HEU plates, and the results are shown in Table 17. The uncertainty of the measurements reported in Table 17 are at the 95% confidence level (2σ). Impurity measurements of each HEU 21/15 ring and a subset of the HEU 15/0 plates are shown in Table 18 and Table 19, respectively; however, impurity measurements for the other HEU plates are not available. Enrichment measurements were performed on all of the HEU plates used in the experiment and are shown in Table 18 (the outer HEU rings) and Table 20 (the inner HEU disks). There are minor differences in enrichment results for plate B-2444-13 (seen in Table 17 and Table 18) and 11018 (seen in Table 17 and Table 20); this difference will be evaluated in Section 2.4.1.

Table 17. U Isotopic Measurements Performed on a Subset of HEU Plates. Measurements Are Recorded as Atom Ratios with Respect to U-235. 2σ Uncertainties Are Reported.[a]

Plate	U-234		U-235		U-236		U-238	
	Atom Ratio	**Weight%**	**Atom Ratio**	**Weight%**	**Atom Ratio**	**Weight%**	**Atom Ratio**	**Weight%**
-13[b]	$(1.06 \pm 0.01) \times 10^{-2}$	0.988 ± 0.006	1.00	93.220 ± 0.037	$(4.63 \pm 0.05) \times 10^{-3}$	0.434 ± 0.004	$(5.67 \pm 0.02) \times 10^{-2}$	5.358 ± 0.021
10493	$(1.15 \pm 0.01) \times 10^{-2}$	1.069 ± 0.004	1.00	93.261 ± 0.037	$(8.40 \pm 0.42) \times 10^{-4}$	0.079 ± 0.004	$(5.92 \pm 0.02) \times 10^{-2}$	5.591 ± 0.022
10458	$(1.11 \pm 0.02) \times 10^{-2}$	1.033 ± 0.02	1.00	93.507 ± 0.037	$<2 \times 10^{-5}$	—	$(5.77 \pm 0.12) \times 10^{-2}$	5.460 ± 0.109
11018	$(1.10 \pm 0.01) \times 10^{-2}$	1.022 ± 0.010	1.00	93.208 ± 0.037	$(5.65 \pm 0.06) \times 10^{-3}$	0.529 ± 0.005	$(5.55 \pm 0.02) \times 10^{-2}$	5.241 ± 0.021
10932	$(1.08 \pm 0.01) \times 10^{-2}$	1.002 ± 0.006	1.00	93.143 ± 0.037	$(3.50 \pm 0.04) \times 10^{-3}$	0.327 ± 0.003	$(5.86 \pm 0.02) \times 10^{-2}$	5.528 ± 0.022

(a) J. H. Cappis, "Mass Spectrometer Analysis – GWK-2336-B P-5," Los Alamos Scientific Laboratory office memorandum CNC-11-MS-264 to G. W. Knobeloch, May 15, 1974.
(b) The HEU 21/15 plates are numbered B-2444-XX, and this is the value for XX.

Table 18. Impurity Measurements for HEU 21/15 Plates Used in the Experiment.[a] Values Are in ppm, Except U-234 and U-235 Are in wt%.[b]

ID[c]	B	Fe	Mn	Ni	Cr	V	Cu	Al	Si	C	Mo	U-234	U-235
-22	0.5	80	5	25	6	<1	7	35	350	450	80	1.00	93.17
-27	0.4	70	6	15	5	<1	5	30	180	550	35	1.01	93.19
-19	0.4	75	6	25	6	<1	7	35	200	420	100	1.01	93.16
-07	0.4	65	4	25	5	<1	6	35	200	420	80	1.01	93.17
-37	0.1	215	8	50	50	<1	3	10	50	300	50	1.03	93.12
-20	0.4	60	3	20	5	<1	3	35	150	550	40	1.02	93.17
-10	0.5	225	6	30	8	<1	10	25	350	500	85	1.02	93.17
-33	0.1	45	3	30	9	<1	4	10	50	380	80	1.03	93.09
-29	0.2	85	5	40	13	1	7	20	160	370	70	1.02	93.16
-36	0.1	50	3	30	8	<1	3	10	100	330	50	1.04	93.16
-01	0.4	60	5	25	7	<1	6	25	220	420	60	1.01	93.16
-24	0.4	75	5	25	5	<1	6	30	250	400	75	0.99	93.18
-02	0.4	60	4	25	13	2	7	35	400	340	120	1.02	93.16
-31	0.3	70	4	20	5	<1	5	20	160	420	70	1.01	93.17

(a) Be $<$ 0.02, Ca $\leq$ 5, Li $<$ 0.1, Co $\leq$ 1, Na $\leq$ 1, Mg $<$ 1, P $<$ 50, Zn $<$ 20, K $<$ 5, Pb $<$ 1, Sn $<$ 1, and Cd $<$ 0.2 ppm for all plates, which is why they are not included in the table.
(b) G. E. McKenzie, "Jemima Plate Information," Los Alamos National Laboratory report LA-UR-19-22751, March 2019.
(c) The HEU 21/15 plates are numbered B-2444-XX, and this is the value for XX.

Table 19. Impurity Measurements for Some of the HEU 15/0 Plates Used in the Experiment.[a] Values Are in ppm.[b]

ID	B	Fe	Mn	Ni	Cr	Cu	Al	Si	C	Mo	Pb
11147	0.6	100	4	20	5	6	50	300	1100	50	5
11149	0.6	190	7	30	15	5	40	400	270	<25	<1
11150	0.3	90	6	20	5	4	20	210	320	<25	<1

(a) Be $<$ 0.1, Ca $<$ 2, Li $<$ 0.1, Co $<$ 5, Na $<$ 1, V $<$ 20 Mg $<$ 1, and Sn $<$ 1 ppm for all plates, which is why they are not included in the table.
(b) From HEU-MET-FAST-072

Table 20. U-235 Enrichments for the Inner HEU Plates.[a]

ID	Part Type	U-235 Enrichment (%)
10477	HEU 15/6	93.35
11150	HEU 15/0	93.17
11149	HEU 15/0	93.24
11017	HEU 15/0	93.31
11018	HEU 15/6	93.19
Q2-16	HEU 6/0	93.14
11019	HEU 15/0	93.18
11147	HEU 15/0	93.17
10489	HEU 15/2.5	93.39
10467	HEU 15/2.5	93.41
10487	HEU 15/2.5	93.26
10464	HEU 15/2.5	93.38
10470	HEU 15/2.5	93.41
10475	HEU 15/2.5	93.40
10491	HEU 15/2.5	93.37

(a) "Final Data Summary for Shipments 05-10 A & B DAF," N:EM:05-031, September 22, 2005.

1.3.2 Non-Fissile Core Components

1.3.2.1 Interstitial Copper Plates

The Cu interstitial plates were made of C11000, a Cu alloy, from Alro Steel Corporation. Two samples from different Cu interstitial plates with central holes (05-04 and 01-11) were sent to NSL Analytical for composition analysis. A combination of ICP-MS, Pyrohydrolysis with Ion Chromatography, and Leco Furnace methods were used to look for: silver (Ag), aluminum (Al), arsenic (As), gold (Au), boron (B), barium (Ba), beryllium (Be), bismuth (Bi), bromine (Br), calcium (Ca), cadmium (Cd), cerium (Ce), chlorine (Cl), cobalt (Co), chromium (Cr), cesium (Cs), copper (Cu), dysprosium (Dy), erbium (Er), europium (Eu), fluorine (F), iron (Fe), gallium (Ga), gadolinium (Gd), germanium (Ge), hafnium (Hf), holmium (Ho), indium (In), iridium (Ir), potassium (K), lanthanum (La), lithium (Li), lutetium (Lu), magnesium (Mg), manganese (Mn), molybdenum (Mo), nitrogen (N), sodium (Na), niobium (Nb), neodymium (Nd), nickel (Ni), oxygen (O), osmium (Os), phosphorus (P), lead (Pb), palladium (Pd), praseodymium (Pr), platinum (Pt), rubidium (Rb), rhenium (Re), rhodium (Rh), ruthenium (Ru), sulfur (S), antimony (Sb), scandium (Sc), selenium (Se), silicon (Si), samarium (Sm), tin (Sn), strontium (Sr), tantalum (Ta), terbium (Tb), tellurium (Te), thorium (Th), titanium (Ti), thallium (Tl), thulium (Tm), uranium (U), vanadium (V), tungsten (W), yttrium (Y), ytterbium (Yb), zinc (Zn), and zirconium (Zr). Table 21 summarizes the results of the two sample compositions (only including values above the detectable limits).

Table 21. Cu Reflector Interstitial Plate Impurities, [wt%]. Cu is the Balance.$^{(a)}$

Element	Cu Interstitial Plate Impurities	
	05-04 (3/16 in.)	**01-11 (2/16 in.)**
Silver	0.001	0.001
Iron	0.007	0.005
Nickel	0.000	0.001
Oxygen	0.014	0.016
Lead	0.003	0.004
Tin	0.003	0.002
Zinc	0.009	0.008

(a) NSL Analytical Test Report (ID:R-20230626-115). PO Number EP140491, June 30, 2023.

1.3.2.2 Aluminum Shims

The Al shims were made from Al 6061-T6 alloy and a chemical analysis was performed by Arconic in November 2018. The analysis looked for silicon (Si), iron (Fe), copper (Cu), manganese (Mn), magnesium (Mg), chromium (Cr), zinc (Zn), and titanium (Ti). The report states that any other elements are <0.05 wt.% individually and <0.15 wt.% in total. The results are shown in Table 22.

Table 22. Chemical Composition of Al Shims (wt%), with Al as the Balance of the Composition.$^{(a)}$

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other (each)	Other (total)
0.63	0.5	0.24	0.06	0.9	0.18	0.07	0.03	<0.05	<0.15

(a) Acronic, "Inspection Certificate", B.L. No.: 11921330, Date of Issue: November 26, 2018.

1.3.2.3 Aluminum Adapter Plates

An analysis of the Al adapter plates was not performed. The only information available, which comes from the engineering drawings, is that the adapter plates were made from Al 1100 alloy.

1.3.3 Copper Reflectors

The same Cu reflectors from HEU-MET-FAST-072, HEU-MET-FAST-073, HEU-MET-FAST-102, IEU-MET-FAST-025, HEU-MET-INTER-006, and HEU-MET-INTER-011 were used in this experiment. The Cu reflectors were obtained from ASARCO in 1996 and 2001. Impurities in the Cu are shown in Table 23. Cast number 60434 refers to the side reflectors, whereas cast number 60472 refers to the bottom reflector, top reflector, and initial corner reflectors (CR1, CR2, CR3, CR4, and CR7). Impurities for the second batch of corner reflectors (CR5 and CR6) are not available.

Table 23. Cu Reflector Impurities in ppm, Except Oxygen (O), which is in wt%. Cu is the Balance.[a]

Element	**Cu Reflector Impurities (ppm)**	
	Cast # 60434	**Cast # 60472**
Antimony	0.8	1.1
Arsenic	0.4	0.1
Bismuth	0.4	0.5
Iron	4.4	3.2
Lead	1.3	0.6
Nickel	3.0	1.0
Selenium	0.2	0.2
Silver	11.0	16.0
Tellurium	0.1	0.1
Tin	0.2	0.1
Zinc	0.3	0.1
Oxygen (wt%)	0.046	0.036

(a) R. P. Damjanovich, "ASARCO Copper Order for the ZEUS Experiments," Los Alamos National Laboratory memorandum NIS6-96:0314RPD, June 24, 1996.

1.3.4 Comet Hardware

1.3.4.1 Steel Diaphragm

A chemical analysis of the steel diaphragm was included in the inspection certificate from Ta Chen International Corporation (the steel diaphragm is referred to as A1802321). The analysis looked for carbon (C), silicon (Si), manganese (Mn), phosphorus (P), sulfur (S), chromium (Cr), nickel (Ni), copper (Cu), aluminum (Al), nitrogen (N), molybdenum (Mo), and titanium (Ti). The reported chemical composition is shown in Table 24, where the balance of the composition is iron (Fe).

Table 24. Chemical Composition of Steel Diaphragm (wt%), with Fe as the Balance of the Composition.[a]

C	**Si**	**Mn**	**P**	**S**	**Cr**	**Ni**	**Cu**	**Al**	**N**	**Mo**	**Ti**
0.017	0.503	1.771	0.023	0.002	18.215	8.091	0.109	—	0.059	—	—

(a) Ta Chen International Corporation, "Inspection Certificate", Certificate No.: ABA081274A, Date of Issue: November 27, 2008.

1.3.4.2 Top Plate, Alignment Tube, Platen, and Platen Adapter Plate

Chemical analysis has not been performed on the Al top plate, alignment tube, platen, or platen adapter plate. However, engineering drawings indicate that all these components were made of Al 6061-T6.

1.4 Temperature

The temperatures for each day of the experiment were recorded in the Comet logbook. Two resistance temperature detectors (RTDs) were used for most of the configurations during the experiment. The first RTD was in the Al alignment tube (also referred to as the spindle) and the second RTD was located outside the assembly to measure the ambient temperature. For the $^5/_{16}$" configuration the RTD was not placed in the Al alignment tube. The systematic uncertainty during calibration for the RTD measurement circuit is ±2°C, which is the highest uncertainty associated with the RTD system. The temperature data files were also searched for the minimum temperature for each day; this information is also included in Table 25.

Table 25. Temperature Measurements.[a]

Config.	Date	Alignment Tube [°C]	Ambient [°C]	Minimum[b] [°C]
$^3/_{16}$	September 13, 2023	15.6	14.3	14.2
$^5/_{16}$	August 10, 2023	N/A	16.2	14.5
$^7/_{16}$	September 20, 2023	15.8	14.0	13.8

(a) From Comet Logbook (August 7 - September 20, 2023).
(b) Temperature data file for August 7 - September 20, 2023 (recorded and saved on Comet computer)

1.5 Supplemental Experimental Measurements

Multiple measurements were applied to the $^5/_{16}$ configuration; including, Rossi-α, reaction rates, and leakage spectra, in addition to the determination of a critical configuration.

2.0 EVALUATION OF EXPERIMENTAL DATA

The sensitivity effects for the four benchmark measurement configurations examined were evaluated using Monte Carlo N-Particle[a, ®] (MCNP®) Version 6.3[b] and ENDF/B-VIII.[c]neutron cross section libraries. Most calculations (exceptions are noted) used 1.2 million neutrons per cycle with 850 active cycles (1000 cycles with 150 skipped cycles), for 1.02 billion active neutron histories. This results in a Monte Carlo statistical uncertainty of ± 0.00002, which means an uncertainty of ± 0.00003 for Δk_{eff}.

All calculations leading to values that are included in the benchmark models are not rounded until the end of the calculation. For some parameters, the standard uncertainty in k_{eff}, $u_{k,i}$, as a result of uncertainty in parameter i with reference value $x_{i,o}$, was calculated as the difference between perturbed values of k_{eff} divided by the number of standard deviations,

$$u_{k,i} = \frac{u_i}{2\delta x_i} |k_{eff}(x_{i,0} + \delta x_i) - k_{eff}(x_{i,0} + \delta x_i)| \tag{1}$$

where u_i is the standard uncertainty in the parameter being perturbed and δx_i is the value of the perturbation. The scaling factor $2\delta x_i/u_i$ is the number of standard deviations by which $x_{i,0}$ was perturbed. The difference in Equation 1 is given as Δk_{eff} in the tables. Sensitivity effects are judged to be negligible when the calculated value of Δk_{eff} is within the Monte Carlo uncertainty of the difference (usually ± 0.00003). In addition, if $u_{k,i}$ is less than 0.00002, the effect is also judged to be negligible (regardless of whether $|\Delta k_{eff}| > 0.00003$). Equation 1 is an uncertainty multiplied by a central-difference approximation of a derivative:

$$u_{k,i} = \pm u_i \frac{\partial k_{eff}}{\partial x_i}\Big|_{x_i = x_{i,0}} \tag{2}$$

Equation 2 can also be written

$$u_{k,i} = \pm \frac{u_i}{x_{i,0}} k_{eff,0} S_{k,x_i}, \tag{3}$$

where $k_{eff,0} = k_{eff}(x_{i,0})$ (in the notation of Equation 1) and S_{k,x_i} is the relative sensitivity of k_{eff} with respect to x_i, defined by

$$S_{k,x_i} = \frac{x_{i,0}}{k_{eff,0}} \frac{\partial k_{eff}}{\partial x_i}\Big|_{x_i = x_{i,0}} \tag{4}$$

For some parameters, the relative sensitivity S_{k,x_i} of Equation 4 can be computed using adjoint methods. Whenever adjoint-based derivatives were available, Equation 3 was used for the uncertainties. If $u_{k,i}$ is less than 0.000005, the uncertainty is judged to be negligible.

[a]MCNP® and Monte Carlo N-Particle® are registered trademarks owned by Triad National Security, LLC, manager and operator of Los Alamos National Laboratory. Any third-party use of such registered marks should be properly attributed to Triad National Security, LLC, including the use of the designation as appropriate. For the purposes of visual clarity, the registered trademark symbol is assumed for all references to MCNP within the remainder of this paper.

[b]M. E. Rising, et.al.. MCNP® Code Version 6.3.0 Release Notes. Los Alamos National Laboratory Tech. Rep. LA-UR-22-33103, Rev. 1. Los Alamos, NM, USA. January 2023.

[c]D. A. Brown, et al. "ENDF/B-VIII. 0: the 8th major release of the nuclear reaction data library with CIELO-project cross sections, new standards and thermal scattering data." Nuclear Data Sheets, 148, 1–142 (2018).

The uncertainties affecting the experiment have been divided into six categories: criticality measurement, mass, dimension, material composition, positioning/surroundings, and temperature. Each category is considered separately and is later combined to compute the total experiment uncertainty. Each standard uncertainty estimate is 1σ.

The first category, criticality measurement, discussed in Section 2.1, explains how the reactivity of each configuration was evaluated. The uncertainty is based on the spread in reproducibility of the experiment results.

The uncertainties evaluated under the second category, mass and density, are discussed in Section 2.2. These were evaluated using adjoint-based relative sensitivities with Equations 3 and 4. The derivatives computed and applied are constant-volume partial derivatives.

The third category, dimensions, evaluated the uncertainties as a result of the dimensions and volumes of each component. These are discussed in Section 2.3. For these uncertainties, direct perturbations were performed and, generally, Equation 1 was applied. In some cases, which are noted, a two-sided difference is not meaningful or possible, so a one-sided analog of Equation 1 was applied:

$$u_{k,i} = \frac{u_i}{\delta x_i} |k_{eff}(x_{i,0} + \delta x_i) - k_{eff}(x_{i,0})| \tag{5}$$

Equation 5 uses a forward or backward estimate of the derivative rather than the central difference used in Equation 1. In some of these cases, which are noted, the sign of $u_{k,i}$ was retained, leading to asymmetric uncertainties. In the direct perturbations, part masses were held constant. Each dimension for every component is examined. Similar components were sometimes varied simultaneously.

The material composition uncertainties were evaluated in the fourth category in Section 2.4. These were evaluated using adjoint-based relative sensitivities with Equations 3 and 4. Some of the calculated sensitivities have large uncertainties ($>$100%) and this is due to the composition being small such that its impact on k_{eff} is negligible.

The positioning uncertainties were considered in the fifth category in Section 2.5. This portion of the evaluation considered the uncertainty of axial gaps in the core stack, possible misalignment of the core stack, the axial position of the alignment tube, and possible gaps in the Cu reflectors. Direct perturbations were done and Equation 1 or 4 was applied.

The uncertainty as a result of the temperature of the surroundings and assembly was determined in Section 2.6.

Section 2.7 considers the bias associated with room return from the floor, ceiling, and walls and other components in the room, including parts of the Comet framework. These uncertainties are applied to the calculation of the simplification bias in Section 3.

These three configurations are judged to be acceptable as benchmark measurements.

2.1 Evaluation of Criticality Measurement

The reactivity of the experiment is calculated based on the measured asymptotic reactor period, which is the input into the Inhour equation:

$$\rho = \frac{\Lambda}{T\beta_{eff}} + \sum_{i=1}^{P} \frac{(\beta_i/\beta)}{1 + \lambda T} \tag{6}$$

where

- ρ is the reactivity in dollars,
- β_{eff}/Λ is the absolute value of the measured Rossi-α at delayed critical, is X s^{-1} (see Appendix **??**)
- β_{eff} is the effective delayed neutron fraction,
- Λ is the prompt neutron lifetime of the system in s,
- T is is the reactor period in s,
- β_i/β is the relative abundance of precursor group i,
- λ_i is the decay constant of precursor group i in s–1, and
- P is the number of delayed neutron precursor groups.

The reactor period is measured using 3 compensated ion chambers that are located along the wall of the building. All measurements are taken at a reasonably high power (E-9 amp scale), but low enough to avoid significant thermal effects. Background corrections are not necessary due to the low background in the facility and because the measurement was taken at a high enough power that the background is negligible. For more information on the reactor period measurement, see Appendix **??**.

The reactivity values reported in Table 1 were from local systems available during the experiment. While these values are adequate during operations, a more detailed analysis of the data from the detectors was performed post-experiment. CONTINUE ...

Table 26. Analyzed Reactivity Measurements.$^{(a)}$

Config.	Period [s]	Reactivity [¢]
$^3/_{16}$		
$^5/_{16}$		
$^7/_{16}$		

(a)

Two sets of delayed neutron parameters, both with P = 6, are investigated in this section, but those used for the reported reactivity results from Table 26 are given in Table 27. Use of these constants assumes that all fission occurs in U-235 for these cases.

Table 27. Delayed Neutron Decay Constants and Relative Abundances for Each of the Delayed Neutron Groups for U-235 Fast Fission Using Six Delayed Neutron Groups.$^{(a)}$

Precursor Group i	Decay Constant λ_i [s^{-1}]	Relative Abundance β_i/β [¢]
1	0.0127 $\pm$ 0.0002	0.038 $\pm$ 0.003
2	0.0137 $\pm$ 0.0008	0.213 $\pm$ 0.005
3	0.115 $\pm$ 0.003	0.188 $\pm$ 0.016
4	0.311 $\pm$ 0.008	0.407 $\pm$ 0.007
5	1.400 $\pm$ 0.081	0.128 $\pm$ 0.008
6	3.870 $\pm$ 0.369	0.026 $\pm$ 0.003

(a) G. R. Keepin, Physics of Nuclear Kinetics. Addison-Wesley Pub. Co., 1965.

The uncertainty associated with the inferred reactivity is assumed to be the standard deviation of the complete data set from the 3 detector systems for a given configuration (see Appendix **??**). The k_{eff} of the assembly is calculated using a β_{eff} of 0.00660.[a] This β_{eff} is a reported value for U-235 fast fission. This is a good assumption for the three configurations and the uncertainty associated with this is detailed in the following paragraphs.

The uncertainty as a result of the delayed neutron parameters is also investigated. There are three possible methods for choosing an appropriate delayed neutron parameter set for use with the Inhour equation to convert a measured reactor period into a corresponding excess reactivity. The first (and best) method is to measure the delayed neutron parameters of the experiment. However, this can be lengthy and complicated. The second method is to simulate the experiment and use simulation tools to determine the delayed neutron parameter set (such as using the KOPTS card in MCNP, which can calculate β_{eff} and the neutron lifetime Λ). However, this method uses potentially flawed nuclear data in the calculation of these delayed neutron parameter sets, so the final excess reactivity calculations could be flawed as well. The third method is to use experimentally determined delayed neutron parameter sets (with measurement uncertainty) to bound the results of the excess reactivity calculations.

The lengthy and complicated measurements needed to experimentally measure the delayed neutron precursor parameters associated with this experiment (Method 1) were not undertaken. Likewise, using potentially flawed nuclear data to simulate the delayed neutron parameter set (Method 2) was not done. Instead, uncertainties in the reported excess reactivities were estimated by bounding the reactivity calculation by using two different sets of delayed neutron parameters (Method 3). In particular, the fast HEU six-group parameter set and the thermal HEU six-group parameter set shown in Table 27 and Table 28, respectively, were used as bounds.

Using the measured reactor periods for each of the cases, the associated Inhour calculations can be found in Table 29. The table shows that the results from both parameter sets do not differ largely (significant differences in the reactivity calculations are not seen until the systems are close to prompt critical, i.e., 80 ¢or higher). If the β_{eff} is modified to a conservatively high value of 0.00726 (which is a 10 % increase), the modified k_{eff} calculations can be found in Table 30.

Table 28. Delayed Neutron Decay Constants and Relative Abundances for Each of the Delayed Neutron Groups for U-235 Thermal Fission Using Six Delayed Neutron Groups.$^{(a)}$

Precursor Group i	**Decay Constant λ_i [s^{-1}]**	**Relative Abundance β_i/β [¢]**
1	0.0124 ± 0.0003	0.033 ± 0.003
2	0.0305 ± 0.0010	0.219 ± 0.009
3	0.111 ± 0.004	0.196 ± 0.022
4	0.301 ± 0.011	0.395 ± 0.011
5	1.14 ± 0.15	0.115 ± 0.009
6	3.01 ± 0.29	0.042 ± 0.008

(a) G. R. Keepin, Physics of Nuclear Kinetics. Addison-Wesley Pub. Co., 1965.

[a] G. R. Keepin, Physics of Nuclear Kinetics. Addison-Wesley Pub. Co., 1965.

Table 29. k_{eff} for Fast and Thermal U Six-Group Parameter Sets Using β_{eff} = 0.00660.

Config.	**Measured Reactor Period [s]**	**k_{eff} Using HEU Fast Parameters**	**k_{eff} Using HEU Thermal Parameters**
$^3/_{16}$			
$^5/_{16}$			
$^7/_{16}$			

Table 30. k_{eff} for Fast and Thermal U Six-Group Parameter Sets Using β_{eff} = 0.00726.

Config.	**Measured Reactor Period [s]**	**k_{eff} Using HEU Fast Parameters**	**k_{eff} Using HEU Thermal Parameters**
$^3/_{16}$			
$^5/_{16}$			
$^7/_{16}$			

From the results in Table 29 and Table 30, the bounds of k_{eff} are summarized in Table 31.

Table 31. Bounding k_{eff} Values Including HEU Fast and Thermal Parameters.

Config.	**Measured Reactor Period [s]**	**k_{eff} Using HEU Fast Parameters ($\beta_{eff} = 0.00660$)**	**k_{eff} Using HEU Thermal Parameters ($\beta_{eff} = 0.00726$)**
$^3/_{16}$			
$^5/_{16}$			
$^7/_{16}$			

Using these bounds and dividing the difference by $\sqrt{6}$ (given for a triangular distribution when the nominal value is at one of the bounds) yields a one-sided uncertainty associated with the delayed neutron data; see Table 31. If the values in Table 31 were true bounds, one could use $\sqrt{18}$ rather than $\sqrt{6}$. Here, it was decided to use $\sqrt{6}$ as some of the assumptions given above may slightly change the bounds given in Table 31. Note that it would not be appropriate to use the midpoint as the nominal values as it is known that the true values are closer to those in the third column (fast parameters with β_{eff} = 0.00660) than the far right column (thermal parameters with β_{eff} = 0.00726) for the reasons stated throughout this section.

The uncertainty in the prompt neutron lifetime Λ of the system was not investigated. It is known that the reactivity is not sensitive to this parameter in Equation 6. It would take a change in Λ greater than three orders of magnitude to result in a k_{eff} change of 1 pcm for any of the three configurations. Therefore, the uncertainty in this term is clearly negligible.

The final evaluated k_{eff} for each case, along with its uncertainty (the combination of uncertainties from Table 26 and Table 32), is given in Table 33. The asymmetric uncertainty bounds are approximated by combining the positives in quadrature separately from the negatives. These uncertainties include those associated with the measurement of the reactor period, the experiment reproducibility, and uncertainties in all parameters used in the inference of k_{eff}.

Table 32. k_{eff} Uncertainty Because of Delayed Neutron Data.

Config.	Measured Reactor Period [s]	u_k
3/16		
5/16		
7/16		

Table 33. k_{eff} and Uncertainty Because of Criticality Measurements.

Config.	$k_{eff} \pm u_k$
3/16	
5/16	
7/16	

2.2 Mass Uncertainties

The uncertainty for the total mass of N components is

$$u_T = \sqrt{Nu_r^2 + N^2u_s^2 + \frac{Nr_r^2}{12}} \tag{7}$$

where u_T is the uncertainty for the total mass, u_r is the random mass measurement uncertainty, u_s is the systematic mass measurement uncertainty, and r_r is the round-off resolution. N is the total number of components in the element when each one has been measured separately. The scales used for these measurements all have a reported random mass measurement uncertainty (u_r) of 0. This method for calculating the mass uncertainties is used unless stated otherwise.

The relative sensitivity for the mass of each component was obtained using the iterated fission probability method in MCNP6.2[a] These are constant-volume partial derivatives. The relative sensitivity of k_{eff} with respect to the mass of a component is identical to the relative sensitivity of k_{eff} with respect to the density of the component. All u_T values are rounded to two digits after the decimal, whereas the relative uncertainty ($\frac{u_T}{Mass}$) is rounded to seven digits after the decimal (five digits when expressed as a percentage). Negligible is considered to be $u_k \leq 0.000005$.

2.2.1 Highly Enriched Uranium Disks and Rings

The HEU disks, rings, and wedges had to be weighed inside a plastic bag because of radiological contamination risks. The mass of the bag was measured first, then the mass of the component and the bag was measured using the same scale. The difference of these measurements was used as the mass of the component. Therefore, Equation 7 needs to be adjusted to account for the measurement of the bag.

Assume there are N_b bags, N_U parts, and N_{U+b} measurements of HEU parts in the bags.[b] The uncertainty of the total mass of the bags is $u_{T,b}$, the uncertainty of the total mass of HEU is $u_{T,U}$, and the uncertainty of the total mass of HEU in bags is $u_{T,U+b}$. Because the same scale is used, u_r, u_s, and r_r are the same for the bag measurements and the HEU-in-bag measurements. The mass of the HEU is the mass of the HEU-in-bags minus the mass of the bags.

[a] This method uses the KSEN and KOPTS cards within MCNP6.2.0.

[b] Derivation provided by J. A. Favorite, Los Alamos National Laboratory, in December 2021.

Therefore, the variance in the calculation is $u^2_{T,U} = u^2_{T,b} + u^2_{T,U+b}$. Using Equation 7, the uncertainty in the total mass of HEU becomes

$$u^2_{T,U} = (N_b u_r^2 + N_b^2 u_s^2 + \frac{N_b r_r^2}{12}) + (N_{U+b} u_r^2 + N_{U+b}^2 U_s^2 + \frac{N_{U+b} r_r^2}{12}) \quad (8)$$

$$= (N_b + N_{U+b}) u_r^2 + (N_b^2 + N_{U+b}^2) u_s^2 + \frac{(N_b + N_{U+b}) r_r^2}{12} \quad (9)$$

If $N_b = N_{U+b}$, Equation 9 becomes

$$u^2_{t,U} = 2N_{U+b} u_r^2 + 2N_{U+b}^2 u_s^2 + \frac{2N_{U+b} r_r^2}{12} \quad (10)$$

and taking the square root yields

$$u_{T,U} = \sqrt{2}\sqrt{N_{U+b} u_r^2 + N_{U+b}^2 u_s^2 + \frac{N_{U+b} r_r^2}{12}} \quad (11)$$

This results in the uncertainty of the total mass of HEU to be $\sqrt{2}$ times larger than Equation 7.

Table 34 gives the masses and mass uncertainties from Equation 11 for the HEU disks and rings used in the assembly. The measurements from 2023 shown in Table 4 were used, since they were taken during the experiment. For the HEU in the assembly N = 1, u_r = 0, $u_s = 0.2\sqrt{3}$, r_r = 0.1, which calculates to a u_T = 0.17 g. Three measurements were performed for the bag mass as well as the bag + HEU mass. In some cases the standard deviation of the measurements is larger than 0.17 g; therefore, the standard deviation is used for those plates.

The uncertainties are the same for all configurations. The sensitivity coefficients for the HEU masses are given with the associated k_{eff} uncertainties in Table 35. The uncertainties for each part are added in quadrature and the total is reported in Section 2.8.

Table 34. Mass Uncertainties for the HEU Plates.

ID	Mass [g]	$\mathbf{u_T}$ [g] (Eq. 11	$\mathbf{u_T}$ [g] (σ)	Final $\mathbf{u_T}$ [g]
HEU 21/15 (B-2444-)				
01	6110.7	0.17		
02	6109.0	0.17		
07	6107.3	0.17		
10	6129.0	0.17		
19	6121.1	0.17		
20	6152.7	0.17		
22	6023.6	0.17		
24	6089.1	0.17		
27	6065.4	0.17		
29	6126.9	0.17		

Continued on next page

Table 34 – *Continued from previous page*

ID	Mass [g]	$\mathbf{u_T}$ [g] (Eq. 11	$\mathbf{u_T}$ [g] (σ)	Final $\mathbf{u_T}$ [g]
31	6165.1	0.17		
33	6155.6	0.17		
36	6124.6	0.17		
37	6122.1	0.17		
HEU 15/0				
11017	6497.0	0.17		
11019	6468.6	0.17		
11147	6511.9	0.17		
11149	6382.4	0.17		
11150	6404.4	0.17		
HEU 15/6				
10477	5498.5	0.17		
11018	5369.0	0.17		
HEU 15/2.5				
10464	6258.3	0.17		
10467	6335.8	0.17		
10470	6278.3	0.17		
10475	6228.0	0.17		
10487	6274.8	0.17		
10489	6343.5	0.17		
10491	6391.7	0.17		
HEU 6/0				
Q2-16	1074.9	0.17		

Table 35. u_k and Associated Uncertainty for the Mass of HEU.

Component	Config.	Relative Uncertainty [$\mathbf{u_T}$/Mass][%]	$\mathbf{S_{k,x_i} \pm 1\sigma_{MC}}$ [%/%]	Final $\mathbf{u_k}$
HEU 21/15				
B-2444-01	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
B-2444-02	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
B-2444-07	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	

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Table 35 – *Continued from previous page*

Component	Config.	Relative Uncertainty $[u_T/\text{Mass}][\%]$	$S_{k,x_i} \pm 1\sigma_{MC}$ [%/%]	Final u_k
B-2444-10	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
B-2444-19	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
B-2444-20	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
B-2444-22	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
B-2444-24	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
B-2444-27	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
B-2444-29	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
B-2444-31	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
B-2444-33	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
B-2444-36	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
B-2444-37	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
HEU 15/0				
11017	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
11019	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	

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Table 35 – *Continued from previous page*

Component	Config.	Relative Uncertainty $[\mathbf{u_T}$/Mass][%]	$\mathbf{S_{k,x_i} \pm 1\sigma_{MC}}$ [%/%]	Final $\mathbf{u_k}$
11147	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
11149	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
11150	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
HEU 15/6				
10477	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
11018	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
HEU 15/2.5				
10464	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
10467	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
10470	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
10475	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
10487	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
10489	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
10491	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
HEU 6/0				
Q2-16	$^3/_{16}$	$\pm 0.XX$	X ± X %	

Continued on next page

Table 35 – *Continued from previous page*

Component	Config.	Relative Uncertainty $[\mathbf{u_T}$/Mass][%]	$\mathbf{S_{k,x_i} \pm 1\sigma_{MC}}$ [%/%]	Final $\mathbf{u_k}$
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	

2.2.2 Non-Fissile Core Components

2.2.2.1 Interstitial Copper Disks

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2.2.2.2 Aluminum Shims

Al shims are only used in the $^3/_{16}$ configuration. Table 36 gives the mass and mass uncertainties for the Al shims. The relative sensitivity coefficients for the Al shim masses are given with the associated k_{eff} uncertainties in Table 37. The uncertainties for each part are added in quadrature and the total is reported in Section 2.8.

Table 36. Mass Uncertainties for the Al Shims in the $^3/_{16}$ Configuration.

Components	Mass [g]	N	$\mathbf{u_r}$ [g]	$\mathbf{u_s}$ [g]	$\mathbf{r_r}$ [g]	$\mathbf{u_T}$ [g]
400 mil	6023.0	1	0	$0.2/\sqrt{3}$	0.1	
500 mil	7538.6	1	0	$0.2/\sqrt{3}$	0.1	

Table 37. u_k and Associated Uncertainty for the Mass of Al Shims in the $^3/_{16}$ Configuration.

Component	Relative Uncertainty $[\mathbf{u_T}$/Mass][%]	$\mathbf{S_{k,x_i} \pm 1\sigma_{MC}}$ [%/%]	Final $\mathbf{u_k}$
400 mil			
500 mil			

2.2.2.3 Aluminum Adapter Plates

There are no mass measurements for the adapter plates, which are made of Al 1100; therefore, a density of 2.71 g/cm^3 is assumed.[a] A density uncertainty of 2% is assumed to be bounding (see Table 38). The sensitivity coefficients for the Al adapter masses are given with the associated k_{eff} uncertainties in Table 39. The uncertainties for each part are added in quadrature and the total is reported in Section 2.8.

Table 38. Assumed Density and Mass Uncertainty for the Al Adapter Plates.

Components	Density [g/cm^3]	Uncertainty [%]
Al Adapter	2.71	2

Table 39. u_k and Associated Uncertainty for the Mass of the Al Adapter Plate.

Component	Config.	Relative Uncertainty [u_T/Mass][%]	$S_{k,x_i} \pm 1\sigma_{MC}$ [%/%]	Final u_k
Al Adapter	$^3/_{16}$	—	—	—
	$^5/_{16}$	—	—	—
	$^7/_{16}$	$\pm 0.XX$	X ± X %	

2.2.3 Copper Reflectors

There are more CR1 (Cu corner 5.68 in.) pieces and side reflectors in stock than were used in the experiment, and it is unknown which ones were used. Therefore, the uncertainty for the total mass of N components is

$$u_T = \sqrt{N^2 \left(\left(\frac{N' - N}{N'} \right) \left(\frac{1}{N} \right) (s^2 - u_r^2) + \frac{u_2^2}{N'} + u_s^2 + \frac{r_r^2}{12N'} \right)} \tag{12}$$

where N' is the total number of pieces available and N is the number of pieces used in the experiment. s^2 can be estimated using

$$s^2 = \frac{\sum_{i=1}^{N'} (x_i - \bar{x})^2}{N' - 1} \tag{13}$$

where $\bar{x}$ is based on measurements of N' pieces. Given the masses reported in Table 12, it is assumed that the readout on the scale used for the CR1 (Cu corner 5.68 in.), side reflector, and bottom reflector is ±0.5 lb because there are some masses reported to that fidelity.

The remaining Cu reflector pieces can use Equation 7. Table 40 gives the masses and mass uncertainties for the Cu reflectors. The masses are the average of the part masses listed in Table 12 and added together for the total number of pieces in the experiment as the specific pieces used in the experiment and their position in the assembly are unknown. For all components, u_r is assumed to be 0 because reproducibility measurements were not taken for each part. The

[a] MatWeb - The Online Materials Information Resource. (n.d.). "Aluminum 1100-O." Retrieved October 26, 2022, from https://www.matweb.com/search/DataSheet.aspx?MatGUID=db0307742df14c8f817bd8d62207368e

sensitivity coefficients for the Cu reflectors are given with the associated k_{eff} uncertainties in Table 41. Each type of component is treated as correlated, so their sensitivities are added linearly. The uncertainties for all components are added in quadrature and the total is reported in Section 2.8.

From this point onward, the Cu corner reflectors are named according to their height, so it is more clear which piece is being perturbed. For the bottom, corner 5.68 in., and side reflectors the statement "an absolute standard deviation (1σ) of 1 lb for these measurements is assumed" in HEU-MET-INTER-006 is assumed to mean u_s = 1 lb

Table 40. Mass Uncertainties for the Cu Reflector Pieces.

Component	**Config.**	**Mass [g]**	**N**	**N'**	$\mathbf{s^2}$ **[g²]**	$\mathbf{u_r}$ **[g]**	$\mathbf{u_s}$ **[g]**	$\mathbf{r_r}$ **[g]**	$\mathbf{u_T}$ **[g]**
Bottom	All	279,412.9	1	—	—	0	453.592	453.592	472.11
Corner 5.68 in. (CR1)	3/16	218,437.1	8	28	70.05	0	453.592	453.592	
	5/16	218,431.1	8	28	70.05	0	453.592	453.592	
	7/16	327,655.7	12	28	70.05	0	453.592	453.592	
Corner 3.00 in. (CR2)	3/16	—	0	—	—	0	$0.2/\sqrt{3}$	0.1	—
	5/16	57,561.9	4	—	—	0	$0.2/\sqrt{3}$	0.1	
	7/16	57,561.9	4	—	—	0	$0.2/\sqrt{3}$	0.1	
Corner 0.75 in. (CR3)	3/16	14,242.2	4	—	—	0	$0.2/\sqrt{3}$	0.1	
	5/16	14,242.2	4	—	—	0	$0.2/\sqrt{3}$	0.1	
	7/16	14,242.2	4	—	—	0	$0.2/\sqrt{3}$	0.1	
Corner 1.50 in. (CR4)	3/16	28,575.5	4	—	—	0	$0.2/\sqrt{3}$	0.1	
	5/16	—	0	—	—	0	$0.2/\sqrt{3}$	0.1	—
	7/16	—	0	—	—	0	$0.2/\sqrt{3}$	0.1	—
Corner 0.250 in. (CR6)	3/16	4,743.4	4	—	—	0	$0.2/\sqrt{3}$	0.1	
	5/16	9,486.8	8	—	—	0	$0.2/\sqrt{3}$	0.1	
	7/16	—	0	—	—	0	$0.2/\sqrt{3}$	0.1	—
Corner 0.375 in. (CR7)	3/16	—	0	—	—	0	$0.2/\sqrt{3}$	0.1	—
	5/16	—	0	—	—	0	$0.2/\sqrt{3}$	0.1	—
	7/16	7,191.4	4	—	—	0	$0.2/\sqrt{3}$	0.1	
Top	All	395,600.0	1	—	—	0	$226.8\sqrt{3}$	100	134.09
Side	3/16	2,527,756.9	12	24	956.28	0	453.592	453.592	
	5/16	2,527,756.9	12	24	956.28	0	453.592	453.592	
	7/16	3,370,342.5	16	24	956.28	0	453.592	453.592	7270.42

Table 41. u_k and Associated Uncertainty for the Mass of the Cu Reflector Pieces.

Component	**Config.**	**Relative Uncertainty** $\mathbf{[u_T/Mass][\%]}$	$\mathbf{S_{k,x_i} \pm 1\sigma_{MC}}$ **[%/%]**	**Final** $\mathbf{u_k}$
Bottom	3/16	$\pm 0.XX$	X ± X %	
	5/16	$\pm 0.XX$	X ± X %	

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Table 41 – *Continued from previous page*

Component	Config.	Relative Uncertainty $[u_T/\text{Mass}][\%]$	$S_{k,x_i} \pm 1\sigma_{MC}$ [%/%]	Final u_k
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
Corner 5.68 in. (CR1)	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
Corner 3.00 in. (CR2)	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
Corner 0.75 in. (CR3)	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
Corner 1.50 in. (CR4)	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
Corner 0.250 in. (CR6)	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
Corner 0.375 in. (CR7)	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
Top	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	
Side	$^3/_{16}$	$\pm 0.XX$	X ± X %	
	$^5/_{16}$	$\pm 0.XX$	X ± X %	
	$^7/_{16}$	$\pm 0.XX$	X ± X %	

2.2.4 Comet Hardware

Table 42 gives the mass and mass uncertainty for the diaphragm. Mass measurements for the alignment tube, platen/platen adapter plate, and top plate do not exist, so an assumed density of 2.70 g/cm^3 was used (see Table 43).[a] A 2% uncertainty in the density for the alignment tube, platen/platen adapter plate, and top plate is assumed to be bounding. The sensitivity coefficients for the Comet hardware masses are given with the associated k_{eff} uncertainties in Table 44. The uncertainties of each component are added in quadrature and the total is reported in Section 2.8.

[a] MatWeb - The Online Materials Information Resource. (n.d.-b). "Aluminum 6061-T6; 6061-T651." Retrieved October 26, 2022, from https://www.matweb.com/search/DataSheet.aspx?MatGUID=b8d536e0b9b54bd7b69e4124d8f1d20a&ckck=1

Table 42. Mass Uncertainties for the Diaphragm.

Components	Mass [g]	N	u_r [g]	u_s [g]	r_r [g]	u_T [g]
Diaphragm	11,570.1	1	0	$0.2/\sqrt{3}$	0.1	0.12

Table 43. Assumed Density and Mass Uncertainties for the Alignment Tube, Platen/Platen Adapter Plate, and Top Plate.

Components	Density [g/cm^3]	Uncertainty [%]
Alignment Tube	2.70	2
Platen$^{(a)}$	2.70	2
Top Plate	2.70	2

(a) Platen here refers to the platen and platen adapter plate, which is considered one component in the benchmark model.

Table 44. u_k and Associated Uncertainty for the Mass of Comet Hardware.

Component	Config.	Relative Uncertainty [u_T/Mass][%]	$S_{k,x_i} \pm 1\sigma_{MC}$ [%/%]	Final u_k
Alignment Tube	3/16	± 2%	X ± X %	
	5/16	± 2%	X ± X %	
	7/16	± 2%	X ± X %	
Platen/Platen Adapter Plate	3/16	± 2%	X ± X %	
	5/16	± 2%	X ± X %	
	7/16	± 2%	X ± X %	
Top Plate	3/16	± 2%	X ± X %	
	5/16	± 2%	X ± X %	
	7/16	± 2%	X ± X %	
Diaphragm	3/16	± 0.00104	X ± X %	
	5/16	± 0.00104	X ± X %	
	7/16	± 0.00104	X ± X %	

2.3 Dimension Uncertainties

For all materials in the experiment, dimensions were adjusted in the benchmark model to remove any asymmetric tolerances. When converting from inches to centimeters, all digits associated with the conversion are preserved.

2.3.1 Highly Enriched Uranium Disks and Rings

The HEU heights used in the benchmark models are the average of the individual 2023 measurements reported in Section 1.2.3. Table 45 shows the average heights and standard deviations rounded to one more digit than the measurements, but the benchmark model does not round any of the averages when calculating the volumes. Diameters of the HEU plates were measured with the CMM, but drawing values were used in the benchmark model in order to keep all HEU components consistent. Using the drawing dimensions instead of the CMM to calculate the density has a minimal impact.[a] The dimensions of the HEU plates are shown in Table 46.

Table 45. Height of HEU Components.

ID	Measured Outer Height [mm]	Measured Inner Height [mm]	Average Height [mm]	Standard Deviation [mm]
HEU 21/15 (B-2444-)				
01				
02				
07				
10				
19				
20				
22				
24				
27				
29				
31				
33				
36				
37				
HEU 15/0				
11017		—		
11019		—		
11147		—		
11149		—		
11150		—		
HEU 15/6				
10477				
11018				
HEU 15/2.5				
10464				
10467				
10470				
10475				
10487				
10489				
10491				
HEU 6/0				
Q2-16		—		

[a] K. Amundson, et.al., ”HEU Pancake (Jemima) Plate Preliminary Characterization Report”. Los Alamos National Laboratory (LA-UR-24-20414). January 17, 2024.

Table 46. Dimension and Uncertainty Data for the HEU Components.

ID	Parameter	Dimension	Tolerance	u_T [cm]
HEU 21/15 (B-2444-)				
01	Inner Diameter	15 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		± 0.005 in.	±
02	Inner Diameter	15 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		± 0.005 in.	±
07	Inner Diameter	15 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		± 0.005 in.	±
10	Inner Diameter	15 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		± 0.005 in.	±
19	Inner Diameter	15 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		± 0.005 in.	±
20	Inner Diameter	15 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		± 0.005 in.	±
22	Inner Diameter	15 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		± 0.005 in.	±
24	Inner Diameter	15 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		± 0.005 in.	±
27	Inner Diameter	15 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		± 0.005 in.	±
29	Inner Diameter	15 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		± 0.005 in.	±
31	Inner Diameter	15 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		± 0.005 in.	±
33	Inner Diameter	15 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		± 0.005 in.	±
36	Inner Diameter	15 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	± 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		± 0.005 in.	±

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Table 46 – *Continued from previous page*

ID	Parameter	Dimension	Tolerance	u_T [cm]
37	Inner Diameter	15 in.	$\pm$ 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Outer Diameter	21 in.	$\pm$ 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$
HEU 15/0				
11017	Outer Diameter	15 in.	$\pm$ 0.01 in.	$\pm$ 0.01/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$
11019	Outer Diameter	15 in.	$\pm$ 0.01 in.	$\pm$ 0.01/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$
11147	Outer Diameter	15 in.	$\pm$ 0.01 in.	$\pm$ 0.01/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$
11149	Outer Diameter	15 in.	$\pm$ 0.01 in.	$\pm$ 0.01/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$
11150	Outer Diameter	15 in.	$\pm$ 0.01 in.	$\pm$ 0.01/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$
HEU 15/6				
10477	Inner Diameter	6.0075 in.	$\pm$ 0.0025 in.	$\pm$ 0.0025/$\sqrt{3}$ in.
	Outer Diameter	15 in.	$\pm$ 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$
11018	Inner Diameter	6.0075 in.	$\pm$ 0.0025 in.	$\pm$ 0.0025/$\sqrt{3}$ in.
	Outer Diameter	15 in.	$\pm$ 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$
HEU 15/2.5				
10464	Inner Diameter	2.5125 in.	$\pm$ 0.0025 in.	$\pm$ 0.0025/$\sqrt{3}$ in.
	Outer Diameter	15 in.	$\pm$ 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$
10467	Inner Diameter	2.5125 in.	$\pm$ 0.0025 in.	$\pm$ 0.0025/$\sqrt{3}$ in.
	Outer Diameter	15 in.	$\pm$ 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$
10470	Inner Diameter	2.5125 in.	$\pm$ 0.0025 in.	$\pm$ 0.0025/$\sqrt{3}$ in.
	Outer Diameter	15 in.	$\pm$ 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$
10475	Inner Diameter	2.5125 in.	$\pm$ 0.0025 in.	$\pm$ 0.0025/$\sqrt{3}$ in.
	Outer Diameter	15 in.	$\pm$ 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$
10487	Inner Diameter	2.5125 in.	$\pm$ 0.0025 in.	$\pm$ 0.0025/$\sqrt{3}$ in.
	Outer Diameter	15 in.	$\pm$ 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$
10489	Inner Diameter	2.5125 in.	$\pm$ 0.0025 in.	$\pm$ 0.0025/$\sqrt{3}$ in.
	Outer Diameter	15 in.	$\pm$ 0.005 in.	$\pm$ 0.005/$\sqrt{3}$ in.
	Height		$\pm$ 0.005 in.	$\pm$

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Table 46 – *Continued from previous page*

ID	Parameter	Dimension	Tolerance	u_T [cm]
10491	Inner Diameter	2.5125 in.	± 0.0025 in.	± $0.0025/\sqrt{3}$ in.
	Outer Diameter	15 in.	± 0.005 in.	± $0.005/\sqrt{3}$ in.
	Height		± 0.005 in.	±
HEU 6/0				
Q2-16	Outer Diameter	6 in.	± 0.01 in.	± $0.01/\sqrt{3}$ in.
	Height		± 0.005 in.	±

The largest standard deviation for the height of the HEU plates is ± XXX in., which is fairly close to the value obtained if the drawing tolerance was used ($\pm 0.005/\sqrt{3}$ in. = 0.00289 in.). Therefore, the largest standard deviation for the height was used as the uncertainty for all HEU plate heights.

The volume calculated for each HEU plate using the dimensions given in Table 45 and Table 46 is listed in Table 47. These volumes were used with the masses listed in Table 4 to compute the density of each plate (also listed in Table 47). Here and everywhere else in this evaluation, all digits were preserved when converting units.

Each individual plate's outer and inner (where applicable) diameters were varied as shown in Table 48. The plate density was perturbed to preserve the mass. Only one dimension was varied at a time, so where plates nested (see Figure 9), a one-sided perturbation was done. These are indicated as a "+" or "–" deviation in Table 48 (as opposed to a "±" deviation). The diameters of the HEU pancake plates were not measured, so the drawing tolerance is assumed for the 1σ uncertainty. Table 48 shows that the uncertainty u_k in k_{eff} because of uncertain HEU plate outer and inner diameters is negligible.

Each individual plate's height was varied as shown in Table 49. The plate density was perturbed to preserve the mass. One-sided perturbations were done because, as shown in Table 49, the effect of thickening the plates is much larger than the effect of thinning them. Table 49 shows the uncertainty u_k in k_{eff} as a result of uncertain HEU plate heights.

The uncertainties for each part and each parameter in Table 48 and Table 49 are added in quadrature for each configuration and the total is reported in Section 2.8.

Table 47. Mass Densities of HEU Plates.

ID	Calculated Volume [cm^3]	Density [g/cm^3]
HEU 21/15 (B-2444-)		
01	330.9003	18.4669
02	328.7113	18.5848
07	331.6299	18.4160
10	333.6365	18.3703
19	328.3464	18.6423
20	330.7178	18.6041
22	318.8609	18.8911
24	329.9882	18.4524
27	326.3399	18.5862

Continued on next page

Table 47 – *Continued from previous page*

ID	Calculated Volume [cm^3]	Density [g/cm^3]
29	333.6365	18.3640
31	332.7244	18.5292
33	330.5354	18.6232
36	330.9003	18.5088
37	329.2585	18.5935
HEU 15/0		
11017	344.6878	18.8489
11019	342.7876	18.8706
11147	351.5283	18.5245
11149	343.5477	18.5780
11150	342.0275	18.7247
HEU 15/6		
10477	295.7812	18.5899
11018	289.3998	18.5522
HEU 15/2.5		
10464	337.6027	18.5374
10467	340.1883	18.6244
10470	336.8640	18.6376
10475	334.4631	18.6210
10487	336.4946	18.6476
10489	339.4495	18.6876
10491	346.6522	18.4383
HEU 6/0		
Q2-16	59.1632	18.1678

Table 48. u_k of Outer and Inner Diameter Uncertainty of HEU Plates.

ID	Parameter	Config.	Deviation Used [in.]	$\Delta \mathrm{k_{eff}} \pm 1\sigma_{\mathrm{MC}}$	1σ Uncertainty [in.]	Final $\mathrm{u_k}$
HEU 21/15 (B-2444-)						
01	Inner Diameter	$^3/_{16}$	+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^5/_{16}$	+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^7/_{16}$	+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
	Outer Diameter	$^3/_{16}$	$\pm$ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^5/_{16}$	$\pm$ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^7/_{16}$	$\pm$ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
02	Inner Diameter	$^3/_{16}$	+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^5/_{16}$	+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^7/_{16}$	+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	

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Table 48 – *Continued from previous page*

ID	Parameter	Config.	Deviation Used [in.]	$\Delta k_{eff} \pm 1\sigma_{MC}$	1σ Uncertainty [in.]	Final u_k
	Outer Diameter	$^{3}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
07	Inner Diameter	$^{3}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
	Outer Diameter	$^{3}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
10	Inner Diameter	$^{3}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
	Outer Diameter	$^{3}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
19	Inner Diameter	$^{3}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
	Outer Diameter	$^{3}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
20	Inner Diameter	$^{3}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
	Outer Diameter	$^{3}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
22	Inner Diameter	$^{3}/_{16}$	—	—	—	—
		$^{5}/_{16}$	—	—	—	—
		$^{7}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
	Outer Diameter	$^{3}/_{16}$	—	—	—	—
		$^{5}/_{16}$	—	—	—	—
		$^{7}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
24	Inner Diameter	$^{3}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	+ 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
	Outer Diameter	$^{3}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	± 0.05	0.000XX ± 0.0000X	$\pm 0.005/\sqrt{3}$	

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Table 48 – *Continued from previous page*

ID	Parameter	Config.	Deviation Used [in.]	$\Delta k_{eff} \pm 1\sigma_{MC}$	1σ Uncertainty [in.]	Final u_k
27	Inner Diameter	$^3/_{16}$	—	—	—	—
		$^5/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^7/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
	Outer Diameter	$^3/_{16}$	—	—	—	—
		$^5/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^7/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
29	Inner Diameter	$^3/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^5/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^7/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
	Outer Diameter	$^3/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^5/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^7/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
31	Inner Diameter	$^3/_{16}$	—	—	—	—
		$^5/_{16}$	—	—	—	—
		$^7/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
	Outer Diameter	$^3/_{16}$	—	—	—	—
		$^5/_{16}$	—	—	—	—
		$^7/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
33	Inner Diameter	$^3/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^5/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^7/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
	Outer Diameter	$^3/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^5/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^7/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
36	Inner Diameter	$^3/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^5/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^7/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
	Outer Diameter	$^3/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^5/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^7/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
37	Inner Diameter	$^3/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^5/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^7/_{16}$	+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
	Outer Diameter	$^3/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^5/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^7/_{16}$	$\pm$ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
HEU 15/0						
11017	Outer Diameter	$^3/_{16}$	- 0.1	$0.000XX \pm 0.0000X$	$\pm 0.01/\sqrt{3}$	
		$^5/_{16}$	- 0.1	$0.000XX \pm 0.0000X$	$\pm 0.01/\sqrt{3}$	

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Table 48 – *Continued from previous page*

ID	Parameter	Config.	Deviation Used [in.]	$\Delta k_{eff} \pm 1\sigma_{MC}$	1σ Uncertainty [in.]	Final u_k
		$7/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
11019	Outer Diameter	$3/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
		$5/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
		$7/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
11147	Outer Diameter	$3/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
		$5/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
		$7/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
11149	Outer Diameter	$3/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
		$5/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
		$7/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
11150	Outer Diameter	$3/16$	—	—	—	—
		$5/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
		$7/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
HEU 15/6						
10477	Inner Diameter	$3/16$	—	—	—	—
		$5/16$	—	—	—	—
		$7/16$	+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
	Outer Diameter	$3/16$	—	—	—	—
		$5/16$	—	—	—	—
		$7/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
11018	Inner Diameter	$3/16$	+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$5/16$	+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$7/16$	+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
	Outer Diameter	$3/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$5/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$7/16$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
HEU 15/2.5						
10464	Inner Diameter	$3/16$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$5/16$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$7/16$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
	Outer Diameter	$3/16$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$5/16$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$7/16$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
10467	Inner Diameter	$3/16$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$5/16$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$7/16$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
	Outer Diameter	$3/16$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$5/16$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$7/16$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	

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Table 48 – *Continued from previous page*

ID	Parameter	Config.	Deviation Used [in.]	$\Delta k_{eff} \pm 1\sigma_{MC}$	1σ Uncertainty [in.]	Final u_k
10470	Inner Diameter	$^3/_{16}$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$^5/_{16}$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$^7/_{16}$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
	Outer Diameter	$^3/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^5/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^7/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
10475	Inner Diameter	$^3/_{16}$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$^5/_{16}$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$^7/_{16}$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
	Outer Diameter	$^3/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^5/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^7/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
10487	Inner Diameter	$^3/_{16}$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$^5/_{16}$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$^7/_{16}$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
	Outer Diameter	$^3/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^5/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^7/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
10489	Inner Diameter	$^3/_{16}$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$^5/_{16}$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
		$^7/_{16}$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
	Outer Diameter	$^3/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^5/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^7/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
10491	Inner Diameter	$^3/_{16}$	—	—	—	—
		$^5/_{16}$	—	—	—	—
		$^7/_{16}$	$\pm$ 0.02	0.000XX $\pm$ 0.0000X	$\pm$ 0.0025/$\sqrt{3}$	
	Outer Diameter	$^3/_{16}$	—	—	—	
		$^5/_{16}$	—	—	—	—
		$^7/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
HEU 6/0						
Q2-16	Outer Diameter	$^3/_{16}$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
		$^5/_{16}$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	
		$^7/_{16}$	- 0.1	0.000XX $\pm$ 0.0000X	$\pm$ 0.01/$\sqrt{3}$	

Table 49. u_k of Height Uncertainty of HEU Plates.

ID	Parameter	Config.	Deviation Used [in.]	$\Delta k_{eff} \pm 1\sigma_{MC}$	1σ Uncertainty [in.]	Final u_k
HEU 21/15 (B-2444-)						
01	Height	$^3/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
		$^5/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
		$^7/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
02	Height	$^3/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
		$^5/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
		$^7/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
07	Height	$^3/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
		$^5/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
		$^7/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
10	Height	$^3/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
		$^5/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
		$^7/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
19	Height	$^3/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
		$^5/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
		$^7/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
20	Height	$^3/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
		$^5/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
		$^7/_{16}$	- 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	0.000XX ± 0.0000X	$\pm\ 0.005/\sqrt{3}$	
22	Height	$^3/_{16}$	—	—	—	—

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Table 49 – *Continued from previous page*

ID	Parameter	Config.	Deviation Used [in.]	$\Delta k_{eff} \pm 1\sigma_{MC}$	1σ Uncertainty [in.]	Final u_k
			—	—	—	—
		$^{5}/_{16}$	—	—	—	—
			—	—	—	
		$^{7}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
24	Height	$^{3}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
27	Height	$^{3}/_{16}$	—	—	—	—
			—	—	—	—
		$^{5}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
29	Height	$^{3}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
31	Height	$^{3}/_{16}$	—	—	—	—
			—	—	—	—
		$^{5}/_{16}$	—	—	—	—
			—	—	—	—
		$^{7}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
33	Height	$^{3}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^{7}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
36	Height	$^{3}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
		$^{5}/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm 0.005/\sqrt{3}$	

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Table 49 – *Continued from previous page*

ID	Parameter	Config.	Deviation Used [in.]	$\Delta k_{eff} \pm 1\sigma_{MC}$	1σ Uncertainty [in.]	Final u_k
		$^7/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
37	Height	$^3/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
		$^5/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
		$^7/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
HEU 15/0						
11017	Height	$^3/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
		$^5/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
		$^7/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
11019	Height	$^3/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
		$^5/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
		$^7/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
11147	Height	$^3/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
		$^5/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
		$^7/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
11149	Height	$^3/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
		$^5/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
		$^7/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
11150	Height	$^3/_{16}$	—	—	—	—
			—	—	—	—
		$^5/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	
		$^7/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm\ 0.005/\sqrt{3}$	

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Table 49 – *Continued from previous page*

ID	Parameter	Config.	Deviation Used [in.]	$\Delta \mathrm{k_{eff}} \pm 1\sigma_{\mathrm{MC}}$	1σ Uncertainty [in.]	Final $\mathrm{u_k}$
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
HEU 15/6						
10477	Height	$^{3}/_{16}$	—	—	—	—
			—	—	—	
		$^{5}/_{16}$	—	—	—	—
			—	—	—	—
		$^{7}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
11018	Height	$^{3}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^{5}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^{7}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
HEU 15/2.5						
10464	Height	$^{3}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^{5}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^{7}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
10467	Height	$^{3}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^{5}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^{7}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
10470	Height	$^{3}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^{5}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^{7}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
10475	Height	$^{3}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^{5}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^{7}/_{16}$	- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	

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Table 49 – *Continued from previous page*

ID	Parameter	Config.	Deviation Used [in.]	$\Delta k_{eff} \pm 1\sigma_{MC}$	1σ Uncertainty [in.]	Final u_k
10487	Height	$^3/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
		$^5/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
		$^7/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
10489	Height	$^3/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
		$^5/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
		$^7/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
10491	Height	$^3/_{16}$	—	—	—	—
			—	—	—	—
		$^5/_{16}$	—	—	—	—
			—	—	—	—
		$^7/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
HEU 6/0						
Q2-16	Height	$^3/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
		$^5/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
		$^7/_{16}$	- 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	
			+ 0.05	$0.000XX \pm 0.0000X$	$\pm$ 0.005/$\sqrt{3}$	

2.3.2 Non-Fissile Core Components

2.3.2.1 Interstitial Copper Disks

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

2.3.2.2 Aluminum Shims

No diameter measurements were taken of the Al shims used in the 3/16 configuration, so drawing dimensions were used in the benchmark model and for the 1σ uncertainties. The drawing dimensions and the associated tolerances are summarized in Table 8. Because asymmetric tolerances exist for the inner and outer diameter, the benchmark model adjusted the dimension so the tolerance would be symmetric. Because diameter measurements do not exist, the tolerances are used for the uncertainties. The dimensions and uncertainties used in the benchmark models are listed in Table 50 and the calculated volume and density are in Table 51.

The outer and inner diameter and the height of the Al shims were varied as shown in Table 52. Because there is a measured mass, when the part dimensions were perturbed, the density was adjusted to preserve the mass. One-sided perturbations were done because, as shown in Table 52, the effect of thickening the plates is larger than the effect of thinning them in terms of Δk_{eff} but the final u_k is ???.

The uncertainties for each part and each parameter in Table 52 are added in quadrature for each configuration and the total is reported in Section 2.8.

Table 50. Dimension and Uncertainty Data for Al Shims.

Component	Parameter	Dimension [in.]	Tolerance [in.]	u_T [in.]
400 mil	Inner Diameter	2.505	± 0.005	$\pm 0.005/\sqrt{3}$
	Outer Diameter	20.995	± 0.005	$\pm 0.005/\sqrt{3}$
	Height	0.3990	± 0.005	$\pm 0.005/\sqrt{3}$
500 mil	Inner Diameter	2.505	± 0.005	$\pm 0.005/\sqrt{3}$
	Outer Diameter	20.995	± 0.005	$\pm 0.005/\sqrt{3}$
	Height	0.5015	± 0.005	$\pm 0.005/\sqrt{3}$

Table 51. Mass Densities of Al Shims.

Component	Calculated Volume [cm^3]	Density [g/cm^3]
400 mil	2,231.35515	2.69926
500 mil	2,804.57296	2.68797

Table 52. u_k of Dimension Uncertainty of Al Shims for the 3/16 Configuration.

Component	Parameter	Deviation Used [in.]	$\Delta k_{eff} \pm 1\sigma_{MC}$	1σ Uncertainty [cm]	Final u_k
400 mil	Outer Diameter	± 0.05	x.xxxxx ± x.xxxxx	$\pm 0.005/\sqrt{3}$	
	Inner Diameter	± 0.05	x ± x	$\pm 0.005/\sqrt{3}$	
	Height	+ 0.01	x ± x	$\pm 0.005/\sqrt{3}$	
		- 0.01	x ± x	$\pm 0.005/\sqrt{3}$	
500 mil	Outer Diameter	± 0.05	x.xxxxx ± x.xxxxx	$\pm 0.005/\sqrt{3}$	
	Inner Diameter	± 0.05	x ± x	$\pm 0.005/\sqrt{3}$	
	Height	+ 0.01	x ± x	$\pm 0.005/\sqrt{3}$	
		- 0.01	x ± x	$\pm 0.005/\sqrt{3}$	

2.3.2.3 Aluminum Adapter Plates

No dimension measurements were taken of the Al adapter plate used in the $^7/_{16}$ configuration, so drawing dimensions were used in the benchmark model and for the 1σ uncertainties. The drawing dimensions and the associated tolerances are summarized in Table 10. Because asymmetric tolerances exist for the outer diameter, the benchmark model adjusted the dimension so the tolerance would be symmetric. Because measurements do not exist, the tolerances are used for the dimension uncertainties. The dimensions and uncertainties used in the benchmark models are listed in Table 53 and the calculated volume and density are in Table 54.

The outer and inner diameter and the height of the Al adapter plates were varied as shown in Table 55. Because there is not a measured mass, when the part dimensions were perturbed, the density was kept constant. One-sided perturbations were done because, as shown in Table 55, the effect of thickening the plates is larger than the effect of thinning them in terms of Δk_{eff} but the final u_k is very small or negligible.

The uncertainties for each part and each parameter in Table 55 are added in quadrature for each configuration and the total is reported in Section 2.8.

Table 53. Dimension and Uncertainty Data for Al Adapter Plates.

Component	Parameter	Dimension [in.]	Tolerance [in.]	$\mathbf{u_T}$ [in.]
Al Adapter	Inner Diameter	2.50	± 0.005	$\pm\ 0.005/\sqrt{3}$
	Outer Diameter	5.9925	± 0.0025	$\pm\ 0.0025/\sqrt{3}$
	Height	0.118	± 0.002	$\pm\ 0.002/\sqrt{3}$

Table 54. Mass Densities of Al Adapter Plates.

Component	Calculated Volume [cm^3]	Density [g/cm^3]
Al Adapter	45.04484	2.70$^{(a)}$

(a) Assumed

Table 55. u_k of Dimension Uncertainty of Al Adapter Plate for the $^7/_{16}$ Configuration.

Parameter	Deviation Used [in.]	$\mathbf{\Delta k_{eff} \pm 1\sigma_{MC}}$	1σ Uncertainty [cm]	Final $\mathbf{u_k}$
Outer Diameter	± 0.005	x ± x	$\pm\ 0.005/\sqrt{3}$	
Inner Diameter	± 0.0025	x ± x	$\pm\ 0.0025/\sqrt{3}$	
Height	+ 0.02	x ± x	$\pm\ 0.002/\sqrt{3}$	
	- 0.02	x ± x	$\pm\ 0.002/\sqrt{3}$	

2.3.3 Copper Reflectors

Because the exact location of each Cu reflector piece is not known, the drawing dimensions were used in the benchmark model and for the 1σ uncertainties. The dimensions and uncertainties used in the benchmark models are listed in Table 56.

The volumes calculated for the Cu reflectors using the dimensions given in the figures in Section 1.2.5 are listed in Table 57. Note, the calculated volumes include all feature of the component (e.g., screw holes), for additional details see the figures referenced in Table 57. These volumes were used with the masses listed in Table 12 to compute the density of each component (also listed in Table 57). Note, some of the components have bottom pieces and the only difference between the bottom and normal pieces are the location of some of the holes (see Figure 18 through Figure 22).

The dimensions of the Cu reflectors were varied as shown in Table 58. The part densities were perturbed to preserve the masses. A one-sided perturbation of the length and width of the corner reflectors and top reflector was done because there is a gap of only 0.0025 in. between the outer edge of the corner reflectors and the inner surface of the Cu side reflectors. For components that had multiple parts perturbed at the same time, the uncertainty was divided by the square root of the number N of perturbed components.

The uncertainties for each part and each parameter in Table 58 are added in quadrature for each configuration and the total is reported in Section 2.8.

Table 56. Dimension and Uncertainty Data for Cu Reflectors.

Component	**Parameter**	**Dimension [in.]**	**Tolerance [in.]**	**u_T [in.]**
Top	Length	21.995	$\pm$ 0.005	$\pm$ 0.005/$\sqrt{3}$
	Hole Diameter	0.250	$\pm$ 0.005	$\pm$ 0.005/$\sqrt{3}$
	Height	5.68	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
Bottom	Inner Diameter	2.50	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
	Outer Diameter	21.00	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
	Height	5.68	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
Side	Length	28.38	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
	Width	6.38	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
	Height	8.13	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
CR 5.68 in.	Side Length	10.995	$\pm$ 0.005	$\pm$ 0.005/$\sqrt{3}$
	Inner Radius	10.55	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
	Height	5.68	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
CR 3.00 in.	Side Length	10.995	$\pm$ 0.005	$\pm$ 0.005/$\sqrt{3}$
	Inner Radius	10.55	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
	Height	3.00	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
CR 0.75 in.	Side Length	10.995	$\pm$ 0.005	$\pm$ 0.005/$\sqrt{3}$
	Inner Radius	10.55	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
	Height	0.75	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
CR 1.50 in.	Side Length	10.995	$\pm$ 0.005	$\pm$ 0.005/$\sqrt{3}$
	Inner Radius	10.55	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
	Height	1.50	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
CR 0.250 in.	Side Length	10.995	$\pm$ 0.005	$\pm$ 0.005/$\sqrt{3}$
	Inner Radius	10.55	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
	Height	0.250	$\pm$ 0.005	$\pm$ 0.005/$\sqrt{3}$
CR 0.375 in.	Side Length	10.995	$\pm$ 0.005	$\pm$ 0.005/$\sqrt{3}$
	Inner Radius	10.55	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
	Height	0.375	$\pm$ 0.005	$\pm$ 0.005/$\sqrt{3}$

Table 57. Mass Densities of Cu Reflectors.

Component	Figure	Calculated Volume [cm^3]	Density [g/cm^3]
Top	Figure 21	45,015.31	8.78812
Bottom	Figure 22	32,138.14$^{(a)}$	8.69412
Side	Figure 19	24,113.37	8.73567
Side Bottom	Figure 20	24,109.77	—$^{(b)}$
CR 5.68	Figure 18	3,109.19	8.78190
CR 5.68 Bottom	Figure 18	3,107.50	—$^{(c)}$
CR 3.00	Figure 18	1,639.14	8.77929
CR 0.75	Figure 18	406.83	8.75189
CR 1.50	Figure 18	816.35	8.75103
CR 0.250	Figure 18	135.61	8.74452
CR 0.375	Figure 18	203.42	8.83829

(a) Using 0.1629 in. for the diameter of a #10-24 UNC-2B tap. From Tap Chart UNC/UNF Threads - provides tap sizes, drill sizes, pitch, (threads per inch) basic major diameter, basic effective diameter, basic minor diameter of external threads, and basic minor diameter of internal threads for UNC/UNF threads. (n.d.). Copyright © 2003 Carbide Depot. Retrieved January 6, 2022, from http://www.carbidedepot.com/formulas-tap-standard.htm

(b) The mass of these parts is included in the average of the masses of the Cu side parts. The same density is used.

(c) The mass of these parts is included in the average of the masses of the Cu corner 5.68 in. parts. The same density is used.

Table 58. u_k of Dimension Uncertainty of Cu Reflectors.

Component	Parameter	Config.	N	Deviation Used [in.]	$\Delta k_{eff} \pm 1\sigma_{MC}$	1σ Uncertainty [cm]	Final u_k
Top	Height	$^3/_{16}$		- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
				+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^5/_{16}$		- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
				+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
		$^7/_{16}$		- 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	
				+ 0.05	0.000XX $\pm$ 0.0000X	$\pm$ 0.005/$\sqrt{3}$	

2.3.4 Comet Hardware

No dimension measurements were taken of the diaphragm, top plate, alignment tube, or platen/platen adapter plate, so drawing dimensions were used in the benchmark model and for the 1σ uncertainties. The dimensions and uncertainties used in the benchmark models are listed in Table 59.

The volumes calculated for the diaphragm, alignment tube, top plate, and platen/platen adapter plate using the dimensions given in the figures in Section 1.2.6 are listed in Table 60. These volumes were used with the masses listed in Table 42 to compute the density of the diaphragm (also listed in Table 60). Because the masses of the alignment tube, top plate, and platen/platen adapter plate are unknown, a handbook density for Al 6061 was used for those parts rather than calculating the volume.

The dimensions of the Comet hardware components were varied as shown in Table **??**. The part densities for the diaphragm was perturbed to preserve the mass. A one-sided perturbation of the length and width of the diaphragm was done because there is a gap of only 0.0025 in. between the outer edge of the diaphragm and the inner surface of the Cu side reflectors. For the alignment tube, top plate, and platen/platen adapter plate, the mass density is assumed to remain constant in the perturbations.

The uncertainties for each part and each parameter in Table **??** are added in quadrature for each configuration and the total is reported in Section 2.8.

Table 59. Dimension and Uncertainty Data for Comet Hardware.

Component	Parameter	Dimension [in.]	Tolerance [in.]	u_T [in.]
Diaphragm	Length	21.995	$\pm$ 0.005	$\pm$ 0.005/$\sqrt{3}$
	Height	0.187	$\pm$ 0.005	$\pm$ 0.005/$\sqrt{3}$
Alignment Tube	Inner Diameter$^{(a)}$	2.00	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
	Outer Diameter	2.480	$\pm$ 0.002	$\pm$ 0.002/$\sqrt{3}$
	Length	18.50	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
Top Plate	Inner Diameter	21.100	$\pm$ 0.005	$\pm$ 0.005/$\sqrt{3}$
	Length$^{(b)}$	45.00	$\pm$ 0.03	$\pm$ 0.03/$\sqrt{3}$
	Height	1.00	$\pm$ 0.1	$\pm$ 0.1/$\sqrt{3}$
Platen$^{(c),(d)}$	Inner Diameter	3.75	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
	Outer Diameter	21.00	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$
	Height	2.50	$\pm$ 0.01	$\pm$ 0.01/$\sqrt{3}$

(a) STK. is assumed to mean the tolerance provided on the engineering drawing.
(b) Including the length of the cut-out corners.
(c) Platen here refers to the platen and platen adapter plate, which is considered one component in the benchmark model.
(d) Since the platen and platen adapter plate have the same tolerances, those values are used for the dimension perturbations.

Table 60. Mass Densities of Comet Hardware.

Component	Figure	Calculated Volume [cm^3]	Density [g/cm^3]
Diaphragm	Figure 23	1,477.93	7.82856
Alignment Tube	Figure 25	—	2.70$^{(a)}$
Top Plate	Figure 24	—	2.70$^{(a)}$
Platen$^{(b)}$	Figure 26 & 27	—	2.70$^{(a)}$

(a) Assumed.
(b) Platen here refers to the platen and platen adapter plate, which is considered one component in the benchmark model.

2.4 Composition Uncertainties

Negligible is considered to be a $u_k \leq 0.000005$.

2.4.1 Highly Enriched Uranium Disks and Rings

Each HEU part used in the experiment has its own composition definition and density. U-235 enrichment values are available for all the HEU plates. However, there are contradictory measurements for enrichment as seen in Section 1.3.1. The 1974 U isotopic measurements (Table 17) were used for the HEU plate that was used in the experiment configurations (11018). For the HEU 21/15 plates, the U-235 and U-234 measurements performed in 1961 were used (Table 18). In the benchmark model, the U-236 and U-238 compositions for the HEU 21/15 plates were determined by normalizing the U-236 and U-238 measurements from the B-2444-13 plate (even though it was not used in the experiment), since it is the only HEU 21/15 plate with complete U isotopic measurements. The normalization is

$$\frac{{}^{Y}_{-13}U}{100-({}^{234}_{-13}U+{}^{235}_{-13}U)}=\frac{{}^{Y}_{-X}U}{100-({}^{234}_{-X}U+{}^{235}_{-X}U)} \tag{14}$$

where U represents the weight fraction of a U isotope relative to the total weight fraction of U in the plate, Y is 236 or 238, and -X is the HEU 21/15 plate of interest (note, the full plate ID is B-2444-X, but has been appreviated in Equation 14). Impurity measurements of all the HEU 21/15 plates were taken in 1961 (Table 18) and these values are used in the benchmark model. These values are assumed to be given in parts per million by weight of the part. These values are used in the benchmark model as reported. When measurements were reported as "$<$ W", $\frac{2}{3}$×W was used. The impurities and the U were combined for each part by preserving the impurity compositions and normalizing the U isotopic weight fractions to one minus the sum of the impurity weight fractions. Table 61 and Table 62 shows the resulting composition for the HEU 21/15 components.

Table 61. HEU 21/15 Plate (B-2444-01 through B-2444-22) Compositions [wt%].

Element or Isotope	B-2444-01	B-2444-02	B-2444-07	B-2444-10	B-2444-19	B-2444-20	B-2444-22
Li	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06
Be	1.3333E-06	1.3333E-06	1.3333E-06	1.3333E-06	1.3333E-06	1.3333E-06	1.3333E-06
B	4.0000E-05	4.0000E-05	4.0000E-05	5.0000E-05	4.0000E-05	4.0000E-05	5.0000E-05
C	4.2000E-02	3.4000E-02	4.2000E-02	5.0000E-02	4.2000E-02	5.5000E-02	4.5000E-02

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Table 61 – *Continued from previous page*

Element or Isotope	B-2444-01	B-2444-02	B-2444-07	B-2444-10	B-2444-19	B-2444-20	B-2444-22
Na	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Mg	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Al	2.5000E-03	3.5000E-03	3.5000E-03	2.5000E-03	3.5000E-03	3.5000E-03	3.5000E-03
Si	2.2000E-02	4.0000E-02	2.0000E-02	3.5000E-02	2.0000E-02	1.5000E-02	3.5000E-02
P	3.3333E-03	3.3333E-03	3.3333E-03	3.3333E-03	3.3333E-03	3.3333E-03	3.3333E-03
K	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04
Ca	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	5.0000E-04
V	6.6667E-05	2.0000E-04	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Cr	7.0000E-04	1.3000E-03	5.0000E-04	8.0000E-04	6.0000E-04	5.0000E-04	6.0000E-04
Mn	5.0000E-04	4.0000E-04	4.0000E-04	6.0000E-04	6.0000E-04	3.0000E-04	5.0000E-04
Fe	6.0000E-03	6.0000E-03	6.5000E-03	2.2500E-02	7.5000E-03	6.0000E-03	8.0000E-03
Co	6.6667E-05	6.6667E-05	6.6667E-05	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
Ni	2.5000E-03	2.5000E-03	2.5000E-03	3.0000E-03	2.5000E-03	2.0000E-03	2.5000E-03
Cu	6.0000E-04	7.0000E-04	6.0000E-04	1.0000E-03	7.0000E-04	3.0000E-04	7.0000E-04
Zn	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03
Mo	6.0000E-03	1.2000E-02	8.0000E-03	8.5000E-03	1.0000E-02	4.0000E-03	8.0000E-03
Cd	1.3333E-05	1.3333E-05	1.3333E-05	1.3333E-05	1.3333E-05	1.3333E-05	1.3333E-05
Sn	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Pb	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
U-234	1.0091E+00	1.0189E+00	1.0091E+00	1.0187E+00	1.0091E+00	1.0191E+00	9.9890E-01
U-235	9.3077E+01	9.3061E+01	9.3086E+01	9.3049E+01	9.3073E+01	9.3084E+01	9.3068E+01
U-236	4.3646E-01	4.3563E-01	4.3571E-01	4.3478E-01	4.3644E-01	4.3495E-01	4.3637E-01
U-238	5.3884E+00	5.3782E+00	5.3791E+00	5.3677E+00	5.3881E+00	5.3697E+00	5.3872E+00

Table 62. HEU 21/15 Plate (B-2444-24 through B-2444-37) Compositions [wt%].

Element or Isotope	B-2444-24	B-2444-27	B-2444-29	B-2444-31	B-2444-33	B-2444-36	B-2444-37
Li	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06
Be	1.3333E-06	1.3333E-06	1.3333E-06	1.3333E-06	1.3333E-06	1.3333E-06	1.3333E-06
B	4.0000E-05	4.0000E-05	2.0000E-05	3.0000E-05	1.0000E-05	1.0000E-05	1.0000E-05
C	4.0000E-02	5.5000E-02	3.7000E-02	4.2000E-02	3.8000E-02	3.3000E-02	3.0000E-02
Na	6.6667E-05	6.6667E-05	1.0000E-04	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Mg	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Al	3.0000E-03	3.0000E-03	2.0000E-03	2.0000E-03	1.0000E-03	1.0000E-03	1.0000E-03
Si	2.5000E-02	1.8000E-02	1.6000E-02	1.6000E-02	5.0000E-03	1.0000E-02	5.0000E-03
P	3.3333E-03	3.3333E-03	3.3333E-03	3.3333E-03	3.3333E-03	3.3333E-03	3.3333E-03
K	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04
Ca	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04

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Table 62 – *Continued from previous page*

Element or Isotope	B-2444-24	B-2444-27	B-2444-29	B-2444-31	B-2444-33	B-2444-36	B-2444-37
V	6.6667E-05	6.6667E-05	1.0000E-04	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Cr	5.0000E-04	5.0000E-04	1.3000E-03	5.0000E-04	9.0000E-04	8.0000E-04	5.0000E-03
Mn	5.0000E-04	6.0000E-04	5.0000E-04	4.0000E-04	3.0000E-04	3.0000E-04	8.0000E-04
Fe	7.5000E-03	7.0000E-03	8.5000E-03	7.0000E-03	4.5000E-03	5.0000E-03	2.1500E-02
Co	6.6667E-05	6.6667E-05	1.0000E-04	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Ni	2.5000E-03	1.5000E-03	4.0000E-03	2.0000E-03	3.0000E-03	3.0000E-03	5.0000E-03
Cu	6.0000E-04	5.0000E-04	7.0000E-04	5.0000E-04	4.0000E-04	3.0000E-04	3.0000E-04
Zn	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03
Mo	7.5000E-03	3.5000E-03	7.0000E-03	7.0000E-03	8.0000E-03	5.0000E-03	5.0000E-03
Cd	1.3333E-05	1.3333E-05	1.3333E-05	1.3333E-05	1.3333E-05	1.3333E-05	1.3333E-05
Sn	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Pb	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
U-234	9.8908E-01	1.0090E+00	1.0192E+00	1.0092E+00	1.0293E+00	1.0393E+00	1.0292E+00
U-235	9.3093E+01	9.3101E+01	9.3083E+01	9.3092E+01	9.3028E+01	9.3100E+01	9.3046E+01
U-236	4.3644E-01	4.3418E-01	4.3574E-01	4.3574E-01	4.4030E-01	4.3432E-01	4.3800E-01
U-238	5.3881E+00	5.3603E+00	5.3794E+00	5.3794E+00	5.4358E+00	5.3620E+00	5.4074E+00

U-235 enrichment measurements of all the HEU plates were taken when they were transported to Nevada in 2005 (Table 20). These U-235 enrichment values are used for the remaining inner HEU plates (6/0, 15/6, 15/0, 15/2.5). The remaining U isotopics (U-234, U-236, and U-238) were determined by taking an average of the inner plates from the 1974 measurements, which are all the plates in Table 17. Table 63 shows the average values with finite precision, but the averages were not rounded in these calculations.

Table 63. Average U-234, U-236, U-238 Isotopics for Inner HEU Plates.

Nuclide	Average [wt%]
U-234	1.0315
U-236	0.23375
U-238	5.455

Because the measurements did not add up to 100%, the values for the U isotopics (U-235 from Table 20 and U-234, U-236, and U-238 from the average of the inner plates in Table 17) were then normalized to 100%. The values were then normalized again to account for impurities using

$$ {}^{Y}_{X}U = \frac{{}^{Y}_{X}U' \times (100 - I)}{100} \tag{15} $$

where Y is 234, 235, 236, or 238; X is the inner plate of interest; U’ is the U weight fraction before normalizing to include impurities; and I is the weight fraction of all the impurities. Impurity measurements were performed on three of the HEU 15/0 plates (11147, 11149, and 11150) as seen in Table 19, and that description is used in the benchmark model.

For the remaining inner HEU plates, an average value (conserving all digits) for each impurity is used. These values are assumed to be given in parts per million by weight of the part. When measurements were reported as "$<$ W", $\frac{2}{3}$×W was used as the value. The resulting compositions for the inner HEU plates are shown in Table 64 through Table 66.

Table 64. HEU 15/0 and HEU 15/6 Plate Compositions [wt%].

Element or Isotope	11017	11019	11147	11149	11150
Li	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06
Be	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06
B	5.0000E-05	5.0000E-05	6.0000E-05	6.0000E-05	3.0000E-05
C	5.6333E-02	5.6333E-02	1.1000E-01	2.7000E-02	3.2000E-02
Na	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Mg	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Al	3.6667E-03	3.6667E-03	5.0000E-03	4.0000E-03	2.0000E-03
Si	3.0333E-02	3.0333E-02	3.0000E-02	4.0000E-02	2.1000E-02
Ca	1.3333E-04	1.3333E-04	1.3333E-04	1.3333E-04	1.3333E-04
V	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03
Cr	8.3333E-04	8.3333E-04	5.0000E-05	1.5000E-03	5.0000E-04
Mn	5.6667E-04	5.6667E-04	4.0000E-04	7.0000E-04	6.0000E-04
Fe	1.2667E-02	1.2667E-02	1.0000E-02	1.9000E-02	9.0000E-03
Co	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04
Ni	2.3333E-03	2.3333E-03	2.0000E-03	3.0000E-03	2.0000E-03
Cu	5.0000E-04	5.0000E-04	6.0000E-04	5.0000E-04	4.0000E-04
Mo	2.7778E-03	2.7778E-03	5.0000E-03	1.6667E-03	1.6667E-03
Sn	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Pb	2.1111E-04	2.1111E-04	5.0000E-04	6.6667E-05	6.6667E-05
U-234	1.0300E+00	1.0314E+00	1.0309E+00	1.0309E+00	1.0319E+00
U-235	9.3177E+01	9.3168E+01	9.3117E+01	9.3184E+01	9.3206E+01
U-236	2.3342E-01	2.3372E-01	2.3362E-01	2.3361E-01	2.3384E-01
U-238	5.4472E+00	5.4543E+00	5.4519E+00	5.4517E+00	5.4571E+00

Table 65. HEU 15/6 and HEU 6/0 Plate Compositions [wt%].

Element or Isotope	10477	11018	Q2-16
Li	6.6667E-06	6.6667E-06	6.6667E-06
Be	6.6667E-06	6.6667E-06	6.6667E-06
B	5.0000E-05	5.0000E-05	5.0000E-05
C	5.6333E-02	5.6333E-02	5.6333E-02
Na	6.6667E-05	6.6667E-05	6.6667E-05
Mg	6.6667E-05	6.6667E-05	6.6667E-05
Al	3.6667E-03	3.6667E-03	3.6667E-03

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Table 65 – *Continued from previous page*

Element or Isotope	10477	11018	Q2-16
Si	3.0333E-02	3.0333E-02	3.0333E-02
Ca	1.3333E-04	1.3333E-04	1.3333E-04
V	1.3333E-03	1.3333E-03	1.3333E-03
Cr	8.3333E-04	8.3333E-04	8.3333E-04
Mn	5.6667E-04	5.6667E-04	5.6667E-04
Fe	1.2667E-02	1.2667E-02	1.2667E-02
Co	3.3333E-04	3.3333E-04	3.3333E-04
Ni	2.3333E-03	2.3333E-03	2.3333E-03
Cu	5.0000E-04	5.0000E-04	5.0000E-04
Mo	2.7778E-03	2.7778E-03	2.7778E-03
Sn	6.6667E-05	6.6667E-05	6.6667E-05
Pb	2.1111E-04	2.1111E-04	2.1111E-04
U-234	1.0296E+00	1.0209E+00	1.0318E+00
U-235	9.3180E+01	9.3103E+01	9.3166E+01
U-236	2.3332E-01	5.2841E-01	2.3381E-01
U-238	5.4450E+00	5.2351E+00	5.4565E+00

Table 66. HEU 15/2.5 Plate Compositions [wt%].

Element or Isotope	10464	10467	10470	10475	10487	10489	10491
Li	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06
Be	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06	6.6667E-06
B	5.0000E-05	5.0000E-05	5.0000E-05	5.0000E-05	5.0000E-05	5.0000E-05	5.0000E-05
C	5.6333E-02	5.6333E-02	5.6333E-02	5.6333E-02	5.6333E-02	5.6333E-02	5.6333E-02
Na	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Mg	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05
Al	3.6667E-03	3.6667E-03	3.6667E-03	3.6667E-03	3.6667E-03	3.6667E-03	3.6667E-03
Si	3.0333E-02	3.0333E-02	3.0333E-02	3.0333E-02	3.0333E-02	3.0333E-02	3.0333E-02
Ca	1.3333E-04	1.3333E-04	1.3333E-04	1.3333E-04	1.3333E-04	1.3333E-04	1.3333E-04
V	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03	1.3333E-03
Cr	8.3333E-04	8.3333E-04	8.3333E-04	8.3333E-04	8.3333E-04	8.3333E-04	8.3333E-04
Mn	5.6667E-04	5.6667E-04	5.6667E-04	5.6667E-04	5.6667E-04	5.6667E-04	5.6667E-04
Fe	1.2667E-02	1.2667E-02	1.2667E-02	1.2667E-02	1.2667E-02	1.2667E-02	1.2667E-02
Co	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04	3.3333E-04
Ni	2.3333E-03	2.3333E-03	2.3333E-03	2.3333E-03	2.3333E-03	2.3333E-03	2.3333E-03
Cu	5.0000E-04	5.0000E-04	5.0000E-04	5.0000E-04	5.0000E-04	5.0000E-04	5.0000E-04
Mo	2.7778E-03	2.7778E-03	2.7778E-03	2.7778E-03	2.7778E-03	2.7778E-03	2.7778E-03
Sn	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05	6.6667E-05

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Table 66 – *Continued from previous page*

Element or Isotope	10464	10467	10470	10475	10487	10489	10491
Pb	2.1111E-04	2.1111E-04	2.1111E-04	2.1111E-04	2.1111E-04	2.1111E-04	2.1111E-04
U-234	1.0293E+00	1.0290E+00	1.0290E+00	1.0291E+00	1.0305E+00	1.0292E+00	1.0294E+00
U-235	9.3182E+01	9.3184E+01	9.3184E+01	9.3183E+01	9.3174E+01	9.3182E+01	9.3181E+01
U-236	2.3325E-01	2.3318E-01	2.3318E-01	2.3321E-01	2.3353E-01	2.3323E-01	2.3328E-01
U-238	5.4434E+00	5.4418E+00	5.4418E+00	5.4423E+00	5.4500E+00	5.4429E+00	5.4440E+00

Measurement uncertainties were reported for the U isotopics in Table 17. These are 2σ uncertainties. No measurement uncertainties were reported for the U-235 enrichment in Table 20 or any of the impurity measurements in Table 18 or Table 19. The largest relative uncertainty for each U isotope given in Table 17 was applied for every part and the uncertainty for the impurities is assumed. These uncertainties are shown in Table 67.

U isotopic uncertainties and impurity composition uncertainties were evaluated separately. For U isotopics except for U-238, control parameter adjustment was used with U-238 as the control parameter, meaning that a change in a U isotope composition would be balanced by an equal and opposite change in the U-238 composition. For U-238, full normalization was used, meaning that a change in the U-238 composition would be balanced by renormalizing all the U isotope compositions, keeping the total U composition constant. For impurities, control parameter adjustment was used with U-238 as the control parameter. The sensitivities of all impurities were added linearly, essentially treating them as perfectly correlated.

Sensitivities and uncertainties are reported in Table 68. The uncertainties for each component and each parameter are added in quadrature and the total is reported in Section 2.8. Sensitivities of the impurities in the HEU plates are only reported if the final u_k is non-negligible for at least one configuration. If no impurity has a u_k that is non-negligible, then the value for Fe is reported.

Table 67. HEU Composition Uncertainties.

Nuclide	Average [wt%]
U-234	1
U-235	0.02
U-236	100
U-238	1
Impurities	10

Table 68. u_k and Associated Uncertainty for the HEU Composition.

Component	Parameter	Config.	Relative Uncertainty $[u_T/\%][\%]$	$S_{k,x_i} \pm 1\sigma_{MC}$ [%/%]	Final u_k
B-2444-01	Fe	$^3/_{16}$	$\pm 10/\sqrt{3}$	X ± X %	Negligible
		$^5/_{16}$	$\pm 10/\sqrt{3}$	X ± X %	Negligible
		$^7/_{16}$	$\pm 10/\sqrt{3}$	X ± X %	Negligible

2.4.2 Non-Fissile Core Components

2.4.2.1 Interstitial Copper Disks

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2.4.2.2 Aluminum Shims

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2.4.2.3 Aluminum Adapter Plates

The Al adapter plate is made of Al 1100, but a composition analysis was not performed. Specifications for this material and the composition that was used in the benchmark models is shown in Table 69. The midpoint of a range was used, and two-thirds of an upper bound was used, with Al as the balance. The assumed uncertainties for the Al adapter plate constituents are listed in Table 70. These uncertainties are assumed to be bounding. Note, an Al adapter plate was only used in the $^{7}/_{16}$ configuration.

Full normalization was used for Al. For impurities, control parameter adjustment was used with Al as the control parameter, meaning that a change in an impurity composition would be balanced by an equal and opposite change in the Al composition.

Sensitivities and uncertainties are reported in Table 71. The uncertainties for each component and each parameter are added in quadrature and the total is reported in Section 2.8.

Table 69. Specification and Modeled Composition for Al 1100.[a]

Element	Specification [wt%]	Benchmark Composition [wt%]
Al	$\geq$ 99.00	99.141133
Be	$\leq$ 0.0008	0.00053333
Cu	0.05 - 0.20	0.1250000
Mn	$\leq$ 0.05	0.0333333
Si + Fe	$\leq$ 0.95	Si: 0.3166667
		Fe: 0.3166667
Zn	$\leq$ 0.10	0.0666667
Other (total)	$\leq$ 0.15	0.0
Other (each)	$\leq$ 0.05	0.0

(a) MatWeb - The Online Materials Information Resource. (n.d.). "Aluminum 1100-O." Retrieved October 26, 2022, from https://www.matweb.com/search/DataSheet.aspx?MatGUID=db0307742df14c8f817bd8d62207368e

Table 70. Al Adapter Composition Uncertainties.

Constituent	Relative Weight Fraction Uncertainty [%]
Al	0.5
Impurities	20

Table 71. u_k and Associated Uncertainty for the Composition of Al Adapter.[a]

Parameter	Relative Uncertainty $[\mathbf{u_T}/\%][\%]$	$\mathbf{S_{k,x_i} \pm 1\sigma_{MC}}$ [%/%]	Final $\mathbf{u_k}$
Cu	$\pm 20/\sqrt{3}$	X $\pm$ X %	Negligible

(a) Because the uncertainties for all impurities were negligible, the values for Cu are shown.

2.4.3 Copper Reflectors

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2.4.4 Comet Hardware

The platen, platen adapter plate, top plate, and alignment tube are Al 6061-T6. The Al 6061 composition is given in Table 72 which is from a Kaiser Aluminum certified test report. The uncertainties given in Table 73 were assumed. Full normalization was used for Al. For impurities, control parameter adjustment was used with Al as the control parameter, meaning that a change in an impurity composition would be balanced by an equal and opposite change in the Al composition.

Table 72. Specification and Modeled Composition for Al 6061 Components (platen, platen adapter plate, top plate, alignment tube).[a]

Element	Lower Limit [wt%]	Upper Limit [wt%]	Benchmark Composition [wt%]
Al	Balance		97.03
Si	0.40	0.80	0.600
Fe	—	0.70	0.4667
Cu	0.15	0.40	0.275
Mn	—	0.15	0.1
Mg	0.80	1.20	1.0
Cr	0.04	0.35	0.195
Zn	—	0.25	0.1667
Ti	—	0.15	0.1
V	—	0.05	0.0333
Zr	—	0.05	0.0333
Other	0.05 (each)	0.15 (total)	—

(a) Kaiser Aluminum, “Certified Test Report”, Kaiser Order No.: 1194164, Ship Date: July 15, 2015.

Table 73. Al 6061 Component Composition Uncertainties.

Constituent	Relative Weight Fraction Uncertainty [%]
Al	0.5
Impurities	20

The diaphragm is 304 stainless steel and the measured composition is shown in Table 24. The balance is assumed to be Fe. The composition as modeled is given in Table 74. No uncertainties were reported, so the uncertainties assumed for the constituents of the diaphragm are given in Table 75. These uncertainties are assumed to be bounding. For Fe in the diaphragm, full normalization was used; for other elements, control parameter adjustment was used with Fe as the control parameter.

Table 74. Composition of the Diaphragm

Element	Benchmark Composition [wt%]
Fe	71.210
C	0.017
Si	0.503
Mn	1.771
P	0.023
S	0.002
Cr	18.215
Ni	8.091
Cu	0.109
N	0.059

Table 75. Al Adapter Composition Uncertainties.

Constituent	Relative Weight Fraction Uncertainty [%]
Fe	1
Cr	5
Ni	5
Other	20

Sensitivities and uncertainties are reported in Table 76. The platen, platen adapter plate, and top plate compositions were treated as perfectly correlated, meaning that the sensitivities for these parts for each parameter were added linearly. The uncertainties for each component and each parameter are added in quadrature and the total is reported in Section 2.8.

Table 76. u_k and Associated Uncertainty for the Composition of The Comet Hardware.[(a)]

Component	Parameter	Config.	Relative Uncertainty $[\mathbf{u_T}/\%][\%]$	$\mathbf{S_{k,x_i} \pm 1\sigma_{MC}}$ [%/%]	Final $\mathbf{u_k}$
Alignment Tube	Cu	3/16	$\pm 20/\sqrt{3}$	X ± X %	Negligible
		5/16	$\pm 20/\sqrt{3}$	X ± X %	Negligible
		7/16	$\pm 20/\sqrt{3}$	X ± X %	Negligible
Platen PAP	Cu	3/16	$\pm 20/\sqrt{3}$	X ± X %	Negligible
		5/16	$\pm 20/\sqrt{3}$	X ± X %	Negligible
		7/16	$\pm 20/\sqrt{3}$	X ± X %	Negligible
Top Plate	Cu	3/16	$\pm 20/\sqrt{3}$	X ± X %	Negligible
		5/16	$\pm 20/\sqrt{3}$	X ± X %	Negligible
		7/16	$\pm 20/\sqrt{3}$	X ± X %	Negligible
Diaphragm	Cu	3/16	$\pm 20/\sqrt{3}$	X ± X %	Negligible
		5/16	$\pm 20/\sqrt{3}$	X ± X %	Negligible
		7/16	$\pm 20/\sqrt{3}$	X ± X %	Negligible

(a) Because the uncertainties for all impurities were negligible, the values for Cu are shown.

2.5 Positioning Uncertainties

2.5.1 Axial Position of the Alignment Tube

In the experiment, the alignment tube is not flush with the top of the lower core. Instead, the alignment tube is rotated down a quarter of a turn (by hand), which corresponds to 0.03125 in. (0.079375 cm). The benchmark model assumes that the top of the alignment tube is 0.07935 cm below the top of the lower core. The assumed uncertainty of this position is ±0.079375 cm, which is considered bounding. The results of the direct perturbation and their effect on keff are shown in Table 77.

Table 77. Uncertainty Associated with the Axial Position of the Al Alignment Tube.

Deviation Used [cm]	Config.	$\mathbf{\Delta k_{eff} \pm 1\sigma_{MC}}$	1σ Uncertainty [cm]	Final $\mathbf{u_k}$
±0.079375	3/16		$\pm 0.079375/\sqrt{3}$	
	5/16		$\pm 0.079375/\sqrt{3}$	
	7/16		$\pm 0.079375/\sqrt{3}$	

2.5.2 Alignment of the Core

The core stacks below and above the diaphragm may be off-center. The misalignment of the bottom core stack is limited to 0.01 in. (0.0254 cm) by the gap between the alignment tube and the inner radial surface of the ???. Misalignment of the top core stack is limited to 0.05 in. (0.127 cm) by the gap between the corner reflectors and the outer surface of the outer (21/15) HEU rings. In perturbation calculations, the bottom core stack was moved 0.0252 cm toward the opening to the room, and in the same calculation, the top core stack was moved 0.126 cm toward and away from the opening to the room (separately). These perturbations are assumed to bound the uncertainty. Results are shown in Table 78.

Table 78. Uncertainty Associated with Alignment of Core Stack.

Config.	Deviation Used [cm] Bottom Stack	Deviation Used [cm] Top Stack	$\Delta k_{eff} \pm 1\sigma_{MC}$	1σ Uncertainty [cm]	Final u_k
$^3/_{16}$	+	+0.126		Deviation/$\sqrt{3}$	
	+	-0.126		Deviation/$\sqrt{3}$	
$^5/_{16}$	+	+0.126		Deviation/$\sqrt{3}$	
	+	-0.126		Deviation/$\sqrt{3}$	
$^7/_{16}$	+	+0.126		Deviation/$\sqrt{3}$	
	+	-0.126		Deviation/$\sqrt{3}$	

2.5.3 Gaps Within the Copper Side Reflector

The Cu side reflectors are stacked and aligned side-by-side to form a wall enclosing the assembly on the sides. The Cu corner reflectors are stacked and provide reflection very close to the outer surface of the core stack. There are likely to be gaps in these assemblies.

Each Cu side reflector was translated 0.006 in. parallel to its width as shown in Figure 29. This perturbation added 0.006 in. (0.01524 cm) to the gap between the square side of the Cu corner reflectors and the inside of the Cu side reflectors. The masses of the Cu side reflectors were not perturbed. The Δk_{eff} for these perturbations are shown in Table 79. The actual size of any gaps is unknown. A bounding value equal to the drawing tolerance, 0.01 in. (0.0254 cm) for all dimensions, was used for the uncertainty. The uncertainty associated with gaps in the Cu side reflectors is shown in Table 79.

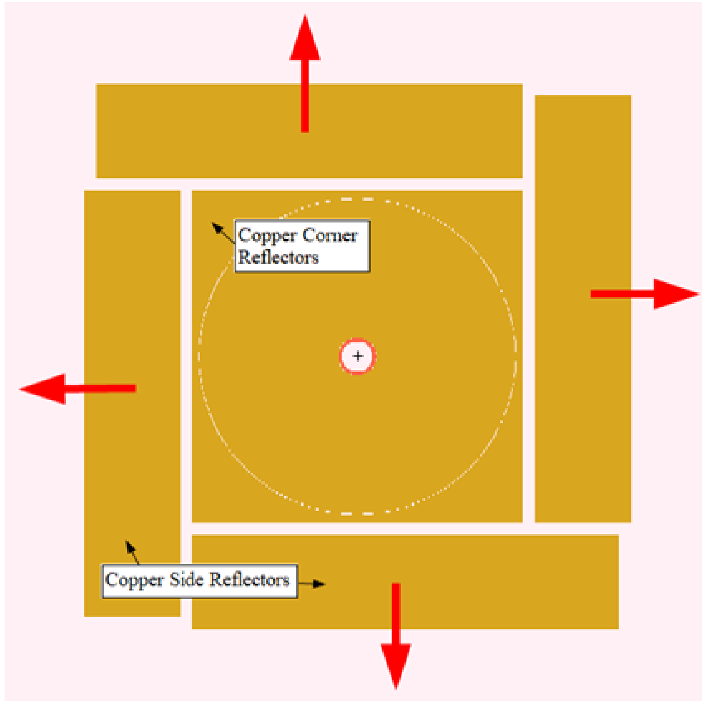

Figure 29. Plan View Showing How Gaps Were Formed Between Surfaces of the Side Reflectors. Side reflectors were translated 0.006 in. in the direction of the red arrows. For clarity, the gaps here are 2 cm wide rather than 0.01524 cm wide as in the calculations. Figure is from HEU-MET-INTER-011.

Table 79. Δ k_{eff} and Uncertainty as a Result of Gaps Between Vertical and Horizontal Surfaces in Cu Side Reflectors.

Config.	**Gap Used [cm]**	$\Delta k_{eff} \pm 1\sigma_{MC}$	**1σ Uncertainty [cm]**	**Final u_k**
$^3/_{16}$	+0.01524		$0.0254/\sqrt{3}$	
$^5/_{16}$	+0.01524		$0.0254/\sqrt{3}$	
$^7/_{16}$	+0.01524		$0.0254/\sqrt{3}$	

Potential gaps in the copper side reflector stack were also evaluated. Gaps were introduced above each copper side reflector and below the copper top reflector (i.e., above the uppermost copper corner reflector). The size of each gap was equal to the drawing tolerance of the height, which is $\pm$ 0.01 in. (0.0254 cm), of the part above the gap divided by $\sqrt{3}$. The part dimensions were preserved, meaning that the distance from the top plate to the diaphragm increased, and the distance from the diaphragm to the copper top reflector increased. The Δk_{eff} for these perturbations are shown in Table 80 along with the resulting uncertainties.

Table 80. Δ k_{eff} and Uncertainty as a Result of Gaps Between Horizontal Surfaces in Copper Side Reflectors When Gaps Are Introduced by Translating Parts.

Config.	**Gap Used [cm]**	$\Delta \mathbf{k_{eff}} \pm 1\sigma_{MC}$	**1σ Uncertainty [cm]**	**Final u_k**
$3/16$	$+0.0254/\sqrt{3}$		$0.0254/\sqrt{3}$	
$5/16$	$+0.0254/\sqrt{3}$		$0.0254/\sqrt{3}$	
$7/16$	$+0.0254/\sqrt{3}$		$0.0254/\sqrt{3}$	

The uncertainties from Table 79 and Table 80 are added in quadrature and the total is reported in Section 2.8.

2.5.4 Gaps Within the Core

Stack height measurements were performed on the top and bottom stack for each configuration and those measurements are summarized in Section 1.2.2. The average of all measurements was used for the benchmark model. An additional stack height measurement was performed for the $3/16$ configuration, which removed the Al shims that were used in the bottom stack. The average stack height measurements, the associated standard deviation, and a comparison between the expected stack height and the measurements is shown in Table 81. Given that the results with and without the Al shims for the $3/16$ configuration have a similar size gaps/unit, the measurement that removed the Al shims is not included in the benchmark model.

Table 81. Determination of the Gap/Unit Based of Stack Height Measurements.

Config.	**Stack**	**Avg. Stack Height [cm]**	**Expected Height[a] [cm]**	**# of Units**	**Gap/Unit[b] [cm]**
$3/16$	Top	6.40325 ± 0.00952	6.31881	5	0.01689
	Bottom	9.52675 ± 0.00377	9.36796	6	0.02647
	Bottom (without Al)	7.23675 ± 0.00750	7.08069	6	0.02601
$5/16$	Top	10.71520 ± 0.00426	10.60441	6	0.01847
	Bottom	10.81500 ± 0.00474	10.58739	6	0.03794
$7/16$	Top	17.11200 ± 0.01125	16.98201	7	0.01857
	Bottom	16.51250 ± 0.00698	16.31246	7	0.02858

(a) The expected stack height is the sum of individual parts based off measurements in Table **??**
(b) Calculated using the following equation: $\frac{Avg.StackHeight - ExpectedHeight}{\#ofunits}$

In all configurations, the stack height is greater than the expected height which implies that there are gaps within each stack. Therefore, gaps are included in the benchmark model below each layer of HEU, which are the values reported in Table 81 as the Gap/Unit. However, for some configurations including the calculated gaps in Table 81 in the benchmark model are too large for the space available (i.e., the top stack was taller than the corner reflectors). The experimenters ensured that the corner reflectors were taller than the top stack in order to prevent an increased weight on the fuel. In the circumstance where the measured stack heights cannot be used for the gap, the maximum space available was used has the difference between the average stack height and the expected stack height. In the cases where the maximum space available is used for the gap, only a one-sided uncertainty can be performed (i.e., reducing the size of the gaps). The uncertainty used for these gaps is the standard deviation of the average stack height measurements, which is used to calculate a new gaps/unit value. The benchmark model assumes each component, including gaps, is flat (i.e., not deformed).

The uncertainties from Table 82 are reported in Section 2.8.

Table 82. Determination of the Gap/Unit Based of Stack Height Measurements.

Config.	Stack	Gap Used [cm]	$\Delta k_{eff} \pm 1\sigma_{MC}$	1σ Uncertainty [cm]	Final u_k
3/16	Top	−0.00623		−0.00623	
	Bottom	± 0.00377		± 0.00377	
5/16	Top	± 0.00426		± 0.00426	
	Bottom	± 0.00474		± 0.00474	
7/16	Top	± 0.01125		± 0.01125	
	Bottom	± 0.00698		± 0.00698	

In addition to the gaps described in Table 81, there are additional gaps due to nested components having different heights. However, the uncertainty of the gaps due to nested components having different heights is assumed to be bounded by the dimension perturbations in Section 2.3.

2.6 Temperature Uncertainties

Ambient room and RTD temperatures recorded during the benchmark experiments are reported in Table 25 (Section 1.4). The actual operating temperature of the assembly is uncertain; therefore, the minimum temperature observed is assigned to each configuration. The uncertainty is assumed to be ±5°C. The effect of this uncertainty on the nuclear data was estimated by running calculations at 250 K (23.154°C). The temperature was changed by using nuclear data at 250 K (2.1543E-08 MeV) and by changing the free-gas thermal temperature of each cell to -23°C (2.1543E-08 MeV) using the TMP card. Results are shown in Table 83.

Thermal expansion and contraction of parts must also be considered. The linear thermal expansion coefficients (αT) for the materials in this experiment are shown in Table 84. The coefficient for 304 stainless steel was used because it is the largest of the steels. Where there is a range, the analysis used the midpoint. The change Δx in dimension x because of a change in temperature ΔT is

$$\Delta x = \Delta T \alpha_T x_o \tag{16}$$

where x_o is the initial dimension.

Direct perturbations were done for temperature changes of ±10°C about 20°C. Radial interface locations between nested HEU rings were not perturbed, but every other linear dimension was perturbed using Equation 16. Densities were perturbed to preserve part masses. Results are shown in Table 85.

Table 83. u_k and Uncertainty as a Result of Temperature Effect on Cross Sections.

Config.	T_{min} [°C]	Deviation Used [°C]	$\Delta k_{eff} \pm 1\sigma_{MC}$ [cm]	1σ Uncertainty [°C]	Final u_k
3/16	14.2	-37.4	0.000XX ± 0.00003	±5	
5/16	14.5	-37.7	0.000XX ± 0.00003	±5	
7/16	13.8	-37.0	0.000XX ± 0.00003	±5	

Table 84. Linear Thermal Expansion Coefficients, αT.[(a)]

Material	α_T [× 10^{-6} cm/(cm · K)]
Uranium	13.4
Copper	16 - 16.7
Aluminum	21 - 24
Steel 304	17.3

(a) Thermal Expansion - Linear Expansion Coefficients. (n.d.). Retrieved February 27, 2024, from https://www.engineeringtoolbox.com/linear-expansion-coefficients-d_95.html

Table 85. u_k and Uncertainty as a Result of Thermal Expansion and Contraction.

Config.	Deviation Used [°C]	$\Delta k_{eff} \pm 1\sigma_{MC}$ [cm]	1σ Uncertainty [°C]	Final u_k
$^3/_{16}$	$\pm$10	0.000XX $\pm$ 0.00003	$\pm$5	
$^5/_{16}$	$\pm$10	0.000XX $\pm$ 0.00003	$\pm$5	
$^7/_{16}$	$\pm$10	0.000XX $\pm$ 0.00003	$\pm$5	

2.7 Facility Bias

The components evaluated in this section are not included in the benchmark models in Section 3. The uncertainties derived in this section are applied to the simplification effects (see Section 3.1.1).

2.7.1 Concrete Walls, Floor, and Ceiling

Dimensions of the room are given in Section 1.2.7. The model of the room is shown in Figure 30; note that the opening to the room is not modeled. The floor, ceiling, and walls were modeled as Portland concrete very similar to that used in FUND-NCERC-PU-HE3-MULT-001 (BERP/Ni), FUND-NCERC-PU-HE3-MULT-002 (BERP/W), FUND-NCERC-PU-HE3-MULT-003 (SCRaP), HEU-MET-INTER-011, and HEU-MET-FAST-102. The composition for Portland concrete is given in Table 86; its density is 2.3 g/cm3. The difference in k_{eff} between the model with the floor, ceiling, and walls and the model without is shown in Table 87.

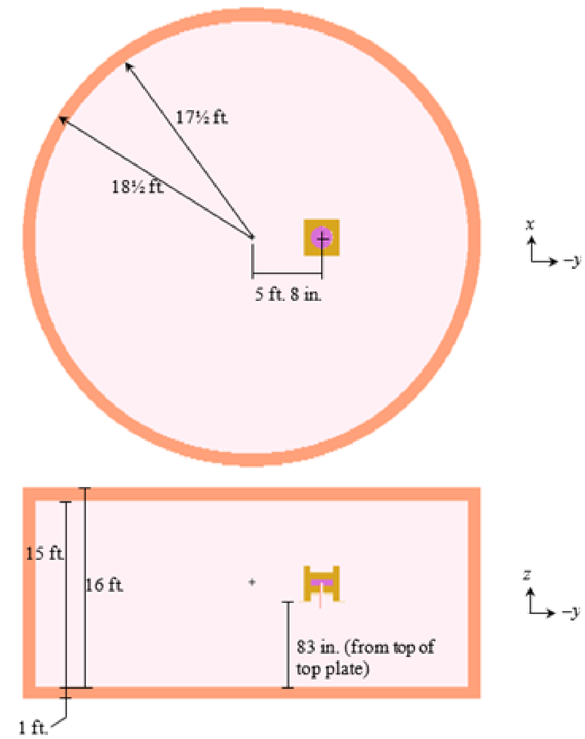

Figure 30. Room Model. The opening to the room would be in the +x direction (at the top of the top figure), but it was not modeled. Figure is from HEU-MET-INTER-011.

Table 86. Composition of Portland Concrete.[a]

Element	Composition (mass fraction)
H	0.010000
C	0.001000
O	0.529107
Na	0.016000
Mg	0.002000
Al	0.033872
Si	0.337021
K	0.013000
Ca	0.044000
Fe	0.014000

(a) Data Mining Analysis and Modeling Cell. "Compendium of Material Composition Data for Radiation Transport Modeling," Material #108, Pacific Northwest National Laboratory report PNNL-15870, Rev. 2, 200-DMAMC-128170, April 2021; https://doi.org/10.2172/1782721.

Table 87. Δ k_{eff} as a Result of the Floor, Ceiling, and Walls.

Config.	$\Delta k_{eff} \pm 1\sigma_{MC}$
3/16	0.000XX $\pm$ 0.00003
5/16	0.000XX $\pm$ 0.00003
7/16	0.000XX $\pm$ 0.00003

The adjoint-based sensitivity of k_{eff} to the concrete density is shown in Table 88. An uncertainty of $\pm$10% in the concrete density was assumed. Table 88 indicates that the Δk_{eff}'s of Table 87 are insensitive to modeling approximations associated with the density of the concrete.

Table 88. u_k and Associated Uncertainty for the Density of Concrete.

Config.	Relative Uncertainty [u_T/Density][%]	$S_{k,x_i} \pm 1\sigma_{MC}$ [%/%]	Final u_k
3/16	$\pm$ 10	X $\pm$ X %	
5/16	$\pm$ 10	X $\pm$ X %	
7/16	$\pm$ 10	X $\pm$ X %	

The adjoint-based sensitivity of keff to the concrete composition is shown in Table 89 for all non-negligible values. Since full normalization was used, the sensitivity is performed by isotope rather than element. An uncertainty of $\pm$10% for each isotope of the concrete composition was assumed. Table 89 indicates that the Δk_{eff}'s of Table 87 have a minimal impact to the modeling approximations associated with the composition of the concrete.

Table 89. u_k and Associated Uncertainty for the Composition of Concrete.

Config.	ZAID	Relative Uncertainty [u_T/%][%]	$S_{k,x_i} \pm 1\sigma_{MC}$ [%/%]	Final u_k
3/16		$\pm$ 10	X $\pm$ X %	
5/16		$\pm$ 10	X $\pm$ X %	
7/16		$\pm$ 10	X $\pm$ X %	

2.7.2 Startup Detectors

Each of the four startup detectors was modeled as a right circular cylinder 4 in. in diameter and 12 in. in length composed of pure polyethylene. The material composition is given in Table 16 (the isotopic values do not sum exactly to the elemental values given in the Pacific Northwest National Laboratory (PNNL) Materials Compendium because of rounding); its density is 0.93 g/cm^3. The S(α,β) table for hydrogen (H) in polyethylene was applied. The detectors were oriented vertically - i.e., their axes were parallel to the Comet z axis. All four detectors were located 36 in. from the Cu side reflectors toward the wall opposite of the entrance. The locations of each detector are shown in Figure **??**.

The difference in k_{eff} between the model with the startup detectors and the model without is shown in Table 91. Both sets of models included the floor, ceiling, and walls. Based on these results, the bias associated with neglecting the startup detectors is negligible, and the uncertainty of that bias can be approximated as negligible also. Therefore, no further simulations include the startup detectors.

Table 90. Composition of Polyethylene.[a]

Nuclide	Atom Density [1/(b·cm)]
H-1	7.9845E-02
H-2	1.1979E-05
C-12	3.9489E-02
C-13	4.3921E-04
Total	1.1979E-01

(a) Data Mining Analysis and Modeling Cell. "Compendium of Material Composition Data for Radiation Transport Modeling," Material #275, Pacific Northwest National Laboratory report PNNL-15870, Rev. 2, 200-DMAMC-128170, April 2021; https://doi.org/10.2172/1782721.

Table 91. Δ k_{eff} as a Result of Startup Detectors.

Config.	$\Delta k_{eff} \pm 1\sigma_{MC}$
3/16	0.000XX $\pm$ 0.00003
5/16	0.000XX $\pm$ 0.00003
7/16	0.000XX $\pm$ 0.00003

2.7.3 Godiva-IV

Godiva-IV was modeled very simply as an outer cylindrical annulus representing the six rings, two control rods, and burst rod and an inner cylindrical annulus representing the upper sub-assembly. The Godiva-IV model is shown in Figure 31. Its location in the room is shown in Figure 32. Its centerline is 6 ft above the floor. The material composition, a mass-weighted average of the number densities given in HEU-MET-FAST-086, Table 35 (masses are given in HEU-MET-FAST-086, Table 7), is given in Table 92. Its mass density is 18.22565 g/cm^3.

Calculations that include Godiva-IV are tricky because of the large separation between two fissile masses. The Shannon entropy test for eigenfunction convergence was checked. The initial neutron source distribution covered Godiva and the assembly on Comet. Godiva-IV had both control rods inserted even though this would not occur because only one machine can be operated at a time.

The difference in k_{eff} between the model with Godiva-IV and the model without is shown in Table 93. Both sets of models included the floor, ceiling, and walls. Based on these results, the bias associated with neglecting Godiva-IV is negligible for all configurations. Therefore, Godiva-IV is not included in any future models.

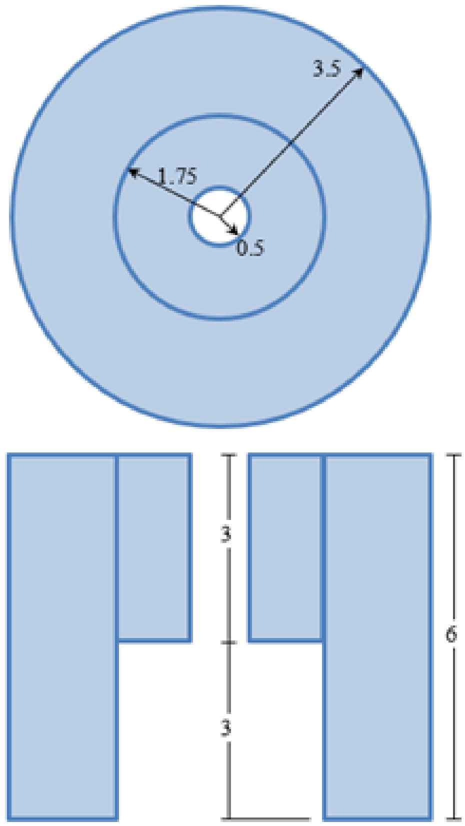

Figure 31. Simple Godiva-IV Model (Dimensions in Inches). Figure is from HEU-MET-INTER-011.

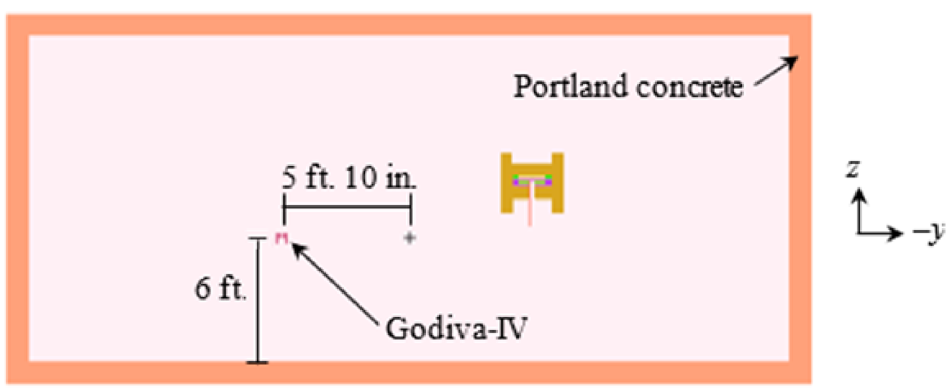

Figure 32. Location of Godiva-IV in the Room. Figure is from HEU-MET-INTER-011. Godiva-IV is modeled as a cylinder with a height of 6 in. and a radius of 3.5 in. with 6 ft being the distance between the floor and centerline of Godiva-IV.

Table 92. Composition of Godiva-IV.

Nuclide	Atom Density [1/(b·cm)]
Mo-92	2.5225E-04
Mo-94	1.5723E-04
Mo-95	2.7060E-04
Mo-96	2.8352E-04
Mo-97	1.6233E-04
Mo-98	4.1016E-04
Mo-100	1.6369E-04
U-233	4.6398E-06
U-234	4.7073E-04
U-235	4.2852E-02
U-236	3.1149E-04
U-238	2.3345E-03
Total	4.7673E-02

Table 93. Δ k_{eff} as a Result of Godiva-IV.

Config.	$\mathbf{\Delta k_{eff} \pm 1\sigma_{MC}}$
$^3/_{16}$	0.000XX $\pm$ 0.00003
$^5/_{16}$	0.000XX $\pm$ 0.00003
$^7/_{16}$	0.000XX $\pm$ 0.00003

2.7.4 Air

So far, all the models have replaced the air that would be present with a void, and this section will evaluate that simplification. The composition of the atmosphere in the DAF is unknown. It was estimated from a standard[a] for United States (U.S.) air. The DAF is at an elevation of 3750 ft above sea level, corresponding to an atmospheric pressure[b] of 883.285 mb. Applying the ideal gas law with Avogadro's number equal to 6.022169×10^{26} /kmol and the gas constant equal to[c] 8314.32 Nm/(kmol·K) and at a temperature of 293.249 K yields a density of 2.18168×10^{-5}/(b·cm). The assumed composition of dry air by volume is shown in Table 94. Multiplying the fractional volumes by the atom density yields the atom density of each species and multiplying these by the molecular weight and dividing by Avogadro's number yields the mass densities. The sum of the mass densities is the density of dry air, 1.0493×10^{-3} g/cm^3. Relative humidity of 15% was subsequently added using a saturation vapor density (at 20°C) of[d] 17.25551 g/m^3; 15% of this is 2.588×10^{-6} g/cm^3 of water, which was added to the gases of Table 94. The resulting composition of air is given in Table 95 with a density is 0.001052 g/cm^3.

[a] "U.S. Standard Atmosphere, 1976," National Oceanic and Atmospheric Administration report NOAA–S/T 76 1562, October 1976.
[b] Ibid., Table IV.
[c] Ibid., Table 2, but note the typo in the value of R*: The exponent should be +3 as in the text on p. 3.
[d] "Relative Humidity Calculation," http://hyperphysics.phy-astr.gsu.edu/hbase/Kinetic/relhum.html.

Table 94. Molecular Weights and Assumed Fractional-Volume Composition of Sea-Level Dry Air.[a]

Gas Species	Molecular Weight [kg/kmol]	Fractional Volume	Atom Density [1/b·cm]	Mass Density [g/cm^3]
N_2	28.0134	0.78084	1.704E-05	7.9244E-04
O_2	31.9988	0.209476	4.570E-06	2.4283E-04
Ar	39.948	0.00934	2.038E-07	1.3517E-05
CO_2	44.009995	0.000314	6.850E-09	5.0063E-07
Ne	20.183	0.00001818	3.966E-10	1.3293E-08
He	4.0026	0.00000524	1.143E-10	7.5982E-10
Kr	83.8	0.00000114	2.487E-11	3.4609E-09
Xe	131.3	0.000000087	1.898E-12	4.1383E-10
CH_4	16.04303	0.000002	4.363E-11	1.1624E-09
H_2	2.01594	0.0000005	1.091E-11	3.6516E-11

(a) "U.S. Standard Atmosphere, 1976," National Oceanic and Atmospheric Administration report NOAA–S/T 76 1562, October 1976, Table 3.

Table 95. Composition of Air.

Element	Composition (mass fraction)
N	7.533E-01
O	2.334E-01
Ar	1.285E-02
C	1.307E-04
Ne	1.264E-05
He	7.223E-07
Kr	3.290E-06
Xe	3.934E-07
H	2.756E-04

Table 96. Δ k_{eff} as a Result of Including Air.

Config.	$\Delta k_{eff} \pm 1\sigma_{MC}$
$^3/_{16}$	0.000XX $\pm$ 0.00003
$^5/_{16}$	0.000XX $\pm$ 0.00003
$^7/_{16}$	0.000XX $\pm$ 0.00003

2.7.5 Crane

The crane model consists of a rail, a motor, and three identical junction boxes. The entire crane setup is modeled as a solid parallelepiped along a diameter that makes an angle of 52° with respect to the diameter containing the axes of Godiva-IV and Comet. The dimensions of the parallelepiped are based off the dimensions of the rail, which is an I-beam.

The dimensions of the crane I-beam were determined from a combination of scaling the drawing[a] and measuring or estimating dimensions in the building, including the 52° angle. Unfortunately, details of the crane, such as its dimensions, are proprietary, so they cannot be given in this evaluation.

The crane components were assumed to be made of steel A36 like the Comet framework. The composition of steel A36 is given in Table 97; its density is 7.8 g/cm^3. The iron content is slightly larger than the specification, so the composition would sum to 100 wt%.

The difference in k_{eff} between the model with the crane and the model without is shown in Table 98. Both sets of models included the floor, ceiling, and walls and air in the room. Based on these results, the bias associated with neglecting crane is negligible for all configurations. Therefore, the crane is not included in any future models.

Table 97. Composition of Steel A36.

Element	Specified Composition$^{(a)}$ (mass fraction)	Modeled Composition (mass fraction)
C	0.0025 - 0.0029	0.0027
Cu	0.0020	0.002
Fe	0.98	0.9816
Mn	0.0103	0.0103
P	$\leq$ 0.0004	0.0002667
Si	0.0028	0.0028
S	$\leq$ 0.0005	0.0003333

(a) MatWeb - The Online Materials Information Resource. (n.d.). “ASTM A36 Steel, plate.” Retrieved October 26, 2022, from http://www.matweb.com/search/datasheet.aspx?MatGUID=afc003f4fb40465fa3df05129f0e88e6

Table 98. Δ k_{eff} as a Result of the Crane.

Config.	$\mathbf{\Delta k_{eff} \pm 1\sigma_{MC}}$
$^3/_{16}$	0.000XX $\pm$ 0.00003
$^5/_{16}$	0.000XX $\pm$ 0.00003
$^7/_{16}$	0.000XX $\pm$ 0.00003

2.7.6 Comet Framework

The Comet framework model consists of the Comet top plate, the struts and pads below the Zeus top plate, the ram table, the platen table, the base plate, the bottom plate, the poles below the platen, the poles below the Comet top plate, and the poles that support the frame. The Comet top plate, which is steel, must not be conflated with the Zeus top plate, which is made of Al and is included in the benchmark models (Section 3.2.1.4). A three-dimensional rendering of the Comet framework model is shown in Figure 33.

Figure 34 is a two-dimensional schematic showing many of the part dimensions and locations. The Comet top plate, ram table and platen table, and base plate are shown in Figure 35, Figure 36, and Figure 37, respectively. The three poles

[a] “4 Ton Capacity Single Girder Polar Crane w/(2) 2 Ton X-SAM Underwing Hoists,” Ederer Incorporated drawing PA-1743 (March 22, 1990), incorporated into National Security Technologies LLC drawing PA-1743 (June 2, 2014).

below the top plate are centered in the outer holes shown in Figure 36, and the three poles below the platen are centered in the inner holes. Only the poles below the top plate extend through the platen table as shown in Figure 34. The heights of the ram table and platen table are estimated; they were not measured during the operations.

The struts and pads are shown in Figure 38 and Figure 39, respectively. The top surface of the pads is the bottom surface of the Zeus top plate, and the bottom surface of the pads is the top surface of the struts.

The four poles that support the frame are specified as 3-in. standard steel pipe.[a] This size pipe has an outer diameter of 3.500 in. and an inner diameter of 2.900 in. to 3.068 in.[b] The latter was used in the model. The outer diameter was verified by measuring the part on Comet. The length of the pipes in the model is 75.125 in. They are centered on the corners of a square with side length 42 in. in the x-y plane, symmetric with the assembly axis, so they do not appear in Figure 34. They are shown in Figure 40. The top surface of these poles is the bottom surface of the struts, and the bottom surface of the poles is the top surface of the bottom plate.

The bottom plate is a rectangle with side lengths 53 in. in the x direction and 60 in. in the y direction (using the same x-y orientation as in Figure 40). These dimensions were measured. Most of the Comet framework components are specified as steel A36. The composition of steel A36 is given in Table 97; its density is 7.8 g/cm^3. All the Comet framework components are modeled as steel A36.

The difference in k_{eff} between the model with the Comet framework and the model without is shown in Table 99. Both sets of models included the floor, ceiling, and walls.

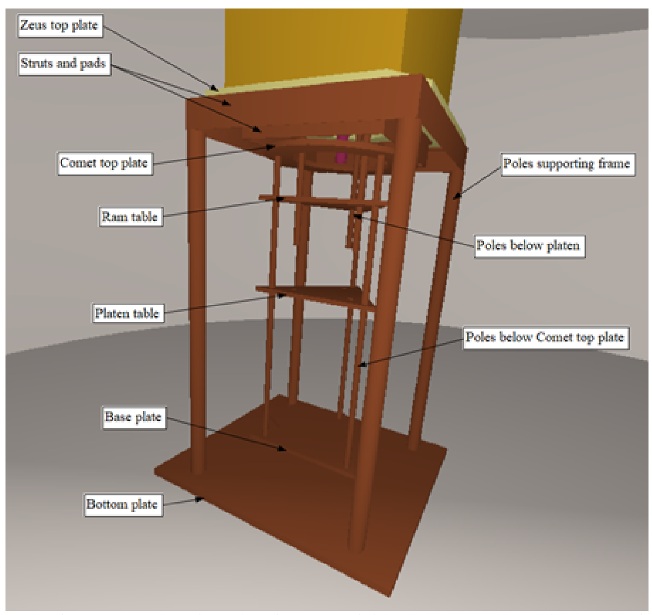

Figure 33. Assembly and Comet framework with the floor, ceiling, and walls. Figure is from HEU-MET-INTER-011.

[a]"Comet—Upgrade, Leg Support Column Detail," Los Alamos National Laboratory drawing 128Y1720120, March 16, 2009.
[b]Standard Pipe Dimensions. (2021, October 3). Archtoolbox. https://www.archtoolbox.com/standard-pipe-dimensions/

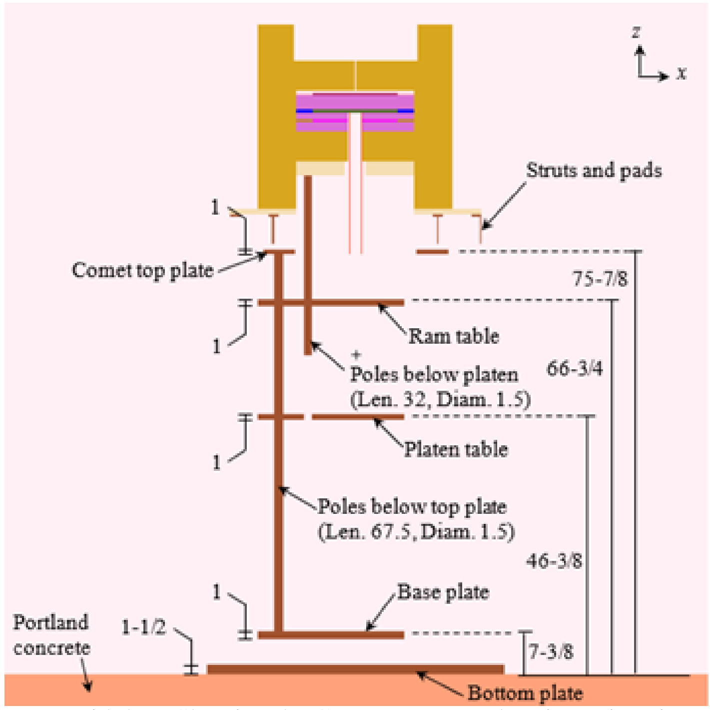

Figure 34. Slice Through the x-z Midplane Showing the Comet Framework (Dimensions in Inches). The 1 in.-thick plates do not look the same thickness in this rendering, but they are. Figure is from HEU-MET-INTER-011.

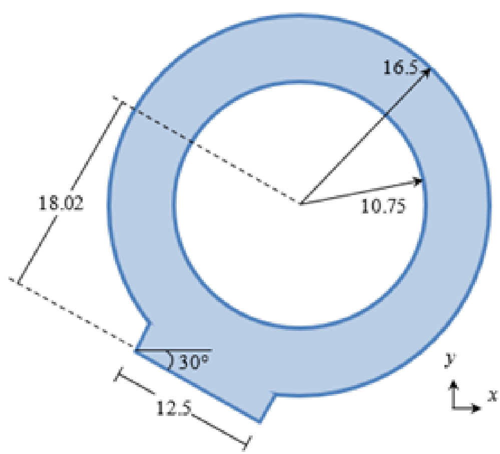

Figure 35. Comet Top Plate (Dimensions in Inches). Thickness is 1 in. (Figure 34). Figure is from HEU-MET-INTER-011.

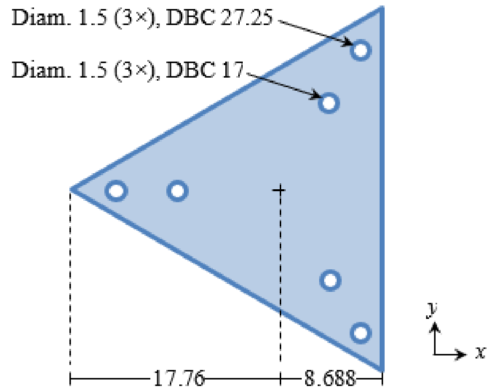

Figure 36. Ram Table and Platen Table: They Are Equilateral Triangles (Dimensions in Inches). Thicknesses are 1 in. (Figure 34). “DBC” is the diameter of the bolt circle. Figure is from HEU-MET-INTER-011.

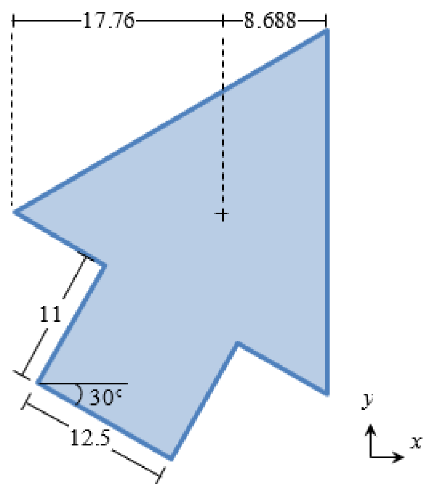

Figure 37. Base Plate: The Triangle Is Equilateral (Dimensions in Inches). Thickness is 1 in. (Figure 34). Figure is from HEU-MET-INTER-011.

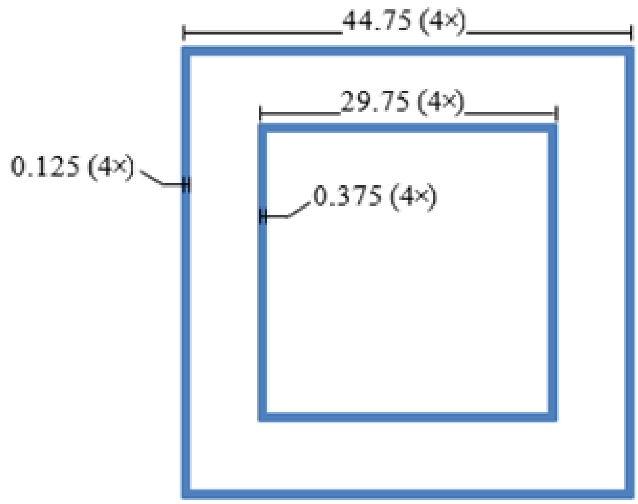

Figure 38. Struts (Dimensions in Inches). Height (z dimension) is 4.875 in. Figure is from HEU-MET-INTER-011.

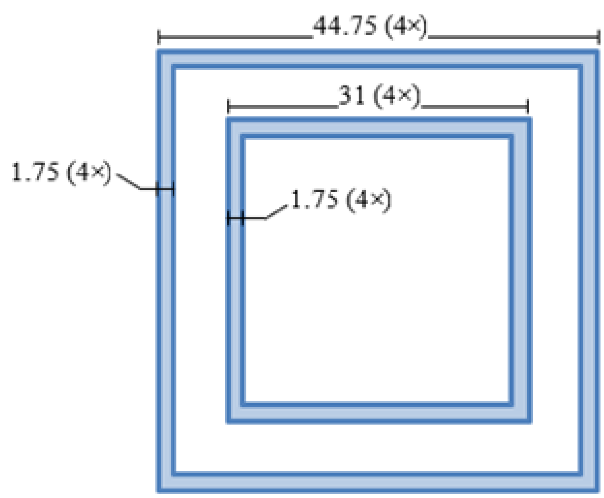

Figure 39. Pads (Dimensions in Inches). Height (z dimension) is 0.5 in. Figure is HEU-MET-INTER-011.

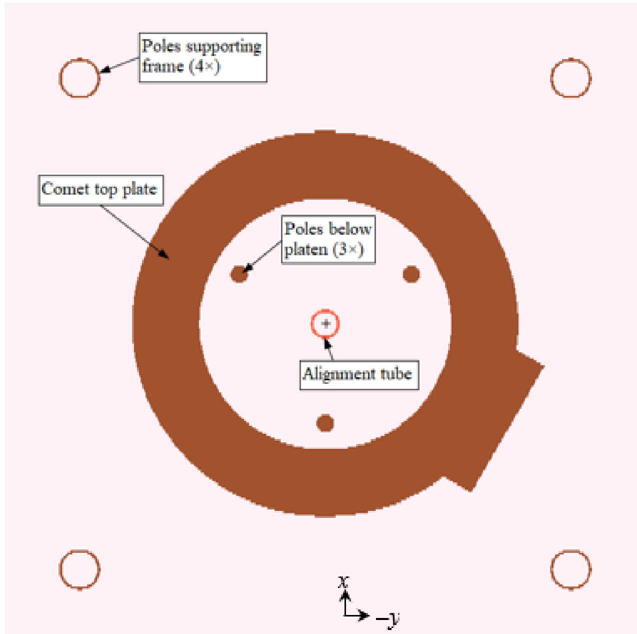

Figure 40. Plan View at z = –59 cm Showing Parts of the Frame. The rectangular protrusion of the base plate (Figure 37) has the same orientation as the rectangular protrusion of the top plate. The orientation of the ram table and platen table (Figure 36) can be determined by comparing the coordinate axes. The opening to the room would be in the +x direction. Figure is from HEU-MET-INTER-011.

Table 99. Δ k_{eff} as a Result of the Comet Framework.

Config.	$\Delta k_{eff} \pm 1\sigma_{MC}$
3/16	0.000XX ± 0.00003
5/16	0.000XX ± 0.00003
7/16	0.000XX ± 0.00003

2.8 Total Uncertainty

Table 100 summarizes the uncertainties evaluated in Sections 2.1 through 2.6, with 1σ relative uncertainties of the uncertainties and a total uncertainty. The asymmetric uncertainty bounds are approximated by combining the positives in quadrature separately from the negatives. Except for the uncertainty of the uncertainty of the criticality measurement, the uncertainties of the k_{eff} uncertainties are solely because of Monte Carlo statistics and are propagated from the sensitivity and Δk_{eff} uncertainties given in the preceding sections. The uncertainty of the uncertainty of the criticality measurement ($\pm 10\%$) is estimated.

Table 100. Summary of Uncertainties (with 1σ Relative Uncertainties of the Uncertainties).

Parameter	Section	Config.	k_{eff} Combined Standard Uncertainty
Criticality Measurement	2.1	$^{3}/_{16}$	$0.00XXX \pm 0.00003$
		$^{5}/_{16}$	$0.00XXX \pm 0.00003$
		$^{7}/_{16}$	$0.00XXX \pm 0.00003$
Mass of HEU Plates	2.2.1	$^{3}/_{16}$	$0.00XXX \pm 0.00003$
		$^{5}/_{16}$	$0.00XXX \pm 0.00003$
		$^{7}/_{16}$	$0.00XXX \pm 0.00003$
Mass of Interstitial Cu Plates	2.2.2.1	$^{3}/_{16}$	$0.00XXX \pm 0.00003$
		$^{5}/_{16}$	$0.00XXX \pm 0.00003$
		$^{7}/_{16}$	$0.00XXX \pm 0.00003$
Mass of Al Shims	2.2.2.2	$^{3}/_{16}$	$0.00XXX \pm 0.00003$
		$^{5}/_{16}$	—
		$^{7}/_{16}$	—
Mass of Al Adapter Plates	2.2.2.3	$^{3}/_{16}$	—
		$^{5}/_{16}$	—
		$^{7}/_{16}$	$0.00XXX \pm 0.00003$
Mass of Cu Reflectors	2.2.3	$^{3}/_{16}$	$0.00XXX \pm 0.00003$
		$^{5}/_{16}$	$0.00XXX \pm 0.00003$
		$^{7}/_{16}$	$0.00XXX \pm 0.00003$
Mass of Comet Hardware	2.2.4	$^{3}/_{16}$	$0.00XXX \pm 0.00003$
		$^{5}/_{16}$	$0.00XXX \pm 0.00003$
		$^{7}/_{16}$	$0.00XXX \pm 0.00003$
HEU Plate Dimensions, Negative Perturbation	2.3.1	$^{3}/_{16}$	$0.00XXX \pm 0.00003$
		$^{5}/_{16}$	$0.00XXX \pm 0.00003$
		$^{7}/_{16}$	$0.00XXX \pm 0.00003$
HEU Plate Dimensions, Positive Perturbation	2.3.1	$^{3}/_{16}$	$0.00XXX \pm 0.00003$
		$^{5}/_{16}$	$0.00XXX \pm 0.00003$
		$^{7}/_{16}$	$0.00XXX \pm 0.00003$
Interstitial Cu Plate Dimensions, Negative Perturbation	2.3.2.1	$^{3}/_{16}$	$0.00XXX \pm 0.00003$
		$^{5}/_{16}$	$0.00XXX \pm 0.00003$
		$^{7}/_{16}$	$0.00XXX \pm 0.00003$
Interstitial Cu Plate Dimensions, Positive Perturbation	2.3.2.1	$^{3}/_{16}$	$0.00XXX \pm 0.00003$
		$^{5}/_{16}$	$0.00XXX \pm 0.00003$
		$^{7}/_{16}$	$0.00XXX \pm 0.00003$
Al Shim Dimensions, Negative Perturbation	2.3.2.2	$^{3}/_{16}$	$0.00XXX \pm 0.00003$
		$^{5}/_{16}$	—
		$^{7}/_{16}$	—
Al Shim Dimensions, Positive Perturbation	2.3.2.2	$^{3}/_{16}$	$0.00XXX \pm 0.00003$
		$^{5}/_{16}$	—
		$^{7}/_{16}$	—
Al Adapter Dimensions, Negative Perturbation	2.3.2.3	$^{3}/_{16}$	—

Continued on next page

Table 100 – *Continued from previous page*

Parameter	Section	Config.	k_{eff} Combined Standard Uncertainty
		5/16	—
		7/16	0.00XXX ± 0.00003
Al Adapter Dimensions, Positive Perturbation	2.3.2.3	3/16	—
		5/16	—
		7/16	0.00XXX ± 0.00003
Cu Reflector Dimensions	2.3.3	3/16	0.00XXX ± 0.00003
		5/16	0.00XXX ± 0.00003
		7/16	0.00XXX ± 0.00003
Comet Hardware Dimension	2.3.4	3/16	0.00XXX ± 0.00003
		5/16	0.00XXX ± 0.00003
		7/16	0.00XXX ± 0.00003
HEU Plate Composition	2.4.1	3/16	0.00XXX ± 0.00003
		5/16	0.00XXX ± 0.00003
		7/16	0.00XXX ± 0.00003
Interstitial Cu Plate Composition	2.4.2.1	3/16	0.00XXX ± 0.00003
		5/16	0.00XXX ± 0.00003
		7/16	0.00XXX ± 0.00003
Al Shim Composition	2.4.2.2	3/16	0.00XXX ± 0.00003
		5/16	—
		7/16	—
Al Adapter Plate Composition	2.4.2.3	3/16	—
		5/16	—
		7/16	0.00XXX ± 0.00003
Cu Reflector Composition	2.4.3	3/16	0.00XXX ± 0.00003
		5/16	0.00XXX ± 0.00003
		7/16	0.00XXX ± 0.00003
Comet Hardware Composition	2.4.4	3/16	0.00XXX ± 0.00003
		5/16	0.00XXX ± 0.00003
		7/16	0.00XXX ± 0.00003
Axial Position of the Alignment Tube	2.5.1	3/16	0.00XXX ± 0.00003
		5/16	0.00XXX ± 0.00003
		7/16	0.00XXX ± 0.00003
Alignment of the Core	2.5.2	3/16	0.00XXX ± 0.00003
		5/16	0.00XXX ± 0.00003
		7/16	0.00XXX ± 0.00003
Gaps Within Cu Side Reflector	2.5.3	3/16	0.00XXX ± 0.00003
		5/16	0.00XXX ± 0.00003
		7/16	0.00XXX ± 0.00003
Gaps Within the Core	2.5.4	3/16	0.00XXX ± 0.00003
		5/16	0.00XXX ± 0.00003

Continued on next page

Table 100 – *Continued from previous page*

Parameter	**Section**	**Config.**	**k_{eff} Combined Standard Uncertainty**
		$^7/_{16}$	0.00XXX ± 0.00003
Temperature	2.6	$^3/_{16}$	0.00XXX ± 0.00003
		$^5/_{16}$	0.00XXX ± 0.00003
		$^7/_{16}$	0.00XXX ± 0.00003
Total		$^3/_{16}$	0.00XXX ± 0.00003
		$^5/_{16}$	0.00XXX ± 0.00003
		$^7/_{16}$	0.00XXX ± 0.00003

3.0 BENCHMARK SPECIFICATIONS

3.1 Description of Benchmark Models

3.1.1 Detailed Model

The benchmark models started as detailed models of the experiment configurations, excluding the screws and screw holes in the Cu reflectors. The screws are made of the same material as the Cu reflectors and fit tightly within the screw holes; therefore, the effect of this simplification is deemed negligible by engineering judgement. The density of the Cu reflectors was preserved for this simplification.

The environment, room, Comet framework, and equipment were not included in the detailed model. The simplification effect associated with neglecting the equipment in the room (e.g., carts, toolboxes, cables, etc.) is judged to be negligible. The simplification effect associated with neglecting additional components in the building and the critical assembly machine was evaluated by approximately modeling the components as described in Section 2.7.

The effect of including the room and components within the room is shown in Table 101. These are the same values given in Section 2.7. Table 101 shows that only the floor, ceiling, walls, XXX, and Comet framework are unambiguously important.

Table 101. Δk_{eff} for Additions to Base Model.

Addition	Config.	Δ **k$_{eff}$** $\pm$ **1**$\sigma_{MC}$$^{(a)}$
(A) Add Floor, Ceiling, and Walls to (B) Base Model	3/16	0.00XXX $\pm$ 0.00003
	5/16	0.00XXX $\pm$ 0.00003
	7/16	0.00XXX $\pm$ 0.00003
(A) Add Startup Detectors to (B) Model with Floor Ceiling, and Walls	3/16	0.00XXX $\pm$ 0.00003
	5/16	0.00XXX $\pm$ 0.00003
	7/16	0.00XXX $\pm$ 0.00003
(A) Add Godiva-IV to (B) Model with Floor Ceiling, and Walls	3/16	0.00XXX $\pm$ 0.00003
	5/16	0.00XXX $\pm$ 0.00003
	7/16	0.00XXX $\pm$ 0.00003
(A) Replace Voids with Air to (B) Model with Floor Ceiling, and Walls	3/16	0.00XXX $\pm$ 0.00003
	5/16	0.00XXX $\pm$ 0.00003
	7/16	0.00XXX $\pm$ 0.00003
(A) Add Crane to (B) Model with Floor Ceiling, and Walls	3/16	0.00XXX $\pm$ 0.00003
	5/16	0.00XXX $\pm$ 0.00003
	7/16	0.00XXX $\pm$ 0.00003
(A) Add Comet Framework to (B) Model with Floor Ceiling, and Walls	3/16	0.00XXX $\pm$ 0.00003
	5/16	0.00XXX $\pm$ 0.00003
	7/16	0.00XXX $\pm$ 0.00003

(a) Δk_{eff} = k_{eff} of A minus k_{eff} of B.

Based on the results shown in Table 101, the simplification bias of the detailed model was computed by including the floor, ceiling, walls, XXX, and Comet framework. Results are shown in Table 102. Each uncertainty includes the Monte Carlo uncertainty of Δkeff (±0.00003).

Table 102. Simplification Bias of Experiment to Detailed Model.

Addition	Config.	Δ $\mathbf{k_{eff}} \pm 1\sigma_{MC}{}^{(a)}$	Bias
Remove Floor, Ceiling, Walls, XXX, and Comet Framework	3/16	0.00XXX ± 0.00003	0.00XXX ± 0.000XX
	5/16	0.00XXX ± 0.00003	0.00XXX ± 0.000XX
	7/16	0.00XXX ± 0.00003	0.00XXX ± 0.000XX

(a) Δk_{eff} = k_{eff} of base model minus k_{eff} of model with added components.

There is also a bias as a result of temperature because the operating temperature was lower than the benchmark temperature. For this purpose, the operating temperature is assumed to be the minimum temperatures for each configuration listed in Table 25 (the minimum was also used to compute uncertainties in Section 2.6). The benchmark temperature is 20°C. The bias as a result of the temperature effect on cross sections is calculated in Table 103, and the bias as a result of thermal contraction is calculated in Table 104. Uncertainties of ±100% are estimated for these biases.

Table 103. Bias as a Result of Temperature Effect on Cross Section

Config.	T (°C)	Slope (/°C)	ΔT (°C)	Bias$^{(a)}$
3/16	14.2	(X.XXXXX ± 0.00003) / (-XX.X)	-X.X	X.XXXXX ± X.XXXXX
5/16	14.5	(X.XXXXX ± 0.00003) / (-XX.X)	-X.X	X.XXXXX ± X.XXXXX
7/16	13.8	(X.XXXXX ± 0.00003) / (-XX.X)	-X.X	X.XXXXX ± X.XXXXX

(a) Bias = -Slope × ΔT. The uncertainty is estimated from the Monte Carlo uncertainty and the temperature measurement uncertainty

Table 104. Bias as a Result of Thermal Contraction

Config.	T (°C)	Slope (/°C)	ΔT (°C)	Bias$^{(a)}$
3/16	14.2	(X.XXXXX ± 0.00003) / (-XX.X)	-X.X	X.XXXXX ± X.XXXXX
5/16	14.5	(X.XXXXX ± 0.00003) / (-XX.X)	-X.X	X.XXXXX ± X.XXXXX
7/16	13.8	(X.XXXXX ± 0.00003) / (-XX.X)	-X.X	X.XXXXX ± X.XXXXX

(a) Bias = -Slope × ΔT. The uncertainty is estimated from the Monte Carlo uncertainty and the temperature measurement uncertainty

The total bias, which is the sum in quadrature of the entries in Table 102, Table 103, and Table 104, is given in Table 105. This bias is applied to the inferred experimental k_{eff} in Section 3.5.

Table 105. Total Bias

Config.	Bias
3/16	X.XXXXX ± X.XXXXX
5/16	X.XXXXX ± X.XXXXX
7/16	X.XXXXX ± X.XXXXX

3.1.2 Simplified Model

The simplified model has X main differences from the detailed model: (1) .... The simplifications and their effect is shown in Table 106.

Potential simplifications: removing Comet hardware (e.g. alignment tube, platen, PAP, top plate), same core diameters, removing impurities, smearing outer Cu reflectors, etc.)

The bias was calculated as the k_{eff} of the model with the simplification minus the k_{eff} of the base case, which is the detailed model. Also shown in Table 106 is the k_{eff} of the model with the simplification minus the k_{eff} of the model with all the preceding simplifications.) The final simplification bias is shown in Table 106.

Table 106. Cumulative Simplification Bias for Detailed to Simplified Model

Simplification	**Config.**	Δ $\mathbf{k_{eff}} \pm \mathbf{1}\sigma_{MC}$ (Difference from Preceding Simplification)	Δ $\mathbf{k_{eff}} \pm \mathbf{1}\sigma_{MC}$ (Difference from Detailed Model for Combined Simplifications)
Removing $^{(a)}$	$^{3}/_{16}$	0.00XXX $\pm$ 0.00003	0.00XXX $\pm$ 0.00003
	$^{5}/_{16}$	0.00XXX $\pm$ 0.00003	0.00XXX $\pm$ 0.00003
	$^{7}/_{16}$	0.00XXX $\pm$ 0.00003	0.00XXX $\pm$ 0.00003
Removing	$^{3}/_{16}$	0.00XXX $\pm$ 0.00003	0.00XXX $\pm$ 0.00003
	$^{5}/_{16}$	0.00XXX $\pm$ 0.00003	0.00XXX $\pm$ 0.00003
	$^{7}/_{16}$	0.00XXX $\pm$ 0.00003	0.00XXX $\pm$ 0.00003

(a) ??

3.2 Dimensions

3.2.1 Detailed Model

The benchmark model uses metric units for all dimensions; however, some of the measurements and the engineering drawings use imperial units. All digits of the conversion and averaging are preserved even though the actual measurements are not that precise. Every plate within the core has an individual height that does not always match the other plates in that layer; therefore, gaps exist within the core (see Figure 41). The gaps associated with the small differences in the component heights are included in all the benchmark models. The stack height measurements (see Table 2) are larger than the sum of the measurements of individual parts, which means additional gaps exist in the core. These gaps are distributed evenly throughout its representative stack. Section 2.5.4 discusses how the uncertainty associated with gaps and the gap size was determined.

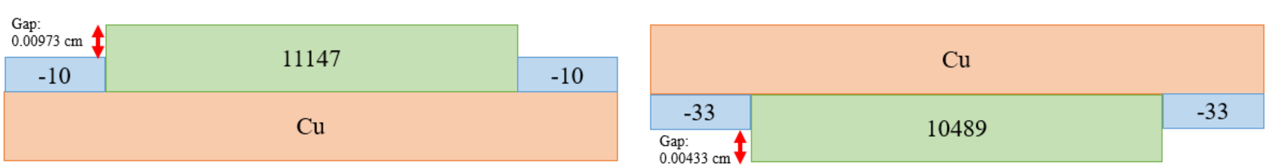

Figure 41. Example of Gaps Within the Core Due to Nested Components Having Different Heights. The image on the left is from the lowest unit in the upper core (U1), which exists in all configurations. The image on the right is from the highest unit in the lower core, which has the same HEU components in all configurations. These images is not to scale.

The upper core was modeled from the diaphragm up, so the gaps due to differing component heights are located above its respective plate in the benchmark model. However, the lower core was modeled from the diaphragm down, so gaps due to differing component heights are located below its respective plate in the benchmark model. Although this does not match reality, it was determined that this would not significantly affect k_{eff} because the overall spacing between HEU plates is conserved.

Measured dimensions were used in the benchmark models for the HEU, Cu interstitial, and Al shim heights. All remaining dimensions were taken from the engineering drawings. The benchmark models adjust the drawing dimensions such that the positive and negative tolerances are equal, which removes many of the asymmetric tolerances, so two-sided perturbations can be performed for the uncertainty analysis.

Similar components were used for all three configurations; however, they are placed in different orders and locations. The components used in the benchmark model are described in Section 3.2.1.1 through Section 3.2.1.4, while their location in each configuration is described in Section 3.2.1.5 through Section 3.2.1.7.

3.2.1.1 Upper Core Layers

The upper core is different for each configuration; however, similar components are used. Figure 42 show the Cu interstitial layers that exist in the upper core (radial dimension are the same, the only difference is the height). Figure 43 and Figure 44 show the two types of HEU layers that are present in the upper core for every configuration. The third type of HEU layer is shown in Figure 45, which is only present in the $^{7}/_{16}$ configuration.

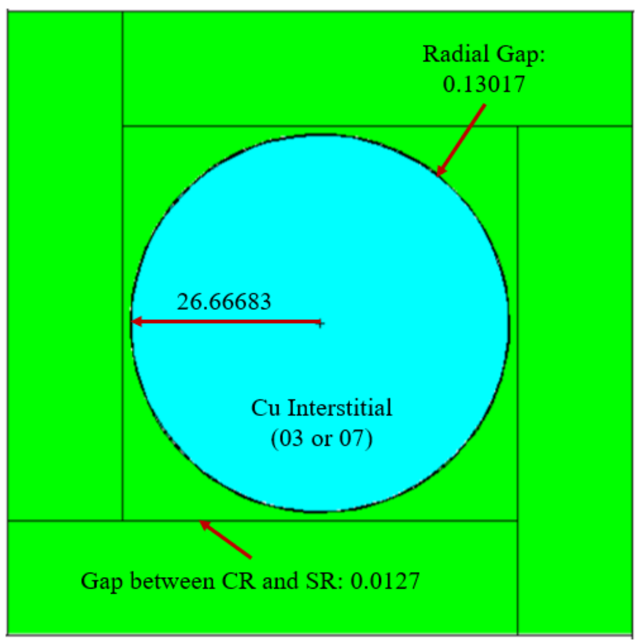

Figure 42. x-y View of the Cu Interstitial Layers (03 and 07) in the Upper Core. The radial gap between the Cu interstitial layers and the corner reflectors is the same for all Cu interstitial layers. The components in green are the side and corner reflectors. The gap between the corner reflectors and side reflectors is the same for all layers. All dimensions are in centimeters.

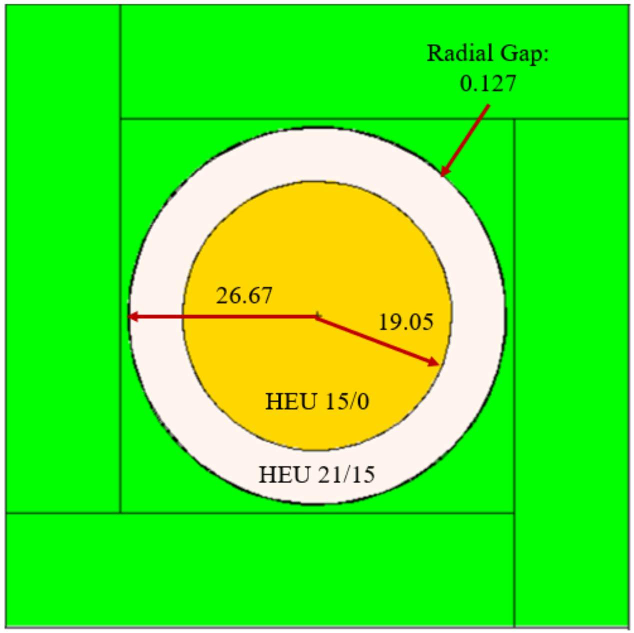

Figure 43. x-y View of One Type HEU Layer Present in the Upper Core for All Configurations. The radial gap between the HEU layers and the corner reflectors is the same for all HEU layers. The components in green are the side and corner reflectors. All dimensions are in centimeters.

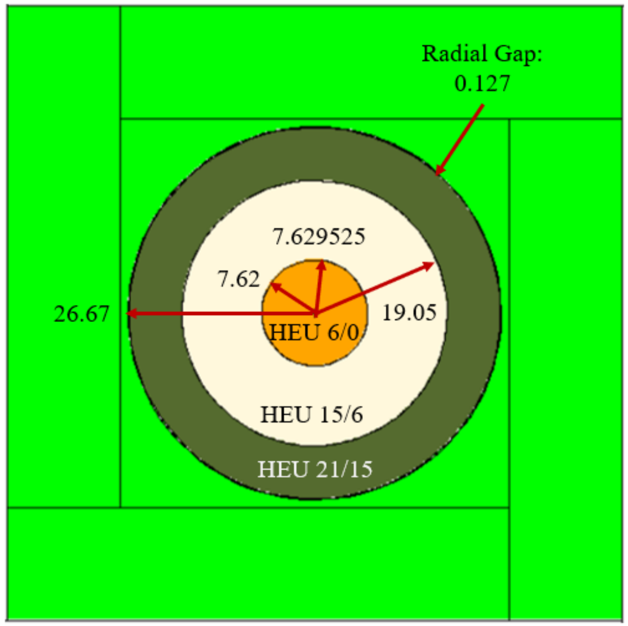

Figure 44. x-y View of One Type HEU Layer Present in the Upper Core for All Configurations. The radial gap between the HEU layers and the corner reflectors is the same for all HEU layers. The components in light green are the side and corner reflectors. All dimensions are in centimeters.

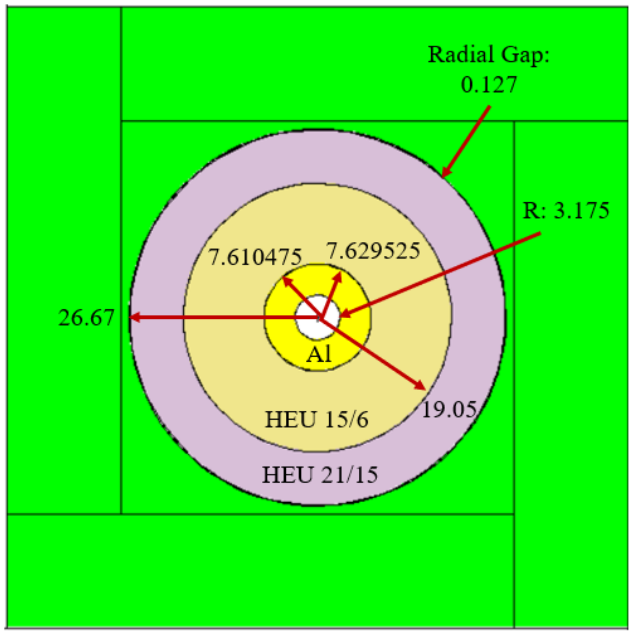

Figure 45. x-y View of HEU Layer Present in the Uppermost Unit of the 7/16 Configuration. The radial gap between the HEU layers and the corner reflectors is the same for all HEU layers. The central region of this layer is a void. The components in green are the side and corner reflectors. All dimensions are in centimeters.

3.2.1.2 Lower Core Layers

The lower core is different for each configuration; however, similar components are used. In addition, Comet hardware components are included in the lower core (i.e., the aluminum alignment tube) and are described in Section 3.2.1.4. Figure 46 shows the Cu interstitial layers that exist in the lower core (radial dimension are the same, the only difference is the height). There is only one type of HEU layer for all configurations in the lower core, which is shown in Figure 47. Two Al shims were used in the 3/16 configuration, which are shown in Figure 48. The radial dimensions are the same for both Al shims.

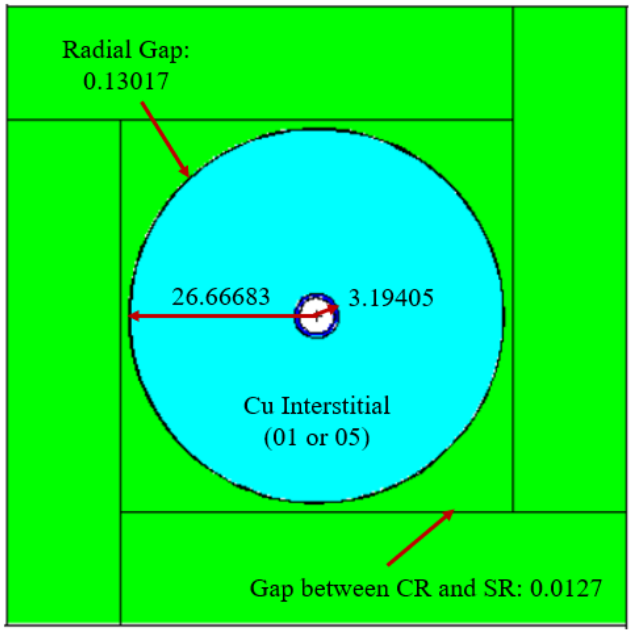

Figure 46. x-y View of the Cu Interstitial Layers (01 or 05) in the Lower Core. The radial gap between the Cu interstitial layers and the corner reflectors is the same for all Cu interstitial layers. The gap between the corner reflectors and side reflectors is the same for all layers. The components in green are the side and corner reflectors. Dimensions for the Al alignment tube can be found in Figure 57. All dimensions are in centimeters.

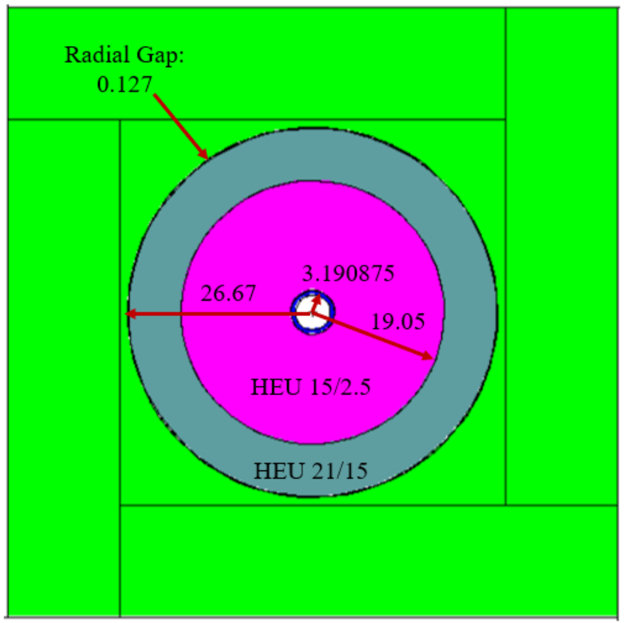

Figure 47. x-y View of the HEU Layer Present in the Lower Core for All Configurations. The radial gap between the HEU layers and the corner reflectors is the same for all HEU layers. The components in green are the side and corner reflectors. Dimensions for the Al alignment tube can be found in Figure 57. All dimensions are in centimeters.

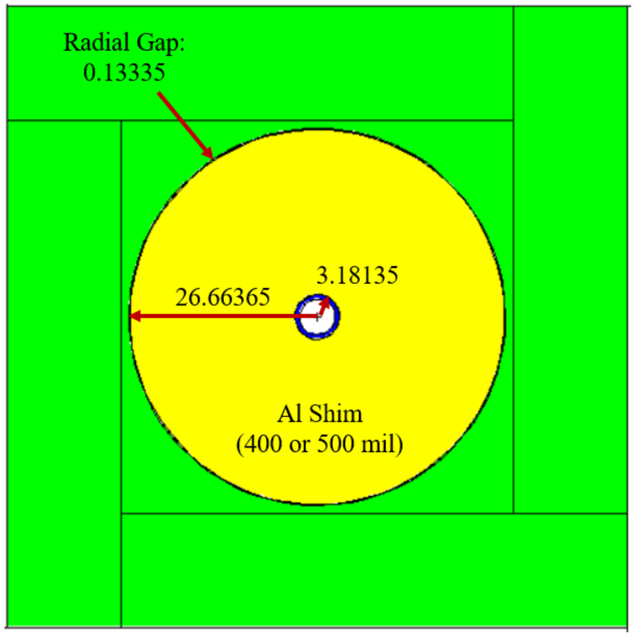

Figure 48. x-y View of Al Shims Present in the Lower Core of the 3/16 configuration. The radial gap between the Al shim layers and the corner reflectors is the same for both Al shim layers. The components in green are the side and corner reflectors. Dimensions for the Al alignment tube can be found in Figure 57. All dimensions are in centimeters.

3.2.1.3 Cu Reflector Components

All the components listed in this section are used in all three configurations; however, the number in each configuration varies. Regarding the corner reflectors, the type of corner reflector also varies but the only difference between parts is the height.

The corner reflectors (Figure 49) are stacked to surround the lower core (when inserted) and upper core. The radius of the corner reflector is larger than the outer radius of the core, creating a gap between the core and the inside surface of the corner reflector. In the benchmark model, the edge surfaces of the corner reflectors are assumed to fit tightly, with no gaps between separate corner reflectors. Dimensions from engineering drawings are used for each corner reflector layer of the benchmark model. The numbers used to identify the corner reflectors correspond to their height, which is why some corner reflector numbers appear more than once in the assembly. The inner radius of the corner reflector pieces describes the surface that borders the core.

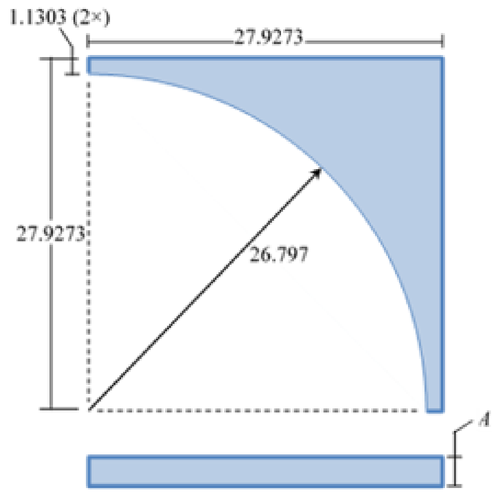

Figure 49. Description of the Corner Reflectors Used in the Detailed Model. Dimension A is the height and the values are included in Tables 110, 114, and 118 along with their location in the assembly. Dimensions are in centimeters. Figure is from HEU-MET-INTER-011.

The side reflectors surround the corner reflectors and are stacked in such a way as to minimize streaming paths that could cause neutrons to leak from the system (see Figure 50). The exact location of every side reflector is not known, so dimensions from engineering drawings are used in the benchmark model (see Figure 51). In the benchmark model, the side reflectors are assumed to fit tightly, with no gaps between separate side reflectors. However, the model does have separate side reflector pieces and the tolerances were investigated in Section 2.5.3. For the side reflectors to make a perfect square, a gap between the corner reflectors and the side reflectors is created.

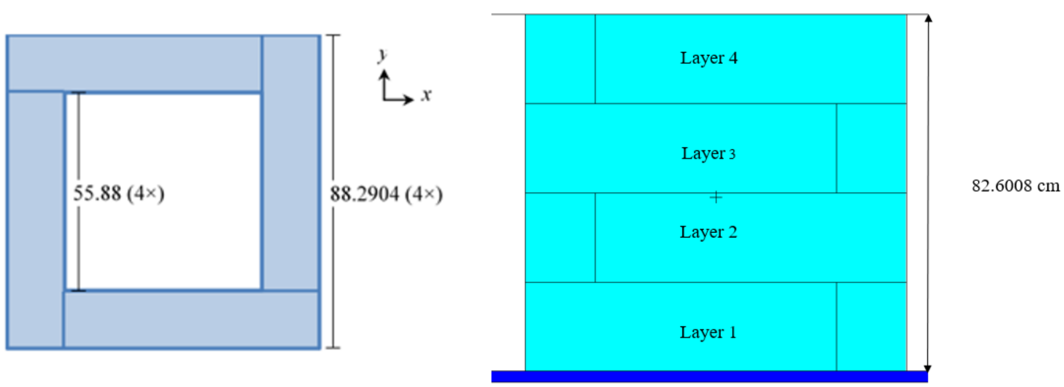

Figure 50. Description of the Side Reflector Configuration for the Detailed Model. Right image shows four side reflector layers, which is only applicable for the 7/16 configuration. Dimensions are in centimeters. Figure is from HEU-MET-INTER-011.

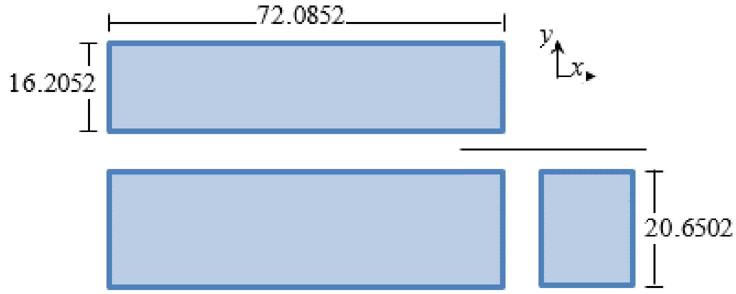

Figure 51. Description of the Side Reflector Dimensions for the Detailed Model. Dimensions are in centimeters. Figure is from HEU-MET-INTER-011.

The top reflector is placed on top of the uppermost corner reflector layer. There is a small through hole in the top reflector and the taps shown in the engineering drawing (Figure 21 were plugged with Cu pieces. Therefore the benchmark model does not include the taps (see Figure 52).

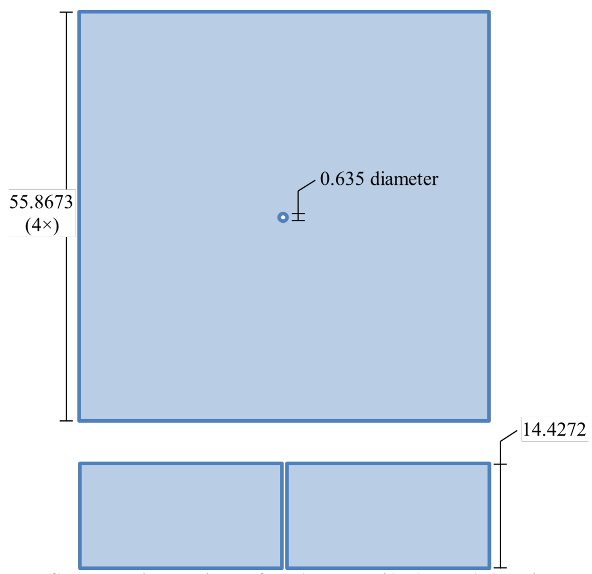

Figure 52. Description of the Top Reflector Dimensions for the Detailed Model. Dimensions are in centimeters. Figure is from HEU-MET-INTER-011.

The bottom reflector is above the platen and platen adapter plate, and all are below the lower core. There is a central through hole that is filled with the aluminum alignment tube. The benchmark model of the bottom reflector is shown in Figure 53.

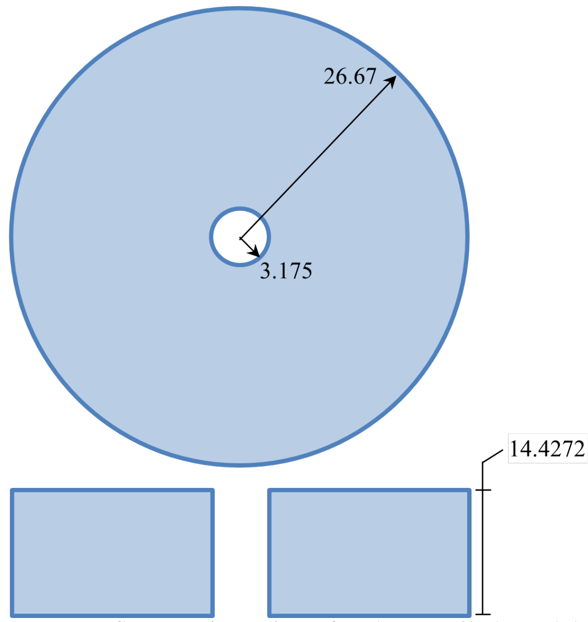

Figure 53. Description of the Bottom Reflector Dimensions for the Detailed Model. Dimensions are in centimeters. Figure is from HEU-MET-INTER-011.

3.2.1.4 Comet Hardware

All the components mentioned in this section are used in all three configurations.

The diaphragm (see Figure 54) is attached to a corner reflector layer in the stack. Because of differences in the tolerances, the diaphragm outer dimensions are slightly larger than the corner reflectors, creating another gap, which is between the corner and side reflectors.

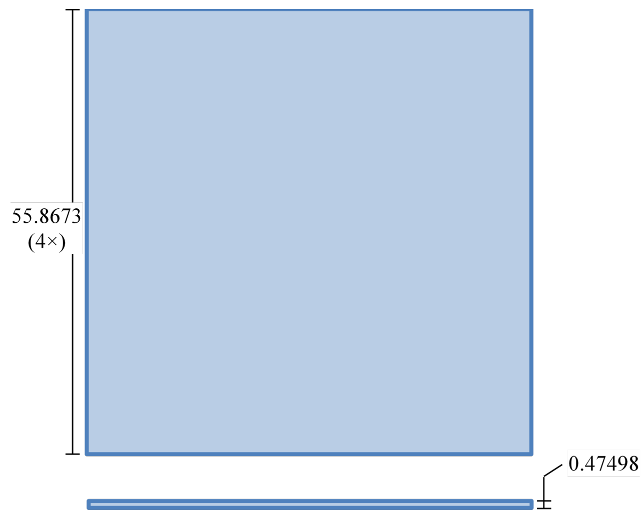

Figure 54. Description of the Diaphragm Dimensions for the Detailed Model. Dimensions are in centimeters. Figure is from HEU-MET-INTER-011.

The top plate is below the first side reflector layer. The inner radius for the top plate describes the central hole that the lower core passes though while being inserted (see Figure 55).

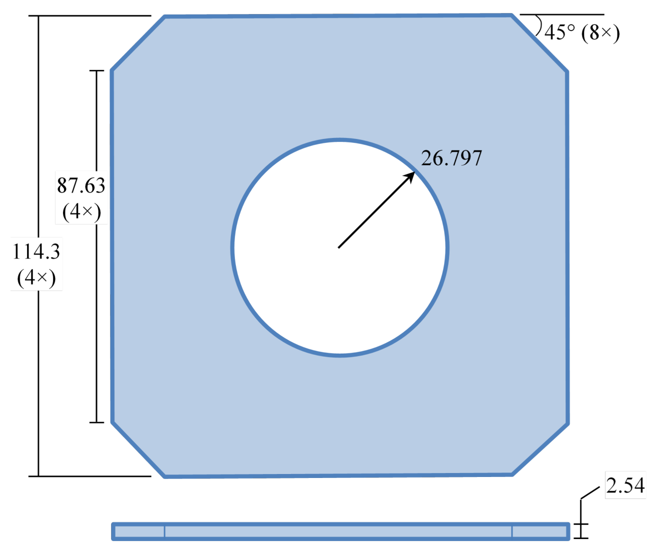

Figure 55. Description of the Top Plate Dimensions for the Detailed Model. Dimensions are in centimeters. Figure is from HEU-MET-INTER-011.

The platen and platen adapter plate are located below the bottom reflector and are modeled as one component in the benchmark model. Since the platen and platen adapter plate have the same diameters, are made of the same material, and are on the outside of the assembly, this simplification is deemed negligible. The benchmark model of the platen/platen adapter plate is shown in Figure 56.

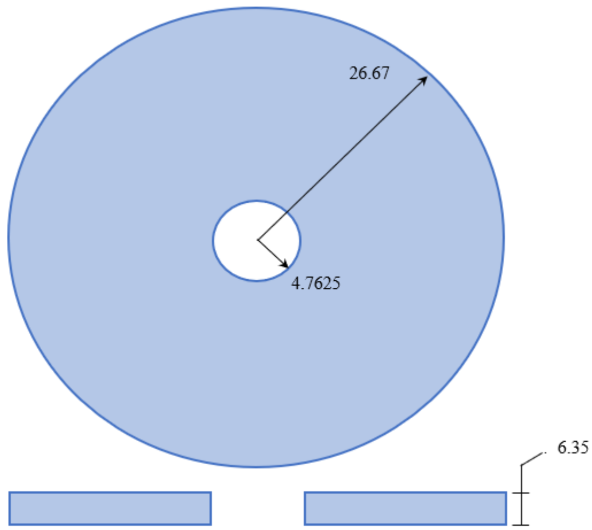

Figure 56. Description of the Platen/Platen Adapter Plate Dimensions for the Detailed Model. Dimensions are in centimeters. Figure is from HEU-MET-INTER-011.

The aluminum alignment tube is used to align the lower core of the assembly, so components do not move as the lower core is raised into contact with the upper core. The benchmark model of the aluminum alignment tube is shown in Figure 57.

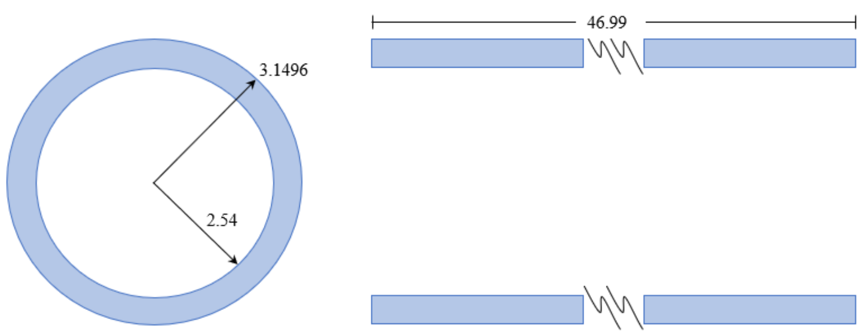

Figure 57. Description of the Aluminum Alignment Tube Dimensions for the Detailed Model. Dimensions are in centimeters.

3.2.1.5 $^3/_{16}$ Configuration, Case 1

The $^3/_{16}$ configuration was designed to have a $^3/_{16}$ in. thick Cu plate above and below each layer of HEU. However, a few units within the assembly do not have $^3/_{16}$ inches of Cu above and below each HEU in order to achieve a delayed critical configuration. Tables 107 and 108 provide the dimensions and gaps, derived from the stack height measurements, within the core. Note, these tables do not include dimensions for the Comet hardware (e.g., top plate, diaphragm, platen, etc.) or the Cu reflectors. Information on other components that are part of the benchmark model are shown in Table 109 and Table 110. Gaps present in the assembly can be modeled in multiple ways, without impacting the results of the benchmark model. Therefore, gaps associated with nested parts having different heights are not included in Table 107 and Table 108, but the gaps derived from the stack height measurements are included.

Table 107. Dimensions for the Upper Core of the $^3/_{16}$ Configuration. See Figure 3 for a visual of the upper core.

Unit	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius [cm]	Inner Radius [cm]
Above Units	Void	0.00004	6.82498	6.82494	26.666830	—
U5	Cu 07-10	0.47803	6.82494	6.34691	26.666830	—
	B-2444-19	0.30000	6.34558	6.04558	26.670000	19.050000
	11149	0.30133	6.34691	6.04558	19.050000	—
	Gap	0.00623	6.04558	6.03935	26.666830	—
	Cu 07-09	0.47832	6.03935	5.56103	26.666830	—
U4	Cu 07-08	0.47663	5.56103	5.08440	26.666830	—
	B-2444-07	0.30300	5.08440	4.78140	26.670000	19.050000
	11017	0.30233	5.08373	4.78140	19.050000	—
	Gap	0.00623	4.78140	4.77517	26.666830	—
	Cu 07-07	0.47794	4.77517	4.29723	26.666830	—
U3	Cu 07-06	0.47943	4.29723	3.81780	26.666830	—
	B-2444-37	0.30083	3.79430	3.49347	26.670000	19.050000
	11018	0.30233	3.79580	3.49347	19.050000	7.629525
	Q2-16	0.32433	3.81780	3.49347	7.620000	—
	Gap	0.00623	3.49347	3.48724	26.666830	—
	Cu 07-05	0.47790	3.48724	3.00934	26.666830	—
U2	Cu 07-04	0.47680	3.00934	2.53254	26.666830	—
	B-2444-20	0.30217	2.53254	2.23037	26.670000	19.050000
	11019	0.30067	2.53104	2.23037	19.050000	—
	Gap	0.00623	2.23037	2.22414	26.666830	—
	Cu 07-03	0.47926	2.22414	1.74488	26.666830	—
U1	Cu 07-02	0.47782	1.74488	1.26706	26.666830	—
	B-2444-10	0.30483	1.25733	0.95873	26.670000	19.050000
	11147	0.30833	1.26706	0.95873	19.050000	—
	Gap	0.00623	0.95873	0.95250	26.666830	—
	Cu 07-01	0.47752	0.95250	0.47498	26.666830	—

Table 108. Dimensions for the Lower Core of the 3/16 Configuration. See Figure 3 for a visual of the lower core.

Unit	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius [cm]	Inner Radius [cm]
Al Shims	400 mil	1.01346	0.00000	-1.01346	26.66365	3.18135
	500 mil	1.27381	-1.01346	-2.28727	26.66365	3.18135
B6	Cu 05-12	0.47718	-2.28727	-2.76445	26.666830	3.194050
	B-2444-33	0.30200	-2.76445	-3.06645	26.670000	19.050000
	10489	0.30633	-2.76445	-3.07078	19.050000	3.190875
	Gap	0.02647	-3.07078	-3.09725	26.666830	3.194050
	Cu 05-11	0.47722	-3.09725	-3.57447	26.666830	3.194050
B5	Cu 05-10	0.47790	-3.57447	-4.05237	26.666830	3.194050
	B-2444-29	0.30483	-4.05237	-4.35720	26.670000	19.050000
	10467	0.30700	-4.05237	-4.35937	19.050000	3.190875
	Gap	0.02647	-4.35937	-4.38584	26.666830	3.194050
	Cu 05-09	0.47913	-4.38584	-4.86497	26.666830	3.194050
B4	Cu 05-08	0.47782	-4.86497	-5.34279	26.666830	3.194050
	B-2444-36	0.30233	-5.34279	-5.64512	26.670000	19.050000
	10487	0.30367	-5.34279	-5.64646	19.050000	3.190875
	Gap	0.02647	-5.64646	-5.67293	26.666830	3.194050
	Cu 05-07	0.47663	-5.67293	-6.14956	26.666830	3.194050
B3	Cu 05-06	0.47816	-6.14956	-6.62772	26.666830	3.194050
	B-2444-01	0.30233	-6.62772	-6.93005	26.670000	19.050000
	10464	0.30467	-6.62772	-6.93239	19.050000	3.190875
	Gap	0.02647	-6.93239	-6.95886	26.666830	3.194050
	Cu 05-05	0.47676	-6.95886	-7.43562	26.666830	3.194050
B2	Cu 05-03	0.47777	-7.43562	-7.91339	26.666830	3.194050
	B-2444-24	0.30150	-7.91339	-8.21489	26.670000	19.050000
	10470	0.30400	-7.91339	-8.21739	19.050000	3.190875
	Gap	0.02647	-8.21739	-8.24386	26.666830	3.194050
	Cu 05-02	0.47663	-8.24386	-8.72049	26.666830	3.194050
B1	Cu 05-01	0.47799	-8.72049	-9.19848	26.666830	3.194050
	B-2444-02	0.30033	-9.19848	-9.49881	26.670000	19.050000
	10475	0.30183	-9.19848	-9.50031	19.050000	3.190875
	Gap	0.02647	-9.50031	-9.52678	26.666830	3.194050

Table 109. Dimensions for the Comet Hardware of the 3/16 Configuration. See Figure 3 for a visual of the assembly.

Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius or Half-Length$^{(a)}$ [cm]	Inner Radius [cm]
Top Plate	2.54000	-28.85440	-31.39440	57.1500	26.79700
Diaphragm	0.47498	0.47498	0.00000	27.93365	—
Al Alignment Tube	46.99000	-0.079375	-47.069375	3.14960	2.54000
Platen/Platen Adapter Plate	6.35000	-23.95398	-30.30398	26.67000	4.76250

(a) Half-length refers to the +x, -x, +y, and -y values used to define the component in the benchmark model.

Table 110. Dimensions for the Cu Reflectors of the 3/16 Configuration. See Figure 3 for a visual of the assembly.

Region	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius or Half-Length$^{(a)}$ [cm]	Inner Radius or Half-Length$^{(b)}$ [cm]
Side Reflector	Layer 1 (Bottom)	20.6502	-8.20420	-28.85440	44.14520	27.94000
	Layer 2	20.6502	12.44600	-8.20420	44.14520	27.94000
	Layer 3 (Top)	20.6502	33.09620	12.44600	44.14520	27.94000
Corner Reflectors	CR1 (Bottom)	14.42720	-14.42720	-28.85440	27.92730	26.79700
	CR1	14.42720	0.00000	-14.42720	27.92730	26.79700
	CR4	3.81000	4.28498	0.47498	27.92730	26.79700
	CR3	1.90500	6.18998	4.28498	27.92730	26.79700
	CR6 (Top)	0.63500	6.82498	6.18998	27.92730	26.79700
Bottom Reflector		14.4272	-9.52678	-23.95398	26.67000	3.17500
Top Reflector		14.4272	21.25218	6.82498	27.93365	0.31750

(a) Half-length refers to the +x, -x, +y, and -y values used to define the component (i.e., top reflector) or the outside surface of the component layer (i.e., side and corner reflector) in the benchmark model.
(b) Half-length refers to the +x, -x, +y, and -y values used to define the inside surface of the side reflectors in the benchmark model.

3.2.1.6 5/16 Configuration, Case 2

The 5/16 configuration was designed to have a 5/16 in. thick Cu plate above and below each layer of HEU. However, a few units within the assembly do not have 5/16 inches of Cu above and below each HEU in order to achieve a delayed critical configuration. Tables 111 and 112 provide the dimensions and gaps, derived from the stack height measurements, within the core. Note, these tables do not include dimensions for the Comet hardware (e.g., top plate, diaphragm, platen, etc.) or the Cu reflectors. Information on other components that are part of the benchmark model are shown in Table 113 and Table 114. Gaps present in the assembly can be modeled in multiple ways, without impacting the results of the benchmark model. Therefore, gaps associated with nested parts having different heights are not included in Table 111 and Table 112, but the gaps derived from the stack height measurements are included.

Table 111. Dimensions for the Upper Core of the $^{5}/_{16}$ Configuration. See Figure 4 for a visual of the upper core.

Unit	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius [cm]	Inner Radius [cm]
Above Units	Void	0.07977	11.26998	11.19021	26.666830	—
U6	B-2444-27	0.29817	11.18838	10.89021	26.670000	19.050000
	11150	0.30000	11.19021	10.89021	19.050000	—
	Gap	0.01847	10.89021	10.87174	26.666830	—
	Cu 03-11	0.32008	10.87174	10.55166	26.666830	—
	Cu 07-11	0.47760	10.55166	10.07406	26.666830	—
U5	Cu 07-10	0.47803	10.07406	9.59603	26.666830	—
	Cu 03-10	0.31818	9.59603	9.27785	26.666830	—
	B-2444-19	0.30000	9.27652	8.97652	26.670000	19.050000
	11149	0.30133	9.27785	8.97652	19.050000	—
	Gap	0.01847	8.97652	8.95805	26.666830	—
	Cu 03-09	0.31750	8.95805	8.64055	26.666830	—
	Cu 07-09	0.47832	8.64055	8.16223	26.666830	—
U4	Cu 07-08	0.47663	8.16223	7.68560	26.666830	—
	Cu 03-08	0.31742	7.68560	7.36818	26.666830	—
	B-2444-07	0.30300	7.36818	7.06518	26.670000	19.050000
	11017	0.30233	7.36751	7.06518	19.050000	—
	Gap	0.01847	7.06518	7.04671	26.666830	—
	Cu 03-07	0.31936	7.04671	6.72735	26.666830	—
	Cu 07-07	0.47794	6.72735	6.24941	26.666830	—
U3	Cu 07-06	0.47943	6.24941	5.76998	26.666830	—
	Cu 03-06	0.32000	5.76998	5.44998	26.666830	—
	B-2444-37	0.30083	5.42648	5.12565	26.670000	19.050000
	11018	0.30233	5.42798	5.12565	19.050000	7.629525
	Q2-16	0.32433	5.44998	5.12565	7.620000	—
	Gap	0.01847	5.12565	5.10718	26.666830	—
	Cu 03-05	0.31822	5.10718	4.78896	26.666830	—
	Cu 07-05	0.47790	4.78896	4.31106	26.666830	—
U2	Cu 07-04	0.47680	4.31106	3.83426	26.666830	—
	Cu 03-04	0.31941	3.83426	3.51485	26.666830	—
	B-2444-20	0.30217	3.51485	3.21268	26.670000	19.050000
	11019	0.30067	3.51335	3.21268	19.050000	—
	Gap	0.01847	3.21268	3.19421	26.666830	—
	Cu 03-03	0.31953	3.19421	2.87468	26.666830	—
	Cu 07-03	0.47926	2.87468	2.39542	26.666830	—
U1	Cu 07-02	0.47782	2.39542	1.91760	26.666830	—
	Cu 03-02	0.31843	1.91760	1.59917	26.666830	—
	B-2444-10	0.30483	1.59567	1.29084	26.670000	19.050000
	11147	0.30833	1.59917	1.29084	19.050000	—

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Table 111 – *Continued from previous page*

Unit	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius [cm]	Inner Radius [cm]
	Gap	0.01847	1.29084	1.27237	26.666830	—
	Cu 03-01	0.31987	1.27237	0.95250	26.666830	—
	Cu 07-01	0.47752	0.95250	0.47498	26.666830	—

Table 112. Dimensions for the Lower Core of the $^{5}/_{16}$ Configuration. See Figure 5 for a visual of the lower core.

Unit	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius [cm]	Inner Radius [cm]
B6	Cu 05-12	0.47718	0.00000	-0.47718	26.666830	3.194050
	Cu 01-12	0.31847	-0.47718	-0.79565	26.666830	3.194050
	B-2444-33	0.30200	-0.79565	-1.09765	26.670000	19.050000
	10489	0.30633	-0.79565	-1.10198	19.050000	3.190875
	Gap	0.03794	-1.10198	-1.13992	26.666830	3.194050
	Cu 01-10	0.31742	-1.13992	-1.45734	26.666830	3.194050
	Cu 05-11	0.47722	-1.45734	-1.93456	26.666830	3.194050
B5	Cu 05-10	0.47790	-1.93456	-2.41246	26.666830	3.194050
	Cu 01-09	0.31907	-2.41246	-2.73153	26.666830	3.194050
	B-2444-29	0.30483	-2.73153	-3.03636	26.670000	19.050000
	10467	0.30700	-2.73153	-3.03853	19.050000	3.190875
	Gap	0.03794	-3.03853	-3.07647	26.666830	3.194050
	Cu 01-08	0.31979	-3.07647	-3.39626	26.666830	3.194050
	Cu 05-09	0.47913	-3.39626	-3.87539	26.666830	3.194050
B4	Cu 05-08	0.47782	-3.87539	-4.35321	26.666830	3.194050
	Cu 01-07	0.31860	-4.35321	-4.67181	26.666830	3.194050
	B-2444-36	0.30233	-4.67181	-4.97414	26.670000	19.050000
	10487	0.30367	-4.67181	-4.97548	19.050000	3.190875
	Gap	0.03794	-4.97548	-5.01342	26.666830	3.194050
	Cu 01-06	0.31856	-5.01342	-5.33198	26.666830	3.194050
	Cu 05-07	0.47663	-5.33198	-5.80861	26.666830	3.194050
B3	Cu 05-06	0.47816	-5.80861	-6.28677	26.666830	3.194050
	Cu 01-05	0.31839	-6.28677	-6.60516	26.666830	3.194050
	B-2444-01	0.30233	-6.60516	-6.90749	26.670000	19.050000
	10464	0.30467	-6.60516	-6.90983	19.050000	3.190875
	Gap	0.03794	-6.90983	-6.94777	26.666830	3.194050
	Cu 01-04	0.31797	-6.94777	-7.26574	26.666830	3.194050
	Cu 05-05	0.47676	-7.26574	-7.74250	26.666830	3.194050
B2	Cu 05-03	0.47777	-7.74250	-8.22027	26.666830	3.194050
	Cu 01-03	0.31919	-8.22027	-8.53946	26.666830	3.194050

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Table 112 – *Continued from previous page*

Unit	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius [cm]	Inner Radius [cm]
	B-2444-24	0.30150	-8.53946	-8.84096	26.670000	19.050000
	10470	0.30400	-8.53946	-8.84346	19.050000	3.190875
	Gap	0.03794	-8.84346	-8.88140	26.666830	3.194050
	Cu 01-02	0.31996	-8.88140	-9.20136	26.666830	3.194050
	Cu 05-02	0.47663	-9.20136	-9.67799	26.666830	3.194050
B1	Cu 05-01	0.47799	-9.67799	-10.15598	26.666830	3.194050
	Cu 01-01	0.31928	-10.15598	-10.47526	26.666830	3.194050
	B-2444-02	0.30033	-10.47526	-10.77559	26.670000	19.050000
	10475	0.30183	-10.47526	-10.77709	19.050000	3.190875
	Gap	0.03794	-10.77709	-10.81503	26.666830	3.194050

Table 113. Dimensions for the Comet Hardware of the 5/16 Configuration. See Figure 4 and Figure 5 for a visual of the assembly.

Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius or Half-Length$^{(a)}$ [cm]	Inner Radius [cm]
Top Plate	2.54000	-28.85440	-31.39440	57.1500	26.79700
Diaphragm	0.47498	0.47498	0.00000	27.93365	—
Al Alignment Tube	46.99000	-0.079375	-47.069375	3.14960	2.54000
Platen/Platen Adapter Plate	6.35000	-25.24223	-31.59223	26.67000	4.76250

(a) Half-length refers to the +x, -x, +y, and -y values used to define the component in the benchmark model.

Table 114. Dimensions for the Cu Reflectors of the $^{5}/_{16}$ Configuration. See Figure 4 and Figure 5 for a visual of the assembly.

Region	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius or Half-Length$^{(a)}$ [cm]	Inner Radius or Half-Length$^{(b)}$ [cm]
Side Reflector	Layer 1 (Bottom)	20.6502	-8.20420	-28.85440	44.14520	27.94000
	Layer 2	20.6502	12.44600	-8.20420	44.14520	27.94000
	Layer 3 (Top)	20.6502	33.09620	12.44600	44.14520	27.94000
Corner Reflectors	CR1 (Bottom)	14.42720	-14.42720	-28.85440	27.92730	26.79700
	CR1	14.42720	0.00000	-14.42720	27.92730	26.79700
	CR2	7.62000	8.09498	0.47498	27.92730	26.79700
	CR3	1.90500	9.99998	8.09498	27.92730	26.79700
	CR6	0.63500	10.63498	9.99998	27.92730	26.79700
	CR6 (Top)	0.63500	11.26998	10.63498	27.92730	26.79700
Bottom Reflector		14.4272	-10.81503	-25.24223	26.67000	3.17500
Top Reflector		14.4272	25.69718	11.26998	27.93365	0.31750

(a) Half-length refers to the +x, -x, +y, and -y values used to define the component (i.e., top reflector) or the outside surface of the component layer (i.e., side and corner reflector) in the benchmark model.
(b) Half-length refers to the +x, -x, +y, and -y values used to define the inside surface of the side reflectors in the benchmark model.

3.2.1.7 $^{7}/_{16}$ Configuration, Case 3

The $^{7}/_{16}$ configuration was designed to have a $^{7}/_{16}$ in. thick Cu plate above and below each layer of HEU. However, a few units within the assembly do not have $^{7}/_{16}$ inches of Cu above and below each HEU in order to achieve a delayed critical configuration. Tables 115 and 116 provide the dimensions and gaps, derived from the stack height measurements, within the core. Note, these tables do not include dimensions for the Comet hardware (e.g., top plate, diaphragm, platen, etc.) or the Cu reflectors. Information on other components that are part of the benchmark model are shown in Table 117 and Table 118. Gaps present in the assembly can be modeled in multiple ways, without impacting the results of the benchmark model. Therefore, gaps associated with nested parts having different heights are not included in Table 115 and Table 116, but the gaps derived from the stack height measurements are included.

Table 115. Dimensions for the Upper Core of the $^{7}/_{16}$ Configuration. See Figure 6 for a visual of the upper core.

Unit	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius [cm]	Inner Radius [cm]
Above Units	Void		17.75968	17.58698	26.666830	—
U7	Cu 03-27	0.31991	17.58698	17.26707	26.666830	—
	B-2444-22	0.29133	17.24940	16.95807	26.670000	19.050000
	10477	0.30900	17.26707	16.95807	19.050000	7.629525
	Al Adapter	0.29972	17.25779	16.95807	7.610475	3.175000
	Void	0.29972	17.25779	16.95807	3.75000	—
	Gap	0.01857	16.95807	16.93950	26.666830	—

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Table 115 – *Continued from previous page*

Unit	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius [cm]	Inner Radius [cm]
	Cu 03-26	0.32025	16.93950	16.61925	26.666830	—
	Cu 03-25	0.31860	16.61925	16.30065	26.666830	—
	Cu 07-13	0.47752	16.30065	15.82313	26.666830	—
U6	Cu 07-12	0.47578	15.82313	15.34735	26.666830	—
	Cu 03-24	0.31864	15.34735	15.02871	26.666830	—
	Cu 03-23	0.32072	15.02871	14.70799	26.666830	—
	B-2444-27	0.29817	14.70616	14.40799	26.670000	19.050000
	11150	0.30000	14.70799	14.40799	19.050000	—
	Gap	0.01857	14.40799	14.38942	26.666830	—
	Cu 03-22	0.32017	14.38942	14.06925	26.666830	—
	Cu 03-21	0.32029	14.06925	13.74896	26.666830	—
	Cu 07-11	0.47760	13.74896	13.27136	26.666830	—
U5	Cu 07-10	0.47803	13.27136	12.79333	26.666830	—
	Cu 03-20	0.31987	12.79333	12.47346	26.666830	—
	Cu 03-19	0.31945	12.47346	12.15401	26.666830	—
	B-2444-19	0.30000	12.15268	11.85268	26.670000	19.050000
	11149	0.30133	12.15401	11.85268	19.050000	—
	Gap	0.01857	11.85268	11.83411	26.666830	—
	Cu 03-18	0.32097	11.83411	11.51314	26.666830	—
	Cu 03-17	0.31953	11.51314	11.19361	26.666830	—
	Cu 07-09	0.47832	11.19361	10.71529	26.666830	—
U4	Cu 07-08	0.47663	10.71529	10.23866	26.666830	—
	Cu 03-16	0.31953	10.23866	9.91913	26.666830	—
	Cu 03-15	0.31907	9.91913	9.60006	26.666830	—
	B-2444-07	0.30300	9.60006	9.29706	26.670000	19.050000
	11017	0.30233	9.59939	9.29706	19.050000	—
	Gap	0.01857	9.29706	9.27849	26.666830	—
	Cu 03-14	0.31902	9.27849	8.95947	26.666830	—
	Cu 03-13	0.31987	8.95947	8.63960	26.666830	—
	Cu 07-07	0.47794	8.63960	8.16166	26.666830	—
U3	Cu 07-06	0.47943	8.16166	7.68223	26.666830	—
	Cu 03-12	0.31941	7.68223	7.36282	26.666830	—
	Cu 03-11	0.32008	7.36282	7.04274	26.666830	—
	B-2444-37	0.30083	7.01924	6.71841	26.670000	19.050000
	11018	0.30233	7.02074	6.71841	19.050000	7.629525
	Q2-16	0.32433	7.04274	6.71841	7.62000	—
	Gap	0.01857	6.71841	6.69984	26.666830	—
	Cu 03-10	0.31818	6.69984	6.38166	26.666830	—
	Cu 03-09	0.31750	6.38166	6.06416	26.666830	—
	Cu 07-05	0.47790	6.06416	5.58626	26.666830	—

Continued on next page

Table 115 – *Continued from previous page*

Unit	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius [cm]	Inner Radius [cm]
U2	Cu 07-04	0.47680	5.58626	5.10946	26.666830	—
	Cu 03-08	0.31742	5.10946	4.79204	26.666830	—
	Cu 03-07	0.31936	4.79204	4.47268	26.666830	—
	B-2444-20	0.30217	4.47268	4.17051	26.670000	19.050000
	11019	0.30067	4.47118	4.17051	19.050000	—
	Gap	0.01857	4.17051	4.15194	26.666830	—
	Cu 03-06	0.32000	4.15194	3.83194	26.666830	—
	Cu 03-05	0.31822	3.83194	3.51372	26.666830	—
	Cu 07-03	0.47926	3.51372	3.03446	26.666830	—
U1	Cu 07-02	0.47782	3.03446	2.55664	26.666830	—
	Cu 03-04	0.31941	2.55664	2.23723	26.666830	—
	Cu 03-03	0.31953	2.23723	1.91770	26.666830	—
	B-2444-10	0.30483	1.91420	1.60937	26.670000	19.050000
	11147	0.30833	1.91770	1.60937	19.050000	—
	Gap	0.01857	1.60937	1.59080	26.666830	—
	Cu 03-02	0.31843	1.59080	1.27237	26.666830	—
	Cu 03-01	0.31987	1.27237	0.95250	26.666830	—
	Cu 07-01	0.47752	0.95250	0.47498	26.666830	—

Table 116. Dimensions for the Lower Core of the 7/16 Configuration. See Figure 7 for a visual of the lower core.

Unit	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius [cm]	Inner Radius [cm]
B7	Cu 05-14	0.47824	0.00000	-0.47824	26.666830	3.194050
	Cu 01-26	0.31856	-0.47824	-0.79680	26.666830	3.194050
	B-2444-33	0.30200	-0.79680	-1.09880	26.670000	19.050000
	10489	0.30633	-0.79680	-1.10313	19.050000	3.190875
	Gap	0.02858	-1.10313	-1.13171	26.666830	3.194050
	Cu 01-25	0.31716	-1.13171	-1.44887	26.666830	3.194050
	Cu 01-24	0.31890	-1.44887	-1.76777	26.666830	3.194050
	Cu 05-13	0.47752	-1.76777	-2.24529	26.666830	3.194050
B6	Cu 05-12	0.47718	-2.24529	-2.72247	26.666830	3.194050
	Cu 01-23	0.31877	-2.72247	-3.04124	26.666830	3.194050
	Cu 01-22	0.31805	-3.04124	-3.35929	26.666830	3.194050
	B-2444-29	0.30483	-3.35929	-3.66412	26.670000	19.050000
	10467	0.30700	-3.35929	-3.66629	19.050000	3.190875
	Gap	0.02858	-3.66629	-3.69487	26.666830	3.194050
	Cu 01-21	0.31902	-3.69487	-4.01389	26.666830	3.194050

Continued on next page

Table 116 – *Continued from previous page*

Unit	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius [cm]	Inner Radius [cm]
	Cu 01-20	0.31864	-4.01389	-4.33253	26.666830	3.194050
	Cu 05-11	0.47722	-4.33253	-4.80975	26.666830	3.194050
B5	Cu 05-10	0.47790	-4.80975	-5.28765	26.666830	3.194050
	Cu 01-19	0.31792	-5.28765	-5.60557	26.666830	3.194050
	Cu 01-18	0.31941	-5.60557	-5.92498	26.666830	3.194050
	B-2444-36	0.30233	-5.92498	-6.22731	26.670000	19.050000
	10487	0.30367	-5.92498	-6.22865	19.050000	3.190875
	Gap	0.02858	-6.22865	-6.25723	26.666830	3.194050
	Cu 01-17	0.31814	-6.25723	-6.57537	26.666830	3.194050
	Cu 01-16	0.31784	-6.57537	-6.89321	26.666830	3.194050
	Cu 05-09	0.47913	-6.89321	-7.37234	26.666830	3.194050
B4	Cu 05-08	0.47782	-7.37234	-7.85016	26.666830	3.194050
	Cu 01-15	0.31835	-7.85016	-8.16851	26.666830	3.194050
	Cu 01-14	0.31767	-8.16851	-8.48618	26.666830	3.194050
	B-2444-01	0.30233	-8.48618	-8.78851	26.670000	19.050000
	10464	0.30467	-8.48618	-8.79085	19.050000	3.190875
	Gap	0.02858	-8.79085	-8.81943	26.666830	3.194050
	Cu 01-13	0.31805	-8.81943	-9.13748	26.666830	3.194050
	Cu 01-12	0.31847	-9.13748	-9.45595	26.666830	3.194050
	Cu 05-07	0.47663	-9.45595	-9.93258	26.666830	3.194050
B3	Cu 05-06	0.47816	-9.93258	-10.41074	26.666830	3.194050
	Cu 01-10	0.31742	-10.41074	-10.72816	26.666830	3.194050
	Cu 01-09	0.31907	-10.72816	-11.04723	26.666830	3.194050
	B-2444-24	0.30150	-11.04723	-11.34873	26.670000	19.050000
	10470	0.30400	-11.04723	-11.35123	19.050000	3.190875
	Gap	0.02858	-11.35123	-11.37981	26.666830	3.194050
	Cu 01-08	0.31979	-11.37981	-11.69960	26.666830	3.194050
	Cu 01-07	0.31860	-11.69960	-12.01820	26.666830	3.194050
	Cu 05-05	0.47676	-12.01820	-12.49496	26.666830	3.194050
B2	Cu 05-03	0.47777	-12.49496	-12.97273	26.666830	3.194050
	Cu 01-06	0.31856	-12.97273	-13.29129	26.666830	3.194050
	Cu 01-05	0.31839	-13.29129	-13.60968	26.666830	3.194050
	B-2444-02	0.30033	-13.60968	-13.91001	26.670000	19.050000
	10475	0.30183	-13.60968	-13.91151	19.050000	3.190875
	Gap	0.02858	-13.91151	-13.94009	26.666830	3.194050
	Cu 01-04	0.31797	-13.94009	-14.25806	26.666830	3.194050
	Cu 01-03	0.31919	-14.25806	-14.57725	26.666830	3.194050
	Cu 05-02	0.47663	-14.57725	-15.05388	26.666830	3.194050
B1	Cu 05-01	0.47799	-15.05388	-15.53187	26.666830	3.194050
	Cu 01-02	0.31996	-15.53187	-15.85183	26.666830	3.194050

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Table 116 – *Continued from previous page*

Unit	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius [cm]	Inner Radius [cm]
	Cu 01-01	0.31928	-15.85183	-16.17111	26.666830	3.194050
	B-2444-31	0.30400	-16.17111	-16.47511	26.670000	19.050000
	10491	0.31283	-16.17111	-16.48394	19.050000	3.190875
	Gap	0.02858	-16.48394	-16.51252	26.666830	3.194050

Table 117. Dimensions for the Comet Hardware of the 7/16 Configuration. See Figure 6 and Figure 7 for a visual of the assembly.

Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius or Half-Length$^{(a)}$ [cm]	Inner Radius [cm]
Top Plate	2.54000	-36.47440	-39.01440	57.1500	26.79700
Diaphragm	0.47498	0.47498	0.00000	27.93365	—
Al Alignment Tube	46.99000	-0.079375	-47.069375	3.14960	2.54000
Platen/Platen Adapter Plate	6.35000	-30.93972	-37.28972	26.67000	4.76250

(a) Half-length refers to the +x, -x, +y, and -y values used to define the component in the benchmark model.

Table 118. Dimensions for the Cu Reflectors of the $^{7}/_{16}$ Configuration. See Figure 6 and Figure 7 for a visual of the assembly.

Region	Component	Height [cm]	Top Plane [cm]	Bottom Plane [cm]	Outer Radius or Half-Length$^{(a)}$ [cm]	Inner Radius or Half-Length$^{(b)}$ [cm]
Side Reflector	Layer 1 (Bottom)	20.6502	-15.82420	-36.47440	44.14520	27.94000
	Layer 2	20.6502	4.82600	-15.82420	44.14520	27.94000
	Layer 3	20.6502	25.47620	4.82600	44.14520	27.94000
	Layer 4 (Top)	20.6502	46.12640	25.47620	44.14520	27.94000
Corner Reflectors	CR1 (Bottom)	14.42720	-22.04720	-36.47440	27.92730	26.79700
	CR1	14.42720	-7.62000	-22.04720	27.92730	26.79700
	CR2	7.62000	0.00000	-7.62000	27.92730	26.79700
	CR1	14.42720	14.90218	0.47498	27.92730	26.79700
	CR3	1.90500	16.80718	14.90218	27.92730	26.79700
	CR7 (Top)	0.9525	17.75968	16.80718	27.92730	26.79700
Bottom Reflector		14.4272	-16.51252	-30.93972	26.67000	3.17500
Top Reflector		14.4272	32.18688	17.75968	27.93365	0.31750

(a) Half-length refers to the +x, -x, +y, and -y values used to define the component (i.e., top reflector) or the outside surface of the component layer (i.e., side and corner reflector) in the benchmark model.
(b) Half-length refers to the +x, -x, +y, and -y values used to define the inside surface of the side reflectors in the benchmark model.

3.2.2 Simplified Model

3.2.2.1 $^{3}/_{16}$ Configuration, Case 1

TBD

3.2.2.2 $^{5}/_{16}$ Configuration, Case 2

TBD

3.2.2.3 $^{7}/_{16}$ Configuration, Case 3

TBD

3.3 Material Data

3.3.1 Detailed Model

All atomic weights and abundances used to make the atom density calculations were obtained from the International Criticality Safety Benchmark Evaluation Project (ICSBEP) Document Content and Format Guide that was applicable in 2024. When calculating the atom densities, all digits of the mass density calculation were preserved.

3.3.1.1 Highly Enriched Uranium Disks and Rings

Mass measurements were taken for all the HEU plates (Table 4 in Section 1.2.3); therefore, the density of each plate can be calculated. The calculations used to determine the wt% of each HEU component is described in Section 2.4.1. The HEU plate mass densities used in the detailed model are shown in Table 119. Table 120 through Table 134 show the atom densities broken down by isotope and element for all the HEU plates.

Table 119. HEU Mass Densities [g/cm^3].

Part Type	**ID**$^{(a)}$	**Mass Density**
HEU 21/15	-01	18.4669
	-02	18.5848
	-07	18.4160
	-10	18.3703
	-19	18.6423
	-20	18.6041
	-22	18.8911
	-24	18.4524
	-27	18.5862
	-29	18.3640
	-31	18.5292
	-33	18.6232
	-36	18.5088
	-37	18.5935
HEU 15/2.5	10464	18.5374
	10467	18.6244
	10470	18.6376
	10475	18.6210
	10487	18.6476
	10489	18.6876
	10491	18.4383
HEU 15/0	11017	18.8489
	11019	18.8706
	11147	18.5245
	11149	18.5780
	11150	18.7247
HEU 15/6	11018	18.5522
	10477	18.5899
HEU 6/0	Q2-16	18.1678

(a) The HEU 21/15 plates are numbered B-2444-XX, and this is the value for XX.

Table 120. Atom Density of HEU 6/0 Plate (Q2-16) [1/(b·cm)].

Element	Atom Density	Isotope	Atom Density
Li	1.0509E-07	Li-6	7.8814E-09
		Li-7	9.7204E-08
Be	8.0934E-08	Be-9	8.0934E-08
B	5.0600E-07	B-10	1.0069E-07
		B-11	4.0531E-07
C	5.1314E-04	C-12	5.0750E-04
		C-13	5.6445E-06
Na	3.1727E-07	Na-23	3.1727E-07
Mg	3.0010E-07	Mg-24	2.3705E-07
		Mg-25	3.0010E-08
		Mg-26	3.3041E-08
Al	1.4868E-05	Al-27	1.4868E-05
Si	1.1817E-04	Si-28	1.0898E-04
		Si-29	5.5183E-06
		Si-30	3.6631E-06
Ca	3.6399E-07	Ca-40	3.5285E-07
		Ca-42	2.3550E-09
		Ca-43	4.9138E-10
		Ca-44	7.5927E-09
		Ca-46	1.4559E-11
		Ca-48	6.8065E-10
V	2.8636E-06	V-50	7.1591E-09
		V-51	2.8565E-06
Cr	1.7535E-06	Cr-50	7.6188E-08
		Cr-52	1.4692E-06
		Cr-53	1.6658E-07
		Cr-54	4.1470E-08
Mn	1.1285E-06	Mn-55	1.1285E-06
Fe	2.4816E-05	Fe-54	1.4642E-06
		Fe-56	2.2762E-05
		Fe-57	5.2114E-07
		Fe-58	6.9486E-08
Co	6.1883E-07	Co-59	6.1883E-07
Ni	4.3499E-06	Ni-58	2.9697E-06
		Ni-60	1.1353E-06
		Ni-61	4.9154E-08
		Ni-62	1.5616E-07
		Ni-64	3.9584E-08
Cu	8.6087E-07	Cu-63	5.9546E-07
		Cu-65	2.6540E-07

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Table 120 – *Continued from previous page*

Element	Atom Density	Isotope	Atom Density
Mo	3.1680E-06	Mo-92	4.7013E-07
		Mo-94	2.9304E-07
		Mo-95	5.0435E-07
		Mo-96	5.2843E-07
		Mo-97	3.0255e-07
		Mo-98	7.6444E-07
		Mo-100	3.0508E-07
Sn	6.1443E-08	Sn-112	5.9600E-10
		Sn-114	3.9938E-10
		Sn-115	2.2119E-10
		Sn-116	8.9277E-09
		Sn-117	4.7188E-09
		Sn-118	1.4881E-08
		Sn-119	5.2718E-09
		Sn-120	2.0024E-08
		Sn-122	2.8448E-09
		Sn-124	3.5575E-09
Pb	1.1146E-07	Pb-204	1.5605E-09
		Pb-206	2.6863E-08
		Pb-207	2.4634E-08
		Pb-208	5.8407E-08
U-234			4.8233E-04
U-235			4.3367E-02
U-236			1.0834E-04
U-238			2.5078E-03
Total		**4.7153E-02**	

Table 121. Atom Density of HEU 15/6 Plates [1/(b·cm)].

11018				**10477**			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0731E-07	Li-6	8.0481E-09	Li	1.0753E-07	Li-6	8.0645E-09
		Li-7	9.9260E-08			Li-7	9.9462E-08
Be	8.2646E-08	Be-9	8.2646E-08	Be	8.2814E-08	Be-9	8.2814E-08
B	5.1671E-07	B-10	1.0283E-07	B	5.1776E-07	B-10	1.0303E-07
		B-11	4.1388E-07			B-11	4.1472E-07
C	5.2400E-04	C-12	5.1823E-04	C	5.2506E-04	C-12	5.1928E-04

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Table 121 – *Continued from previous page*

11018				10477			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		C-13	5.7640E-06			C-13	5.7757E-06
Na	3.2398E-07	Na-23	3.2398E-07	Na	3.2464E-07	Na-23	3.2464E-07
Mg	3.0645E-07	Mg-24	2.4206E-07	Mg	3.0707E-07	Mg-24	2.4255E-07
		Mg-25	3.0645E-08			Mg-25	3.0707E-08
		Mg-26	3.3740E-08			Mg-26	3.3808E-08
Al	1.5183E-05	Al-27	1.5183E-05	Al	1.5214E-05	Al-27	1.5214E-05
Si	1.2067E-04	Si-28	1.1129E-04	Si	1.2091E-04	Si-28	1.1152E-04
		Si-29	5.6351E-06			Si-29	5.6465E-06
		Si-30	3.7406E-06			Si-30	3.7482E-06
Ca	3.7169E-07	Ca-40	3.6032E-07	Ca	3.7244E-07	Ca-40	3.6105E-07
		Ca-42	2.4048E-09			Ca-42	2.4097E-09
		Ca-43	5.0178E-10			Ca-43	5.0279E-10
		Ca-44	7.7534E-09			Ca-44	7.7691E-09
		Ca-46	1.4867E-11			Ca-46	1.4898E-11
		Ca-48	6.9505E-10			Ca-48	6.9646E-10
V	2.9242E-06	V-50	7.3106E-09	V	2.9302E-06	V-50	7.3254E-09
		V-51	2.9169E-06			V-51	2.9228E-06
Cr	1.7906E-06	Cr-50	7.7800E-08	Cr	1.7942E-06	Cr-50	7.7958E-08
		Cr-52	1.5003E-06			Cr-52	1.5034E-06
		Cr-53	1.7010E-07			Cr-53	1.7045E-07
		Cr-54	4.2347E-08			Cr-54	4.2433E-08
Mn	1.1524E-06	Mn-55	1.1524E-06	Mn	1.1547E-06	Mn-55	1.1547E-06
Fe	2.5341E-05	Fe-54	1.4951E-06	Fe	2.5393E-05	Fe-54	1.4982E-06
		Fe-56	2.3243E-05			Fe-56	2.3290E-05
		Fe-57	5.3217E-07			Fe-57	5.3325E-07
		Fe-58	7.0956E-08			Fe-58	7.1100E-08
Co	6.3192E-07	Co-59	6.3192E-07	Co	6.3320E-07	Co-59	6.3320E-07
Ni	4.4419E-06	Ni-58	3.0325E-06	Ni	4.4510E-06	Ni-58	3.0387E-06
		Ni-60	1.1593E-06			Ni-60	1.1617E-06
		Ni-61	5.0194E-08			Ni-61	5.0296E-08
		Ni-62	1.5947E-07			Ni-62	1.5979E-07
		Ni-64	4.0422E-08			Ni-64	4.0504E-08
Cu	8.7908E-07	Cu-63	6.0806E-07	Cu	8.8086E-07	Cu-63	6.0929E-07
		Cu-65	2.7102E-07			Cu-65	2.7157E-07
Mo	3.2350E-06	Mo-92	4.8008E-07	Mo	3.2416E-06	Mo-92	4.8106E-07
		Mo-94	2.9924E-07			Mo-94	2.9985E-07
		Mo-95	5.1502E-07			Mo-95	5.1607E-07
		Mo-96	5.3961E-07			Mo-96	5.4070E-07
		Mo-97	3.0895E-07			Mo-97	3.0957E-07

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Table 121 – *Continued from previous page*

11018				10477			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Mo-98	7.8062E-07			Mo-98	7.8220E-07
		Mo-100	3.1153E-07			Mo-100	3.1217E-07
Sn	6.2743E-08	Sn-112	6.0861E-10	Sn	6.2870E-08	Sn-112	6.0984E-10
		Sn-114	4.0783E-10			Sn-114	4.0866E-10
		Sn-115	2.2587E-10			Sn-115	2.2633E-10
		Sn-116	9.1165E-09			Sn-116	9.1350E-09
		Sn-117	4.8186E-09			Sn-117	4.8284E-09
		Sn-118	1.5196E-08			Sn-118	1.5227E-08
		Sn-119	5.3833E-09			Sn-119	5.3943E-09
		Sn-120	2.0448E-08			Sn-120	2.0489E-08
		Sn-122	2.9050E-09			Sn-122	2.9109E-09
		Sn-124	3.6328E-09			Sn-124	3.6402E-09
Pb	1.1382E-07	Pb-204	1.5935E-09	Pb	1.1405E-07	Pb-204	1.5968E-09
		Pb-206	2.7431E-08			Pb-206	2.7487E-08
		Pb-207	2.5155E-08			Pb-207	2.5206E-08
		Pb-208	5.9643E-08			Pb-208	5.9764E-08
U-234			4.8732E-04	U-234			4.9250E-04
U-235			4.4255E-02	U-235			4.4381E-02
U-236			2.5010E-04	U-236			1.1066E-04
U-238			2.4570E-03	U-238			2.5607E-03
Total		**4.8151E-02**		**Total**		**4.8248E-02**	

Table 122. Atom Density of HEU 15/0 Plates [1/(b·cm)].

11017				11019			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0902E-07	Li-6	8.1769E-09	Li	1.0915E-07	Li-6	8.1863E-09
		Li-7	1.0085E-07			Li-7	1.0096E-07
Be	8.3968E-08	Be-9	8.3968E-08	Be	8.4064E-08	Be-9	8.4064E-08
B	5.2497E-07	B-10	1.0447E-07	B	5.2558E-07	B-10	1.0459E-07
		B-11	4.2050E-07			B-11	4.2099E-07
C	5.3238E-04	C-12	5.2652E-04	C	5.3299E-04	C-12	5.2713E-04
		C-13	5.8562E-06			C-13	5.8629E-06
Na	3.2916E-07	Na-23	3.2916E-07	Na	3.2954E-07	Na-23	3.2954E-07
Mg	3.1135E-07	Mg-24	2.4593E-07	Mg	3.1171E-07	Mg-24	2.4622E-07
		Mg-25	3.1135E-08			Mg-25	3.1171E-08

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Table 122 – *Continued from previous page*

11017				11019			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Mg-26	3.4280E-08			Mg-26	3.4319E-08
Al	1.5426E-05	Al-27	1.5426E-05	Al	1.5443E-05	Al-27	1.5443E-05
Si	1.2260E-04	Si-28	1.1307E-04	Si	1.2274E-04	Si-28	1.1320E-04
		Si-29	5.7252E-06			Si-29	5.7318E-06
		Si-30	3.8004E-06			Si-30	3.8048E-06
Ca	3.7763E-07	Ca-40	3.6608E-07	Ca	3.7806E-07	Ca-40	3.6650E-07
		Ca-42	2.4433E-09			Ca-42	2.4461E-09
		Ca-43	5.0980E-10			Ca-43	5.1039E-10
		Ca-44	7.8774E-09			Ca-44	7.8864E-09
		Ca-46	1.5105E-11			Ca-46	1.5123E-11
		Ca-48	7.0617E-10			Ca-48	7.0698E-10
V	2.9710E-06	V-50	7.4275E-09	V	2.9744E-06	V-50	7.4360E-09
		V-51	2.9636E-06			V-51	2.9670E-06
Cr	1.8192E-06	Cr-50	7.9045E-08	Cr	1.8213E-06	Cr-50	7.9135E-08
		Cr-52	1.5243E-06			Cr-52	1.5261E-06
		Cr-53	1.7282E-07			Cr-53	1.7302E-07
		Cr-54	4.3024E-08			Cr-54	4.3074E-08
Mn	1.1708E-06	Mn-55	1.1708E-06	Mn	1.1722E-06	Mn-55	1.1722E-06
Fe	2.5747E-05	Fe-54	1.5191E-06	Fe	2.5776E-05	Fe-54	1.5208E-06
		Fe-56	2.3615E-05			Fe-56	2.3642E-05
		Fe-57	5.4068E-07			Fe-57	5.4130E-07
		Fe-58	7.2091E-08			Fe-58	7.2174E-08
Co	6.4203E-07	Co-59	6.4203E-07	Co	6.4276E-07	Co-59	6.4276E-07
Ni	4.5130E-06	Ni-58	3.0810E-06	Ni	4.5182E-06	Ni-58	3.0845E-06
		Ni-60	1.1779E-06			Ni-60	1.1792E-06
		Ni-61	5.0997E-08			Ni-61	5.1055E-08
		Ni-62	1.6202E-07			Ni-62	1.6220E-07
		Ni-64	4.1068E-08			Ni-64	4.1115E-08
Cu	8.9314E-07	Cu-63	6.1778E-07	Cu	8.9416E-07	Cu-63	6.1849E-07
		Cu-65	2.7535E-07			Cu-65	2.7567E-07
Mo	3.2868E-06	Mo-92	4.8776E-07	Mo	3.2906E-06	Mo-92	4.8832E-07
		Mo-94	3.0403E-07			Mo-94	3.0438E-07
		Mo-95	5.2326E-07			Mo-95	5.2386E-07
		Mo-96	5.4824E-07			Mo-96	5.4887E-07
		Mo-97	3.1389E-07			Mo-97	3.1425E-07
		Mo-98	7.9310E-07			Mo-98	7.9401E-07
		Mo-100	3.1652E-07			Mo-100	3.1688E-07
Sn	6.3746E-08	Sn-112	6.1834E-10	Sn	6.3820E-08	Sn-112	6.1905E-10
		Sn-114	4.1435E-10			Sn-114	4.1483E-10

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Table 122 – *Continued from previous page*

11017				11019			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Sn-115	2.2949E-10			Sn-115	2.2975E-10
		Sn-116	9.2624E-09			Sn-116	9.2730E-09
		Sn-117	4.8957E-09			Sn-117	4.9013E-09
		Sn-118	1.5439E-08			Sn-118	1.5457E-08
		Sn-119	5.4694E-09			Sn-119	5.4757E-09
		Sn-120	2.0775E-08			Sn-120	2.0799E-08
		Sn-122	2.9515E-09			Sn-122	2.9548E-09
		Sn-124	3.6909E-09			Sn-124	3.6952E-09
Pb	1.1564E-07	Pb-204	1.6190E-09	Pb	1.1578E-07	Pb-204	1.6209E-09
		Pb-206	2.7870E-08			Pb-206	2.7902E-08
		Pb-207	2.5557E-08			Pb-207	2.5587E-08
		Pb-208	6.0597E-08			Pb-208	6.0667E-08
U-234			4.9957E-04	U-234			5.0079E-04
U-235			4.4998E-02	U-235			4.5046E-02
U-236			1.1225E-04	U-236			1.1252E-04
U-238			2.5974E-03	U-238			2.6038E-03
Total		**4.8921E-02**		**Total**		**4.8977E-02**	

Table 123. Atom Density of HEU 15/0 Plates [1/(b·cm)].

11147				11149			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0715E-07	Li-6	8.0361E-09	Li	1.0746E-07	Li-6	8.0593E-09
		Li-7	9.9112E-08			Li-7	9.9399E-08
Be	8.2523E-08	Be-9	8.2523E-08	Be	8.2761E-08	Be-9	8.2761E-08
B	6.1913E-07	B-10	1.2321E-07	B	6.2091E-07	B-10	1.2356E-07
		B-11	4.9592E-07			B-11	4.9735E-07
C	1.0217E-03	C-12	1.0104E-03	C	2.5150E-04	C-12	2.4873E-04
		C-13	1.1238E-05			C-13	2.7665E-06
Na	3.2350E-07	Na-23	3.2350E-07	Na	3.2443E-07	Na-23	3.2443E-07
Mg	3.0599E-07	Mg-24	2.4170E-07	Mg	3.0687E-07	Mg-24	2.4240E-07
		Mg-25	3.0599E-08			Mg-25	3.0687E-08
		Mg-26	3.3690E-08			Mg-26	3.3787E-08
Al	2.0673E-05	Al-27	2.0673E-05	Al	1.6586E-05	Al-27	1.6586E-05
		Si-28	1.0990E-04	Si		Si-28	1.4696E-04
Si	1.1916E-04	Si-29	5.5648E-06		1.5934E-04	Si-29	7.4412E-06

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Table 123 – *Continued from previous page*

11147				11149			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Si-30	3.6940E-06			Si-30	4.9395E-06
Ca	3.7113E-07	Ca-40	3.5978E-07	Ca	3.7220E-07	Ca-40	3.6082E-07
		Ca-42	2.4012E-09			Ca-42	2.4082E-09
		Ca-43	5.0103E-10			Ca-43	5.0247E-10
		Ca-44	7.7418E-09			Ca-44	7.7641E-09
		Ca-46	1.4845E-11			Ca-46	1.4888E-11
		Ca-48	6.9402E-10			Ca-48	6.9602E-10
V	2.9199E-06	V-50	7.2997E-09	V	2.9283E-06	V-50	7.3207E-09
		V-51	2.9126E-06			V-51	2.9210E-06
Cr	1.0727E-06	Cr-50	4.6611E-08	Cr	3.2275E-06	Cr-50	1.4024E-07
		Cr-52	8.9885E-07			Cr-52	2.7043E-06
		Cr-53	1.0191E-07			Cr-53	3.0661E-07
		Cr-54	2.5370E-08			Cr-54	7.6331E-07
Mn	8.1224E-07	Mn-55	8.1224E-07	Mn	1.4255E-06	Mn-55	1.4255E-06
Fe	1.9977E-05	Fe-54	1.1786E-06	Fe	3.8065E-05	Fe-54	2.2458E-06
		Fe-56	1.8322E-05			Fe-56	3.4913E-05
		Fe-57	4.1951E-07			Fe-57	7.9937E-07
		Fe-58	5.5934E-08			Fe-58	1.0658E-07
Co	6.3098E-07	Co-59	6.3098E-07	Co	6.3280E-07	Co-59	6.3280E-07
Ni	3.8017E-06	Ni-58	2.5954E-06	Ni	5.7190E-06	Ni-58	3.9044E-06
		Ni-60	9.9224E-07			Ni-60	1.4927E-06
		Ni-61	4.2959E-08			Ni-61	6.4625E-08
		Ni-62	1.3648E-07			Ni-62	2.0531E-07
		Ni-64	3.4595E-08			Ni-64	5.2043E-08
Cu	1.0533E-06	Cu-63	7.2858E-07	Cu	8.8030E-07	Cu-63	6.0890E-07
		Cu-65	3.2474E-07			Cu-65	2.7140E-07
Mo	5.8144E-06	Mo-92	8.6286E-07	Mo	1.9437E-06	Mo-92	2.8845E-07
		Mo-94	5.3783E-07			Mo-94	1.7979E-07
		Mo-95	9.2565E-07			Mo-95	3.0944E-07
		Mo-96	9.6984E-07			Mo-96	3.2421E-07
		Mo-97	5.5528E-07			Mo-97	1.8563E-07
		Mo-98	1.4030E-06			Mo-98	4.6902E-07
		Mo-100	5.5993E-07			Mo-100	1.8718E-07
Sn	6.2649E-08	Sn-112	6.0770E-10	Sn	6.2830E-08	Sn-112	6.0945E-10
		Sn-114	4.0722E-10			Sn-114	4.0840E-10
		Sn-115	2.2554E-10			Sn-115	2.2619E-10
		Sn-116	9.1029E-09			Sn-116	9.1292E-09
		Sn-117	4.8115E-09			Sn-117	4.8254E-09
		Sn-118	1.5174E-08			Sn-118	1.5217E-08

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Table 123 – *Continued from previous page*

11147				11149			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Sn-119	5.3753E-09			Sn-119	5.3908E-09
		Sn-120	2.0417E-08			Sn-120	2.0476E-08
		Sn-122	2.9007E-09			Sn-122	2.9090E-09
		Sn-124	3.6274E-09			Sn-124	3.6379E-09
Pb	2.6918E-07	Pb-204	3.7685E-09	Pb	3.5994E-08	Pb-204	5.0392E-10
		Pb-206	6.4872E-08			Pb-206	8.6746E-09
		Pb-207	5.9488E-08			Pb-207	7.9547E-09
		Pb-208	1.4105E-07			Pb-208	1.8861E-08
U-234			4.9139E-04	U-234			4.9279E-04
U-235			4.4195E-02	U-235			4.4355E-02
U-236			1.1041E-04	U-236			1.1072E-04
U-238			2.5549E-03	U-238			2.5622E-03
Total		**4.8552E-04**		**Total**		**4.8005E-02**	

Table 124. Atom Density of HEU 15/0 and HEU 15/2.5 Plates [1/(b·cm)].

11150				10464			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0831E-07	Li-6	8.1230E-09	Li	1.0722E-07	Li-6	8.0417E-09
		Li-7	1.0018E-07			Li-7	9.9181E-08
Be	8.3414E-08	Be-9	8.3414E-08	Be	8.2580E-08	Be-9	8.2580E-08
B	3.1291E-07	B-10	6.2269E-08	B	5.1630E-07	B-10	1.0274E-07
		B-11	2.5064E-07			B-11	4.1355E-07
C	3.0042E-04	C-12	2.9712E-04	C	5.2358E-04	C-12	5.1782E-04
		C-13	3.3046E-06			C-13	5.7594E-06
Na	3.2699E-07	Na-23	3.2699E-07	Na	3.2372E-07	Na-23	3.2372E-07
Mg	3.0930E-07	Mg-24	2.4431E-07	Mg	3.0620E-07	Mg-24	2.4187E-07
		Mg-25	3.0930E-08			Mg-25	3.0620E-08
		Mg-26	3.4054E-08			Mg-26	3.3713E-08
Al	8.3585E-06	Al-27	8.3585E-06	Al	1.5171E-05	Al-27	1.5171E-05
Si	8.4314E-05	Si-28	7.7763E-05	Si	1.2057E-04	Si-28	1.1120E-04
		Si-29	3.9375E-06			Si-29	5.6306E-06
		Si-30	2.6137E-06			Si-30	3.7376E-06
Ca	3.7514E-07	Ca-40	3.6367E-07	Ca	3.7139E-07	Ca-40	3.6003E-07
		Ca-42	2.4272E-09			Ca-42	2.4029E-09
		Ca-43	5.0644E-10			Ca-43	5.0137E-10

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Table 124 – *Continued from previous page*

11150				10464			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Ca-44	7.8255E-09			Ca-44	7.7472E-09
		Ca-46	1.5006E-11			Ca-46	1.4856E-11
		Ca-48	7.0152E-10			Ca-48	6.9450E-10
V	2.9514E-06	V-50	7.3785E-09	V	2.9219E-06	V-50	7.3047E-09
		V-51	2.9440E-06			V-51	2.9146E-06
Cr	1.0843E-06	Cr-50	4.7114E-08	Cr	1.7891E-06	Cr-50	7.7738E-08
		Cr-52	9.0856E-07			Cr-52	1.4991E-06
		Cr-53	1.0301E-07			Cr-53	1.6997E-07
		Cr-54	2.5644E-08			Cr-54	4.2313E-08
Mn	1.2315E-06	Mn-55	1.2315E-06	Mn	1.1515E-06	Mn-55	1.1515E-06
Fe	1.8173E-05	Fe-54	1.0722E-06	Fe	2.5321E-05	Fe-54	1.4939E-06
		Fe-56	1.6668E-05			Fe-56	2.3225E-05
		Fe-57	3.8164E-07			Fe-57	5.3174E-07
		Fe-58	5.0885E-08			Fe-58	7.0899E-08
Co	6.3780E-07	Co-59	6.3780E-07	Co	6.3141E-07	Co-59	6.3141E-07
Ni	3.8428E-06	Ni-58	2.6235E-06	Ni	4.4384E-06	Ni-58	3.0301E-06
		Ni-60	1.0030E-06			Ni-60	1.1584E-06
		Ni-61	4.3423E-08			Ni-61	5.0154E-08
		Ni-62	1.3796E-07			Ni-62	1.5934E-07
		Ni-64	3.4969E-08			Ni-64	4.0389E-08
Cu	7.0980E-07	Cu-63	4.9097E-07	Cu	8.7838E-07	Cu-63	6.0757E-07
		Cu-65	2.1883E-07			Cu-65	2.7080E-07
Mo	1.9591E-06	Mo-92	2.9073E-07	Mo	3.2325E-06	Mo-92	4.7970E-07
		Mo-94	1.8121E-07			Mo-94	2.9900E-07
		Mo-95	3.1189E-07			Mo-95	5.1461E-07
		Mo-96	3.2677E-07			Mo-96	5.3917E-07
		Mo-97	1.8709E-07			Mo-97	3.0870E-07
		Mo-98	4.7273E-07			Mo-98	7.7999E-07
		Mo-100	1.8866E-07			Mo-100	3.1129E-07
Sn	6.3326E-08	Sn-112	6.1426E-10	Sn	6.2693E-08	Sn-112	6.0812E-10
		Sn-114	4.1162E-10			Sn-114	4.0750E-10
		Sn-115	2.2797E-10			Sn-115	2.2569E-10
		Sn-116	9.2013E-09			Sn-116	9.1092E-09
		Sn-117	4.8635E-09			Sn-117	4.8148E-09
		Sn-118	1.5338E-08			Sn-118	1.5184E-08
		Sn-119	5.4334E-09			Sn-119	5.3790E-09
		Sn-120	2.0638E-08			Sn-120	2.0432E-08
		Sn-122	2.9320E-09			Sn-122	2.9027E-09
		Sn-124	3.6666E-09			Sn-124	3.6299E-09

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Table 124 – *Continued from previous page*

11150				10464			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Pb	3.6278E-08	Pb-204	5.0790E-10	Pb	1.1373E-07	Pb-204	1.5922E-09
		Pb-206	8.7431E-09			Pb-206	2.7409E-08
		Pb-207	8.0175E-09			Pb-207	2.5135E-08
		Pb-208	1.9010E-08			Pb-208	5.9595E-08
U-234			4.9717E-04	U-234			4.9096E-04
U-235			4.4715E-02	U-235			4.4257E-02
U-236			1.1171E-04	U-236			1.1031E-04
U-238			2.5850E-03	U-238			2.5527E-03
Total		**4.8335E-02**		**Total**		**4.8112E-02**	

Table 125. Atom Density of HEU 15/2.5 Plates [1/(b·cm)].

10467				10470			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0773E-07	Li-6	8.0795E-09	Li	1.0780E-07	Li-6	8.0852E-09
		Li-7	9.9647E-08			Li-7	9.9717E-08
Be	8.2967E-08	Be-9	8.2967E-08	Be	8.3026E-08	Be-9	8.3026E-08
B	5.1872E-07	B-10	1.0323E-07	B	5.1909E-07	B-10	1.0330E-07
		B-11	4.1550E-07			B-11	4.1579E-07
C	5.2604E-04	C-12	5.2025E-04	C	5.2641E-04	C-12	5.2062E-04
		C-13	5.7864E-06			C-13	5.7905E-06
Na	3.2524E-07	Na-23	3.2524E-07	Na	3.2547E-07	Na-23	3.2547E-07
Mg	3.0764E-07	Mg-24	2.4300E-07	Mg	3.0786E-07	Mg-24	2.4318E-07
		Mg-25	3.0764E-08			Mg-25	3.0786E-08
		Mg-26	3.3871E-08			Mg-26	3.3895E-08
Al	1.5242E-05	Al-27	1.5242E-05	Al	1.5253E-05	Al-27	1.5253E-05
Si	1.2113E-04	Si-28	1.1172E-04	Si	1.2122E-04	Si-28	1.1180E-04
		Si-29	5.6570E-06			Si-29	5.6610E-06
		Si-30	3.7552E-06			Si-30	3.7578E-06
Ca	3.7313E-07	Ca-40	3.6172E-07	Ca	3.7340E-07	Ca-40	3.6197E-07
		Ca-42	2.4142E-09			Ca-42	2.4159E-09
		Ca-43	5.0373E-10			Ca-43	5.0409E-10
		Ca-44	7.7835E-09			Ca-44	7.7890E-09
		Ca-46	1.4925E-11			Ca-46	1.4936E-11
		Ca-48	6.9776E-10			Ca-48	6.9825E-10
V	2.9356E-06	V-50	7.3390E-09	V	2.9377E-06	V-50	7.3442E-09

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Table 125 – *Continued from previous page*

10467				10470			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		V-51	2.9283E-06			V-51	2.9303E-06
Cr	1.7975E-06	Cr-50	7.8103E-08	Cr	1.7988E-06	Cr-50	7.8158E-08
		Cr-52	1.5062E-06			Cr-52	1.5072E-06
		Cr-53	1.7077E-07			Cr-53	1.7089E-07
		Cr-54	4.2512E-08			Cr-54	4.2542E-08
Mn	1.1569E-06	Mn-55	1.1569E-06	Mn	1.1577E-06	Mn-55	1.1577E-06
Fe	2.5440E-05	Fe-54	1.5010E-06	Fe	2.5458E-05	Fe-54	1.5020E-06
		Fe-56	2.3334E-05			Fe-56	2.3350E-05
		Fe-57	5.3424E-07			Fe-57	5.3462E-07
		Fe-58	7.1232E-08			Fe-58	7.1283E-08
Co	6.3438E-07	Co-59	6.3438E-07	Co	6.3483E-07	Co-59	6.3483E-07
Ni	4.4592E-06	Ni-58	3.0443E-06	Ni	4.4624E-06	Ni-58	3.0465E-06
		Ni-60	1.1639E-06			Ni-60	1.1647E-06
		Ni-61	5.0389E-08			Ni-61	5.0425E-08
		Ni-62	1.6009E-07			Ni-62	1.6020E-07
		Ni-64	4.0579E-08			Ni-64	4.0608E-08
Cu	8.8250E-07	Cu-63	6.1042E-07	Cu	8.8312E-07	Cu-63	6.1086E-07
		Cu-65	2.7207E-07			Cu-65	2.7227E-07
Mo	3.2476E-06	Mo-92	4.8195E-07	Mo	3.2499E-09	Mo-92	4.8229E-07
		Mo-94	3.0041E-07			Mo-94	3.0062E-07
		Mo-95	5.1702E-07			Mo-95	5.1739E-07
		Mo-96	5.4171E-07			Mo-96	5.4209E-07
		Mo-97	3.1015E-07			Mo-97	3.1037E-07
		Mo-98	7.8365E-07			Mo-98	7.8421E-07
		Mo-100	3.1275E-07			Mo-100	3.1297E-07
Sn	6.2987E-08	Sn-112	6.1097E-10	Sn	6.3032E-08	Sn-112	6.1141E-10
		Sn-114	4.0942E-10			Sn-114	4.0971E-10
		Sn-115	2.2675E-10			Sn-115	2.2691E-10
		Sn-116	9.1520E-09			Sn-116	9.1585E-09
		Sn-117	4.8374E-09			Sn-117	4.8408E-09
		Sn-118	1.5255E-08			Sn-118	1.5266E-08
		Sn-119	5.4043E-09			Sn-119	5.4081E-09
		Sn-120	2.0527E-08			Sn-120	2.0542E-08
		Sn-122	2.9163E-09			Sn-122	2.9184E-09
		Sn-124	3.6469E-09			Sn-124	3.6495E-09
Pb	1.1427E-07	Pb-204	1.5997E-09	Pb	1.1435E-07	Pb-204	1.6009E-09
		Pb-206	2.7538E-08			Pb-206	2.7558E-08
		Pb-207	2.5253E-08			Pb-207	2.5271E-08
		Pb-208	5.9875E-08			Pb-208	5.9918E-08

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Table 125 – *Continued from previous page*

10467				10470			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
U-234			4.9312E-04	U-234			4.9347E-04
U-235			4.4465E-02	U-235			4.4497E-02
U-236			1.1080E-04	U-236			1.1088E-04
U-238			2.5639E-03	U-238			2.5657E-03
Total		**4.8338E-02**		**Total**		**4.8372E-02**	

Table 126. Atom Density of HEU 15/2.5 Plates [1/(b·cm)].

10475				10487			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0771E-07	Li-6	8.0780E-09	Li	1.0786E-07	Li-6	8.0895E-09
		Li-7	9.9628E-08			Li-7	9.9771E-08
Be	8.2952E-08	Be-9	8.2952E-08	Be	8.3071E-08	Be-9	8.3071E-08
B	5.1863E-07	B-10	1.0321E-07	B	5.1937E-07	B-10	1.0335E-07
		B-11	4.1542E-07			B-11	4.1601E-07
C	5.2594E-04	C-12	5.2015E-04	C	5.2669E-04	C-12	5.2090E-04
		C-13	5.7853E-06			C-13	5.7936E-06
Na	3.2518E-07	Na-23	3.2518E-07	Na	3.2565E-07	Na-23	3.2565E-07
Mg	3.0758E-07	Mg-24	2.4296E-07	Mg	3.0802E-07	Mg-24	2.4331E-07
		Mg-25	3.0758E-08			Mg-25	3.0802E-08
		Mg-26	3.3865E-08			Mg-26	3.3913E-08
Al	1.5239E-05	Al-27	1.5239E-05	Al	1.5261E-05	Al-27	1.5261E-05
Si	1.2111E-04	Si-28	1.1170E-04	Si	1.2129E-04	Si-28	1.1186E-04
		Si-29	5.6560E-06			Si-29	5.6641E-06
		Si-30	3.7545E-06			Si-30	3.7599E-06
Ca	3.7306E-07	Ca-40	3.6165E-07	Ca	3.7360E-07	Ca-40	3.6217E-07
		Ca-42	2.4137E-09			Ca-42	2.4172E-09
		Ca-43	5.0364E-10			Ca-43	5.0436E-10
		Ca-44	7.7821E-09			Ca-44	7.7933E-09
		Ca-46	1.4923E-11			Ca-46	1.4944E-11
		Ca-48	6.9763E-10			Ca-48	6.9863E-10
V	2.9351E-06	V-50	7.3377E-09	V	2.9393E-06	V-50	7.3482E-09
		V-51	2.9277E-06			V-51	2.9319E-06
Cr	1.7972E-06	Cr-50	7.8089E-08	Cr	1.7998E-06	Cr-50	7.8201E-08
		Cr-52	1.5059E-06			Cr-52	1.5080E-06
		Cr-53	1.7073E-07			Cr-53	1.7098E-07

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Table 126 – *Continued from previous page*

10475				10487			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Cr-54	4.2504E-08			Cr-54	4.2565E-08
Mn	1.1567E-06	Mn-55	1.1567E-06	Mn	1.1583E-06	Mn-55	1.1583E-06
Fe	2.5435E-05	Fe-54	1.5007E-06	Fe	2.5472E-05	Fe-54	1.5028E-06
		Fe-56	2.3329E-05			Fe-56	2.3363E-05
		Fe-57	5.3414E-07			Fe-57	5.3491E-07
		Fe-58	7.1219E-08			Fe-58	7.1321E-08
Co	6.3426E-07	Co-59	6.3426E-07	Co	6.3517E-07	Co-59	6.3517E-07
Ni	4.4584E-06	Ni-58	3.0438E-06	Ni	4.4648E-06	Ni-58	3.0481E-06
		Ni-60	1.1636E-06			Ni-60	1.1653E-06
		Ni-61	5.0380E-08			Ni-61	5.0452E-08
		Ni-62	1.6006E-07			Ni-62	1.6029E-07
		Ni-64	4.0571E-08			Ni-64	4.0630E-08
Cu	8.8234E-07	Cu-63	6.1031E-07	Cu	8.8360E-07	Cu-63	6.1119E-07
		Cu-65	2.7202E-07			Cu-65	2.7241E-07
Mo	3.2470E-06	Mo-92	4.8186E-07	Mo	3.2517E-06	Mo-92	4.8255E-07
		Mo-94	3.0035E-07			Mo-94	3.0078E-07
		Mo-95	5.1693E-07			Mo-95	5.1767E-07
		Mo-96	5.4161E-07			Mo-96	5.4238E-07
		Mo-97	3.1009E-07			Mo-97	3.1054E-07
		Mo-98	7.8351E-07			Mo-98	7.8463E-07
		Mo-100	3.1269E-07			Mo-100	3.1314E-07
Sn	6.2975E-08	Sn-112	6.1086E-10	Sn	6.3066E-08	Sn-112	6.1174E-10
		Sn-114	4.0934E-10			Sn-114	4.0993E-10
		Sn-115	2.2671E-10			Sn-115	2.2704E-10
		Sn-116	9.1503E-09			Sn-116	9.1634E-09
		Sn-117	4.8365E-09			Sn-117	4.8434E-09
		Sn-118	1.5253E-08			Sn-118	1.5274E-08
		Sn-119	5.4033E-09			Sn-119	5.4110E-09
		Sn-120	2.0524E-08			Sn-120	2.0553E-08
		Sn-122	2.9158E-09			Sn-122	2.9199E-09
		Sn-124	3.6463E-09			Sn-124	3.6515E-09
Pb	1.1424E-07	Pb-204	1.5994E-09	Pb	1.1441E-07	Pb-204	1.6017E-09
		Pb-206	2.7533E-08			Pb-206	2.7572E-08
		Pb-207	2.5248E-08			Pb-207	2.5284E-08
		Pb-208	5.9864E-08			Pb-208	5.9950E-08
U-234			4.9308E-04	U-234			4.9448E-04
U-235			4.4457E-02	U-235			4.4516E-02
U-236			1.1079E-04	U-236			1.1110E-04
U-238			2.5637E-03	U-238			2.5710E-03

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Table 126 – *Continued from previous page*

10475				10487			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Total		**4.8329E-02**		**Total**		**4.8398E-02**	

Table 127. Atom Density of HEU 15/2.5 Plates [1/(b·cm)].

10489				10491			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0809E-07	Li-6	8.1069E-09	Li	1.0665E-07	Li-6	7.9987E-09
		Li-7	9.9985E-08			Li-7	9.8651E-08
Be	8.3249E-08	Be-9	8.3249E-08	Be	8.2138E-08	Be-9	8.2138E-08
B	5.2048E-07	B-10	1.0358E-07	B	5.1354E-07	B-10	1.0219E-07
		B-11	4.1691E-07			B-11	4.1134E-07
C	5.2782E-04	C-12	5.2201E-04	C	5.2078E-04	C-12	5.1505E-04
		C-13	5.8060E-06			C-13	5.7286E-06
Na	3.2634E-07	Na-23	3.2634E-07	Na	3.2199E-07	Na-23	3.2199E-07
Mg	3.0868E-07	Mg-24	2.4383E-07	Mg	3.0457E-07	Mg-24	2.4058E-07
		Mg-25	3.0868E-08			Mg-25	3.0457E-08
		Mg-26	3.3986E-08			Mg-26	3.3533E-08
Al	1.5294E-05	Al-27	1.5294E-05	Al	1.5089E-05	Al-27	1.5089E-05
Si	1.2155E-04	Si-28	1.1210E-04	Si	1.1992E-04	Si-28	1.1061E-04
		Si-29	5.6762E-06			Si-29	5.6005E-06
		Si-30	3.7679E-06			Si-30	3.7176E-06
Ca	3.7440E-07	Ca-40	3.6295E-07	Ca	3.6940E-07	Ca-40	3.5810E-07
		Ca-42	2.4224E-09			Ca-42	2.3900E-09
		Ca-43	5.0544E-10			Ca-43	4.9869E-10
		Ca-44	7.8100E-09			Ca-44	7.7057E-09
		Ca-46	1.4976E-11			Ca-46	1.4776E-11
		Ca-48	7.0013E-10			Ca-48	6.9078E-10
V	2.9456E-06	V-50	7.3639E-09	V	2.9063E-06	V-50	7.2657E-09
		V-51	2.9382E-06			V-51	2.8990E-06
Cr	1.8036E-06	Cr-50	7.8368E-08	Cr	1.7796E-06	Cr-50	7.7322E-08
		Cr-52	1.5113E-06			Cr-52	1.4911E-06
		Cr-53	1.7135E-07			Cr-53	1.6906E-07
		Cr-54	4.2656E-08			Cr-54	4.2087E-08
Mn	1.1608E-06	Mn-55	1.1608E-06	Mn	1.1453E-06	Mn-55	1.1453E-06
Fe	2.5526E-05	Fe-54	1.5061E-06	Fe	2.5186E-05	Fe-54	1.4860E-06
		Fe-56	2.3413E-05			Fe-56	2.3100E-05

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Table 127 – *Continued from previous page*

10489				10491			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Fe-57	5.3605E-07			Fe-57	5.2890E-07
		Fe-58	7.1474E-08			Fe-58	7.0520E-08
Co	6.3653E-07	Co-59	6.3653E-07	Co	6.2804E-07	Co-59	6.2804E-07
Ni	4.4744E-06	Ni-58	3.0546E-06	Ni	4.4147E-06	Ni-58	3.0139E-06
		Ni-60	1.1678E-06			Ni-60	1.1522E-06
		Ni-61	5.0560E-08			Ni-61	4.9886E-08
		Ni-62	1.6063E-07			Ni-62	1.549E-07
		Ni-64	4.0717E-08			Ni-64	4.0173E-08
Cu	8.8549E-07	Cu-63	6.1250E-07	Cu	8.7368E-07	Cu-63	6.0432e-07
		Cu-65	2.7300e-07			Cu-65	2.6936E-07
Mo	3.2587E-06	Mo-92	4.8358E-07	Mo	3.2152E-06	Mo-92	4.7713E-07
		Mo-94	3.0143E-07			Mo-94	2.9740E-07
		Mo-95	5.1878E-07			Mo-95	5.1186E-07
		Mo-96	5.4354E-07			Mo-96	5.3629E-07
		Mo-97	3.1120E-07			Mo-97	3.0705E-07
		Mo-98	7.8631E-07			Mo-98	7.7582E-07
		Mo-100	3.1381E-07			Mo-100	3.0962E-07
Sn	6.3201E-08	Sn-112	6.1305E-10	Sn	6.2358E-08	Sn-112	6.0487E-10
		Sn-114	4.1081E-10			Sn-114	4.0532E-10
		Sn-115	2.2752E-10			Sn-115	2.2449E-10
		Sn-116	9.1831e-09			Sn-116	9.0605E-09
		Sn-117	4.8538E-09			Sn-117	4.7891E-09
		Sn-118	1.5307E-08			Sn-118	1.5103E-08
		Sn-119	5.4226E-09			Sn-119	5.3503E-09
		Sn-120	2.0597e-08			Sn-120	2.0322E-08
		Sn-122	2.9262E-09			Sn-122	2.8872E-09
		Sn-124	3.6593E-09			Sn-124	3.6105E-09
Pb	1.1465E-07	Pb-204	1.6052E-09	Pb	1.1312E-07	Pb-204	1.5837E-09
		Pb-206	2.7632E-08			Pb-206	2.7263E-08
		Pb-207	2.5338E-08			Pb-207	2.5000E-08
		Pb-208	6.0078E-08			Pb-208	5.9277E-08
U-234			4.9489E-04	U-234			4.8839E-04
U-235			4.4616E-02	U-235			4.4020E-02
U-236			1.1120E-04	U-236			1.0973E-04
U-238			2.5731E-03	U-238			2.5393E-03
Total		**4.8502E-02**		**Total**		**4.7855E-02**	

Table 128. Atom Density of HEU 21/15 Plates [1/(b·cm)].

B-2444-01				B-2444-02			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0682E-07	Li-6	8.0111E-09	Li	1.0750E-07	Li-6	8.0623E-09
		Li-7	9.8804E-08			Li-7	9.9435E-08
Be	1.6453E-08	Be-9	1.6453E-08	Be	1.6558E-08	Be-9	1.6558E-08
B	4.1147E-07	B-10	8.1882E-08	B	4.1409E-07	B-10	8.2405E-08
		B-11	3.2959E-07			B-11	3.3169E-07
C	3.8888E-04	C-12	3.8460E-04	C	3.1681E-04	C-12	3.1333E-04
		C-13	4.2776E-06			C-13	3.4850E-06
Na	3.2249E-07	Na-23	3.2249E-07	Na	3.2455E-07	Na-23	3.2455E-07
Mg	3.0504E-07	Mg-24	2.4095E-07	Mg	3.0699E-07	Mg-24	2.4249E-07
		Mg-25	3.0504E-08			Mg-25	3.0699E-08
		Mg-26	3.3585E-08			Mg-26	3.3799E-08
Al	1.0304E-05	Al-27	1.0304E-05	Al	1.4518E-05	Al-27	1.4518E-05
Si	8.7113E-05	Si-28	8.0344E-05	Si	1.5940E-04	Si-28	1.4701E-04
		Si-29	4.0682E-06			Si-29	7.4439E-06
		Si-30	2.7005E-06			Si-30	4.9413E-06
P	1.1968E-05	P-31	1.1968E-05	P	1.2045E-05	P-31	1.2045E-05
K	9.4812E-07	K-39	8.8420E-07	K	9.5417E-07	K-39	8.8984E-07
		K-40	1.1093E-10			K-40	1.1164E-10
		K-41	6.3810E-08			K-41	6.4218E-08
Ca	9.2494E-07	Ca-40	8.9665E-07	Ca	9.3085E-07	Ca-40	9.0237E-07
		Ca-42	5.9844E-09			Ca-42	6.0226E-09
		Ca-43	1.2487E-09			Ca-43	1.2566E-09
		Ca-44	1.9294E-08			Ca-44	1.9417E-08
		Ca-46	3.6998E-11			Ca-46	3.7234E-11
		Ca-48	1.7296E-09			Ca-48	1.7407E-09
V	1.4554E-07	V-50	3.6385E-10	V	4.3940E-07	V-50	1.0985E-09
		V-51	1.4517E-07			V-51	4.3831E-07
Cr	1.4972E-06	Cr-50	6.5052E-08	Cr	2.7982E-06	Cr-50	1.2158E-07
		Cr-52	1.2545E-06			Cr-52	2.3446E-06
		Cr-53	1.4223E-07			Cr-53	2.6583E-07
		Cr-54	3.5408E-08			Cr-54	6.6177E-08
Mn	1.0121E-06	Mn-55	1.0121E-06	Mn	8.1488E-07	Mn-55	8.1488E-07
Fe	1.1949E-05	Fe-54	7.0497E-07	Fe	1.2025E-05	Fe-54	7.0947E-07
		Fe-56	1.0959E-05			Fe-56	1.1029E-05
		Fe-57	2.5092E-07			Fe-57	2.5252E-07
		Fe-58	3.3456E-08			Fe-58	3.3670E-08
Co	1.2580E-07	Co-59	1.2580E-07	Co	1.2661E-07	Co-59	1.2661E-07
Ni	4.7373E-06	Ni-58	3.2342E-06	Ni	4.7676E-06	Ni-58	3.2548E-06
		Ni-60	1.2364E-06			Ni-60	1.2443E-06

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Table 128 – *Continued from previous page*

B-2444-01				B-2444-02			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Ni-61	5.3532E-08			Ni-61	5.3874E-08
		Ni-62	1.7007E-07			Ni-62	1.7116E-07
		Ni-64	4.3110E-08			Ni-64	4.3385E-08
Cu	1.0500E-06	Cu-63	7.2632E-07	Cu	1.2329E-06	Cu-63	8.5278E-07
		Cu-65	3.2373E-07			Cu-65	3.8009E-07
Zn	2.2674E-06	Zn-64	1.1020E-06	Zn	2.2819E-06	Zn-64	1.1090E-06
		Zn-66	6.3260E-07			Zn-66	6.3664E-07
		Zn-67	9.2963E-08			Zn-67	9.3557E-08
		Zn-68	4.2627E-07			Zn-68	4.2899E-07
		Zn-70	1.3604E-08			Zn-70	1.3691E-08
Mo	6.9556E-06	Mo-92	1.0322E-06	Mo	1.4000E-05	Mo-92	2.0776E-06
		Mo-94	6.4339E-07			Mo-94	1.2950E-06
		Mo-95	1.1073E-06			Mo-95	2.2288E-06
		Mo-96	1.1602E-06			Mo-96	2.3352E-06
		Mo-97	6.6426E-07			Mo-97	1.3370E-06
		Mo-98	1.6784E-06			Mo-98	3.3782E-06
		Mo-100	6.6982E-07			Mo-100	1.3482E-06
Cd	1.3191E-08	Cd-106	1.6488E-10	Cd	1.3275E-08	Cd-106	1.6594E-10
		Cd-108	1.1740E-10			Cd-108	1.1815E-10
		Cd-110	1.6475E-09			Cd-110	1.6580E-09
		Cd-111	1.6884E-09			Cd-111	1.6992E-09
		Cd-112	3.1829E-09			Cd-112	3.2033E-09
		Cd-113	1.6119E-09			Cd-113	1.6222E-09
		Cd-114	3.7897E-09			Cd-114	3.8139E-09
		Cd-116	9.8799E-10			Cd-116	9.9430E-10
Sn	6.2454E-08	Sn-112	6.0581E-10	Sn	6.2853E-08	Sn-112	6.0967E-10
		Sn-114	4.0595E-10			Sn-114	4.0854E-10
		Sn-115	2.2484E-10			Sn-115	2.2627E-10
		Sn-116	9.0746E-09			Sn-116	9.1326E-09
		Sn-117	4.7965E-09			Sn-117	4.8271E-09
		Sn-118	1.5126E-08			Sn-118	1.5223E-08
		Sn-119	5.3586E-09			Sn-119	5.3928E-09
		Sn-120	2.0354E-08			Sn-120	2.0484E-08
		Sn-122	2.8916E-09			Sn-122	2.9101E-09
		Sn-124	3.6161E-09			Sn-124	3.6392E-09
Pb	3.5779E-08	Pb-204	5.0090E-10	Pb	3.6007E-08	Pb-204	5.0410E-10
		Pb-206	8.6227E-09			Pb-206	8.6777E-09
		Pb-207	7.9071E-09			Pb-207	7.9576E-09
		Pb-208	1.8748E-08			Pb-208	1.8868E-08

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Table 128 – *Continued from previous page*

B-2444-01				B-2444-02			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
U-234			4.7950E-04	U-234			4.8725E-04
U-235			4.4039E-02	U-235			4.4312E-02
U-236			2.0563E-04	U-236			2.0655E-04
U-238			2.5173E-03	U-238			2.5285E-03
Total		**4.7773E-02**		**Total**		**4.8079E-02**	

Table 129. Atom Density of HEU 21/15 Plates [1/(b·cm)].

B-2444-07				B-2444-10			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0652E-07	Li-6	7.9891E-09	Li	1.0626E-07	Li-6	7.9692E-09
		Li-7	9.8532E-08			Li-7	9.8287E-08
Be	1.6408E-08	Be-9	1.6408E-08	Be	1.6367E-08	Be-9	1.6367E-08
B	4.1033E-07	B-10	8.1656E-08	B	5.1164E-07	B-10	1.0182E-07
		B-11	3.2868E-07			B-11	4.0983E-07
C	3.8780E-04	C-12	3.8354E-04	C	4.6053E-04	C-12	4.5546E-04
		C-13	4.2658E-06			C-13	5.0658E-06
Na	3.2160E-07	Na-23	3.2160E-07	Na	3.2080E-07	Na-23	3.2080E-07
Mg	3.0420E-07	Mg-24	2.4029E-07	Mg	3.0344E-07	Mg-24	2.3969E-07
		Mg-25	3.0420E-08			Mg-25	3.0344E-08
		Mg-26	3.3492E-08			Mg-26	3.3409E-08
Al	1.4386E-05	Al-27	1.4386E-05	Al	1.0250E-05	Al-27	1.0250E-05
Si	7.8975E-05	Si-28	7.2839E-05	Si	1.3786E-04	Si-28	1.2715E-04
		Si-29	3.6881E-06			Si-29	6.4382E-06
		Si-30	2.4482E-06			Si-30	4.2738E-06
P	1.1935E-05	P-31	1.1935E-05	P	1.1906E-05	P-31	1.1906E-05
K	9.4551E-07	K-39	8.8176E-07	K	9.4316E-07	K-39	8.7957E-07
		K-40	1.1062E-10			K-40	1.1035E-10
		K-41	6.3634E-08			K-41	6.3477E-08
Ca	9.2239E-07	Ca-40	8.9418E-07	Ca	9.2010E-07	Ca-40	8.9196E-07
		Ca-42	5.9679E-09			Ca-42	5.9531E-09
		Ca-43	1.2452E-09			Ca-43	1.2421E-09
		Ca-44	1.9241E-08			Ca-44	1.9193E-08
		Ca-46	3.6896E-11			Ca-46	3.6804E-11
		Ca-48	1.7249E-09			Ca-48	1.7206E-09
V	1.4514E-07	V-50	3.6284E-10	V	1.4478E-07	V-50	3.6194E-10

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Table 129 – *Continued from previous page*

B-2444-07				B-2444-10			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		V-51	1.4477E-07			V-51	1.4442E-07
Cr	1.0665E-06	Cr-50	4.6337E-08	Cr	1.7021E-06	Cr-50	7.3956E-08
		Cr-52	8.9358E-07			Cr-52	1.4262E-06
		Cr-53	1.0131E-07			Cr-53	1.6170E-07
		Cr-54	2.5222E-08			Cr-54	4.0254E-08
Mn	8.0748E-07	Mn-55	8.0748E-07	Mn	1.2082E-06	Mn-55	1.2082E-06
Fe	1.2909E-05	Fe-54	7.6161E-07	Fe	4.4573E-05	Fe-54	2.6298E-06
		Fe-56	1.1840E-05			Fe-56	4.0882E-05
		Fe-57	2.7108E-07			Fe-57	9.3603E-07
		Fe-58	3.6144E-08			Fe-58	1.2480E-07
Co	1.2546E-07	Co-59	1.2546E-07	Co	1.8772E-07	Co-59	1.8772E-07
Ni	4.7243E-06	Ni-58	3.2253E-06	Ni	5.6551E-06	Ni-58	3.8607E-06
		Ni-60	1.2330E-06			Ni-60	1.4760E-06
		Ni-61	5.3384E-08			Ni-61	6.3902E-08
		Ni-62	1.6960E-07			Ni-62	2.0302E-07
		Ni-64	4.2991E-08			Ni-64	5.1461E-08
Cu	1.0472E-06	Cu-63	7.2431E-07	Cu	1.7409E-06	Cu-63	1.2042E-06
		Cu-65	3.2284E-07			Cu-65	5.3672E-07
Zn	2.2611E-06	Zn-64	1.0989E-06	Zn	2.2555E-06	Zn-64	1.0962E-06
		Zn-66	6.3086E-07			Zn-66	6.2929E-07
		Zn-67	9.2707E-08			Zn-67	9.2477E-08
		Zn-68	4.2510E-07			Zn-68	4.2404E-07
		Zn-70	1.3567E-08			Zn-70	1.3533E-08
Mo	9.2485E-06	Mo-92	1.3725E-06	Mo	9.8022E-06	Mo-92	1.4546E-06
		Mo-94	8.5549E-07			Mo-94	9.0670E-07
		Mo-95	1.4724E-06			Mo-95	1.5605E-06
		Mo-96	1.5427E-06			Mo-96	1.6350E-06
		Mo-97	8.8324E-07			Mo-97	9.3611E-07
		Mo-98	2.2317E-06			Mo-98	2.3653E-06
		Mo-100	8.9063E-07			Mo-100	9.4395E-07
Cd	1.3154E-08	Cd-106	1.6443E-10	Cd	1.3122E-08	Cd-106	1.6402E-10
		Cd-108	1.1707E-10			Cd-108	1.1678E-10
		Cd-110	1.6430E-09			Cd-110	1.6389E-09
		Cd-111	1.6838E-09			Cd-111	1.6796E-09
		Cd-112	3.1742E-09			Cd-112	3.1663E-09
		Cd-113	1.6075E-09			Cd-113	1.6035E-09
		Cd-114	3.7793E-09			Cd-114	3.7699E-09
		Cd-116	9.8526E-10			Cd-116	9.8282E-10
		Sn-112	6.0414E-10			Sn-112	6.0264E-10

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Sn 6.2282E-08 Sn 6.2128E-08

Table 129 – *Continued from previous page*

B-2444-07				**B-2444-10**			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Sn-114	4.0483E-10			Sn-114	4.0383E-10
		Sn-115	2.2422E-10			Sn-115	2.2366E-10
		Sn-116	9.0496E-09			Sn-116	9.0271E-09
		Sn-117	4.7833E-09			Sn-117	4.7714E-09
		Sn-118	1.5085E-08			Sn-118	1.5047E-08
		Sn-119	5.3438E-09			Sn-119	5.3306E-09
		Sn-120	2.0298E-08			Sn-120	2.0247E-08
		Sn-122	2.8837E-09			Sn-122	2.8765E-09
		Sn-124	3.6061E-09			Sn-124	3.5972E-09
Pb	3.5680E-08	Pb-204	4.9952E-10	Pb	3.5592E-08	Pb-204	4.9828E-10
		Pb-206	8.5989E-09			Pb-206	8.5776E-09
		Pb-207	7.8853E-09			Pb-207	7.8657E-09
		Pb-208	1.8696E-08			Pb-208	1.8650E-08
U-234			4.7817E-04	U-234			4.8151E-04
U-235			4.3922E-02	U-235			4.3795E-02
U-236			2.0471E-04	U-236			2.0377E-04
U-238			2.5060E-03	U-238			2.4945E-03
Total		**4.7639E-02**		**Total**		**4.7666E-02**	

Table 130. Atom Density of HEU 21/15 Plates [1/(b·cm)].

B-2444-19				**B-2444-20**			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0783E-07	Li-6	8.0872E-09	Li	1.0761E-07	Li-6	8.0706E-09
		Li-7	9.9742E-08			Li-7	9.9538E-08
Be	1.6609E-08	Be-9	1.6609E-08	Be	1.6575E-08	Be-9	1.6575E-08
B	4.1538E-07	B-10	8.2660E-08	B	4.1452E-07	B-10	8.2490E-08
		B-11	3.3272E-07			B-11	3.3203E-07
C	3.9257E-04	C-12	3.8825E-04	C	5.1302E-04	C-12	5.0738E-04
		C-13	4.3183E-06			C-13	5.6433E-06
Na	3.2555E-07	Na-23	3.2555E-07	Na	3.2488E-07	Na-23	3.2488E-07
Mg	3.0794E-07	Mg-24	2.4324E-07	Mg	3.0730E-07	Mg-24	2.4274E-07
		Mg-25	3.0794E-08			Mg-25	3.0730E-08
		Mg-26	3.3904E-08			Mg-26	3.3834E-08
Al	1.4563E-05	Al-27	1.4563E-05	Al	1.4533E-05	Al-27	1.4533E-05
Si	7.9946E-05	Si-28	7.3734E-05	Si	5.9836E-05	Si-28	5.5187E-05

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Table 130 – *Continued from previous page*

B-2444-19				B-2444-20			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Si-29	3.7335E-06			Si-29	2.7944E-06
		Si-30	2.4783E-06			Si-30	1.8549E-06
P	1.2082E-05	P-31	1.2082E-05	P	1.2057E-05	P-31	1.2057E-05
K	9.5712E-07	K-39	8.9260E-07	K	9.5516E-07	K-39	8.9077E-07
		K-40	1.1198E-10			K-40	1.1175E-10
		K-41	6.4416E-08			K-41	6.4284E-08
Ca	9.3373E-07	Ca-40	9.0516E-07	Ca	9.3181E-07	Ca-40	9.0331E-07
		Ca-42	6.0412E-09			Ca-42	6.0288E-09
		Ca-43	1.2605E-09			Ca-43	1.2579E-09
		Ca-44	1.9478E-08			Ca-44	1.9438E-08
		Ca-46	3.7349E-11			Ca-46	3.7272E-11
		Ca-48	1.7461E-09			Ca-48	1.7425E-09
V	1.4692E-07	V-50	3.6730E-10	V	1.4662E-07	V-50	3.6655E-10
		V-51	1.4655E-07			V-51	1.4625E-07
Cr	1.2955E-06	Cr-50	5.6288E-08	Cr	1.0773E-06	Cr-50	4.6811E-08
		Cr-52	1.0855E-06			Cr-52	9.0271E-07
		Cr-53	1.2307E-07			Cr-53	1.0235E-07
		Cr-54	3.0638E-08			Cr-54	2.5479E-08
Mn	1.2261E-06	Mn-55	1.2261E-06	Mn	6.1179E-07	Mn-55	6.1179E-07
Fe	1.5078E-05	Fe-54	8.8958E-07	Fe	1.2037E-05	Fe-54	7.1021E-07
		Fe-56	1.3829E-05			Fe-56	1.1041E-05
		Fe-57	3.1663E-07			Fe-57	2.5279E-07
		Fe-58	4.2217E-08			Fe-58	3.3705E-08
Co	1.9050E-07	Co-59	1.9050E-07	Co	1.9011E-07	Co-59	1.9011E-07
Ni	4.7823E-06	Ni-58	3.2649E-06	Ni	3.8180E-06	Ni-58	2.6066E-06
		Ni-60	1.2482E-06			Ni-60	9.9650E-07
		Ni-61	5.4040E-08			Ni-61	4.3144E-08
		Ni-62	1.7169E-07			Ni-62	1.3707E-07
		Ni-64	4.3519E-08			Ni-64	3.4744E-08
Cu	1.2367E-06	Cu-63	8.5542E-07	Cu	5.2892E-07	Cu-63	3.6586E-07
		Cu-65	3.8127E-07			Cu-65	1.6307E-07
Zn	2.2889E-06	Zn-64	1.1124E-06	Zn	2.2842E-06	Zn-64	1.1101E-06
		Zn-66	6.3861E-07			Zn-66	6.3730E-07
		Zn-67	9.3846E-08			Zn-67	9.3654E-08
		Zn-68	4.3032E-07			Zn-68	4.2944E-07
		Zn-70	1.3734E-08			Zn-70	1.3705E-08
Mo	1.1703E-05	Mo-92	1.7367E-06	Mo	4.6715E-06	Mo-92	6.9325E-07
		Mo-94	1.0825E-06			Mo-94	4.3211E-07
		Mo-95	1.8631E-06			Mo-95	7.4370E-07

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Table 130 – *Continued from previous page*

B-2444-19				B-2444-20			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Mo-96	1.9520E-06			Mo-96	7.7921E-07
		Mo-97	1.1176E-06			Mo-97	4.4613E-07
		Mo-98	2.8239E-06			Mo-98	1.1272E-06
		Mo-100	1.1270E-06			Mo-100	4.4986E-07
Cd	1.3316E-08	Cd-106	1.6645E-10	Cd	1.3289E-08	Cd-106	1.6611E-10
		Cd-108	1.1851E-10			Cd-108	1.1827E-10
		Cd-110	1.6632E-09			Cd-110	1.6598E-09
		Cd-111	1.7045E-09			Cd-111	1.7010E-09
		Cd-112	3.2132E-09			Cd-112	3.2066E-09
		Cd-113	1.6272E-09			Cd-113	1.6239E-09
		Cd-114	3.8257E-09			Cd-114	3.8179E-09
		Cd-116	9.9737E-10			Cd-116	9.9533E-10
Sn	6.3048E-08	Sn-112	6.1156E-10	Sn	6.2918E-08	Sn-112	6.1031E-10
		Sn-114	4.0981E-10			Sn-114	4.0897E-10
		Sn-115	2.2697E-10			Sn-115	2.2651E-10
		Sn-116	9.1608E-09			Sn-116	9.1420E-09
		Sn-117	4.8421E-09			Sn-117	4.8321E-09
		Sn-118	1.5270E-08			Sn-118	1.5239E-08
		Sn-119	5.4095E-09			Sn-119	5.3984E-09
		Sn-120	2.0547E-08			Sn-120	2.0505E-08
		Sn-122	2.9191E-09			Sn-122	2.9131E-09
		Sn-124	3.6505E-09			Sn-124	3.6430E-09
Pb	3.6119E-08	Pb-204	5.0566E-10	Pb	3.6045E-08	Pb-204	5.0462E-10
		Pb-206	8.7046E-09			Pb-206	8.6867E-09
		Pb-207	7.9822E-09			Pb-207	7.9658E-09
		Pb-208	1.8926E-08			Pb-208	1.8887E-08
U-234			4.8403E-04	U-234			4.8782E-04
U-235			4.4455E-02	U-235			4.4369E-02
U-236			2.0758E-04	U-236			2.0644E-04
U-238			2.5411E-03	U-238			2.5272E-03
Total		**4.8228E-02**		**Total**		**4.8219E-02**	

Table 131. Atom Density of HEU 21/15 Plates [1/(b·cm)].

B-2444-22				B-2444-24			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0927E-07	Li-6	8.1952R-09	Li	1.0673E-07	Li-6	8.0048E-09
		Li-7	1.0107E-07			Li-7	9.8726E-08
Be	1.6831E-08	Be-9	1.6831E-08	Be	1.6440E-08	Be-9	1.6440E-08
B	5.2615E-07	B-10	1.0470E-07	B	4.1114E-07	B-10	8.1818E-08
		B-11	4.2145E-07			B-11	3.2933E-07
C	4.2622E-04	C-12	4.2153E-04	C	3.7007E-04	C-12	3.6600E-04
		C-13	4.6885E-06			C-13	4.0707E-06
Na	3.2990E-07	Na-23	3.2990E-07	Na	3.2224E-07	Na-23	3.2224E-07
Mg	3.1205E-07	Mg-24	2.4648E-07	Mg	3.0480E-07	Mg-24	2.4076E-07
		Mg-25	3.1205E-08			Mg-25	3.0480E-08
		Mg-26	3.4356E-08			Mg-26	3.3558E-08
Al	1.4757E-05	Al-27	1.4757E-05	Al	1.2355E-05	Al-27	1.2355E-05
Si	1.4177E-04	Si-28	1.3076E-04	Si	9.8914E-05	Si-28	9.1229E-05
		Si-29	6.6208E-06			Si-29	4.6193E-06
		Si-30	4.3949E-06			Si-30	3.0663E-06
P	1.2243E-05	P-31	1.2243E-05	P	1.1959E-05	P-31	1.1959E-05
K	9.6990E-07	K-39	9.0451E-07	K	9.4737E-07	K-39	8.8350E-07
		K-40	1.1348E-10			K-40	1.1084E-10
		K-41	6.5276E-08			K-41	6.3760E-08
Ca	1.4193E-06	Ca-40	1.3759E-06	Ca	9.2421E-07	Ca-40	8.9594E-07
		Ca-42	9.1828E-09			Ca-42	5.9797E-09
		Ca-43	1.9160E-09			Ca-43	1.2477E-09
		Ca-44	2.9606E-08			Ca-44	1.9279E-08
		Ca-46	5.6771E-11			Ca-46	3.6969E-11
		Ca-48	2.6541E-09			Ca-48	1.7283E-09
V	1.4888E-07	V-50	3.7220E-10	V	1.4542E-07	V-50	3.6356E-10
		V-51	1.4851E-07			V-51	1.4506E-07
Cr	1.3128E-06	Cr-50	5.7039E-08	Cr	1.0686E-06	Cr-50	4.6429E-08
		Cr-52	1.1000E-06			Cr-52	8.9535E-07
		Cr-53	1.2471E-07			Cr-53	1.0151E-07
		Cr-54	3.1047E-08			Cr-54	2.5271E-08
Mn	1.0354E-06	Mn-55	1.0354E-06	Mn	1.0113E-06	Mn-55	1.0113E-06
Fe	1.6297E-05	Fe-54	9.6155E-07	Fe	1.4924E-05	Fe-54	8.8052E-07
		Fe-56	1.4948E-05			Fe-56	1.3688E-05
		Fe-57	3.4225E-07			Fe-57	3.1341E-07
		Fe-58	4.5633E-08			Fe-58	4.1787E-08
Co	1.9304E-07	Co-59	1.9304E-07	Co	1.2570E-07	Co-59	1.2570E-07
Ni	4.8462E-06	Ni-58	3.3085E-06	Ni	4.7336E-06	Ni-58	3.2316E-06
		Ni-60	1.2648E-06			Ni-60	1.2355E-06

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Table 131 – *Continued from previous page*

B-2444-22				B-2444-24			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Ni-61	5.4762E-08			Ni-61	5.3490E-08
		Ni-62	1.7398E-07			Ni-62	1.6994E-07
		Ni-64	4.4100E-08			Ni-64	4.3076E-08
Cu	1.2532E-06	Cu-63	8.6683E-07	Cu	1.0492E-06	Cu-63	7.2574E-07
		Cu-65	3.8636E-07			Cu-65	3.2347E-07
Zn	2.3195E-06	Zn-64	1.1273E-06	Zn	2.2656E-06	Zn-64	1.1011E-06
		Zn-66	6.4713E-07			Zn-66	6.3211E-07
		Zn-67	9.5099E-08			Zn-67	9.2890E-08
		Zn-68	4.3606E-07			Zn-68	4.2594E-07
		Zn-70	1.3917E-08			Zn-70	1.3594E-08
Mo	9.4871E-06	Mo-92	1.4079E-06	Mo	8.6876E-06	Mo-92	1.2892E-06
		Mo-94	8.7756E-07			Mo-94	8.0361E-07
		Mo-95	1.5104E-06			Mo-95	1.3831E-06
		Mo-96	1.5825E-06			Mo-96	1.4491E-06
		Mo-97	9.0602E-07			Mo-97	8.2967E-07
		Mo-98	2.2892E-06			Mo-98	2.0963E-06
		Mo-100	9.1361E-07			Mo-100	8.3662E-07
Cd	1.3494E-08	Cd-106	1.6867E-10	Cd	1.3180E-08	Cd-106	1.6475E-10
		Cd-108	1.2009E-10			Cd-108	1.1731E-10
		Cd-110	1.6854E-09			Cd-110	1.6462E-09
		Cd-111	1.7272E-09			Cd-111	1.6871E-09
		Cd-112	3.2560E-09			Cd-112	3.1804E-09
		Cd-113	1.6489E-09			Cd-113	1.6106E-09
		Cd-114	3.8768E-09			Cd-114	3.7867E-09
		Cd-116	1.0107E-09			Cd-116	9.8721E-10
Sn	6.3889E-08	Sn-112	6.1972E-10	Sn	6.2405E-08	Sn-112	6.0533E-10
		Sn-114	4.1528E-10			Sn-114	4.0563E-10
		Sn-115	2.300E-10			Sn-115	2.2466E-10
		Sn-116	9.2831E-09			Sn-116	9.0675E-09
		Sn-117	4.9067E-09			Sn-117	4.7927E-09
		Sn-118	1.5474E-08			Sn-118	1.5115E-08
		Sn-119	5.4817E-09			Sn-119	5.3544E-09
		Sn-120	2.0821E-08			Sn-120	2.0338E-08
		Sn-122	2.9581e-09			Sn-122	2.8894E-09
		Sn-124	3.6992E-09			Sn-124	3.6133E-09
Pb	3.6601E-08	Pb-204	5.1241E-10	Pb	3.5751E-08	Pb-204	5.0051E-10
		Pb-206	8.8208E-09			Pb-206	8.6159E-09
		Pb-207	8.0887E-09			Pb-207	7.9009E-09
		Pb-208	1.9179E-08			Pb-208	1.8733E-08

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Table 131 – *Continued from previous page*

B-2444-22				B-2444-24			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
U-234			4.8555E-04	U-234			4.6961E-04
U-235			4.5046E-02	U-235			4.4012E-02
U-236			2.1031E-04	U-236			2.0546E-04
U-238			2.5745E-03	U-238			2.5152E-03
Total		**4.8952E-02**		**Total**		**4.7733E-02**	

Table 132. Atom Density of HEU 21/15 Plates [1/(b·cm)].

B-2444-27				B-2444-29			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0751E-07	Li-6	8.0629E-09	Li	1.0622E-07	Li-6	7.9665E-09
		Li-7	9.9443E-08			Li-7	9.8253E-08
Be	1.6560E-08	Be-9	1.6560E-08	Be	1.6362E-08	Be-9	1.6362E-08
B	4.1413E-07	B-10	8.2411E-08	B	2.0459E-07	B-10	4.0713E-08
		B-11	3.3172E-07			B-11	1.6387E-07
C	5.1253E-04	C-12	5.0690E-04	C	3.4067E-04	C-12	3.3692E-04
		C-13	5.6379E-06			C-13	3.7474E-06
Na	3.2457E-07	Na-23	3.2457E-07	Na	4.8104E-07	Na-23	4.8104E-07
Mg	3.0701E-07	Mg-24	2.4251E-07	Mg	3.0334E-07	Mg-24	2.3961E-07
		Mg-25	3.0701e-08			Mg-25	3.0334E-08
		Mg-26	3.3802E-08			Mg-26	3.3398E-08
Al	1.2445E-05	Al-27	1.2445E-05	Al	8.1975E-06	Al-27	8.1975E-06
Si	7.1735E-05	Si-28	6.6161E-05	Si	6.3002E-05	Si-28	5.8107E-05
		Si-29	3.3500E-06			Si-29	2.9422E-06
		Si-30	2.2238E-06			Si-30	1.9531E-06
P	1.2045E-05	P-31	1.2045E-05	P	1.1901E-05	P-31	1.1901E-05
K	9.5425E-07	K-39	8.8991E-07	K	9.4284E-07	K-39	8.7927E-07
		K-40	1.1165E-10			K-40	1.1031E-10
		K-41	6.4223E-08			K-41	6.3455E-08
Ca	9.3092E-07	Ca-40	9.0244E-07	Ca	9.1979E-07	Ca-40	8.9165E-07
		Ca-42	6.0230E-09			Ca-42	5.9510E-09
		Ca-43	1.2567E-09			Ca-43	1.2417E-09
		Ca-44	1.9419E-08			Ca-44	1.9187E-08
		Ca-46	3.7237E-11			Ca-46	3.6792E-11
		Ca-48	1.7408E-09			Ca-48	1.7200E-09
V	1.4648E-07	V-50	3.6620E-10	V	2.1709E-07	V-50	5.4273E-10

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Table 132 – *Continued from previous page*

B-2444-27				B-2444-29			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		V-51	1.4611E-07			V-51	2.1655E-07
Cr	1.0763E-06	Cr-50	4.6766E-08	Cr	2.7650E-06	Cr-50	1.2014E-07
		Cr-52	9.0184E-07			Cr-52	2.3168E-06
		Cr-53	1.0225E-07			Cr-53	2.6267E-07
		Cr-54	2.5455E-08			Cr-54	6.5391E-08
Mn	1.2224E-06	Mn-55	1.2224E-06	Mn	1.0065E-06	Mn-55	1.0065E-06
Fe	1.4030E-05	Fe-54	8.2778E-07	Fe	1.6833E-05	Fe-54	9.9314E-07
		Fe-56	1.2868E-05			Fe-56	1.5439E-05
		Fe-57	2.9463E-07			Fe-57	3.5349E-07
		Fe-58	3.9284E-08			Fe-58	4.7132E-08
Co	1.2662E-07	Co-59	1.2662E-07	Co	1.8765E-07	Co-59	1.8765E-07
Ni	2.8608E-06	Ni-58	1.9530E-06	Ni	7.5375E-06	Ni-58	5.1458E-06
		Ni-60	7.4666E-07			Ni-60	1.9673E-06
		Ni-61	3.2327E-08			Ni-61	8.5174E-08
		Ni-62	1.0270E-07			Ni-62	2.7060E-07
		Ni-64	2.6033E-08			Ni-64	6.8591E-08
Cu	8.8069E-07	Cu-63	6.0917E-07	Cu	1.2182E-06	Cu-63	8.4265E-07
		Cu-65	2.7152E-07			Cu-65	3.7558E-07
Zn	2.2820E-06	Zn-64	1.1091E-06	Zn	2.2548E-06	Zn-64	1.0958E-06
		Zn-66	6.3669E-07			Zn-66	6.2908E-07
		Zn-67	9.3564E-08			Zn-67	9.2445E-08
		Zn-68	4.2903E-07			Zn-68	4.2390E-07
		Zn-70	1.3692E-08			Zn-70	1.3529E-08
Mo	4.0836E-06	Mo-92	6.0601E-07	Mo	8.0696E-06	Mo-92	1.1975E-06
		Mo-94	3.7774E-07			Mo-94	7.4644E-07
		Mo-95	6.5012E-07			Mo-95	1.2847E-06
		Mo-96	6.8115E-07			Mo-96	1.3460E-06
		Mo-97	3.8999E-07			Mo-97	7.7065E-07
		Mo-98	9.8538E-07			Mo-98	1.9472E-06
		Mo-100	3.9325E-07			Mo-100	7.7710E-07
Cd	1.3276E-08	Cd-106	1.6595E-10	Cd	1.3117E-08	Cd-106	1.6397E-10
		Cd-108	1.1816E-10			Cd-108	1.1674E-10
		Cd-110	1.6582E-09			Cd-110	1.6383E-09
		Cd-111	1.6993E-09			Cd-111	1.6790E-09
		Cd-112	3.2035E-09			Cd-112	3.1652E-09
		Cd-113	1.6223E-09			Cd-113	1.6029E-09
		Cd-114	3.8142E-09			Cd-114	3.7686E-09
		Cd-116	9.9437E-10			Cd-116	9.8248E-10
		Sn-112	6.0972E-10			Sn-112	6.0243E-10

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Sn 6.2858E-08 Sn 6.2106E-08

Table 132 – *Continued from previous page*

B-2444-27				B-2444-29			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Sn-114	4.0858E-10			Sn-114	4.0369E-10
		Sn-115	2.2629E-10			Sn-115	2.2358E-10
		Sn-116	9.1333E-09			Sn-116	9.0241E-09
		Sn-117	4.8275E-09			Sn-117	4.7698E-09
		Sn-118	1.5224E-08			Sn-118	1.5042E-08
		Sn-119	5.3932E-09			Sn-119	5.3287E-09
		Sn-120	2.0485E-08			Sn-120	2.0240E-08
		Sn-122	2.9103E-09			Sn-122	2.8755E-09
		Sn-124	3.6395E-09			Sn-124	3.5960E-09
Pb	3.6010E-08	Pb-204	5.0414E-10	Pb	3.5579E-08	Pb-204	4.9811E-10
		Pb-206	8.6784E-09			Pb-206	8.5746E-09
		Pb-207	7.9582E-09			Pb-207	7.8631E-09
		Pb-208	1.8869E-08			Pb-208	1.8644E-08
U-234			4.8256E-04	U-234			4.8157E-04
U-235			4.4335E-02	U-235			4.3796E-02
U-236			2.0588E-04	U-236			2.0415E-04
U-238			2.5203E-03	U-238			2.4991E-03
Total		**4.8182E-02**		**Total**		**4.7448E-02**	

Table 133. Atom Density of HEU 21/15 Plates [1/(b·cm)].

B-2444-31				B-2444-33			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0718E-07	Li-6	8.0382E-09	Li	1.0772E-07	Li-6	8.0789E-09
		Li-7	9.9138E-08			Li-7	9.9640E-08
Be	1.6509E-08	Be-9	1.6509E-08	Be	1.6592E-08	Be-9	1.6592E-08
B	3.0964E-07	B-10	6.1619E-08	B	1.0374E-07	B-10	2.0644E-08
		B-11	2.4802E-07			B-11	8.3094E-08
C	3.9019E-04	C-12	3.8590E-04	C	3.5482E-04	C-12	3.5092E-04
		C-13	4.2921E-06			C-13	3.9030E-06
Na	3.2358E-07	Na-23	3.2358E-07	Na	3.2522E-07	Na-23	3.2522E-07
Mg	3.0607E-07	Mg-24	2.4176E-07	Mg	3.0762E-07	Mg-24	2.4299E-07
		Mg-25	3.0607E-08			Mg-25	3.0762E-08
		Mg-26	3.3698E-08			Mg-26	3.3869E-08
Al	8.2712E-06	Al-27	8.2712E-06	Al	4.1566E-06	Al-27	4.1566E-06
Si	6.3569E-05	Si-28	5.8629E-05	Si	1.9966E-05	Si-28	1.8415E-05

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Table 133 – *Continued from previous page*

B-2444-31				B-2444-33			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Si-29	2.9687E-06			Si-29	9.3241E-07
		Si-30	1.9706E-06			Si-30	6.1895E-07
P	1.2009E-05	P-31	1.2009E-05	P	1.2069E-05	P-31	1.2069E-05
K	9.5132E-07	K-39	8.8718E-07	K	9.5614E-07	K-39	8.9168E-07
		K-40	1.1130E-10			K-40	1.1187E-10
		K-41	6.4026E-08			K-41	6.4350E-08
Ca	9.2806E-07	Ca-40	8.9967E-07	Ca	9.3277E-07	Ca-40	9.0424E-07
		Ca-42	6.0046E-09			Ca-42	6.0350E-09
		Ca-43	1.2529E-09			Ca-43	1.2592E-09
		Ca-44	1.9359E-08			Ca-44	1.9458E-08
		Ca-46	3.7123E-11			Ca-46	3.7311E-11
		Ca-48	1.7355E-09			Ca-48	1.7443E-09
V	1.4603E-07	V-50	3.6508E-10	V	1.4677E-07	V-50	3.6693E-10
		V-51	1.4567E-07			V-51	1.4640E-07
Cr	1.0730E-06	Cr-50	4.6622E-08	Cr	1.9412E-06	Cr-50	8.4346E-08
		Cr-52	8.9908E-07			Cr-52	1.6265E-06
		Cr-53	1.0194E-07			Cr-53	1.8442E-07
		Cr-54	2.5377E-08			Cr-54	4.5910E-08
Mn	8.1244E-07	Mn-55	8.1244E-07	Mn	6.1242E-07	Mn-55	6.1242E-07
Fe	1.3987E-05	Fe-54	8.2524E-07	Fe	9.0373E-06	Fe-54	5.3320E-07
		Fe-56	1.2829E-05			Fe-56	8.2890E-06
		Fe-57	2.9373E-07			Fe-57	1.8978E-07
		Fe-58	3.9164E-08			Fe-58	2.5305E-08
Co	1.2623E-07	Co-59	1.2623E-07	Co	1.2687E-07	Co-59	1.2687E-07
Ni	3.8027E-06	Ni-58	2.5961E-06	Ni	5.7329E-06	Ni-58	3.9139E-06
		Ni-60	9.9249E-07			Ni-60	1.4963E-06
		Ni-61	4.2970E-08			Ni-61	6.4782E-08
		Ni-62	1.3652E-07			Ni-62	2.0581E-07
		Ni-64	3.4604E-08			Ni-64	5.2170E-08
Cu	8.7799E-07	Cu-63	6.0731E-07	Cu	7.0595E-07	Cu-63	4.8831E-07
		Cu-65	2.7068E-07			Cu-65	2.1765E-07
Zn	2.2751E-06	Zn-64	1.1057E-06	Zn	2.2866E-06	Zn-64	1.1113E-06
		Zn-66	6.3474E-07			Zn-66	6.3796E-07
		Zn-67	9.3277E-08			Zn-67	9.3750E-08
		Zn-68	4.2771E-07			Zn-68	4.2988E-07
		Zn-70	1.3650E-08			Zn-70	1.3720E-08
Mo	8.1422E-06	Mo-92	1.2083E-06	Mo	9.3526E-06	Mo-92	1.3879E-06
		Mo-94	7.5316E-07			Mo-94	8.6512E-07
		Mo-95	1.2962E-06			Mo-95	1.4889E-06

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Table 133 – *Continued from previous page*

B-2444-31				B-2444-33			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Mo-96	1.3581E-06			Mo-96	1.5600E-06
		Mo-97	7.7758E-07			Mo-97	8.9317E-07
		Mo-98	1.9647E-06			Mo-98	2.2568E-06
		Mo-100	7.8410E-07			Mo-100	9.0066E-07
Cd	1.3235E-08	Cd-106	1.6544E-10	Cd	1.3302E-08	Cd-106	1.6628E-10
		Cd-108	1.1779E-10			Cd-108	1.1839E-10
		Cd-110	1.6531E-09			Cd-110	1.6615E-09
		Cd-111	1.6941E-09			Cd-111	1.7027E-09
		Cd-112	3.1937E-09			Cd-112	3.2099E-09
		Cd-113	1.6174E-09			Cd-113	1.6256E-09
		Cd-114	3.8025E-09			Cd-114	3.8218E-09
		Cd-116	9.9132E-10			Cd-116	9.9635E-10
Sn	6.2665E-08	Sn-112	6.0785E-10	Sn	6.2983E-08	Sn-112	6.1094E-10
		Sn-114	4.0732E-10			Sn-114	4.0939E-10
		Sn-115	2.2559E-10			Sn-115	2.2674E-10
		Sn-116	9.1053E-09			Sn-116	9.1514E-09
		Sn-117	4.8127E-09			Sn-117	4.8371E-09
		Sn-118	1.5178E-08			Sn-118	1.5254E-08
		Sn-119	5.3767E-09			Sn-119	5.4039E-09
		Sn-120	2.0423E-08			Sn-120	2.0526E-08
		Sn-122	2.9014E-09			Sn-122	2.9161E-09
		Sn-124	3.6283E-09			Sn-124	3.6467E-09
Pb	3.5900E-08	Pb-204	5.0259E-10	Pb	3.6082E-08	Pb-204	5.0514E-10
		Pb-206	8.6518E-09			Pb-206	8.6957E-09
		Pb-207	7.9338E-09			Pb-207	7.9740E-09
		Pb-208	1.8811E-08			Pb-208	1.8907E-08
U-234			4.8114E-04	U-234			4.9324E-04
U-235			4.4195E-02	U-235			4.4388E-02
U-236			2.0598E-04	U-236			2.0920E-04
U-238			2.5216E-03	U-238			2.5609E-03
Total		**4.7912E-02**		**Total**		**4.8075E-02**	

Table 134. Atom Density of HEU 21/15 Plates [1/(b·cm)].

B-2444-36				B-2444-37			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Li	1.0706E-07	Li-6	8.0293E-09	Li	1.0755E-07	Li-6	8.0661E-09
		Li-7	9.9028E-08			Li-7	9.9481E-08
Be	1.6491E-08	Be-9	1.6491E-08	Be	1.6566E-08	Be-9	1.6566E-08
B	1.0310E-07	B-10	2.0517E-08	B	1.0357E-07	B-10	2.0611E-08
		B-11	8.2583E-08			B-11	8.2961E-08
C	3.0624E-04	C-12	3.0287E-04	C	2.7967E-04	C-12	2.7660E-04
		C-13	3.3686E-06			C-13	3.0764E-06
Na	3.2322E-07	Na-23	3.2322E-07	Na	3.2470E-07	Na-23	3.2470E-07
Mg	3.0573E-07	Mg-24	2.4150E-07	Mg	3.0713E-07	Mg-24	2.4260E-07
		Mg-25	3.0573E-08			Mg-25	3.0713E-08
		Mg-26	3.3661E-08			Mg-26	3.3815E-08
Al	4.1310E-06	Al-27	4.1310E-06	Al	4.1500E-06	Al-27	4.1500E-06
Si	3.9687E-05	Si-28	3.6603E-05	Si	1.9934E-05	Si-28	1.8385E-05
		Si-29	1.8534E-06			Si-29	9.3092E-07
		Si-30	1.2303E-06			Si-30	6.1796E-07
P	1.1995E-05	P-31	1.1995E-05	P	1.2050E-05	P-31	1.2050E-05
K	9.5027E-07	K-39	8.8620E-07	K	9.5462E-07	K-39	8.9026E-07
		K-40	1.1118E-10			K-40	1.1169E-10
		K-41	6.3955E-08			K-41	6.4248E-08
Ca	9.2704E-07	Ca-40	8.9868E-07	Ca	9.3128E-07	Ca-40	9.0279E-07
		Ca-42	5.9980E-09			Ca-42	6.0254E-09
		Ca-43	1.2515E-09			Ca-43	1.2572E-09
		Ca-44	1.9338E-08			Ca-44	1.9427E-08
		Ca-46	3.7082E-11			Ca-46	3.7251E-11
		Ca-48	1.7336E-09			Ca-48	1.7415E-09
V	1.4587E-07	V-50	3.6467E-10	V	1.4654E-07	V-50	3.6634E-10
		V-51	1.4550E-07			V-51	1.4617E-07
Cr	1.7149E-06	Cr-50	7.4514E-08	Cr	1.0767E-05	Cr-50	4.6784E-07
		Cr-52	1.4369E-06			Cr-52	9.0219E-06
		Cr-53	1.6292E-07			Cr-53	1.0229E-06
		Cr-54	4.0558E-08			Cr-54	2.5465E-07
Mn	6.0866E-07	Mn-55	6.0866E-07	Mn	1.6305E-06	Mn-55	1.6305E-06
Fe	9.9798E-06	Fe-54	5.8881E-07	Fe	4.3109E-05	Fe-54	2.5435E-06
		Fe-56	9.1535E-06			Fe-56	3.9540E-05
		Fe-57	2.0958E-07			Fe-57	9.0530E-07
		Fe-58	2.7943E-08			Fe-58	1.2071E-07
Co	1.2609E-07	Co-59	1.2609E-07	Co	1.2667E-07	Co-59	1.2667E-07
Ni	5.6977E-06	Ni-58	3.8898E-06	Ni	9.5396E-06	Ni-58	6.5127E-06
		Ni-60	1.4871E-06			Ni-60	2.4898E-06

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Table 134 – *Continued from previous page*

B-2444-36				B-2444-37			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Ni-61	6.4384E-08			Ni-61	1.0780E-07
		Ni-62	2.0455E-07			Ni-62	3.4247E-07
		Ni-64	5.1849E-08			Ni-64	8.6810E-08
Cu	5.2621E-07	Cu-63	3.6398E-07	Cu	5.2862E-07	Cu-63	3.6565E-07
		Cu-65	1.6223E-07			Cu-65	1.6297E-07
Zn	2.2725E-06	Zn-64	1.1045E-06	Zn	2.2829E-06	Zn-64	1.1095E-06
		Zn-66	6.3404E-07			Zn-66	6.3694E-07
		Zn-67	9.3174E-08			Zn-67	9.3601E-08
		Zn-68	4.2724E-07			Zn-68	4.2919E-07
		Zn-70	1.3635E-08			Zn-70	1.3698E-08
Mo	5.8095E-06	Mo-92	8.6212E-07	Mo	5.8360E-06	Mo-92	8.6607E-07
		Mo-94	5.3738E-07			Mo-94	5.3983E-07
		Mo-95	9.2487E-07			Mo-95	9.2910E-07
		Mo-96	9.6902E-07			Mo-96	9.7345E-07
		Mo-97	5.5480E-07			Mo-97	5.5734E-07
		Mo-98	1.4018E-06			Mo-98	1.4082E-06
		Mo-100	5.5945E-07			Mo-100	5.6201E-07
Cd	1.3221E-08	Cd-106	1.6526E-10	Cd	1.3281E-08	Cd-106	1.6601E-10
		Cd-108	1.1766E-10			Cd-108	1.1820E-10
		Cd-110	1.6513E-09			Cd-110	1.6588E-09
		Cd-111	1.6922E-09			Cd-111	1.7000E-09
		Cd-112	3.1902E-09			Cd-112	3.2047E-09
		Cd-113	1.6156E-09			Cd-113	1.6230E-09
		Cd-114	3.7983E-09			Cd-114	3.8157E-09
		Cd-116	9.9023E-10			Cd-116	9.9476E-10
Sn	6.2596E-08	Sn-112	6.0718E-10	Sn	6.2882E-08	Sn-112	6.0996E-10
		Sn-114	4.0687E-10			Sn-114	4.0874E-10
		Sn-115	2.2535E-10			Sn-115	2.2638E-10
		Sn-116	9.0952E-09			Sn-116	9.1368E-09
		Sn-117	4.8074E-09			Sn-117	4.8294E-09
		Sn-118	1.5161E-08			Sn-118	1.5230E-08
		Sn-119	5.3707E-09			Sn-119	5.3953E-09
		Sn-120	2.0400E-08			Sn-120	2.0493E-08
		Sn-122	2.8982E-09			Sn-122	2.9115E-09
		Sn-124	3.6243E-09			Sn-124	3.6409E-09
Pb	3.5860E-08	Pb-204	5.0204E-10	Pb	3.6024E-08	Pb-204	5.0434E-10
		Pb-206	8.6423E-09			Pb-206	8.6818E-09
		Pb-207	7.9251E-09			Pb-207	7.9613E-09
		Pb-208	1.8791E-08			Pb-208	1.8877E-08

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Table 134 – *Continued from previous page*

B-2444-36				B-2444-37			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		U-234	4.9498E-04			U-234	4.9239E-04
		U-235	4.4150E-02			U-235	4.4326E-02
		U-236	2.0509E-04			U-236	2.0777E-04
		U-238	2.5106E-03			U-238	2.5435E-03
Total		**4.7752E-02**		**Total**		**4.7962E-02**	

3.3.1.2 Copper Interstitial

The benchmark model uses the average density for the Cu interstitial plates, rather than each piece having its own density. Therefore, the average density of the Cu interstitial plates present in each configuration was the total mass divided by the total volume. Chemical analysis was performed on two separate plates (see Table 21), an average of the two analysis results was used as the impurity composition for the benchmark model. Table 135 shows the average mass density for each configuration, while Table 136 and Table 137 show the composition in atom density.

Table 135. Cu Interstitial Mass Densities [g/cm^3].

Config.	**Mass Density**
$^3/_{16}$	8.8994
$^5/_{16}$	8.9062
$^7/_{16}$	8.9105

Table 136. Atom Density of Cu Interstitial Plates for the 3/16 and 5/16 Configuration [1/(b·cm)].

3/16 Configuration				**5/16 Configuration**			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
O	5.0246E-05	O-16	5.0125E-05	O	5.0284E-05	O-16	5.0163E-05
		O-17	2.0098E-08			O-17	2.0114E-08
		O-18	1.0049E-07			O-18	1.0057E-07
Fe	5.7582E-06	Fe-54	3.3973E-07	Fe	5.7625E-06	Fe-54	3.3999E-07
		Fe-56	5.2814E-06			Fe-56	5.2854E-06
		Fe-57	1.2092E-07			Fe-57	1.2101E-07
		Fe-58	1.6123E-08			Fe-58	1.6135E-08
Ni	4.5659E-07	Ni-58	3.1172E-07	Ni	4.5694E-07	Ni-58	3.1195E-07
		Ni-60	1.1917E-07			Ni-60	1.1926E-07
		Ni-61	5.1595E-09			Ni-61	5.1634E-09
		Ni-62	1.6392E-08			Ni-62	1.6404E-08
		Ni-64	4.1550E-09			Ni-64	4.1582E-09
Cu	8.4307E-02	Cu-63	5.8315E-02	Cu	8.4371E-02	Cu-63	5.8359E-02
		Cu-65	2.5992E-02			Cu-65	2.6011E-02
Zn	6.9659E-06	Zn-64	3.3854E-06	Zn	6.9711E-06	Zn-64	3.3880E-06
		Zn-66	1.9435E-06			Zn-66	1.9449E-06
		Zn-67	2.8560E-07			Zn-67	2.8582E-07
		Zn-68	1.3096E-06			Zn-68	1.3106E-06
		Zn-70	4.1795E-08			Zn-70	4.1827E-08
Ag	4.9684E-07	Ag-107	2.5756E-07	Ag	4.9722E-07	Ag-107	2.5775E-07
		Ag-109	2.3928E-07			Ag-109	2.3946E-07
Sn	1.1287E-06	Sn-112	1.0948E-08	Sn	1.1295E-06	Sn-112	1.0956E-08
		Sn-114	7.3362E-09			Sn-114	7.3418E-09
		Sn-115	4.0632E-09			Sn-115	4.0662E-09
		Sn-116	1.6399E-07			Sn-116	1.6412E-07
		Sn-117	8.6681E-08			Sn-117	8.8746E-08
		Sn-118	2.7336E-07			Sn-118	2.7357E-07
		Sn-119	9.6838E-08			Sn-119	9.6912E-08
		Sn-120	3.6783E-07			Sn-120	3.6811E-07
		Sn-122	5.2257E-08			Sn-122	5.2296E-08
		Sn-124	6.5349E-08			Sn-124	6.5399E-08
Pb	9.0521E-07	Pb-204	1.2673E-08	Pb	9.0590E-07	Pb-204	1.2683E-08
		Pb-206	2.1816E-07			Pb-206	2.1832E-07
		Pb-207	2.0005E-07			Pb-207	2.0020E-07
		Pb-208	4.7433E-07			Pb-208	4.7469E-07
Total		**8.4373E-02**		**Total**		**8.4437E-02**	

Table 137. Atom Density of Cu Interstitial Plates for the 7/16 Configuration [1/(b·cm)].

Element	**Atom Density**	**Isotope**	**Atom Density**
O	5.0308E-05	O-16	5.0188E-05
		O-17	2.0123E-08
		O-18	1.0062E-07
Fe	5.7654E-06	Fe-54	3.4016E-07
		Fe-56	5.2880E-06
		Fe-57	1.2107E-07
		Fe-58	1.6143E-08
Ni	4.5716E-07	Ni-58	3.1211E-07
		Ni-60	1.1932E-07
		Ni-61	5.1659E-09
		Ni-62	1.6412E-08
		Ni-64	4.1602E-09
Cu	8.4412E-02	Cu-63	5.8388E-02
		Cu-65	2.6024E-02
Zn	6.9745E-06	Zn-64	3.3896E-06
		Zn-66	1.9459E-06
		Zn-67	2.8596E-07
		Zn-68	1.3112E-06
		Zn-70	4.1847E-08
Ag	4.9746E-07	Ag-107	2.5788E-07
		Ag-109	2.3958E-07
Sn	1.1301E-06	Sn-112	1.0962E-08
		Sn-114	7.3454E-09
		Sn-115	4.0682E-09
		Sn-116	1.6420E-07
		Sn-117	8.6789E-08
		Sn-118	2.7370E-07
		Sn-119	9.6959E-08
		Sn-120	3.6829E-07
		Sn-122	5.2322E-08
		Sn-124	6.5430E-08
Pb	9.0634E-07	Pb-204	1.2689E-08
		Pb-206	2.1843E-07
		Pb-207	2.0030E-07
		Pb-208	4.7492E-07
Total		**8.4478E-02**	

3.3.1.3 Aluminum Shim and Adapter Plates

The Al shims used in the 3/16 configuration were made of Al 6061 and have measured masses (see Table 8) as well as a chemical analysis (see Table 22). Each Al shim has its own mass density and is shown in Table 138, while the atom density is shown in Table 139.

Table 138. Al Shim Mass Densities [g/cm^3].

Part Type	Mass Density
400 mil	2.6993
500 mil	2.6880

Table 139. Atom Density of Al Shims [1/(b·cm)].

400 mil				500 mil			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Mg	6.0192E-04	Mg-24	4.7546E-04	Mg	5.9940E-04	Mg-24	4.7347E-04
		Mg-25	6.0192E-05			Mg-25	5.9940E-05
		Mg-26	6.6271E-05			Mg-26	6.5994E-05
Al	5.8673E-02	Al-27	5.8673E-02	Al	5.8428E-02	Al-27	5.8428E-02
Si	3.6463E-04	Si-28	3.3630E-04	Si	3.6310E-04	Si-28	3.3489E-04
		Si-29	1.7028E-05			Si-29	1.6957E-05
		Si-30	1.1303E-05			Si-30	1.1256E-05
Ti	1.0185E-05	Ti-46	8.1482E-07	Ti	1.0143E-05	Ti-46	8.1142E-07
		Ti-47	7.4353E-07			Ti-47	7.4042E-07
		Ti-48	7.5168E-06			Ti-48	7.4853E-06
		Ti-49	5.6019E-07			Ti-49	5.5785E-07
		Ti-50	5.5001E-07			Ti-50	5.4771E-07
Cr	5.6272E-05	Cr-50	2.4450E-06	Cr	5.6037E-05	Cr-50	2.4348E-06
		Cr-52	4.7150E-05			Cr-52	4.6953E-05
		Cr-53	5.3459E-06			Cr-53	5.3235E-06
		Cr-54	1.3308E-06			Cr-54	1.3253E-06
Mn	1.7753E-05	Mn-55	1.7753E-05	Mn	1.7679E-05	Mn-55	1.7679E-05
Fe	1.4554E-04	Fe-54	8.5870E-06	Fe	1.4493E-04	Fe-54	8.5510E-06
		Fe-56	1.3349E-04			Fe-56	1.3293E-04
		Fe-57	3.0564E-06			Fe-57	3.0436E-06
		Fe-58	4.0752E-07			Fe-58	4.0581E-07
Cu	6.1393E-05	Cu-63	4.2465E-05	Cu	6.1136E-05	Cu-63	4.2288E-05
		Cu-65	1.8927E-05			Cu-65	1.8848E-05
Zn	1.7400E-05	Zn-64	8.4562E-06	Zn	1.7327E-05	Zn-64	8.4208E-06
		Zn-66	4.8545E-06			Zn-66	4.8342E-06
		Zn-67	7.1338E-07			Zn-67	7.1040E-07
		Zn-68	3.2711E-06			Zn-68	3.2574E-06
		Zn-70	1.0440E-07			Zn-70	1.0396E-07
Total		**5.9948E-02**		**Total**		**5.9698E-02**	

The Al adapter plate used in the 7⁄16 configuration was made of Al 1100. Mass measurements have not been performed on the Al adapter plate; therefore, the standard density for Al 1100 (2.71 g/cm^3) was used in the benchmark models. The composition of the Al adapter plates is shown in Table 140.

Table 140. Atom Density of Al Adapter [1/(b·cm)].

Element	Atom Density	Isotope	Atom Density
Be	9.6580E-07	Be-9	9.6580E-07
Al	5.9966E-02	Al-27	5.9966E-02
Si	1.8401E-04	Si-28	1.6971E-04
		Si-29	8.5932E-06
		Si-30	5.7043E-06
Mn	9.9020E-06	Mn-55	9.9020E-06
Fe	9.2544E-05	Fe-54	5.4601E-06
		Fe-56	8.4881E-05
		Fe-57	1.9434E-06
		Fe-58	2.5912E-07
Cu	3.2102E-05	Cu-63	2.2205E-05
		Cu-65	9.8973E-06
Zn	1.6637E-05	Zn-64	8.0855E-06
		Zn-66	4.6417E-06
		Zn-67	6.8211E-07
		Zn-68	3.1277E-06
		Zn-70	9.9821E-08
Total		**6.0302E-02**	

3.3.1.4 Copper Reflector Components

There is information for two of the three Cu casts used to make the Cu reflector components (see Section 1.3.3). In the benchmark model, the Cu reflector composition was averaged between the two casts. Although the composition is averaged, each Cu reflector component has its own density (see Table 141). Average densities for each type of corner reflector and side reflector are used because their exact location is unknown. While screw holes are ignored in the detailed model they were accounted for when calculating the density. The density (rather than the mass) was preserved into the benchmark model because the components are reflectors. Table 142 through Table 146 show the isotopic and elemental atom density for each Cu part.

Table 141. Cu Reflector Part Mass Densities [g/cm^3].

Part Type	Mass Density
Top Reflector	8.7881
Bottom Reflector	8.8103
Side Reflector	8.7357
CR 1 (5.68 in.)	8.7819
CR2 (3.00 in.)	8.7793
CR3 (0.75 in.)	8.7519
CR4 (1.50 in.)	8.7510
CR6 (0.250 in.)	8.7445
CR7 (0.375 in.)	8.8383

Table 142. Atom Density of the Top and Bottom Reflectors [1/(b·cm)].

Top Cu Reflector				Bottom Cu Reflector			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
O	1.3563E-04	O-16	1.3530E-04	O	1.3596E-04	O-16	1.3564E-04
		O-17	5.4248E-08			O-17	5.4386E-08
		O-18	2.7124E-07			O-18	2.7193E-07
Fe	3.6013E-07	Fe-54	2.1247E-08	Fe	3.6104E-07	Fe-54	2.1301E-08
		Fe-56	3.3031E-07			Fe-56	3.3114E-07
		Fe-57	7.5626E-09			Fe-57	7.5817E-09
		Fe-58	1.0083E-09			Fe-58	1.0109E-09
Ni	1.8036E-07	Ni-58	1.2313E-07	Ni	1.8081E-07	Ni-58	1.2344E-07
		Ni-60	4.7072E-08			Ni-60	4.7191E-08
		Ni-61	2.0380E-09			Ni-61	2.0432E-09
		Ni-62	6.4747E-09			Ni-62	6.4911E-09
		Ni-64	1.6412E-09			Ni-64	1.6454E-09
Cu	8.3247E-02	Cu-63	5.7582E-02	Cu	8.3458E-02	Cu-63	5.7728E-02
		Cu-65	2.5730E-02			Cu-65	2.5730E-02
Zn	1.6088E-08	Zn-64	7.8661E-09	Zn	1.6226E-08	Zn-64	7.8859E-09
		Zn-66	4.5157E-09			Zn-66	4.5271E-09
		Zn-67	6.6360E-10			Zn-67	6.6528E-10
		Zn-68	3.0428E-09			Zn-68	3.0505E-09
		Zn-70	9.7112E-11			Zn-70	9.7357E-11
As	1.7659E-08	As-75	1.7659E-08	As	1.7704E-08	As-75	1.7704E-08
Se	1.3402E-08	Se-74	1.2062E-10	Se	1.3436E-08	Se-74	1.2092E-10
		Se-76	1.2196E-09			Se-76	1.2227E-09
		Se-77	1.0186E-09			Se-77	1.0211E-09
		Se-78	3.1629E-09			Se-78	3.1709E-09
		Se-80	6.6876E-09			Se-80	6.7045E-09
		Se-82	1.1928E-09			Se-82	1.1958E-09

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Table 142 – *Continued from previous page*

Top Cu Reflector				Bottom Cu Reflector			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Ag	6.6234E-07	Ag-107	3.4335E-07	Ag	6.6402E-07	Ag-107	3.4422E-07
		Ag-109	3.1899E-07			Ag-109	3.1980E-07
Sn	6.6873E-09	Sn-112	6.4866E-11	Sn	6.7042E-09	Sn-112	6.5030E-11
		Sn-114	4.3467E-11			Sn-114	4.3577E-11
		Sn-115	2.4074E-11			Sn-115	2.4135E-11
		Sn-116	9.7166E-10			Sn-116	9.7411E-10
		Sn-117	5.1358E-10			Sn-117	5.1488E-10
		Sn-118	1.6197E-09			Sn-118	1.6237E-09
		Sn-119	5.7377E-10			Sn-119	5.7522R-10
		Sn-120	2.1794E-09			Sn-120	2.1894E-09
		Sn-122	3.0962E-10			Sn-122	3.1040E-10
		Sn-124	3.8719E-10			Sn-124	3.8817E-10
Sb	4.1293E-08	Sb-121	2.3702E-08	Sb	4.1398E-08	Sb-121	2.3762E-08
		Sb-123	1.7591E-08			Sb-123	1.7635E-08
Te	4.1479E-09	Te-120	3.9405E-12	Te	4.1584E-09	Te-120	3.9505E-12
		Te-122	1.0743E-10			Te-122	1.0770E-10
		Te-123	3.7538E-11			Te-123	3.7633E-11
		Te-124	1.9868E-10			Te-124	1.9919E-10
		Te-125	2.9533E-10			Te-125	2.9608E-10
		Te-126	7.8520E-10			Te-126	7.8718E-10
		Te-128	1.3149E-09			Te-128	1.3182E-09
		Te-130	1.4049E-09			Te-130	1.4084E-09
Pb	2.4263E-08	Pb-204	3.3968E-10	Pb	2.4324E-08	Pb-204	3.4054E-10
		Pb-206	5.8474E-09			Pb-206	5.8621E-09
		Pb-207	5.3621E-09			Pb-207	5.3757E-09
		Pb-208	1.2714E-08			Pb-208	1.2746E-08
Bi	1.1396E-08	B-209	1.1396E-08	Bi	1.1425E-08	Bi-209	1.1425E-08
Total		**8.3384E-02**		**Total**		**8.3595E-02**	

Table 143. Atom Density of the Side Reflectors [1/(b·cm)].

Element	**Atom Density**	**Isotope**	**Atom Density**
O	1.3481E-04	O-16	1.3449E-04
		O-17	5.3925E-08
		O-18	2.6962E-07
Fe	3.5797E-07	Fe-54	2.1121E-08
		Fe-56	3.2833E-07

Continued on next page

Table 143 – *Continued from previous page*

Element	Atom Density	Isotope	Atom Density
		Fe-57	7.5175E-09
		Fe-58	1.0023E-09
Ni	1.7927E-07	Ni-58	1.2239E-07
		Ni-60	4.6791E-08
		Ni-61	2.0258E-09
		Ni-62	6.4361E-09
		Ni-64	1.6314E-09
Cu	8.2750E-02	Cu-63	5.7238E-02
		Cu-65	2.5512E-02
Zn	1.5992E-08	Zn-64	7.8191E-09
		Zn-66	4.4887E-09
		Zn-67	6.5964E-10
		Zn-68	3.0247E-09
		Zn-70	9.6532E-11
As	1.7554E-08	As-75	1.7554E-08
Se	1.3322E-08	Se-74	1.1990E-10
		Se-76	1.2123E-09
		Se-77	1.0125E-09
		Se-78	3.1440E-09
		Se-80	6.6477E-09
		Se-82	1.1857E-09
Ag	6.5839E-07	Ag-107	3.4130E-07
		Ag-109	3.1709E-07
Sn	6.6474E-09	Sn-112	6.4479E-11
		Sn-114	4.3208E-11
		Sn-115	2.3930E-11
		Sn-116	9.6586E-10
		Sn-117	5.1052E-10
		Sn-118	1.6100E-09
		Sn-119	5.7034E-10
		Sn-120	2.1664E-09
		Sn-122	3.0777E-10
		Sn-124	3.8488E-10
Sb	4.1047E-08	Sb-121	2.3561E-08
		Sb-123	1.7486E-08
Te	4.1231E-09	Te-120	3.9170E-12
		Te-122	1.0679E-10
		Te-123	3.7314E-11
		Te-124	1.9750E-10
		Te-125	2.9357E-10

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Table 143 – *Continued from previous page*

Element	Atom Density	Isotope	Atom Density
		Te-126	7.8051E-10
		Te-128	1.3070E-09
		Te-130	1.3965E-09
Pb	2.4118E-08	Pb-204	3.3765E-10
		Pb-206	5.8125E-09
		Pb-207	5.3301E-09
		Pb-208	1.2638E-08
Bi	1.1328E-08	B-209	1.1328E-08
Total		**8.2887E-02**	

Table 144. Atom Density of Cu Corner Reflectors (CR1 & CR2) [1/(b·cm)].

CR1 (5.68 in.)				CR2 (3.00 in.)			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
O	1.3553E-04	O-16	1.3520E-04	O	1.3549E-04	O-16	1.3516E-04
		O-17	5.4210E-08			O-17	5.4194E-08
		O-18	2.7105E-07			O-18	2.7097E-07
Fe	3.5987E-07	Fe-54	2.1232E-08	Fe	3.5976E-07	Fe-54	2.1226E-08
		Fe-56	3.3007E-07			Fe-56	3.2997E-07
		Fe-57	7.5573E-09			Fe-57	7.5573E-09
		Fe-58	1.0076E-09			Fe-58	1.0073E-09
Ni	1.8023E-07	Ni-58	1.2304E-07	Ni	1.8017E-07	Ni-58	1.2300E-07
		Ni-60	47039E-08			Ni-60	4.7025E-08
		Ni-61	2.366E-09			Ni-61	2.0360E-09
		Ni-62	6.4701E-09			Ni-62	6.4682E-09
		Ni-64	1.6401E-09			Ni-64	1.6396E-09
Cu	8.3188E-02	Cu-63	5.7541E-02	Cu	8.3163E-02	Cu-63	5.7524E-02
		Cu-65	2.5647E-02			Cu-65	2.5639E-02
Zn	1.6174E-08	Zn-64	7.8605E-09	Zn	1.6169E-08	Zn-64	7.8581E-09
		Zn-66	4.5125E-09			Zn-66	4.5112E-09
		Zn-67	6.6313E-10			Zn-67	6.6293E-10
		Zn-68	3.0407E-09			Zn-68	3.0398E-09
		Zn-70	9.7043E-11			Zn-70	9.7014E-11
As	1.7647E-08	As-75	1.7647E-08	As	1.7642E-08	As-75	1.7642E-08
Se	1.3393E-08	Se-74	1.2053E-10	Se	1.3389E-08	Se-74	1.2050E-10
		Se-76	1.2187E-09			Se-76	1.2184E-09
		Se-77	1.0178E-09			Se-77	1.0175E-09
		Se-78	3.1607E-09			Se-78	3.1597E-09

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Table 144 – *Continued from previous page*

CR1 (5.68 in.)				CR2 (3.00 in.)			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Se-80	6.6829E-09			Se-80	6.6809E-09
		Se-82	1.1919E-09			Se-82	1.1916E-09
Ag	6.6188E-07	Ag-107	3.4311E-07	Ag	6.6168E-07	Ag-107	3.4301E-07
		Ag-109	3.1877E-07			Ag-109	3.1867E-07
Sn	6.6825E-09	Sn-112	6.4820E-11	Sn	6.6805E-09	Sn-112	6.4801E-11
		Sn-114	4.3436E-11			Sn-114	4.3423E-11
		Sn-115	2.4057E-11			Sn-115	2.4050E-11
		Sn-116	9.7097E-10			Sn-116	9.7068E-10
		Sn-117	5.1322E-10			Sn-117	5.1306E-10
		Sn-118	1.6185E-09			Sn-118	1.6180E-09
		Sn-119	5.7336E-10			Sn-119	5.7319E-10
		Sn-120	2.1778E-09			Sn-120	2.1772E-09
		Sn-122	3.0940E-10			Sn-122	3.0931E-10
		Sn-124	3.8692E-10			Sn-124	3.8680E-10
Sb	4.1263E-08	Sb-121	2.3685E-08	Sb	4.1251E-08	Sb-121	2.3678E-08
		Sb-123	1.7578E-08			Sb-123	1.7573E-08
Te	4.1450E-09	Te-120	3.9377E-12	Te	4.1438E-09	Te-120	3.9365E-12
		Te-122	1.0735E-10			Te-122	1.0732E-10
		Te-123	3.7512E-11			Te-123	3.7501E-11
		Te-124	1.9854E-10			Te-124	1.9848E-10
		Te-125	2.9512E-10			Te-125	2.9503E-10
		Te-126	7.8464E-10			Te-126	7.8441E-10
		Te-128	1.3140E-09			Te-128	1.3136E-09
		Te-130	1.4039E-09			Te-130	1.4035E-09
Pb	2.4246E-08	Pb-204	3.3944E-10	Pb	2.4239E-08	Pb-204	3.3934E-10
		Pb-206	5.8432E-09			Pb-206	5.8415E-09
		Pb-207	5.3583E-09			Pb-207	5.3567E-09
		Pb-208	1.2705E-08			Pb-208	1.2701E-08
Bi	1.1388E-08	B-209	1.1388E-08	Bi	1.1385E-08	Bi-209	1.1385E-08
Total		**8.3325E-02**		**Total**		**8.3300E-02**	

Table 145. Atom Density of Cu Corner Reflectors (CR3 & CR4) [1/(b·cm)].

CR3 (0.75 in.)				CR4 (1.50 in.)			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		O-16	1.3474E-04			O-16	1.3472E-04
O	1.3506E-04			O	1.3504E-04		

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Table 145 – *Continued from previous page*

CR3 (0.75 in.)				CR4 (1.50 in.)			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		O-17	5.4025E-08			O-17	5.4019E-08
		O-18	2.7012E-07			O-18	2.7010E-07
Fe	3.5864E-07	Fe-54	2.1160E-08	Fe	3.5860E-07	Fe-54	2.1158E-08
		Fe-56	3.2894E-07			Fe-56	3.2891E-07
		Fe-57	7.5314E-09			Fe-57	7.5307E-09
		Fe-58	1.0042E-09			Fe-58	1.0041E-09
Ni	1.7961E-07	Ni-58	1.2262E-07	Ni	1.7960E-07	Ni-58	1.2261E-07
		Ni-60	4.6878E-08			Ni-60	4.6874E-08
		Ni-61	2.0296E-09			Ni-61	2.0294E-09
		Ni-62	6.4480E-09			Ni-62	6.4474E-09
		Ni-64	1.6345E-09			Ni-64	1.6343E-09
Cu	8.2904E-02	Cu-63	5.7345E-02	Cu	8.2896E-02	Cu-63	5.7339E-02
		Cu-65	2.5559E-02			Cu-65	2.5557E-02
Zn	1.6119E-08	Zn-64	7.8336E-09	Zn	1.6117E-08	Zn-64	7.8329E-09
		Zn-66	4.4971E-09			Zn-66	4.4966E-09
		Zn-67	6.6086E-10			Zn-67	6.6080E-10
		Zn-68	3.0303E-09			Zn-68	3.0300E-09
		Zn-70	9.6711E-11			Zn-70	9.6702E-11
As	1.7587E-08	As-75	1.7587E-08	As	1.7585E-08	As-75	1.7585E-08
Se	1.3347E-08	Se-74	1.2012E-10	Se	1.3346E-08	Se-74	1.2011E-10
		Se-76	1.2146E-09			Se-76	1.2144E-09
		Se-77	1.0144E-09			Se-77	1.0143E-09
		Se-78	3.1498E-09			Se-78	3.1495E-09
		Se-80	6.6601E-09			Se-80	6.6594E-09
		Se-82	1.1879E-09			Se-82	1.1878E-09
Ag	6.5962E-07	Ag-107	3.4194E-07	Ag	6.5955E-07	Ag-107	3.4190E-07
		Ag-109	3.1768E-07			Ag-109	3.1765E-07
Sn	6.6597E-09	Sn-112	6.4599E-11	Sn	6.6590E-09	Sn-112	6.4592E-11
		Sn-114	4.3288E-11			Sn-114	4.3284E-11
		Sn-115	2.3975E-11			Sn-115	2.3972E-11
		Sn-116	9.6765E-10			Sn-116	9.6756E-10
		Sn-117	5.1146E-10			Sn-117	5.1141E-10
		Sn-118	1.6130E-09			Sn-118	1.6128E-09
		Sn-119	5.7140E-10			Sn-119	5.7134E-10
		Sn-120	2.1704E-09			Sn-120	2.1702E-09
		Sn-122	3.0834E-10			Sn-122	3.0831E-10
		Sn-124	3.8560E-10			Sn-124	3.8556E-10
Sb	4.1123E-08	Sb-121	2.3605E-08	Sb	4.1119E-08	Sb-121	2.3602E-08
		Sb-123	1.7518E-08			Sb-123	1.7517E-08

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Table 145 – *Continued from previous page*

CR3 (0.75 in.)				CR4 (1.50 in.)			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
Te	4.1308E-09	Te-120	3.9242E-12	Te	4.1304E-09	Te-120	3.9239E-12
		Te-122	1.0699E-10			Te-122	1.0698E-10
		Te-123	3.7384E-11			Te-123	3.7380E-11
		Te-124	1.9786E-10			Te-124	1.9785E-10
		Te-125	2.9411E-10			Te-125	2.9408E-10
		Te-126	7.8196E-10			Te-126	7.8188E-10
		Te-128	1.3095E-09			Te-128	1.3093E-09
		Te-130	1.3991E-09			Te-130	1.3990E-09
Pb	2.4162E-08	Pb-204	3.3828E-10	Pb	2.4160E-08	Pb-204	3.3825E-10
		Pb-206	5.8232E-09			Pb-206	5.8227E-09
		Pb-207	5.3400E-09			Pb-207	5.3395E-09
		Pb-208	1.2661E-08			Pb-208	1.2660E-08
Bi	1.1349E-08	B-209	1.1349E-08	Bi	1.1348E-08	Bi-209	1.1348E-08
Total		**8.3041E-02**		**Total**		**8.3032E-02**	

Table 146. Atom Density of Cu Corner Reflectors (CR6 & CR7) [1/(b·cm)].

CR6 (0.250 in.)				CR7 (0.375 in.)			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
O	1.3494E-04	O-16	1.3462E-04	O	1.3640E-04	O-16	1.3607E-04
		O-17	5.3979E-08			O-17	5.4558E-08
		O-18	2.6990E-07			O-18	2.7279E-07
Fe	3.5834E-07	Fe-54	2.1142E-08	Fe	3.6218E-07	Fe-54	2.1369E-08
		Fe-56	3.2867E-07			Fe-56	3.3219E-07
		Fe-57	7.5251E-09			Fe-57	7.6058E-09
		Fe-58	1.0033E-09			Fe-58	1.0141E-09
Ni	1.7946E-07	Ni-58	1.2252E-07	Ni	1.8138E-07	Ni-58	1.2383E-07
		Ni-60	4.6839E-08			Ni-60	4.7341E-08
		Ni-61	2.0279E-09			Ni-61	2.0496E-09
		Ni-62	6.4426E-09			Ni-62	6.5117E-09
		Ni-64	1.6331E-09			Ni-64	1.6506E-09
Cu	8.2834E-02	Cu-63	5.7296E-02	Cu	8.3723E-02	Cu-63	5.7911E-02
		Cu-65	2.5538E-02			Cu-65	2.5812E-02
Zn	1.6105E-08	Zn-64	7.8270E-09	Zn	1.6278E-08	Zn-64	7.9110E-09
		Zn-66	4.4933E-09			Zn-66	4.5415E-09
		Zn-67	6.6030E-10			Zn-67	6.6739E-10
		Zn-68	3.0277E-09			Zn-68	3.0602E-09

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Table 146 – *Continued from previous page*

CR6 (0.250 in.)				CR7 (0.375 in.)			
Element	**Atom Density**	**Isotope**	**Atom Density**	**Element**	**Atom Density**	**Isotope**	**Atom Density**
		Zn-70	9.6630E-11			Zn-70	9.7666E-11
As	1.7572E-08	As-75	1.7572E-08	As	1.7760E-08	As-75	1.7760E-08
Se	1.3336E-08	Se-74	1.2002E-10	Se	1.3479E-08	Se-74	1.2131E-10
		Se-76	1.2135E-09			Se-76	1.2266E-09
		Se-77	1.0135E-09			Se-77	1.0244E-09
		Se-78	3.1472E-09			Se-78	3.1809E-09
		Se-80	6.6545E-09			Se-80	6.7258E-09
		Se-82	1.1869E-09			Se-82	1.1996E-09
Ag	6.5906E-07	Ag-107	3.4165E-07	Ag	6.6612E-07	Ag-107	3.4531E-07
		Ag-109	3.1741E-07			Ag-109	3.2081E-07
Sn	6.6541E-09	Sn-112	6.4544E-11	Sn	6.7254E-09	Sn-112	6.5237E-11
		Sn-114	4.3251E-11			Sn-114	4.3715E-11
		Sn-115	2.3955E-11			Sn-115	2.4212E-11
		Sn-116	9.6684E-10			Sn-116	9.7720E-10
		Sn-117	5.1103E-10			Sn-117	5.1651E-10
		Sn-118	1.6116E-09			Sn-118	1.6289E-09
		Sn-119	5.7092E-10			Sn-119	5.7704E-10
		Sn-120	2.1686E-09			Sn-120	2.1918E-09
		Sn-122	3.0808E-10			Sn-122	3.1139E-10
		Sn-124	3.8527E-10			Sn-124	3.8940E-10
Sb	4.1089E-08	Sb-121	2.3585E-08	Sb	4.1529E-08	Sb-121	2.3838E-08
		Sb-123	1.7504E-08			Sb-123	1.7691E-08
Te	4.1273E-09	Te-120	3.9209E-12	Te	4.1716E-09	Te-120	3.9630E-12
		Te-122	1.0690E-10			Te-122	1.0804E-10
		Te-123	3.7352E-11			Te-123	3.7753E-11
		Te-124	1.9770E-10			Te-124	1.9982E-10
		Te-125	2.9386E-10			Te-125	2.9702E-10
		Te-126	7.8130E-10			Te-126	7.8968E-10
		Te-128	1.3084E-09			Te-128	1.3224E-09
		Te-130	1.3979E-09			Te-130	1.4129E-09
Pb	2.4143E-08	Pb-204	3.3800E-10	Pb	2.4401E-08	Pb-204	3.4162E-10
		Pb-206	5.8183E-09			Pb-206	5.8807E-09
		Pb-207	5.3355E-09			Pb-207	5.3927E-09
		Pb-208	1.2651E-08			Pb-208	1.2786E-08
Bi	1.1339E-08	B-209	1.1339E-08	Bi	1.1461E-08	Bi-209	1.1461E-08
Total		**8.2971E-02**		**Total**		**8.3860E-02**	

3.3.1.5 Comet Hardware

The steel diaphragm used in the experiment is made of 304 stainless steel and has a density of 7.8286 g/cm^3. All digits in the mass density were included in the calculation to preserve the mass. The composition is shown in Table 147.

Table 147. Atom Density of Steel Diaphragm [1/(b·cm)].

Element	**Atom Density**	**Isotope**	**Atom Density**
C	6.6727E-05	C-12	6.5993E-05
		C-13	7.3399E-07
N	1.9858E-04	N-14	1.9785E-04
		N-15	7.3476E-07
Si	8.4434E-04	Si-28	7.7873E-04
		Si-29	3.9431E-05
		Si-30	2.6174E-05
P	3.5008E-05	P-31	3.5008E-05
S	2.9406E-06	S-32	2.7942E-06
		S-33	2.2055E-08
		S-34	1.2380E-07
		S-36	5.8812E-10
Cr	1.6515E-02	Cr-50	7.1759E-04
		Cr-52	1.3838E-02
		Cr-53	1.5690E-03
		Cr-54	3.9059E-04
Mn	1.5198E-03	Mn-55	1.5198E-03
Fe	6.0117E-02	Fe-54	3.5469E-03
		Fe-56	5.5139E-02
		Fe-57	1.2625E-03
		Fe-58	1.6833E-04
Ni	6.4996E-03	Ni-58	4.4372E-03
		Ni-60	1.6964E-03
		Ni-61	7.3445E-05
		Ni-62	2.3333E-04
		Ni-64	5.9146E-05
Cu	8.0867E-05	Cu-63	5.5936E-05
		Cu-65	2.4931E-05
Total		**8.5880E-02**	

Neither a chemical analysis nor mass measurements were performed on the alignment tube, top plate, platen, or platen adapter plate. All the components listed are made of Al 6061, so the benchmark models use the median impurity values for Al 6061 (see Table 148) and a density of 2.7 g/cm^3. Table 160 shows the isotopic and elemental composition used for the top plate, platen, and platen adapter plate.

Table 148. Atom Density of Al Comet Hardware Components [1/(b·cm)].

Element	**Atom Density**	**Isotope**	**Atom Density**
Mg	6.6898E-04	Mg-24	5.2843E-04
		Mg-25	6.6898E-05
		Mg-26	7.3655E-05
Al	5.8473E-02	Al-27	5.8473E-02
Si	3.4736E-04	Si-28	3.2037E-04
		Si-29	1.6222E-05
		Si-30	1.0768E-05
Ti	3.3961E-05	Ti-46	2.7168E-06
		Ti-47	2.4791E-06
		Ti-48	2.5063E-05
		Ti-49	1.8678E-06
		Ti-50	1.8339E-06
V	1.0640E-05	V-50	2.6599E-08
		V-51	1.0613E-05
Cr	6.0979E-05	Cr-50	2.6495E-06
		Cr-52	5.1094E-05
		Cr-53	5.7929E-06
		Cr-54	1.4421E-06
Mn	2.9596E-05	Mn-55	2.9596E-05
Fe	1.3588E-04	Fe-54	8.0167E-06
		Fe-56	1.2463E-04
		Fe-57	2.8534E-06
		Fe-58	3.8045E-07
Cu	7.0366E-05	Cu-63	4.8672E-05
		Cu-65	2.1694E-05
Zn	4.1438E-05	Zn-64	2.0139E-05
		Zn-66	1.1561E-05
		Zn-67	1.6990E-06
		Zn-68	7.7905E-06
		Zn-70	2.4863E-07
Zr	5.9413E-06	Zr-90	3.0568E-06
		Zr-91	6.6662E-07
		Zr-92	1.0189E-06
		Zr-94	1.0326E-06
		Zr-96	1.6636E-07
Total		**5.9878E-02**	

3.3.2 Simplified Model

3.3.2.1 Highly Enriched Uranium Disks and Rings

TBD

3.3.2.2 Copper Interstitial

TBD

3.3.2.3 Aluminum Spacer and Adapter Plates

TBD

3.3.2.4 Copper Reflector Components

TBD

3.3.2.5 Comet Hardware

TBD

3.4 Temperature Data

The benchmark temperature is 20°C (293.15 K) for both the detailed and simplified models.

3.5 Experimental and Benchmark-Model k_{eff}

The benchmark experiment k_{eff} and its uncertainty were determined in Section 2.1 based upon the measured asymptotic reactor period. Several simplifications were made to the benchmark model. These simplifications resulted in a bias that was applied to the experiment k_{eff} to obtain the benchmark model k_{eff}. The experiment uncertainty was estimated by analyzing the effect on k_{eff} for the parameters discussed in Section 2; a summary is given in Section 2.8.

The experiment k_{eff}, uncertainty (from Section 2), simplification biases (from Section 3.1.1 and Section 3.1.2), and benchmark model eigenvalue for each experiment are listed in Table 149 and Table 150.

Table 149. Summary of Experimental and Benchmark k_{eff} Uncertainty, and Bias for the Detailed Model.

Config.	Case	Experimental k_{eff}	Simplification Bias[(a)]	Benchmark Modal k_{eff}
3⁄16	1	1.00XXX (+XXX / -xxx)	XXX ± XXX	XXXX (+XXX / -xxx)
5⁄16	2	1.00XXX (+XXX / -xxx)	XXX ± XXX	XXXX (+XXX / -xxx)
7⁄16	3	1.00XXX (+XXX / -xxx)	XXX ± XXX	XXXX (+XXX / -xxx)

(*a*) From Table X.

Table 150. Summary of Experimental and Benchmark k_{eff} Uncertainty, and Bias for the Simplified Model.

Config.	**Case**	**Experimental k_{eff}**	**Simplification Bias**[(a)]	**Benchmark Modal k_{eff}**
3⁄16	1	1.00XXX (+XXX / -xxx)	XXX ± XXX	XXXX (+XXX / -xxx)
5⁄16	2	1.00XXX (+XXX / -xxx)	XXX ± XXX	XXXX (+XXX / -xxx)
7⁄16	3	1.00XXX (+XXX / -xxx)	XXX ± XXX	XXXX (+XXX / -xxx)

(a) From Table X and Table 149.

4.0 RESULTS OF SAMPLE CALCULATIONS

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5.0 REFERENCES

None.