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Highly Enriched Uranyl Nitrate in Annular Tanks With Concrete Reflection: 1 x 3 Line Array of Nested Pairs of Tanks

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HEU-SOL-THERM-026

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IDENTIFICATION NUMBER: HEU-SOL-THERM-026 SPECTRA

KEY WORDS: acceptable, annular tanks, concrete-reflected, critical experiment, highly enriched, moderated, nitric acid, plaster, solution, thermal, uranium, uranyl nitrate

1.0 DETAILED DESCRIPTION

1.1 Overview of Experiment

A series of seven experiments were performed at the Rocky Flats Critical Mass Laboratory beginning in August, 1980 (References 1 and 2). Highly enriched uranyl nitrate solution was introduced into a 1 × 3 linear array of nested stainless steel annular tanks. The tanks were placed in concentric pairs. Each pair of tanks had only a single tank diameter matching that of a tank in the adjacent pair. The tanks were placed inside a concrete enclosure. Experiments were performed by introducing fissile solution into between two and six annular tanks, then various moderator and absorber materials were placed inside and/or in between the tanks to determine their influence upon the overall reactivity of the system. These moderators and absorbers included boron-free concrete, borated concrete, borated plaster, and cadmium. Figure 9 in Section 1.2.4 provides a general depiction of the layout of the annular tank system.

Two configurations included placing bottles of highly enriched uranyl nitrate between tanks externally. Another experiment involved nested hemispheres of highly enriched uranium placed between tanks externally. These three configurations are not evaluated in this report.

The experiments evaluated here are part of a series of experiments, one set of which is evaluated in HEU-SOL-THERM-033. The experiments in this evaluation and HEU-SOL-THERM-033 were performed in a similar manner. They took place in the same room and used the same tanks, some of the same moderators and absorbers, some of the same reflector panels, and uranyl nitrate solution from the same location. There are probably additional similarities that existed that are not identified here. Thus, many of the descriptions in this report are either the same as or similar to those in the HEU-SOL-THERM-033 report.

Seventeen configurations (sixteen of which were critical) were performed during a series of seven experiments. One of the seventeen configurations was subcritical (see Appendix D). Of the seven experiments, six are evaluated for this benchmark, which comprises a total of thirteen of the original seventeen configurations. Two of the thirteen configurations were identical, except for critical solution height because they were conducted to test repeatability. The solution heights were averaged and the two were evaluated as a single configuration, which reduces the total to twelve evaluated configurations. All twelve critical configurations evaluated were judged acceptable as benchmarks.

1.2 Description of Experimental Configuration

The experiments were first documented soon after completion in a brief summary published in the November 1982 *ANS Transactions* (Reference 1). One of the experimenters wrote a detailed description years later, in 1996 (Reference 2). Two other references were used to verify the configuration of the experiment room layout.[a,b]

1.2.1 Room Layout Description - The experiments took place in the Rocky Flats Critical Mass Laboratory assembly room. This room was 11.28 m in the east-west direction, 10.67 m in the north-south direction, and 9.75 m in height. The walls were steel-reinforced concrete. Reinforcement of the floor or ceiling was not verifiable. The north wall was 1.52-m thick; the other walls were 1.22-m thick. The floor was 0.15-m thick, and the ceiling varied between 0.61-m and 0.71-m thick. The floor rested on compacted earth. There were two layers of crossed steel rebar, one about 80 mm in from the outer surface and the other 80 mm in from the inner surface. The horizontal rebar was #8 gauge placed on 0.3-m centers. The vertical rebar was #6 gauge placed on the same centers. The room had two door openings, each 2.44 m in height. The north opening was 1.07-m wide, and the south opening was 2.44-m wide.

The experiments were set up on a concrete platform in the southeast corner of the room above the south door and 3.15 m above the floor. The platform consisted of eight steel-reinforced concrete panels, each $1.22 \times 1.52 \times 0.203$-m thick, forming total dimensions of $4.88 \times 3.04 \times 0.203$-m thick. Steel I-beams supported the platform. Items on top of the platform included safety railings and an angle-stock structure used to brace experimental constituents. Angle-stock posts were placed at the southwest, northwest, and northeast corners and joined by horizontal lengths of angle stock 2.46 m above the platform.

Other major items in the assembly room included an air-handling deck, a walk-in hood, and a horizontal split table. A five-ton bridge crane was also in the assembly room; its location was not noted during these experiments. Figure 1 shows the assembly room configuration.

1.2.2 Tanks - The experiments used six annular tanks in a nested 1×3 line array configuration; three sets of tanks were made by nesting two together for each. The tanks were listed as #1 (largest), #2, #2*, #3, #3*, and #4 (smallest). Each tank consisted of two cylinders rolled from 6.4-mm-thick sheet metal. The cylinders were joined at the bottoms by 6.4-mm-thick steel to form an annular solution region thickness of design specification 38.1 ± 0.8 mm. Each tank had 18 small-diameter spacing rods in evenly spaced sets of six to maintain the annular thickness. The two larger top rods, 19 mm in diameter, were used for lifting the tank. The other sixteen rods had 6.4-mm diameters. Using the top rod orientations, sets of the smaller-diameter rods were placed at one-third and two-thirds the height of the tank.

The tank bottoms were flat and sloped 2 degrees to one side to facilitate solution drainage. The slope was not achieved by tilting the tanks; the tank walls were vertical. The bottom slope resulted in an uneven solution region in each tank. All tanks had a maximum height of 2.134 m. The tank heights on the shorter side were 2.097 m, 2.101 m, 2.105 m, and 2.110 m for tanks 1 through 4, respectively. Tank 2 was nominally equivalent to Tank 2* and Tank 3 to Tank 3*. Figure 3 shows the slope in the tanks. The nested tank low points are aligned at the same elevation. The nested tank tops are horizontal and even with each other, and open to the ambient environment.

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[a] Rothe, R.E., 1996, Critical Experiments on an Enriched Uranium Solution System Containing Periodically Distributed Strong Thermal Neutron Absorbers, INEL/EXT-97-00293, Idaho National Engineering Laboratory, September 1996.

[b] Rothe, R.E., 1994, Experimental Critical Parameters of Plutonium Metal Cylinders Flooded with Water, INEL-96/0250, Idaho National Engineering Laboratory, September 1994.

As shown in Figure 3, each tank had a cylindrical support skirt formed by extending the tank inner wall, which elevated the tank solution region at least 305 mm above the platform. Six evenly spaced holes, 250 mm in diameter, perforated each support skirt and were centered in the same vertical alignment as the spacer rods mentioned previously. The cross sectional tank view in Figure 3 shows four of the holes in the tank skirts; two holes are in the middle of the skirt and one at each edge. The holes allowed solution-line passage underneath the tanks. A solution fill/drain pipe was welded to the low point of each tank. While being manufactured, triangular fillets with side lengths of 13 mm were placed on the inside annular region at the bottom of Tanks 2* and 3*. This was to prevent accumulation of precipitates due to questionable laminar flow.

Table 1 gives the tank dimensions along the diameters. The design parameters listed in Table 1 were those specified for construction. As built, the tanks were somewhat out of round. The "best" outer diameters given in Table 1 were derived from statistical fits of measured data to a right circular cylinder model. The thickness values for the tank annuli and outer walls were obtained from measured data. Examining the annular thickness values shows that the calculated average value is not directly correlated to the minimum and maximum values. There are no documented thickness measurements for tank inner walls. Figure 4 shows the dimensions of the nested tanks from a top view using the "best" outer diameters and applying a thickness of 6.4 mm to all the tanks' walls.

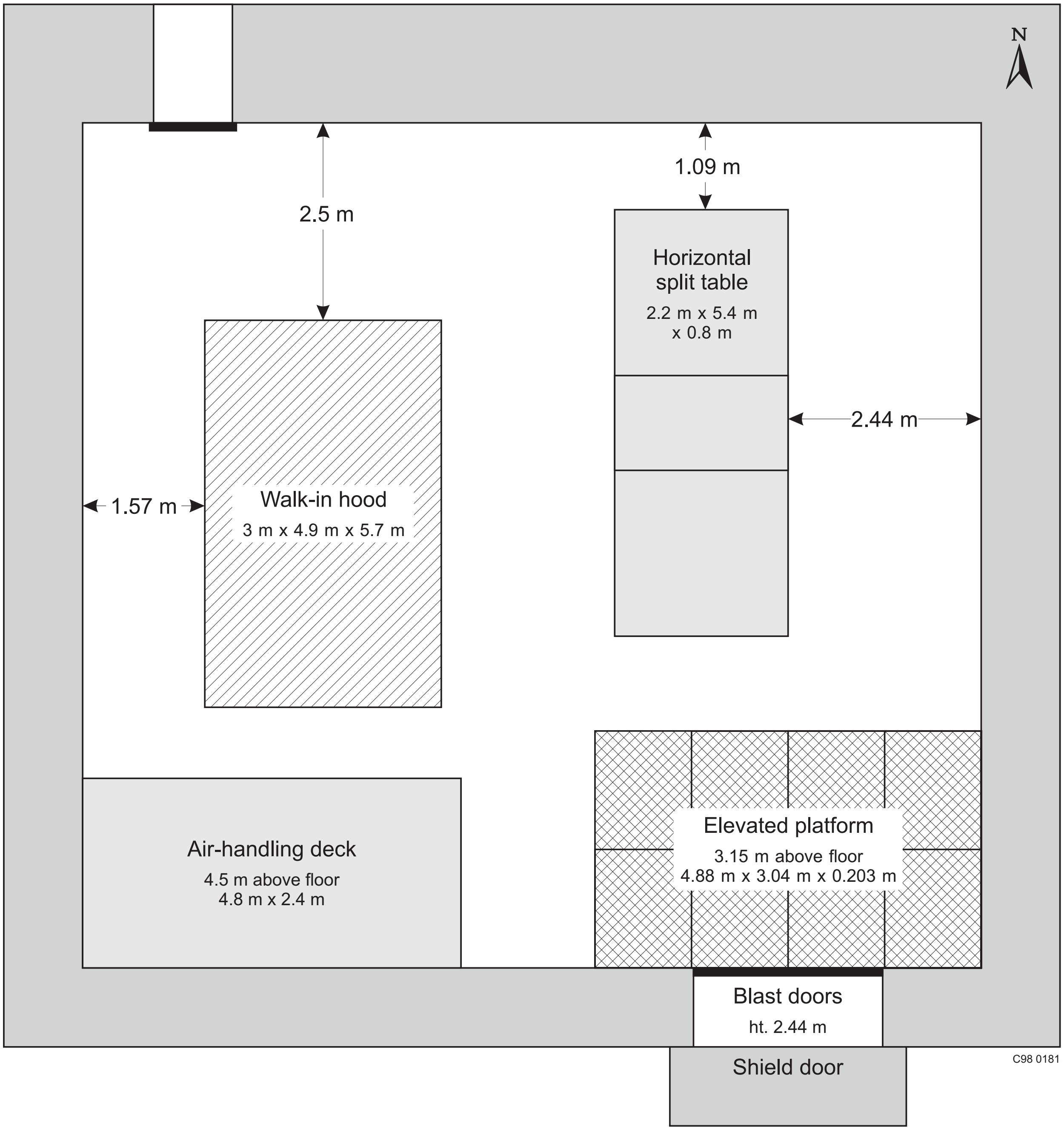

Figure 1. Assembly Room Configuration.

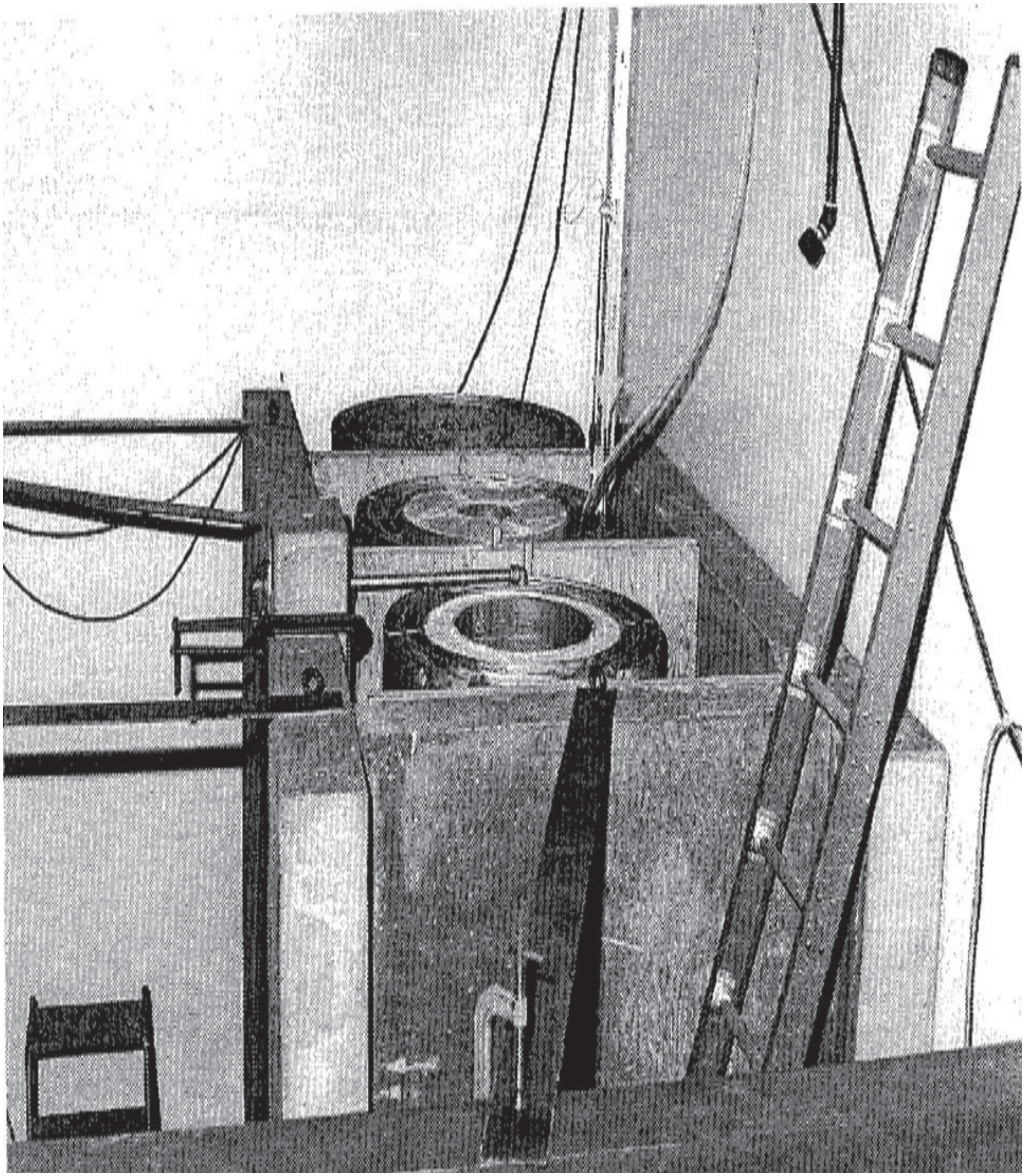

Figure 2. Photograph of Experiment Setup.

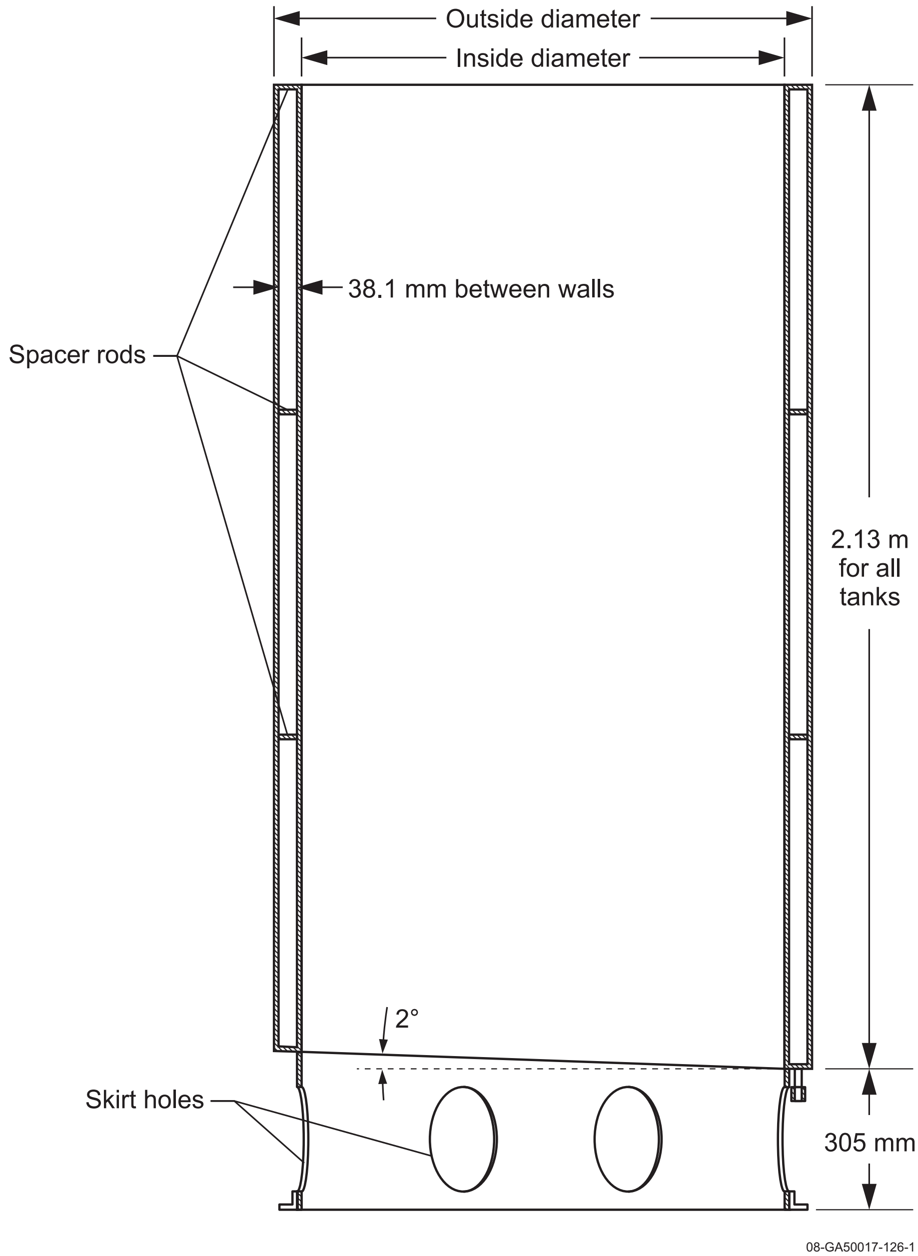

Figure 3. General Tank Cross Section.

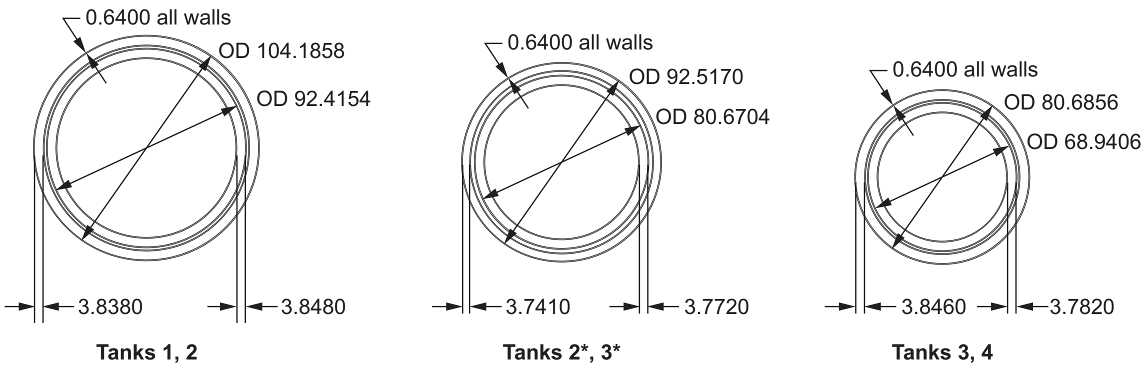

Figure 4. Nested Tank Dimensions, Top View (units are in cm).

Table 1. Annular Tank Dimensions Along the Diameter.

Parameters (all dimensions in mm)	Tank 1	Tank 2	Tank 2*	Tank 3	Tank 3*	Tank 4
DESIGN SPECIFICATIONS						
Outer diameter	1041 ± 6	924 ± 6	924 ± 6	806 ± 6	806 ± 6	689 ± 6
Outer wall thickness	6.4	6.4	6.4	6.4	6.4	6.4
Solution annulus thickness	38.1 ± 0.8	38.1 ± 0.8	38.1 ± 0.8	38.1 ± 0.8	38.1 ± 0.8	38.1 ± 0.8
Inner wall thickness	6.4	6.4	6.4	6.4	6.4	6.4
Inner diameter	940 ± 6	822 ± 6	822 ± 6	705 ± 6	705 ± 6	587 ± 6
MEASURED DIMENSIONS						
"Best" outer diameter	1041.858	924.154	925.17	806.856	806.704	689.406
Outer wall thickness:						
Maximum	6.50	6.55	6.60	6.40	6.60	6.63
Minimum	6.20	6.15	6.20	6.07	6.17	6.27
Solution annulus thickness: average	38.38 ± 0.64	38.48 ± 1.17	37.41 ± 1.17	38.46 ± 0.51	37.72 ± 0.79	37.82 ± 0.48
Maximum	39.40	41.96	39.98	39.95	39.22	39.19
Minimum	37.01	36.63	33.88	36.91	35.79	36.63

The measured diameter data were fit to cylindrical and elliptical cross sections. For Tanks 2* and 4, the data were also fit to a quadratic surface with z-dependence. The resulting equations are given below.

Tank	Right circular cylinder fit: (mm)	Right elliptic cylinder fit: (mm)	Quadratic fit with z-dependence: (inches)
#1	$x^2 + y^2 = (520.929)^2$	$\frac{x^2}{(522.206)^2} + \frac{y^2}{(523.900)^2} = 1$	No fit performed
#2	$x^2 + y^2 = (462.077)^2$	$\frac{x^2}{(455.427)^2} + \frac{y^2}{(463.372)^2} = 1$	No fit performed
#2*	$x^2 + y^2 = (462.585)^2$	$\frac{x^2}{(460.916)^2} + \frac{y^2}{(464.142)^2} = 1$	$1.0139x^2 + y^2 = 333.9151 - 0.0973z + 0.0016$
#3	$x^2 + y^2 = (403.428)^2$	$\frac{x^2}{(402.935)^2} + \frac{y^2}{(405.465)^2} = 1$	No fit performed
#3*	$x^2 + y^2 = (403.352)^2$	$\frac{x^2}{(400.469)^2} + \frac{y^2}{(405.458)^2} = 1$	No fit performed
#4	$x^2 + y^2 = (344.703)^2$	$\frac{x^2}{(341.676)^2} + \frac{y^2}{(343.583)^2} = 1$	$1.0112x^2 + y^2 = 182.9774 + 0.1010z - 0.0011$

Air gaps existed between nested pairs of tanks. Measurements of air gaps were performed for combinations of four tanks nested together; results showed variations in gap widths from 0–18 mm.

1.2.3 Absorbers and Moderators – During some experiments, cylindrical and annular moderators/absorbers, or plugs, were placed in the nested tanks' central regions. Some plugs were made of concrete (one with a cadmium lamination) and others of plaster. Slabs of plaster moderators/absorbers were also placed between tanks during some experiments. The plywood used to cast the plaster slabs was not removed and remained part of the slabs for safety purposes.

Experiment 1 used no central moderators or absorbers and no slabs between tanks. Experiments 2 through 6 used various configurations of concrete or plaster plugs and slabs. Figure 5 shows the 1 × 3 array with plugs and slabs in place. Figure 6 shows various plugs that were built.

Table 2 describes the plugs. The plugs were named according to their nominal inner and outer diameters, in inches, and their boron weight percent. The plugs were formed in paper Sonotube molds, which were not removed prior to the experiments. Each plug had a 6.4-mm-thick steel lifting plate on the bottom and two embedded steel rods with anchors for handling. In Experiment 4, the 22 × 0 concrete plug was "wrapped with a (1.59-mm-thick, 55.2 kg) thin lamination of pure cadmium" (Reference 2, p. 192). The annular plugs had central wooden support discs during casting. As indicated by the wood weights in Table 2, these discs could not always be removed afterward.

For the 30 × 18, 2.5% B plug, a 1.5-mm thick commercial corrugated steel culvert stock was used in place of an inner paper form. The culvert was cut the same length as the paper tubes. The "clearance" inside diameter (minimum diameter across flutes) was 457 mm and the greatest inside diameter across flute gaps was 482 mm. The distance between spiral flutes was 68 mm. Both inner and outer surfaces of the culvert had been galvanized to a thickness of 0.31 mg/mm^2. Though the culvert formed a plug with a corrugated interior, detailed geometry of the inner plug surface was considered unimportant because of the plug thickness.

All central plugs were placed on a wooden stand 305-mm high. The corners of the stand were 89-mm-square wood pieces, joined with 13-mm-thick, 250-mm-wide plywood strips. The stands were said to resemble an open square frame when viewed from above (Reference 2). The overall stand dimensions were not specified.

There were problems during the making of the 30 × 0, 1.2% B concrete plug. It was planned to be a 30 × 16, but the inner Sonotube collapsed when the concrete mixture was poured. The concrete slumped and the decision was made to fill the remainder as though it was a solid plug. The collapsed paper remained inside. The plug looked like a solid plug but had a cavity within in it. Figure 7 shows what the experimenters reported as the assumed dimensions, without considering a probable rough inner top portion and some concrete debris that most likely ended up at the bottom of the plug. Because of the thickness of the annulus portion, it was assumed that the inner smoothness and existence of debris could be ignored.

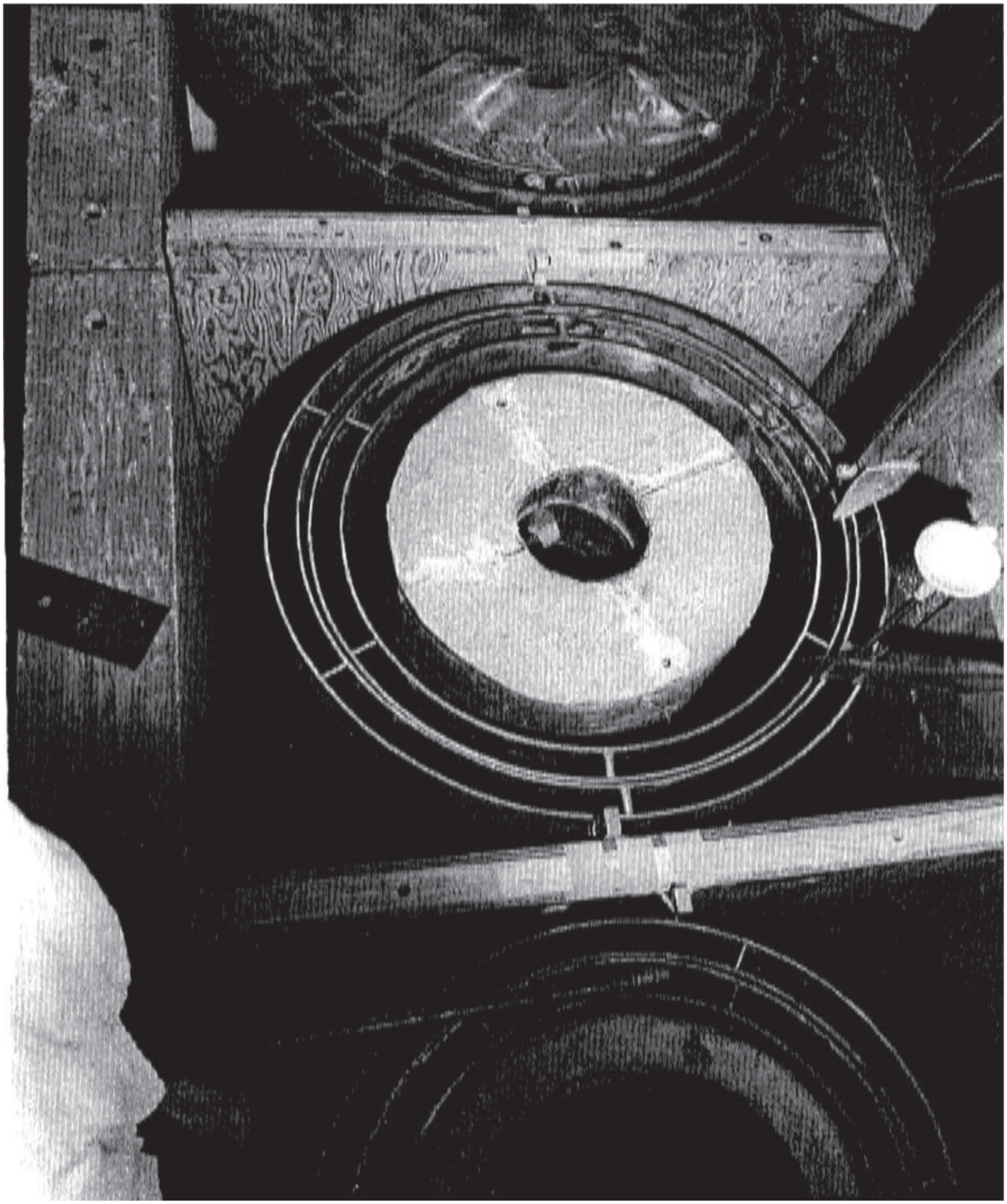

Figure 5. 1 × 3 Array with Absorber/moderator Plugs Inside Tanks and Slabs Between.

Figure 6. Various Plugs Built for the Experiment. (Reference 2)

Table 2. Concrete and Plaster Plug Characteristics.

Characteristics	Concrete Plugs						Plaster Plugs	
	22 × 0 [k] 0% B	22 × 8 [a] 1.2% B	24 × 10[a] 1.2% B	30 × 0 1.2% B	22 × 16 2.5% B	30 × 18[i] 2.5% B	22 × 8 1.1% B	22 × 16 1.1% B
Steel plate OD, mm	558.0	558.0	609.6	762.0	558.0	762.0	558.0	558.0
Steel plate ID, mm	0	209.6	261.6	~0	415.3	(j)	209.6	415.3
Outer paper mold OD, mm	570.2	570.2	621.0	777.2	570.2	777.2	570.2	570.2
Plug OD, mm	558.8	558.8	609.6	762.0	558.8	762.0	558.8	558.8
Plug ID, mm	0	209.6	261.6	~0	415.3	varies[i]	209.6	415.3
Inner paper mold ID, mm	--	203.2	254.0	collapse[l]	406.4	[varies][i]	203.2	406.4
Height, mm [b]	2124	1956	1975	~2124[h]	2121	2121	2134	2127
Paper Sonotube wt., kg	15.1	18.82	20.59	34.93	23.59	26.5	18.82	23.59
Steel wt., kg [c]	16.48	14.75	15.93	20.20	9.47	20.20	14.75	9.47
Wood[d] [steel] wt., kg	0	0.99	1.56	3.50	2.92	[48.7]	0	0
Total plug wt., kg	1220.3[e]	984.3[e]	1115.1[g]	1589.8[g]	458.6[e]	968.8[g]	882.8[e]	468.4[e]
Density, mg/mm^3 [f]	2.29	2.3	2.22	1.58[m]	1.94	1.94	1.89	1.86

(a) Sagged during casting, probable inner Sonotube bulging.
(b) Steel lifting plate not included.
(c) Steel bottom plate and 4.316 kg in 2 rods and anchors.
(d) Wooden discs used for casting; most were removed after casting.
(e) Just prior to use, including embedded steel rods and anchors, paper, and wood.
(f) Using plug weight, minus weight of embedded steel rods, and anchors, paper, and wood.
(g) Three months after casting, including embedded steel rods and anchors, paper, and wood.
(h) Actual height not measured.
(i) Commercial steel culvert stock ASTM A-444 replaced paper; averages were used.
(j) Not specifically mentioned. Assumed to be 471 mm.
(k) This plug also contained a cadmium lamination not mentioned in the table.
(l) The remaining paper had an assumed inner diameter of 408.3 mm.
(m) This was reported but is more likely the same as the other 1.2 wt.% B concrete plugs since they were made from the same batch of concrete.

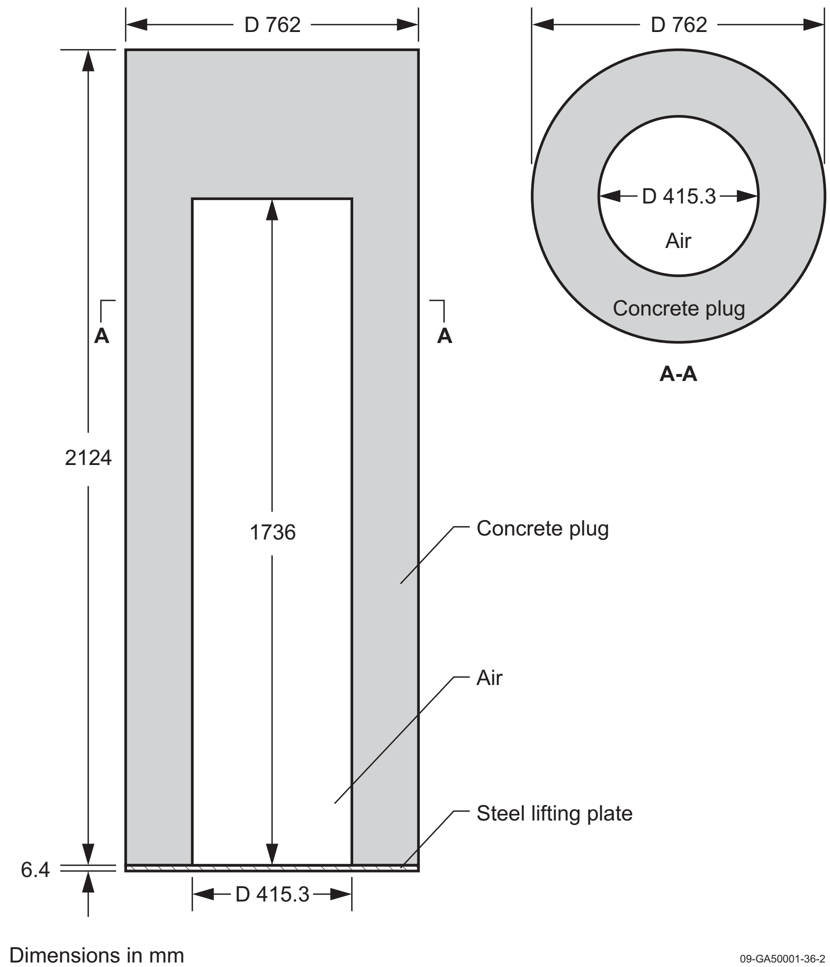

Figure 7. Vertical Cylindrical Cross Section Reported for the 30 × 0, 1.2% B Concrete Plug. (Gray area is concrete, inner area is open cavity—inner paper not shown, steel lifting plate on bottom.)

Four plaster slabs were made with the same ingredients as the plaster plugs. Each contained 1.1-wt.% boron. Two slabs were 51-mm thick, two were 19-mm thick, and each was 1.09-m wide by 2.10-m tall. Each slab could fit between the tanks. Slabs were laminated between two sheets of 13-mm thick plywood 1.17-m wide by 2.44-m high with a perimeter framing of construction-grade lumber; 38 × 51-mm lumber was used for the thicker slabs and 38 × 19 mm for the thinner ones. The plywood remained intact during experiments. A plaster-free region was located up to 305 mm above the floor. The plaster slab extended from 305 mm to 2.40 m above the floor. The plaster portion of the slabs was about equal to the height of the solution region of the tanks. The weights of the slabs were 275.6 kg, 266.1 kg, 121.9 kg, and 117.0 kg. It was not stated which slab was which weight and which thick slab or thin slab was placed where during experiments. Figure 8 shows the cross section of a slab.

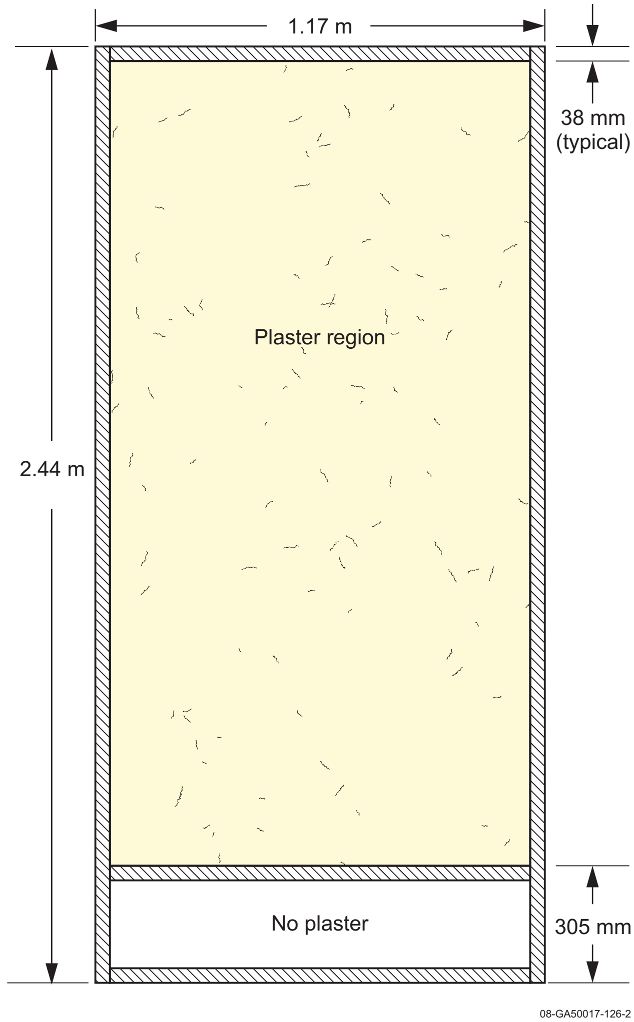

Figure 8. Cross Section of Plaster Slabs (cross-hatched area represents wood).

1.2.4 Enclosure – It was reported that seven vertical reflector panels were placed around the nested-tank assembly array. There was no reflection above and the platform floor was used for reflection from below. The reflector panels were made of steel-reinforced concrete. Each panel was 203-mm thick and 2.44 m in height. The biggest panels were 1.22-m wide; the others were 0.30-, 0.61-, and 0.91-m wide. The narrowest panel was raised 203 mm by placing it on a brick to allow solution lines access into the enclosure. The density of the enclosure panels was 1.85 mg/mm^3. The location of each particular panel was not specified.

The rebar reinforcement in the reflector panels was a ribbed steel commercial product 13 mm in diameter. The rebar was placed in a horizontal and vertical crossed pattern uniformly spaced in both directions and inset from the edges the same distance in the middle of each panel. Vertical pieces were 2.4 m in length, and the widest panels contained four of these. The other panels received two for the 0.30-m wide panel, three for the 0.61-m wide, and three for the 0.91-m wide panel. All panels contained 10 horizontal pieces of rebar that would fit within each width. The lengths of the horizontal rebar in each panel were as follows:

- For the 1.22-m wide panels: 1.14 m
- For the 0.30-m wide panel: 0.24 m
- For the 0.61-m wide panel: 0.54 m
- For the 0.91-m wide panel: 0.84 m.

Lifting and stabilizing anchors were placed on top of each panel.

Figure 9 is a sketch of the experiment on the elevated platform in relation to the adjacent room walls. It was taken from Reference 2. The seven reported panels were not enough to enclose the tanks. The east wall and a small portion of the south wall were used as reflectors. The size of the gap in the southeast corner, measured east to west, is given as 619 mm. The distance from the east wall to the west reflector panel is given as 3221 mm on the south side and 3226 mm on the north side. It was not mentioned whether or not these measurements were made near the tops of the panels or near the bottoms. Table 3 displays north-south dimensions for the enclosure. Table 4 gives the location of the tanks within the enclosure, based on each tank's outer wall.

Table 3. North-South Dimensions for the Enclosure.

Distance From East Room Wall (m)	South Room Wall to the Inside Face of North Reflector Panels (mm)		Between Reflector Panels (mm)	
	Top	Bottom	Top	Bottom
0.0	1429	1473	--	--
0.6	1422	Not given	1219	Not given
1.2	1416	Not given	1200	Not given
1.8	1416	Not given	1178	Not given
2.4	1422	Not given	1187	1216
2.6	Not given	Not given	1191	1195
2.8	1448	Not given	1213	Not given
3.7[(a)]	1451	1464	1232	1241

(a) Outside of enclosure.

Table 4. Distances from the Outer Wall of Largest Tanks to Enclosure Walls and Neighbor Tanks.

From Tank…	To…	Top (mm)	Bottom (mm)
#1	East wall of room	87.3	76.2
	North reflector panel	139.7	136.5
	Edge of south reflector panel	41.3	34.9
	Tank #2*	147.6	158.8
#2*	North reflector panel	130.2	130.2
	South reflector panel	133.4	130.2
	Tank #3	147.6	146.1
#3	North reflector panel	122.2	119.1
	South reflector panel	271.5	277.8
	West reflector panel	68.3	68.3

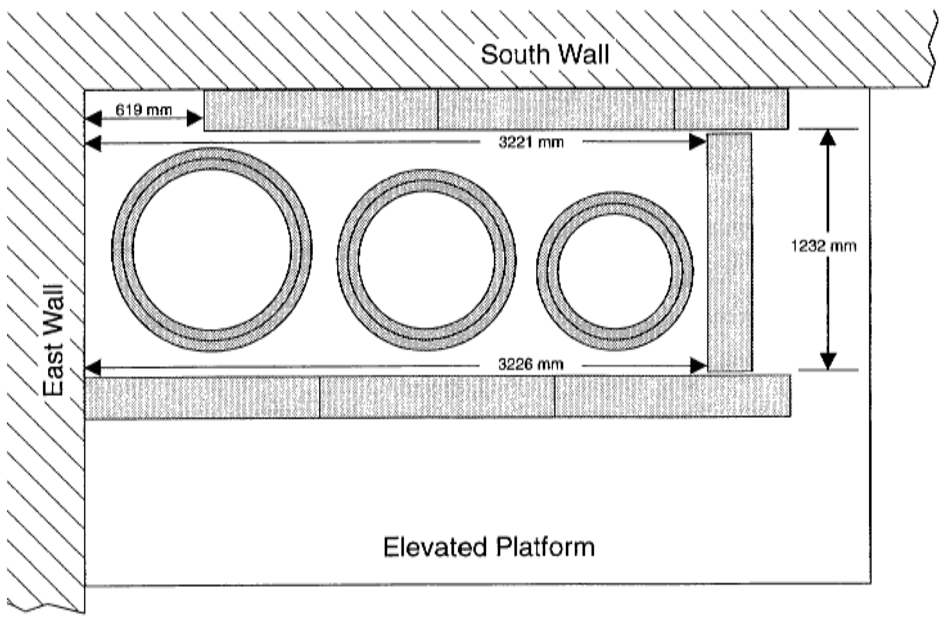

Figure 9. Sketch of Experiment on Elevated Platform. (Reference 2)

1.2.5 Determination of Criticality - A ^{252}Cf neutron source was used during the initial approach to criticality. The experimenters determined the uranyl nitrate solution height using sight gauges and a level detector. The sight gauges were used during the approach to criticality in conjunction with proportional counters for developing a reciprocal multiplication plot. Ionization chambers were also available in case the proportional counters experienced too much dead time. In order for all six tanks to be monitored, two tanks were represented by one sight gauge. Sight gauges were located outside the concrete reflector panels. The switch was made to the level detector and ionization chambers about halfway through the experiment. It was stated that the level detector's probe was usually located in the next-to-smallest tank, but which specific tank was not mentioned. The level detector was placed such that it gave a "zero" reading at 319 mm above the platform, the average elevation or midpoint of the next-to-smallest tank bottom.

Solution was pumped into the tanks; it was drained by gravity. A single line from the solution storage tanks connected to a distribution manifold containing four branches. Two of the branches were plumbed to feed two tanks. The manifold lines were valved so that any combination of the six tanks could be filled or drained at one time. The setup resulted in a single, horizontal solution level for all tanks containing solution.

Solution heights were recorded for two reactor periods. A positive period (supercritical) solution height was always attained first, usually followed by a negative period (subcritical). Sometimes lowering the solution level for a negative period would result in a shutdown, so a second positive period was attained. Experimenters plotted the reciprocal period against solution height. The critical height was determined by linear interpolation between positive and negative periods or by linear extrapolation from two positive periods. Experiment 5e was the only one to have the critical height determined by linear extrapolation of the reciprocal multiplication curve.

The critical height uncertainty was specified as follows: For any particular experiment, the critical height measurement precision would be ±0.01 mm. A second run without equipment reconfiguration would give an uncertainty in critical height of ±0.5 mm. Repeating an experiment after other experiments were run showed an uncertainty in critical height of ±10 mm. Equipment disassembly and reassembly did not occur during these experiments.

1.2.6 Critical Configurations – The differences between experiments were due to which absorber/moderator plugs or slabs were used. The tanks and reflector panels were not moved during the experiments. Up to six different configurations were attempted for a single experiment. A single subcritical experiment was due to the presence of too much absorption material. Appendix D contains information about the subcritical configuration.

Critical configurations are shown in Table 5. For all but one experiment, distances were measured between plugs and the inner tank as shown in Table 6.

Table 5. Experiment Critical Configurations.

Experiment	East Absorbers/Moderators In Tanks 1, 2	Between Tanks	Central Absorbers/Moderators In Tanks 2*, 3*	Between Tanks	West Absorbers/Moderators In Tanks 3, 4	Tanks with Solution	Solution Critical Height[(a)] (mm)
1.a	None	None	None	None	None	1,2,2*,3*,3,4	713.4
b						1,2,2*,3*	841.8
c						2*,3*	1425.8
d						1,2*,3*	1181.4
2.a	30 × 0 (1.2% B) C		24 × 10 (1.2% B) C		22 × 8 (1.2% B) C	1,2,2*,3*,3,4	1346.4
b						1,2,2*,3*	1626.8
3.a [(b)]			22 × 8 (1.1% B) P		22 × 16 (1.1% B) P	1,2,2*,3*,3,4	1331.4
b						1,2,2*,3*	1645.6
4.	30 × 18 (2.5% B) C		22 × 16 (2.5% B) C		22 × 0 (cadmium) C	1,2,2*,3*,3,4	1269.9
5.a [(b)]	30 × 0 (1.2% B) C		22 × 8 (1.1% B) P		22 × 16 (1.1% B) P	1,2,2*,3*,3,4	1322.1
e		Thin slab		Thin slab		1,2,2*,3*,3,4	1760
f			None			1,2,2*,3*,3,4	895.1
6.						2*,3*,3,4	1032.2

(a) Relative to "zero" position at tank 3 bottom midpoint, 319 mm above the platform.
(b) These configurations are the same, and were performed to test repeatability.

Table 6. Distances Between Plugs and Inner Tanks.

Experiment	Plugs (East to West)	Inner tank	Distance N,S,E,W (mm)
2	30 × 0 (1.2% B)C 24 × 10 (1.2% B)C 22 × 8 (1.2% B)C	#2 #3* #4	36, 28, 5, 20 41, 7, 46, 79 0, 5, 14, 16
3	30 × 0 (1.2% B)C 22 × 8 (1.1% B)P 22 × 16 (1.1% B)P	#2 #3* #4	36, 28, 5, 20 64, 70, 60, 67 6, 15, 7, 0
4	30 × 18 (2.5% B)C 22 × 16 (2.5% B)C 22 × 0 (cadmium)C	#2 #3* #4	15, 30, 7, 30 62, 62, 62, 70 8, 0, 8, 15
5	30 × 0 (1.2% B)C 22 × 8 (1.1% B)P 22 × 16 (1.1% B)P	#2 #3* #4	34, 46, 7, 3 62, 69, 70, 66 13, 14, 2, 0

1.3 Description of Material Data

1.3.1 Uranyl Nitrate Solution - The uranyl nitrate solution was used from 1965–1989 in low-power critical experiments. The solution was created by dissolving $UO_2(NO_3)_2 \bullet 6H_2O$, uranyl nitrate hexahydrate, in dilute nitric acid. The solution temperature was not recorded during the experiments; however, from experience with other programs, the experimenter suggested that the solution temperature was close to room temperature, or about 18–22°C (Reference 2).

Solution properties were measured from samples taken during these experiments. The solution concentration was determined by gravimetric titration to be 357.4 ± 3.2 grams uranium/liter. The uncertainty includes measurement error and estimated error in sampling and laboratory techniques. The solution was weighed in a temperature-calibrated 25-mL pycnometer to obtain the solution density of 1.4982 ± 0.0011 mg/mm^3. The free or excess nitric acid in the solution was 0.5751 ± 0.0115 N. The uranium isotopic composition was determined by mass spectrometry. Table 7 gives the uranium breakdown by weight percent.

Table 7. Uranium Isotopic Composition.

Isotope	Weight Percent
^{234}U	0.982 ± 0.010
^{235}U	93.219
^{236}U	0.432 ± 0.002
^{238}U	5.367 ± 0.025

Sampled elemental impurities were reported for the uranyl nitrate solution. Table 8 gives values from the analysis. The data are reported in parts per million (ppm) by weight, relative to the uranium weight.

Table 8. Uranyl Nitrate Solution Average Elemental Impurities.

Element	ppm by wt., relative to U wt.	Element	ppm by wt., relative to U wt.
B	4.4 ± 1.7	Cu	81 ± 26
Mg	250 ± 150	Zn	230 ± 100
Al	350 ± 190	Mo	75 ± 27
Si	43 ± 20	Cd	7.8 ± 2.6
Mn	27 ± 10	Sn	280 ± 190
Fe	515 ± 200	Pb	44 ± 11
Ni	69 ± 37	Bi	6.8 ± 5.1

1.3.2 Stainless Steel 304L - The tanks were constructed of Type 304L, SA-240 stainless steel. Six tanks in four different sizes were built for the nested tank experiments. Tanks 2* and 3* are nominally the same sizes as tanks 2 and 3. Table 9 gives the generic nominal stainless steel composition and density. Table 10 gives the elemental composition from laboratory analysis for the six tanks. Iron was not measured but was assumed to constitute the balance of the steel. Uranium and tungsten were less than 0.05 wt.% for all tanks. The major components, as determined analytically, correspond well with the nominal composition.[ab]

Table 9. Generic Stainless Steel Type 304L Nominal Composition.

Element	Wt.%
C	0.03% max.
Si	1% max.
Cr	18–20%
Ni	8–12%
Fe	Balance
Density:	8.03 mg/mm^3

[a] M. G. Fontana, *Corrosion Engineering*, 3rd ed., New York: McGraw-Hill, 1986; Table 5-2.
[b] R. H. Perry, C. H. Chilton, ed. *Chemical Engineers' Handbook*. 5th ed. New York: McGraw-Hill, 1973; Table 23-5.

Table 10. Stainless Steel Type 304L Elemental Composition by Analysis.

Element	Tank 1 wt.%	Tank 2 wt.%	Tank 2* wt.%	Tank 3 wt.%	Tank 3* wt.%	Tank 4 wt.%
H	0.0004	0.0003	<0.0001	0.0006	0.0007	0.0005
C	0.012	0.013	0.012	0.015	0.014	0.009
N	0.074	0.074	0.076	0.077	0.077	0.078
O	0.044	0.008	0.008	0.009	0.007	0.010
Al	<0.01	<0.01	0.015	<0.01	<0.01	<0.01
S	0.002	0.002	0.002	0.002	0.002	0.002
Ti	<0.01	<0.01	<0.01	0.0100	<0.01	<0.01
V	0.086	0.087	0.091	0.089	0.092	0.091
Cr	19	19	21	21	20	20
Mn	2.5	2.2	2.3	2.3	1.7	2.2
Fe	Balance	Balance	Balance	Balance	Balance	Balance
Co	0.18	0.18	0.20	0.20	0.21	0.20
Ni	10	10	11	11	11	10
Mo	0.18	0.18	0.20	0.21	0.21	0.21
Sn	<0.01	<0.01	<0.01	0.01	0.01	0.01
Pb	<0.01	<0.01	<0.01	0.05	<0.01	<0.01

1.3.3 Boron-Free Concrete - The majority of the concrete used in these experiments was boron-free concrete. The room walls, experimental platform, enclosure reflector panels, and some central plugs were boron-free concrete. Table 11 gives the concrete pour specifications for the plugs, enclosure reflector panels, and experimental platform. A partial specification was reported for the room walls: 307 kg/m^3 Type I Portland cement, maximum 30 kg/m^3 pure water, and aggregate low in amorphous siliceous materials ranging from 6–18 mm in size. The density of the boron-free plug used was 2.29 g/cm^3 and the average density of all boron-free plugs made was 2.267 g/cm^3.

The concrete constituents were cement, sand, aggregate, water, and Pozzalith. Table 12 provides the nominal specifications for Portland cements Types I and II. The loss on ignition is assumed to be from hydrated water that usually is present with gypsum. The sand and aggregate consisted mostly of silica (71–75 wt.%), alumina (11–15 wt.%) and iron oxide (2–6 wt.%). Table 13 summarizes measured impurities for the sand, aggregate, and Portland cement Type II in all plugs.

Table 11. Boron-Free Concrete Constituents, as Poured.[(a)]

Constituent	Plugs	Enclosure Panels	Platform
Portland Type II cement	1059 kg	1412 kg	1194 kg
Moist sand	3034 kg (7.1%)	3416 kg (2.3%)	2957 kg (5%)
Aggregate	3511 kg (1%)	4666 kg (0.9%)	3316 kg (1.7%)
Water	530 kg	607 kg	473 kg
Pozzalith	2 kg	Not recorded	Not recorded
Total water in set concrete	Not specified	1.7% absorbed 7.8% hydrate	Not specified

(a) Values in parentheses indicate percent of constituent weight that is absorbed water.

Table 12. Portland Cement Nominal Specifications.[(a)]

Constituent Formula	Wt.% in Type I			Wt.% in Type II		
	Range (min-max)	Average	Mean	Range (min-max)	Average	Mean
C_3S, tricalcium silicate $3CaO \bullet SiO_2$	40–63	51.5	54	37–68	52.5	55
C_2S, dicalcium silicate $2CaO \bullet SiO_2$	9–31	20	18	6–32	19	19
C_3A, tricalcium aluminate $3CaO \bullet Al_2O_3$	6–14	10	10	2–8	5	6
C_4AF, tetracalcium alumino-ferrite $4CaO \bullet Al_2O_3 \bullet Fe_2O_3$	5–13	9	8	7–15	11	11
SiO_2	18.7–22.0	20.35	20.5	20.0–23.2	21.6	21.2
Al_2O_3	4.7–6.3	5.5	5.4	3.4–5.5	4.45	4.6
Fe_2O_3	1.6–4.4	3.0	2.6	2.4–4.8	3.6	3.5
CaO	60.6–66.3	63.45	63.9	60.2–65.9	63.05	63.8
MgO	0.7–4.2	2.45	2.1	0.6–4.8	2.7	2.1
SO_3	1.8–4.6	3.2	3.0	2.1–4.0	3.05	2.7
Loss on Ignition, %	0.6–2.9	1.75	1.4	0.0–3.1	1.55	1.2
Na_2O eq.	0.11–1.20	0.655	0.61	0.05–1.12	0.585	0.51
Other	Any Remainder					

(a) *Concrete Manual, Concrete Quality and Field Practices*, 4th ed., USA: International Conference of Building Officials, 1998, pp. 80–81.

Table 13. Impurities in Sand, Aggregate, and Portland Type II Cement (all concrete plugs).

Sampled Impurity	Moist Sand (wt.%)			Aggregate (wt.%)			Portland cement Type II (wt.%)
	0%B	1.2%B	2.5%B	0%B	1.2%B	2.5%B	
C	0.004	0.006	0.005	0.005	0.005	0.006	0.02
Na	0.0	0.1	0.0	0.1	0.0	0.1	0.2
Mg	0.2	0.2	0.2	0.7	0.2	0.5	1.2
Al	6.2	6.1	5.8	8.1	6.5	7.4	2.5
Si	23	Not measured	25	24	Not measured	Not measured	7.0
SiO_2	Not measured	72.8 ± 0.5	Not measured	Not measured	71.0 ± 0.5	74.6 ± 0.5	Not measured
S	0.0	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	0.11
K	0.2	0.2	0.2	0.5	0.2	0.3	0.6
Ca	0.2	0.2	0.2	0.7	0.2	0.3	43.4
Ti	0.2	0.3	0.3	0.5	0.3	0.4	0.1
V	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	0.1
Mn	0.0	Not reported	Not reported	0.1	0.0	0.0	0.1
Fe	3.2	2.4	1.5	4.0	1.8	2.6	2.9
Ni	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	0.01
Zn	0.0	0.0	0.0	0.0	0.0	0.0	<0.01
Rb	0.01	0.0	0.0	0.01	0.0	0.0	0.02
Sr	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Zr	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	0.01
Ba	0.1	0.1	0.1	0.1	0.1	0.1	0.06
Ta	Below detection limit	0.1	0.1	Below detection limit	0.1	0.1	0.1
Absorbed H_2O	6.0	3.8	1.9	0.0	0.0	1.8	0.7

1.3.4 Borated Concrete - Two types of borated concrete were mixed for the plugs: 1.2-wt.% boron and 2.5-wt.% boron. Table 14 gives the pour/mix compositions. The 2.5-wt.% boron concrete contained some Portland Type I cement in addition to Type II. Portland cement, sand, and aggregate characteristics were given in Table 12 and Table 13 in the previous section.

Gerstley Borate is the borated constituent. It includes Ulexite, $NaCaB_5O_9 \bullet 5H_2O$; Colemanite, $Ca_2B_6O_{11} \bullet 5H_2O$ (Reference 2); and sand, SiO_2. The Gerstley Borate was divided by particle size into three lots. The chemical analyses consistently showed 7.55 ± 0.38-wt.% boron in the Gerstley Borate. Table 15 gives the weighted-average of chemically analyzed constituents in Gerstley Borate. Two significant components, oxygen and hydrated water, were not reported. Although the raw ingredients in the two borated concrete mixes yield boron contents of only 1.15 and 2.3 wt.%, respectively, it was presumed that water lost after casting increased the boron weight percents to the stated levels of 1.2 and 2.5 wt.% (Reference 2).

Table 14. Mixed Borated Concrete Constituents, as Poured.[(a)]

Constituent	1.2-wt.% Boron	2.5-wt.% Boron
Portland Type I cement	0	271 kg
Portland Type II cement	1196 kg	1542 kg
Moist sand	1668 kg (6.9%)	270 kg (7%)
Aggregate	2291 kg (1%)	1539 kg (1%)
Gerstley Borate	1053 kg (4.17%)	2150 kg (4.17%)
Water	694 kg	1289 kg
Pozzalith	2 kg	3 kg

(a) Values in parentheses indicate percent of constituent weight that is absorbed water.

Table 15. Weighted Average of Gerstley Borate Constituents, as Determined Analytically.

Constituent	Wt.%	Constituent	Wt.%
Li	0.022	S	0.00027
B	7.55	K	0.060
C	0.232	Ca	14.9
Na	3.87	Fe	0.060
Mg	2.63	Sr	0.697
Al	0.347	Ba	0.015
Si	3.03	H_2O absorbed	4.17

1.3.5 Borated Plaster - Two plugs and four slabs were made of borated plaster. Separate plaster mixes were made for each plug and one mix was made for all slabs. Table 16 lists the two sets of plaster mix components for the plugs, after water loss was complete. Again, the boron ingredient was Gerstley Borate. Hydrostone Super X was used, which is a typical gypsum plaster composed primarily of the hemihydrate $2CaSO_4 \bullet H_2O$. Table 17 lists the plaster constituents and impurities for the plugs and slabs. The boron weight percent of the plugs and slabs was 1.1%.

Table 16. Borated Plaster Constituents, After Setting.[(a)]

Constituent	22 × 8 plug	22 × 16 plug
Hydrostone Super X Plaster	602 kg (6.7%)	311.4 kg (6.7%)
Gerstley Borate	121 kg (4.16%)	62.4 kg (4.16%)
Water	126.2 kg	61.5 kg

(a) Values in parentheses indicate percent of constituent weight that is absorbed water.

Table 17. Plaster Components and Impurities.

Constituent	Plugs	Slabs
	Wt.%	Wt.%
C	0.55 ± 5%	0.54 ± 5%
Na	0.07 ± 5%	0.07 ± 5%
Mg	0.17 ± 5%	0.17 ± 5%
Al	0.06 ± 50%	0.06 ± 50%
Si	0.52 ± 5%	0.54 ± 5%
SO_4	62.25 ± 0.1%	61.84 ± 0.1%
K	0.07 ± 50%	0.07 ± 50%
Ca	28.04 ± 0.1%	28.21 ± 0.1%
Fe	0.016 ± 5%	0.025 ± 5%
Sr	0.03 ± 50%	0.05 ± 50%
H_2O absorbed	6.7 ± 5%	6.8 ± 5%

1.3.6 Other Materials - The enclosure panels, elevated platform, and room walls contained steel rebar. The plugs had steel bottom discs, steel anchors, and lifting rods embedded in the concrete. Weights for the steel present in the plugs were given in Table 2. The steel types were not specified.

Paper Sonotubes were used as plug molds. The Sonotube dimensions and weights were given in Table 2. The Sonotubes were recycled pulp paper plies bonded with sodium silicate. The interior surfaces were coated with plastic, the exterior surfaces with beeswax. Compositions for these materials were not provided.

An ASTM A-444 steel stock culvert was used in place of a Sonotube for the 30 × 18, 2.5% B plug. The weight of the culvert is included in Table 2. The composition of the culvert was not given.

Experiments 2, 4, 5, and 6 had wooden discs in the central regions of their annular plugs because the discs could not be removed after casting. Weights for these wooden discs were given in Table 2. Plug stands were constructed of wood and plywood. No weights were specified for the constructed plug stands or materials. Wood was also used with the plaster slabs as a type of frame. The slabs between tanks would rest on blocks of wood that were 38 × 89 × 76 mm and raised the slabs up 38 mm. Small wedges of wood were also used to hold slabs in place. It was stated that the wood was "low mass to minimize reflection" (Reference 2).

The 22 × 0 concrete plug used for Experiment 4 was wrapped with a "pure" cadmium lamination (Reference 2). This metal sheet was 1.59-mm thick and weighed 55.2 kg. The cadmium was bonded to the paper on the outside of the plug using daubs of "Liquid Nails."

The ^{252}Cf source was held in position inside of a hollow tube. No description of the tube was given.

1.4 Supplemental Experimental Measurements

No supplemental experimental measurements were provided.

2.0 EVALUATION OF EXPERIMENTAL DATA

The experiments were documented in the report "Experimental Critical Parameters of Enriched Uranium Solution in Annular Tank Geometries" by experimenter Robert E. Rothe (Reference 2). Experimental components and room geometry are provided. Some additional room layout data and verification was obtained from other experiment reports.[a,b] The first published account was a brief summary which reported boron values of 0.8 and 2.8 wt.% for the borated concrete (Reference 1). The detailed report strongly supports values of 1.2 and 2.5 wt.% B, so the other values are disregarded.

All twelve critical experiments evaluated in this series are accepted as benchmarks. Information regarding the one subcritical configuration is given in Appendix D.

Experiment configuration 5e was the only experiment configuration to have the critical height determined by linear extrapolation of the reciprocal multiplication curve. The reported possible additional uncertainty that might be present in the critical solution height was ±3 mm (Reference 2, pg. 212). The uncertainty used for all solution heights was ±10 mm for all experiment configurations, and configuration 5e had one of the smallest responses to this change. Also, the only data available used for the extrapolation was given in a graph (Reference 2, pg. 213) where only approximate values could be determined. The effort to develop additional uncertainty for experiment configuration 5e was abandoned due to the uncertainty in the additional uncertainty, and the fact that it did not appear that results would be significantly affected.

MCNP5 was used to calculate k_{eff} and evaluate uncertainties and changes to experiments. For uncertainty parameters, MCNP5 calculations used continuous-energy ENDF/B-VI cross sections. A calculation was run for each configuration that the uncertainty parameter affected. The MCNP standard deviation for every calculation was 0.00009.

Uncertainties are given in the detailed experiment report for some data, including the uranyl nitrate solution, annular tank dimensions, and the critical solution height. Other items that bear further evaluation include the tank bottom locations, tank placement, the concrete enclosure dimensions, and concrete parameters such as density and composition.

The dimensions in Tables 3 and 4 were to be used to construct the enclosure and place tanks, but this did not work. When using the given dimensions in Table 3, part of the farthest east tanks overlapped with the east wall. Because of this, only Table 4 was used. The middle set of tanks was placed first and then the other tanks were placed and the enclosure built by using average dimensions given in Table 4 measured from the middle tanks. The biggest observed difference between given dimensions and what was modeled in the benchmark models was that the east set of tanks was closer to the south panels than reported.

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[a] Rothe, R..E., 1996, Critical Experiments on an Enriched Uranium Solution System Containing Periodically Distributed Strong Thermal Neutron Absorbers, INEL/EXT-97-00293, Idaho National Engineering Laboratory, September 1996.

[b] Rothe, R..E., 1994, Experimental Critical Parameters of Plutonium Metal Cylinders Flooded with Water, INEL-96/0250, Idaho National Engineering Laboratory, September 1994.

The experiment report mentions that there were only seven concrete reflector panels used, but after unsuccessfully trying to place the seven panels specified into the given dimensions of the enclosure, it became apparent that the reported seven panels must have been an error in the report. Another set of experiments was conducted with the same tanks in a 1 × 2 nested array, and a drawing of the enclosure setup for those experiments contained in Reference 2 shows that there were eight panels. Also, Reference 1 shows the 1 × 3 array experiment setup with eight panels noted; therefore, eight panels are assumed to have been used for the 1 × 3 array also. In Figure 2 the placement and number of panels can partially be seen as well. Figure 10 shows the most likely position of the panels assumed for the models. The 300 mm panel was reported to be raised to allow tubing to pass underneath, but this panel was modeled level with the others.

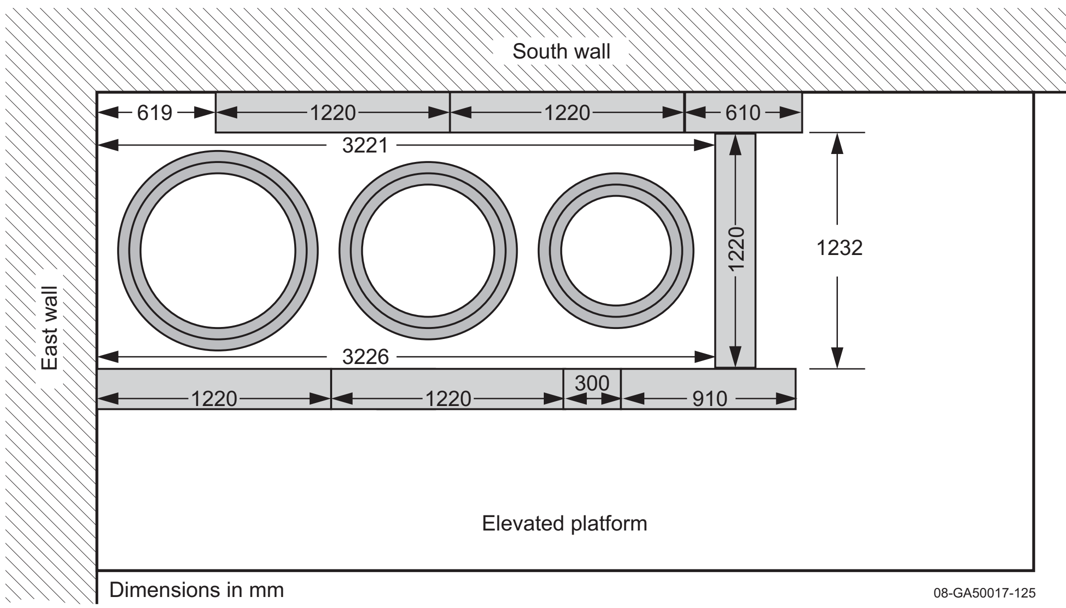

Figure 10. Approximate Experiment Layout.

Pozzalith was used in making the concrete, but it was a small part of the concrete mix and there was no information provided about its composition. It was therefore left out of the concrete composition used in the models.

The critical solution height reported for Experiment 5f was not clear in the experiment report. On page 214 of the report, a value of 895.1 mm is given, but on page 216, in Table XIX, a value of 865.1 is shown. The model for Experiment 5f was built using 895.1 mm for the critical solution height. The result was a low k_{eff} value. Based on this result, the 865.1 mm value was ruled out since it would have given an unreasonably low k_{eff} value.

The 22 × 8 and 24 × 10, 1.2-wt.% boron concrete plugs used in configurations 2a and 2b sagged during casting. The effects of the sagging were not considered. These plugs were shorter than the rest of the plugs, but they were still 329.2 mm above the solution at a minimum.

The plug steel bottom disks were treated the same as the tank steel. Common carbon steel is assumed for the rebar and steel reinforcement as shown in Table 18. Elements other than carbon and iron may have been present in the steel, but none were included since no information was provided.

Table 18. General Carbon Steel Composition.

Density (g/cm^3)	7.82
Component	Wt.%
C	0.5
Fe	99.5

Table 19 lists the average composition of a steel culvert as taken from *ASTM* standards *A 446/A 446M* and *A 444/A 444M* and from the *Material Safety Data Sheet for CONTECH Products* for Zinc-Coated Steel Products which gave a density of 8 g/cm^3.

Table 19. ASTM A-444 Steel Stock Culvert Average Composition.

Component	Wt.%
C	0.2920
P	0.0867
S	0.0400
Fe	97.5837

2.1 Critical Solution Height

Two factors affected the critical solution height uncertainty: the reported precision in the measurement and the accuracy of the reported level-detector placement. The reported precision in the critical solution height measurement for the experiments was ±0.5 mm. In trying to repeat an experiment, the difference in critical heights was 10 mm.

The locations of the annular tank bottoms are also important to the critical solution height determination. The solution height is relative to the platform floor, with the level detector zeroed at the stated midpoint of the bottom of tank 3, 319 mm above the floor. The tank bottom locations are reported four ways in the experimental write-up, as indicated in Table 20. Each yields a slightly different midpoint tank bottom location. The difference between tank midpoints was only 0.5 mm for tanks 2, 2*, 3, 3*, and 4, but for tank 1, it was up to 1.5 mm. Because of all the above stated factors, the uncertainty chosen to run calculations on was ±10 mm for the solution height to ensure that extreme cases will be covered. Table 21 shows the Δk_{eff} values for the ±10 mm uncertainty (judged to be bounding) for the solution height. All solution heights in each tank were changed at the same time.

Table 20. Reported and Calculated Tank Bottom Locations.

(All dimensions are in mm.)

Description (from Reference 2)	Diametrically Opposite Difference[(a)]				Tank Bottom Midpoint, from the Floor[(a)]			
	#1	#2, #2*	#3, #3*	#4	#1	#2, #2*	#3, #3*	#4
"...diametrically opposite side of the four different tanks were 36, 32, 28, and 24 mm shorter..." (p.69)	**36**	**32**	**28**	**24**	323	321	319	317
Tall height 2134 mm, Short height 2097 mm, 2101 mm, 2105 mm, 2110 mm (p.70, Table V)	37	33	29	24	323.5	321.5	319.5	317
"...diametrically opposite 'bottom' was 328, 333, 337, and 340 mm above the floor..." (p.182)	35	32	28	23	322.5	321	319	316.5
"...for each of the four sizes was 317, 319, 321, and 322 mm above the floor..." (p.182)	34	32	28	24	**322**	**321**	**319**	**317**

(a) Reported values are in boldface, other values were calculated.

Table 21. Calculated Uncertainties in k_{eff} — Solution Height ±10 mm.

Configuration No.	Number of Tanks	$+\Delta k_{eff}$	$+\Delta k_{eff}/\sqrt{3}$	$-\Delta k_{eff}$	$-\Delta k_{eff}/\sqrt{3}$
1a	6	0.00335	0.00193	-0.00348	-0.00201
1b	4	0.00266	0.00154	-0.00255	-0.00147
1c	2	0.00125	0.00072	-0.00117	-0.00068
1d	3	0.00162	0.00094	-0.00164	-0.00095
2a	6	0.00069	0.00040	-0.00099	-0.00057
2b	4	0.00026	0.00015	-0.00065	-0.00038
3a5a	6	0.00084	0.00048	-0.00068	-0.00039
3b	4	0.00032	0.00018	-0.00053	-0.00031
4	6	0.00106	0.00061	-0.00087	-0.00050
5e	6	0.00074	0.00043	-0.00032	-0.00018
5f	6	0.00191	0.00110	-0.00207	-0.00120
6	4	0.00155	0.00089	-0.00184	-0.00106

2.2 Uranyl Nitrate Solution

Specific values and uncertainties were given in the experiment report for excess nitric acid, solution density, uranium concentration, impurities, and uranium isotope wt.%. Each parameter can affect the amount of another as well as the calculated amount of water in the solution. Each uncertainty provided was taken to be 1σ.

These five parameters were each considered. Solution values were recalculated as needed to correspond with the change in the affected parameter. The reported uncertainty for the stated parameters by which each was varied was for the excess nitric acid ±0.0115 N, the solution density ±0.0011 g/cm^3, the uranium concentration ±3.2 g/liter, and the total impurities by ±970.4 ppm.

The uranium was specified as 93.219-wt.% ^{235}U, with no listed uncertainty. The ^{235}U was assigned a maximum uncertainty of ±0.037 wt.%, which is the sum of the ^{234}U, ^{236}U, and ^{238}U uncertainties. When the ^{235}U was raised to its maximum wt.%, each of the other uranium isotopes were reduced to their minimum values to compensate. Likewise for ^{235}U; when it was reduced to a minimum, each of the other uranium isotopes was maximized. All Δk_{eff} results for the changes to the uranyl nitrate solution are shown in Tables 22–26.

To estimate the effect of temperature uncertainty (Section 2.14) on the density of the solution, the density formula provided in Appendix B of LEU-MISC-THERM-005 was applied.[a] The variation of ±2ºC in temperature results in ±0.0012 g/cm^3 variation in density. The uncertainty in applying this equation for corrections in density is ±0.0032 g/cm^3. Individual values are reported in Table 23, and then a composite uncertainty in the density is provided, which is the square-root of the sum of the squares of the individual results for uncertainty in the density due to measurement, temperature, and application of the formula. Individual uncertainties in density are determined from linear extrapolation of the Δk_{eff} values determined for the measurement uncertainty in the reported density.

The impurities in the solution are capable of producing nitrate and/or oxide compounds. An analysis similar to that previously established in Section 2.4 of HEU-SOL-THERM-044 was performed, assuming all impurities formed compounds. The atom densities for hydrogen, oxygen, and nitrogen were appropriately adjusted. A Δk_{eff} of 0.00127 was calculated for the difference between a solution containing impurities as purely metallic ions and a solution containing all impurities as nitrate or oxide compounds, representing a bounding condition. The actual solution would contain some mixture between the two cases, but the exact composition would be unclear without the performance of a complex chemistry analysis. The uncertainty for the physical chemistry of the impurities will be treated as one-half of the bounding limit uncertainty. Therefore the uncertainty for the impurity chemistry in all cases will be ±0.00037.

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[a] S. Sakurai and S. Tachimori, "Modified Density Equation for Aqueous Solutions with Plutonium (IV), Uranium (IV), and Nitric Acid," JAERI-M 88-127 (1998), (in Japanese).

Table 22. Calculated Uncertainties in k_{eff} — Excess Acid in Solution ±0.0115 N.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
1a	-0.00031	0.00028
1b	-0.00035	0.00033
1c	-0.00036	0.00026
1d	-0.00013	0.00041
2a	-0.00041	0.00028
2b	-0.00061	0.00007
3a5a	-0.00021	0.00034
3b	-0.00049	0.00043
4	-0.00031	0.00028
5e	-0.00024	0.00064
5f	-0.00048	0.00034
6	-0.00045	0.00030

Table 23. Calculated Uncertainties in k_{eff} — Solution Density: Measurement ±0.0011 g/cm^3, Temperature ±0.0012 g/cm^3, Use of Density Formula ±0.0032 g/cm^3, and Total Uncertainty in Density

Configuration No.	Measurement		Temperature[a]		Formula		Total	
	$+\Delta k_{eff}$	$-\Delta k_{eff}$	$+\Delta k_{eff}$	$-\Delta k_{eff}$	$+\Delta k_{eff}$	$-\Delta k_{eff}$	$+\Delta k_{eff}$	$-\Delta k_{eff}$
1a	0.00054	-0.00049	0.00059	-0.00053	0.00157	-0.00143	0.00176	-0.00160
1b	0.00060	-0.00061	0.00065	-0.00067	0.00175	-0.00177	0.00196	-0.00199
1c	0.00056	-0.00058	0.00061	-0.00063	0.00163	-0.00169	0.00183	-0.00189
1d	0.00075	-0.00056	0.00082	-0.00061	0.00218	-0.00163	0.00245	-0.00183
2a	0.00054	-0.00057	0.00059	-0.00062	0.00157	-0.00166	0.00176	-0.00186
2b	0.00037	-0.00067	0.00040	-0.00073	0.00108	-0.00195	0.00121	-0.00219
3a5a	0.00066	-0.00049	0.00072	-0.00053	0.00192	-0.00143	0.00215	-0.00160
3b	0.00010	-0.00069	0.00011	-0.00075	0.00029	-0.00201	0.00033	-0.00225
4	0.00059	-0.00051	0.00064	-0.00056	0.00142	-0.00148	0.00193	-0.00166
5e	0.00081	-0.00044	0.00088	-0.00048	0.00236	-0.00128	0.00264	-0.00144
5f	0.00052	-0.00069	0.00057	-0.00075	0.00151	-0.00201	0.00170	-0.00225
6	0.00062	-0.00059	0.00068	-0.00064	0.00180	-0.00172	0.00202	-0.00193

(a) The variation in density due to temperature is for a temperature variation of ±2ºC.

Table 24. Calculated Uncertainties in k_{eff} — Solution Uranium Concentration ±3.2 gU/L.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
1a	-0.00182	0.00174
1b	-0.00187	0.00181
1c	-0.00192	0.00218
1d	-0.00178	0.00174
2a	-0.00151	0.00153
2b	-0.00185	0.00115
3a5a	-0.00132	0.00172
3b	-0.00181	0.00135
4	-0.00140	0.00159
5e	-0.00129	0.00153
5f	-0.00177	0.00157
6	-0.00189	0.00178

Table 25. Calculated Uncertainties in k_{eff} — Solution Impurity Total ±970.4 ppm.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
1a	-0.00013	0.00031
1b	-0.00027	0.00022
1c	-0.00016	0.00021
1d	-0.00006	0.00009
2a	-0.00033	-0.00011
2b	-0.00023	0.00017
3a5a	0.00000	0.00036
3b	-0.00037	-0.00002
4	0.00000	0.00019
5e	0.00011	0.00030
5f	-0.00027	0.00038
6	-0.00015	0.00020

Table 26. Calculated Uncertainties in k_{eff} — Solution U-235 ±0.037 wt.%.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
1a	0.00024	-0.00002
1b	0.00020	-0.00013
1c	0.00006	-0.00021
1d	0.00014	-0.00023
2a	-0.00007	-0.00015
2b	-0.00013	-0.00033
3a5a	0.00018	-0.00001
3b	-0.00011	-0.00025
4	0.00019	0.00016
5e	0.00017	0.00014
5f	0.00009	0.00017
6	0.00020	-0.00024

2.3 Tank Stainless Steel Parameters

Tank steel components

The total iron in the stainless steel Type 304L depends on the amount of other constituents. The average composition was used for all tanks from Table 10 in Section 1.3.2, which gives 66.7-wt.% iron. Using the maximum values for the other components gives a minimum iron content of 64.8 wt.%. Using the minimum amounts of the other components yields an iron balance of 68.8 wt.%. All tanks were changed at the same time. There was not a specific uncertainty given, so using the minimum and maximum range of the components was assumed to be a bounding limit. To correct to 1σ, the Δk_{eff} results were divided by $\sqrt{3}$. Results are given in Table 27. A certain fraction of this uncertainty would be systematic; however the exact amount is unknown and the contribution of this uncertainty does not significantly impact the total uncertainty.

Table 27. Calculated Uncertainties in k_{eff} — Tank Steel Maximum/Minimum components (Excluding Iron).

Configuration No.	(Max)Δk_{eff}	(Max)Δk_{eff} (1σ)	(Min)Δk_{eff}	(Min)Δk_{eff} (1σ)
1a	-0.00122	-0.00070	0.00169	0.00098
1b	-0.00103	-0.00059	0.00163	0.00094
1c	-0.00091	-0.00053	0.00130	0.00075
1d	-0.00090	-0.00052	0.00146	0.00084
2a	-0.00138	-0.00080	0.00162	0.00094
2b	-0.00133	-0.00077	0.00160	0.00092
3a5a	-0.00110	-0.00064	0.00179	0.00103
3b	-0.00144	-0.00083	0.00167	0.00096
4	-0.00123	-0.00071	0.00171	0.00099
5e	-0.00096	-0.00055	0.00165	0.00095
5f	-0.00107	-0.00062	0.00144	0.00083
6	-0.00098	-0.00057	0.00131	0.00076

Tank steel density

The tank stainless steel 304L density was modeled as 8.03 g/cm^3 as shown in Table 9. Uncertainty in the steel density was not provided in the experiment report. From various sources that provided densities for 304L stainless steel, it was seen that values differed by about ±0.1 g/cm^3, which was used as the uncertainty in the density. Results are given in Table 28.

Table 28. Calculated Uncertainties in k_{eff} — Tank Steel Density ±0.1 mg/mm^3.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
1a	-0.00023	0.00033
1b	-0.00015	0.00002
1c	0.00016	-0.00018
1d	0.00006	-0.00007
2a	-0.00057	0.00032
2b	-0.00055	-0.00027
3a5a	-0.00008	0.00047
3b	-0.00046	0.00019
4	-0.00001	0.00031
5e	0.00004	0.00039
5f	0.00005	0.00029
6	0.00019	-0.00011

2.4 Tank Parameters

Four annular tank parameters were evaluated: tank wall thickness, tank diameter, solution annulus thickness, and tanks treated as ovals.

Table 1 gives tank dimensions reported by the experimenters. Minimum and maximum values for the outer wall thicknesses were provided. No measurements of the inner wall thicknesses were reported. The design specification for the wall thickness was 6.4 mm for both walls. This was used in the models for both walls since it was close to the average values of the outer wall measurements and both walls should have been about the same. There was no uncertainty given for the wall thickness, so the largest difference, ±0.21 mm, between the average and min/max measurements for the outer wall was used for both walls. The variation was made on the outside of the outer wall and the inside of the inner wall to avoid altering the solution annular region. There was no analysis done on the bottom plate thickness. Because all wall thicknesses were adjusted at the same time, the Δk_{eff} results were divided by $\sqrt{12}$ (2 walls for 6 tanks). Results are given in Table 29.

Tank diameters were changed by simultaneously adjusting both walls of each tank such that the solution annular region thickness remained unchanged. However, the effective surface area and volume of the tanks would then vary with the tank diameter. The only uncertainty provided for the tank diameters was the design specification value of ±6 mm, which was used in the calculations. Since all tanks were changed at the same time, the Δk_{eff} results were corrected by dividing by $\sqrt{6}$ (the number of tanks). Results are shown in Table 30.

The solution annulus thickness was a parameter of concern and care was taken by the experimenters to provide details. The models used the specified solution annular region thicknesses and uncertainties from Table 1. All tanks were changed at the same time according to each tank's specification. To correct for this, the Δk_{eff} results were divided by √6 since there were 6 tanks adjusted at the same time. Results are provided in Table 31.

The effect of oval tanks was assessed by using the elliptical formulas in Section 1.2.2 to compare with the circular tanks used in the model. The circular tanks used the "best" outer diameter given in Table 1. Again, all tanks were changed at the same time and the Δk_{eff} results were divided by √6. Results are given in Table 32.

Table 29. Calculated Uncertainties in k_{eff} — Tank Thickness ±0.21 mm.

Configuration No.	$+\Delta k_{eff}$	$+\Delta k_{eff}/\sqrt{12}$	$-\Delta k_{eff}$	$-\Delta k_{eff}/\sqrt{12}$
1a	-0.00035	-0.00010	0.00024	0.00007
1b	-0.00037	-0.00011	0.00021	0.00006
1c	0.00050	0.00014	-0.00065	-0.00019
1d	0.00020	0.00006	-0.00028	-0.00008
2a	-0.00071	-0.00020	0.00032	0.00009
2b	-0.00066	-0.00019	0.00043	0.00012
3a5a	-0.00025	-0.00007	0.00075	0.00022
3b	-0.00072	-0.00021	0.00025	0.00007
4	-0.00065	-0.00019	0.00066	0.00019
5e	-0.00034	-0.00010	0.00078	0.00023
5f	0.00003	0.00001	0.00003	0.00001
6	0.00015	0.00004	-0.00025	-0.00007

Table 30. Calculated Uncertainties in k_{eff} — Tank Diameter ±6 mm.

Configuration No.	$+\Delta k_{eff}$	$+\Delta k_{eff}/\sqrt{6}$	$-\Delta k_{eff}$	$-\Delta k_{eff}/\sqrt{6}$
1a	0.00180	0.00073	-0.00149	-0.00061
1b	0.00145	0.00059	-0.00148	-0.00060
1c	0.00072	0.00029	-0.00050	-0.00020
1d	0.00114	0.00047	-0.00103	-0.00042
2a	0.00285	0.00116	-0.00307	-0.00125
2b	0.00271	0.00111	-0.00329	-0.00134
3a5a	0.00303	0.00124	-0.00270	-0.00110
3b	0.00280	0.00114	-0.00303	-0.00124
4	0.00291	0.00119	-0.00294	-0.00120
5e	0.00271	0.00111	-0.00251	-0.00102
5f	0.00175	0.00071	-0.00176	-0.00072
6	0.00153	0.00062	-0.00148	-0.00060

Table 31. Calculated Uncertainties in k_{eff} — Maximum/minimum Solution Annular Region.

Configuration No.	(Max) Δk_{eff}	(Max) $\Delta k_{eff}/\sqrt{6}$	(Min) Δk_{eff}	(Min) $\Delta k_{eff}/\sqrt{6}$
1a	0.01261	0.00515	-0.01266	-0.00517
1b	0.01442	0.00589	-0.01500	-0.00612
1c	0.01607	0.00656	-0.01660	-0.00678
1d	0.01524	0.00622	-0.01552	-0.00634
2a	0.01326	0.00541	-0.01353	-0.00552
2b	0.01388	0.00567	-0.01508	-0.00616
3a5a	0.01376	0.00562	-0.01380	-0.00563
3b	0.01405	0.00574	-0.01485	-0.00606
4	0.01338	0.00546	-0.01345	-0.00549
5e	0.01395	0.00570	-0.01397	-0.00570
5f	0.01424	0.00581	-0.01455	-0.00594
6	0.01413	0.00577	-0.01429	-0.00583

Table 32. Calculated Uncertainties in k_{eff} — Oval Tanks.

Configuration No.	Δk_{eff}	$\Delta k_{eff}/\sqrt{6}$
1a	-0.00074	-0.00030
1b	-0.00096	-0.00039
1c	-0.00019	-0.00008
1d	0.00029	0.00012
2a	-0.00055	-0.00022
2b	-0.00033	-0.00013
3a5a	-0.00018	-0.00007
3b	-0.00032	-0.00013
4	-0.00028	-0.00011
5e	-0.00020	-0.00008
5f	-0.00014	-0.00006
6	-0.00034	-0.00014

2.5 Concrete and Plaster Water Content

The concrete water content at the time of the experiments is reported only for the enclosure panels as 9.5-wt.% water. The enclosure reflector panel value was used for the boron-free concrete plugs because their compositions were nearly identical. The same was applied to the room walls as there was little information provided for them. For the borated concrete plugs, the water content was calculated according to the desired boron content, resulting in values of 11.42 wt.% for the 1.2-wt.% boron plugs, and 16.98 wt.% for the 2.5-wt.% boron plugs. Appendix C provides a more detailed discussion. The average of the plaster plug water content is 14.49-wt.% water. The experiment report stated that the same ingredients made up the plaster slabs that made up the plugs without providing details, so the material composition of the plaster plugs was used for the plaster slabs. With no uncertainty in the water content provided for any of the concrete or plaster, the uncertainty in water content for all concrete and plaster was set at a standard value of ±0.5-wt.% water. Results are shown in Tables 33–36.

Table 33. Calculated Uncertainties in k_{eff} — B-free Concrete Water Content ±0.5 wt.%.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
1a	-0.00154	0.00142
1b	-0.00132	0.00133
1c	-0.00087	0.00087
1d	-0.00102	0.00117
2a	-0.00095	0.00087
2b	-0.00108	0.00069
3a5a	-0.00066	0.00099
3b	-0.00105	0.00065
4	-0.00157	0.00166
5e	-0.00095	0.00117
5f	-0.00087	0.00102
6	-0.00095	0.00099

Table 34. Calculated Uncertainties in k_{eff} — 1.2% B Concrete Water Content ±0.5 wt.%.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
2a	-0.00077	0.00235
2b	-0.00070	0.00226
3a5a	-0.00007	0.00131
3b	-0.00009	0.00167
5e	-0.00018	0.00146
5f	-0.00012	0.00076
6	-0.00070	0.00061

Table 35. Calculated Uncertainties in k_{eff} — 2.5% B Concrete Water Content ±0.5 wt.%.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
4	-0.00018	0.00175

Table 36. Calculated Uncertainties in k_{eff} — Plaster Water Content ±0.5 wt.%.

Configuration No.	+Δk_{eff}	-Δk_{eff}
3a5a	-0.00006	0.00036
3b	-0.00036	-0.00014
5e	-0.00026	0.00061
5f	-0.00022	0.00015
6	-0.00027	0.00016

2.6 Concrete and Plaster Boron Weight Percent

Concrete plugs and plaster contained varying boron contents. The desired boron weight percent in the borated concrete was 1.2 wt.% and 2.5 wt.%. An exact measurement showing this was not taken, but these values were assumed. The weight percent of boron in the plaster was 1.1 wt.%. There were no reported uncertainties for these values. Based on the available information for the wt.% B in the concrete and plaster, the 1.2 wt.% B concrete had a range of ±0.1 wt.% B, the 2.5 wt.% B concrete had a range on ±0.2 wt.% B, and the plaster had a range of ±0.1 wt.% B. To take the Δk_{eff} values to 1σ, the initial Δk_{eff} values were divided by $\sqrt{3}$. Results are given in Tables 37–39.

Table 37. Calculated Uncertainties in k_{eff} — 1.2% B Concrete B ±0.1 wt.%.

Configuration No.	+Δk_{eff} (1σ)	-Δk_{eff} (1σ)
2a	-0.00077	0.00119
2b	-0.00076	0.00112
3a5a	-0.00034	0.00030
3b	-0.00047	0.00074
5e	-0.00040	0.00074
5f	-0.00016	0.00026
6	0.00001	-0.00001

Table 38. Calculated Uncertainties in k_{eff} — 2.5% B Concrete B ±0.2 wt.%.

Configuration No.	+Δk_{eff} (1σ)	-Δk_{eff} (1σ)
4	-0.00058	0.00075

Table 39. Calculated Uncertainties in k_{eff} — Plaster B ±0.1 wt.%.

Configuration No.	$+\Delta k_{eff}\,(1\sigma)$	$-\Delta k_{eff}\,(1\sigma)$
3a5a	-0.00026	0.00051
3b	-0.00023	0.00033
5e	-0.00078	0.00140
5f	-0.00058	0.00096
6	-0.00055	0.00093

2.7 Concrete and Plaster Density

Table 2 in Section 1.2.3 gives the densities of the concrete and plaster plugs used.

Boron-free concrete

The density chosen for the boron-free concrete was that of the 20 × 0 boron-free concrete plug, 2.29 g/cm^3. Since all boron-free concrete in the models used the same material, the density of the plug was used for the enclosure panels and room walls as well. The density of the boron-free concrete varied between plugs and enclosure panels and no density was reported for the room walls. The difference in density for plugs and the panels was, at a maximum, 0.44 g/cm^3. Because of this, an uncertainty in the boron-free concrete density was chosen to be ±0.44 g/cm^3. This was taken to be a 1σ variation. The Δk_{eff} results for the boron free concrete density are shown in Table 40.

Table 40. Calculated Uncertainties in k_{eff} —Boron Free Concrete Density ±0.44 g/cm^3.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
1a	0.00303	-0.00532
1b	0.00262	-0.00477
1c	0.00193	-0.00347
1d	0.00249	-0.00430
2a	0.00208	-0.00374
2b	0.00143	-0.00364
3a5a	0.00219	-0.00341
3b	0.00176	-0.00376
4	0.00067	-0.00242
5e	0.00172	-0.00217
5f	0.00191	-0.00317
6	0.00194	-0.00330

1.2- wt.% B concrete

The density used for all the 1.2-wt.% B concrete plugs was the middle density reported for the plugs used in these experiments, 2.22 g/cm^3. The maximum variance between all the 1.2-wt.% B concrete plugs made was about 0.2 g/cm^3. An uncertainty of ±0.2 g/cm^3 was used for calculations. Results are shown in Table 41.

Table 41. Calculated Uncertainties in k_{eff} —1.2-wt.% B Concrete Density ±0.2 g/cm^3.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
2a	-0.00117	0.00325
2b	-0.00103	0.00260
3a5a	-0.00008	0.00131
3b	-0.00014	0.00160
5e	-0.00002	0.00147
5f	-0.00024	0.00082
6	-0.00069	0.00063

2.5 wt.% B concrete

The reported density for the 2.5-wt.% B concrete plugs used was 1.94 g/cm^3. The difference in density between all 2.5-wt.% B plugs made was small. An uncertainty of ±0.1 g/cm^3 was chosen for calculations. Results are shown in Table 42.

Table 42. Calculated Uncertainties in k_{eff} —2.5-wt.% B Concrete Density ±0.1 g/cm^3.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
4	-0.00089	0.00234

Plaster

Two plaster plugs were made and used. The average density between plugs, 1.875 g/cm^3, was used. There was no reported density for the plaster slabs, so the density of the plaster plugs was used. Also, no uncertainty in the density was reported, so an uncertainty of ±0.1 g/cm^3 was used. All plaster components were changed at the same time. Results of the calculations are shown in Table 43.

Table 43. Calculated Uncertainties in k_{eff} —Plaster Density ±0.1 g/cm^3.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
3a5a	-0.00027	0.00092
3b	-0.00048	0.00013
5e	-0.00151	0.00178
5f	-0.00111	0.00139
6	-0.00109	0.00095

2.8 ^{10}B and ^{6}Li Abundances

^{10}B

The nominal isotopic abundance of ^{10}B is 19.9 wt.%, but actual recorded values vary slightly as noted in the 16th edition of the Chart of the Nuclides on pages 19–20. Minimum recorded abundances were reported to be 19.1% and maximum abundances were 20.3%. Boron was present in four of the experiment materials: uranyl nitrate solution, 1.2-wt.% B concrete, 2.5-wt.% B concrete, and 1.1-wt.% B plaster. When the ^{10}B abundance was changed, the ^{11}B abundance was adjusted also. Calculations were run with maximum (20.3%) and minimum (19.1%) ^{10}B abundance values for each material with boron at the same time. This was taken to be a 3σ range, so the Δk_{eff} values were divided by 3 to adjust the results to 1σ. Results are shown in Table 44.

Table 44. Calculated Uncertainties in k_{eff} — Max/Min B-10 % Abundance.

Configuration No.	(Max)Δk_{eff}	(Max)Δk_{eff}/3	(Min)Δk_{eff}	(Min)Δk_{eff}/3
1a	0.00010	0.00003	0.00007	0.00002
1b	-0.00001	0.00000	-0.00001	0.00000
1c	0.00015	0.00005	-0.00003	-0.00001
1d	-0.00011	-0.00004	0.00004	0.00001
2a	0.00052	0.00017	0.00133	0.00044
2b	0.00036	0.00012	0.00144	0.00048
3a5a	0.00007	0.00002	0.00118	0.00039
3b	0.00060	0.00020	0.00158	0.00053
4	0.00055	0.00018	0.00118	0.00039
5e	0.00011	0.00004	0.00210	0.00007
5f	-0.00008	-0.00003	0.00102	0.00034
6	0.00044	0.00015	0.00125	0.00042

^{6}Li

According to the Chart of the Nuclides on pages 19–20, ^{6}Li has had a measured abundance of 3.75%. The nominal value for ^{6}Li is 7.59%. This uncertainty was evaluated by letting the abundance of ^{6}Li be 3.75% and adjusting the ^{7}Li abundance to compensate. The minimum value was taken to be a 3σ value and therefore the k_{eff} results were divided by 3 to adjust them to 1σ. These results are given in Table 45.

Table 45. Calculated Uncertainties in k_{eff} — 3.75% ^{6}Li Abundance.

Configuration No.	Δk_{eff}	$\Delta k_{eff}/3$ (1σ)
2a	0.00096	0.00032
2b	0.00080	0.00027
3a5a	0.00060	0.00020
3b	0.00085	0.00028
4	0.00072	0.00024
5e	0.00078	0.00026
5f	0.00053	0.00018
6	0.00080	0.00027

2.9 Enclosure Panels and Platform Floor Thickness

The enclosure reflector panels and platform were all reported to be 203 mm thick; an uncertainty in this value was not given. A standard uncertainty of ±5 mm was chosen for calculations. All 8 panels and the platform were changed at the same time and the resulting Δk_{eff} values were adjusted to 1σ by dividing by √9. All results are given in Table 46.

Table 46. Calculated Uncertainties in k_{eff} — Enclosure Panels and Platform Floor Thickness ±5 mm.

Configuration No.	$+\Delta k_{eff}$	$+\Delta k_{eff}/\sqrt{9}$	$-\Delta k_{eff}$	$-\Delta k_{eff}/\sqrt{9}$
1a	0.00022	0.00007	-0.00013	-0.00004
1b	0.00002	0.00001	-0.00010	-0.00003
1c	0.00028	0.00009	-0.00020	-0.00007
1d	0.00022	0.00007	-0.00008	-0.00003
2a	0.00016	0.00005	-0.00025	-0.00008
2b	-0.00027	-0.00009	-0.00040	-0.00013
3a5a	0.00038	0.00013	-0.00005	-0.00002
3b	0.00002	0.00001	0.00004	0.00001
4	0.00013	0.00004	-0.00002	-0.00001
5e	0.00003	0.00001	-0.00015	-0.00005
5f	0.00031	0.00010	0.00002	0.00001
6	0.00025	0.00008	0.00023	0.00008

2.10 Plug Thickness

All of the concrete and plaster plugs had varying diameters. Some had annular shapes and others had solid forms. Table 2 in Section 1.2.3 gives details about the plugs. There was no uncertainty in the plug dimensions provided. A standard uncertainty of ±0.5 mm was used. All plugs were changed at the same time by adjusting the diameter from the outside surface of each plug. There were either 2 or 3 plugs adjusted at once in a given configuration and the Δk_{eff} results were adjusted to 1σ by dividing by the square root of the number of plugs changed. Uncertainty calculation results are shown in Table 47.

Table 47. Calculated Uncertainties in k_{eff} — Plug Thickness ±0.5 mm.

Configuration No.	$+\Delta k_{eff}$	$+\Delta k_{eff}/\sqrt{N}$	$-\Delta k_{eff}$	$-\Delta k_{eff}/\sqrt{N}$
2a	-0.00028	-0.00016	-0.00019	-0.00011
2b	-0.00058	-0.00033	-0.00013	-0.00008
3a5a	0.00013	0.00009	0.00008	0.00006
3b	-0.00035	-0.00020	-0.00027	-0.00016
4	-0.00016	-0.00009	0.00032	0.00018
5e	0.00011	0.00006	0.00036	0.00021
5f	-0.00005	-0.00003	0.00014	0.00008
6	-0.00017	-0.00012	0.00023	0.00016

2.11 Slab Dimensions

Two parameters for the uncertainty in the slab dimensions were analyzed: thickness and width. The slabs were reported to have a thickness of 19 mm and a width of 1.09 m. The thickness and the had an uncertainty of ±1 mm applied for calculations since no uncertainty was provided while the width was assessed for an uncertainty of ±5 mm. Uncertainties were performed for variations of ±5 mm and then reduced to ±1 mm for the slab thickness. Both slabs were adjusted at the same time and the Δk_{eff} results were divided by √2 to obtain 1σ values. Results are shown in Tables 48 and 49.

Table 48. Calculated Uncertainties in k_{eff} — Slab Thickness ±1 mm.

Configuration No.	$+\Delta k_{eff}$	$+\Delta k_{eff}/5\sqrt{2}$	$-\Delta k_{eff}$	$-\Delta k_{eff}/5\sqrt{2}$
5e	-0.00501	-0.00071	0.00566	0.00080
5f	-0.00452	-0.00064	0.00437	0.00062
6	-0.00244	-0.00035	0.00265	0.00037

Table 49. Calculated Uncertainties in k_{eff} — Slab Width ±5 mm.

Configuration No.	$+\Delta k_{eff}$	$+\Delta k_{eff}/\sqrt{2}$	$-\Delta k_{eff}$	$-\Delta k_{eff}/\sqrt{2}$
5e	0.00005	0.00004	0.00034	0.00024
5f	-0.00009	-0.00006	0.00022	0.00016
6	-0.00009	-0.00006	-0.00003	-0.00002

2.12 Absorber/Moderator Placement

Plugs

All plugs were modeled centered within the tanks they were placed in. There were no uncertainties about the location of the plugs given. It is known from Table 6 in Section 1.2.6 that the plugs were not completely centered. It was thought that the same results would be obtained no matter which way plugs were shifted, so all plugs were moved 5 mm in the west direction starting with the west plugs, then the middle, and finally the east plugs. The calculated results for Δk_{eff} are given in Tables 50–52.

Table 50. Calculated Uncertainties in k_{eff} — West Plug Moved West 5 mm.

Configuration No.	Δk_{eff}
2a	-0.00009
2b	-0.00013
3a5a	0.00024
3b	-0.00022
4	0.00012
5e	0.00007
5f	0.00017
6	0.00024

Table 51. Calculated Uncertainties in k_{eff} — Middle Plug Moved West 5 mm.

Configuration No.	Δk_{eff}
2a	-0.00013
2b	-0.00014
3a5a	0.00018
3b	0.00008
4	0.00020
5e	0.00011

Table 52. Calculated Uncertainties in k_{eff} — East Plug Moved West 5 mm.

Configuration No.	Δk_{eff}
2a	-0.00014
2b	-0.00044
3a5a	-0.00005
3b	-0.00019
4	-0.00018
5e	-0.00030
5f	0.00009
6	-0.00007

Slabs

There were no specific details on where the slabs were placed other than between the tanks. In the models slabs were placed centered with the middle set of tanks and placed midway between tanks. Both slabs were moved 5 mm in varying directions (south, north, west, east). The slabs were moved together south and north and the Δk_{eff} results of those calculations were divided by $\sqrt{2}$ (the number of slabs). The slabs were moved one at a time in the west and east directions. Results of these Δk_{eff} calculations are provided in Tables 53–58.

Table 53. Calculated Uncertainties in k_{eff} — Slabs Moved South 5 mm.

Configuration No.	Δk_{eff}	$\Delta k_{eff}/\sqrt{2}$
5e	0.00007	0.00005
5f	0.00005	0.00004
6	-0.00003	-0.00002

Table 54. Calculated Uncertainties in k_{eff} — Slabs Moved North 5 mm.

Configuration No.	Δk_{eff}	$\Delta k_{eff}/\sqrt{2}$
5e	0.00013	0.00009
5f	-0.00005	-0.00004
6	0.00008	0.00006

Table 55. Calculated Uncertainties in k_{eff} — West Slab Moved West 5 mm.

Configuration No.	Δk_{eff}
5e	-0.00005
5f	-0.00007
6	-0.00011

Table 56. Calculated Uncertainties in k_{eff} — West Slab Moved East 5 mm.

Configuration No.	Δk_{eff}
5e	0.00043
5f	0.00019
6	0.00000

Table 57. Calculated Uncertainties in k_{eff} — East Slab Moved West 5 mm.

Configuration No.	Δk_{eff}
5e	0.00000
5f	-0.00009
6	0.00027

Table 58. Calculated Uncertainties in k_{eff} — East Slab Moved East 5 mm.

Configuration No.	Δk_{eff}
5e	0.00003
5f	0.00005
6	-0.00001

2.13 Tank Placement

Tanks were modeled as concentric, which was a simplification. They were then moved 5 mm in different ways to see the effect on Δk_{eff}. First, the nested tanks (4, 3*, 2) were moved west. It was assumed that the effect would be the same no matter which way they were moved. The end pairs of tanks were brought closer to the middle tanks and then moved farther out. The Δk_{eff} results from moving the tanks closer and farther were divided by $\sqrt{2}$, since 2 sets of tanks were moved at the same time.

The end tanks were positioned according to Table 4. This gave the east tanks an offset to the south and the west tanks to the north. Effects of moving the east tank north 5 mm and the west tank south 5 mm were calculated separately. All results are given in Tables 59–65.

Table 59. Calculated Uncertainties in k_{eff} — Tank 4 Moved West 5 mm.

Configuration No.	Δk_{eff}
1a	-0.00029
1b	0.00000
1c	0.00015
1d	-0.00010
2a	-0.00029
2b	-0.00029
3a5a	-0.00003
3b	-0.00026
4	-0.00052
5e	0.00014
5f	-0.00040
6	-0.00050

Table 60. Calculated Uncertainties in k_{eff} — Tank 3* Moved West 5 mm.

Configuration No.	Δk_{eff}
1a	-0.00014
1b	-0.00065
1c	0.00006
1d	-0.00021
2a	-0.00051
2b	-0.00117
3a5a	-0.00010
3b	-0.00089
4	0.00002
5e	-0.00045
5f	-0.00014
6	0.00027

Table 61. Calculated Uncertainties in k_{eff} — Tank 2 Moved West 5 mm.

Configuration No.	Δk_{eff}
1a	0.00041
1b	0.00034
1c	0.00007
1d	0.00024
2a	0.00050
2b	0.00040
3a5a	0.00073
3b	0.00063
4	0.00027
5e	0.00068
5f	0.00044
6	-0.00006

Table 62. Calculated Uncertainties in k_{eff} — Tanks Moved Closer East-West 5 mm.

Configuration No.	Δk_{eff}	$\Delta k_{eff}/\sqrt{2}$
1a	0.00096	0.00068
1b	0.00074	0.00052
1c	0.00043	0.00030
1d	0.00076	0.00054
2a	0.00149	0.00105
2b	0.00103	0.00073
3a5a	0.00157	0.00111
3b	0.00109	0.00077
4	0.00124	0.00088
5e	0.00104	0.00074
5f	0.00125	0.00088
6	0.00084	0.00059

Table 63. Calculated Uncertainties in k_{eff} — Tanks Moved Further East-West 5 mm.

Configuration No.	Δk_{eff}	$\Delta k_{eff}/\sqrt{2}$
1a	-0.00073	-0.00052
1b	-0.00080	-0.00057
1c	-0.00016	-0.00011
1d	-0.00074	-0.00052
2a	-0.00148	-0.00105
2b	-0.00164	-0.00116
3a5a	-0.00093	-0.00066
3b	-0.00126	-0.00089
4	-0.00135	-0.00095
5e	-0.00072	-0.00051
5f	-0.00091	-0.00064
6	-0.00101	-0.00071

Table 64. Calculated Uncertainties in k_{eff} — East Tanks Moved North 5 mm.

Configuration No.	Δk_{eff}
1a	-0.00007
1b	-0.00011
1c	-0.00004
1d	-0.00007
2a	0.00005
2b	-0.00041
3a5a	-0.00006
3b	-0.00028
4	0.00015
5e	0.00029
5f	0.00005
6	-0.00002

Table 65. Calculated Uncertainties in k_{eff} — West Tanks Moved South 5 mm.

Configuration No.	Δk_{eff}
1a	0.00006
1b	-0.00007
1c	0.00008
1d	0.00015
2a	0.00010
2b	-0.00023
3a5a	-0.00009
3b	-0.00014
4	0.00017
5e	0.00018
5f	0.00011
6	-0.00004

2.14 Temperature

All experiments were performed at an ambient average temperature of 20°C with variations between 18–22°C. The experiment report stated that all experiments were done in the day after all parts of the experiment setup reached equilibrium. MCNP5 was used to vary the temperature of each piece of the setup by ±50K. To take this to the stated ±2K range, the Δk_{eff} results for the ±50K were divided by 25. These values were assumed to be 3σ values and were therefore corrected to 1σ by dividing the Δk_{eff} results by 3. Table 66 gives the temperature uncertainty results. This uncertainty accounts for the variation in k_{eff} due to temperature variation in the cross section data. The evaluation of the uncertainty in solution density due to temperature variation is found in Section 2.2.

Table 66. Calculated Uncertainties in k_{eff} — Temperature Variation.

Configuration No.	Δk_{eff}+50 K	+Δk_{eff}/25	+Δk_{eff} (1σ)	Δk_{eff}-50 K	-Δk_{eff}/25	-Δk_{eff} (1σ)
1a	0.00281	0.00011	0.00004	-0.00285	-0.00011	-0.00004
1b	0.00268	0.00011	0.00004	-0.00300	-0.00012	-0.00004
1c	0.00148	0.00006	0.00002	-0.00178	-0.00007	-0.00002
1d	0.00209	0.00008	0.00003	-0.00224	-0.00009	-0.00003
2a	0.00186	0.00007	0.00002	-0.00242	-0.00010	-0.00003
2b	0.00172	0.00007	0.00002	-0.00250	-0.00010	-0.00003
3a5a	0.00230	0.00009	0.00003	-0.00238	-0.00010	-0.00003
3b	0.00175	0.00007	0.00002	-0.00235	-0.00009	-0.00003
4	0.00208	0.00008	0.00003	-0.00215	-0.00009	-0.00003
5e	0.00180	0.00007	0.00002	-0.00193	-0.00008	-0.00003
5f	0.00153	0.00006	0.00002	-0.00181	-0.00007	-0.00002
6	0.00158	0.00006	0.00002	-0.00164	-0.00007	-0.00002

2.15 Wood Parameters in Detailed Models

This section deals with two parameters of wood, the thickness and the density, which was modeled in the detailed models only. Little information was provided about the wood used; however, it was reported that the wood was plywood and construction grade lumber of low mass to reduce reflection. Wood was used to frame the plaster slabs and for constructing plug stands. To see how much the presence of wood effects the k_{eff} values, all wood thicknesses were changed at the same time by ±0.3175 cm (1/8 in.), except for the top piece of the slab frames which remained unchanged and level with the tops of the tanks.

A wood density of 0.6 g/cm^3 was used in the models. According to various sources, density for wood varied by ±0.1 g/cm^3. This was used as the uncertainty in the wood density. All results are shown in Tables 67 and 68.

Table 67. Calculated Uncertainties in k_{eff} — Wood Thickness ±0.3175 cm.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
2a	0.00005	0.00003
2b	-0.00013	-0.00031
3a5a	-0.00009	-0.00011
3b	0.00034	0.00010
4	0.00026	0.00003
5e	-0.00146	0.00102
5f	-0.00084	0.00039
6	0.00041	-0.00036

Table 68. Calculated Uncertainties in k_{eff} — Wood Density ±0.1 g/cm^3.

Configuration No.	$+\Delta k_{eff}$	$-\Delta k_{eff}$
2a	-0.00030	-0.00001
2b	0.00005	-0.00019
3a5a	0.00033	0.00017
3b	0.00007	0.00032
4	0.00013	0.00042
5e	-0.00126	0.00072
5f	-0.00086	0.00052
6	-0.00003	-0.00034

2.16 Summary of Uncertainties in k_{eff} and Total Uncertainties for Each Configuration

The following table, Table 69, provides a summary of all the uncertainty calculations and the total uncertainty in k_{eff} for each configuration. The values in the table are the absolute values of the highest 1σ value of each uncertainty. In order to avoid double counting uncertainties, it was decided to take the highest uncertainty value from each of five sets of similar calculations. These included: moving slabs north/south, moving the west slab west/east, moving the east slab west/east, moving tanks closer/further east/west, and moving the east tank north and west tank south. The total uncertainty was calculated by taking the square root of the sum of the squares of each uncertainty for each configuration. Total uncertainties are provided for both the simple and detailed models. The totals differ between models because of the wood uncertainty in the detailed model only. Case numbers in Table 69 refer to the acceptable benchmark cases. Significant contributors to the total uncertainty of each configuration are highlighted in gray.

Table 69. Summary of Uncertainties in k_{eff} and Total Uncertainty for Each Configuration, $\pm\Delta k_{eff}$ (1σ).

Source of Uncertainty	Conf. 1a	Conf. 1b	Conf. 1c	Conf. 1d	Conf. 2a	Conf. 2b
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Solution critical height	0.00201	0.00154	0.00072	0.00095	0.00057	0.00038
Excess acid in solution	0.00031	0.00035	0.00036	0.00041	0.00041	0.00061
Solution density	0.00176	0.00199	0.00189	0.00245	0.00186	0.00219
Solution uranium concentration	0.00182	0.00187	0.00218	0.00178	0.00153	0.00185
Solution impurities	0.00031	0.00027	0.00021	0.00009	0.00033	0.00023
Solution chemistry	0.00037	0.00037	0.00037	0.00037	0.00037	0.00037
Solution U-235	0.00024	0.00020	0.00021	0.00023	0.00015	0.00033
Tank steel impurities	0.00098	0.00094	0.00075	0.00084	0.00094	0.00092
Tank steel density	0.00033	0.00015	0.00018	0.00007	0.00057	0.00055
Tank thickness	0.00010	0.00011	0.00019	0.00008	0.00020	0.00019
Tank diameter	0.00073	0.00060	0.00029	0.00047	0.00125	0.00134
Solution annular region thickness	0.00517	0.00612	0.00678	0.00634	0.00552	0.00616
Oval tanks	0.00030	0.00039	0.00008	0.00012	0.00022	0.00013
B-free concrete water wt.%	0.00154	0.00133	0.00087	0.00117	0.00095	0.00108
1.2% B concrete water wt.%	-	-	-	-	0.00235	0.00226
2.5% B concrete water wt.%	-	-	-	-	-	-
Plaster water wt.%	-	-	-	-	-	-
1.2% B concrete B wt.%	-	-	-	-	0.00119	0.00112
2.5% B concrete B wt.%	-	-	-	-	-	-
Plaster B wt.%	-	-	-	-	-	-
B-free concrete density	0.00532	0.00477	0.00347	0.00430	0.00374	0.00364
1.2% B concrete density	-	-	-	-	0.00325	0.00260
2.5% B concrete density	-	-	-	-	-	-
Plaster density	-	-	-	-	-	-
B-10 % abundance	0.00003	0.00000	0.00005	0.00004	0.00044	0.00048
Li-6 % abundance	-	-	-	-	0.00032	0.00027

Table 69 (cont'd). Summary of Uncertainties in k_{eff} and Total Uncertainty for Each Configuration, $\pm\Delta k_{eff}$ (1σ).

Source of Uncertainty	Conf. 3a5a[a]	Conf. 3b	Conf. 4	Conf. 5e	Conf. 5f	Conf. 6
	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12
Solution critical height	0.00048	0.00031	0.00061	0.00043	0.00120	0.00106
Excess acid in solution	0.00034	0.00049	0.00031	0.00064	0.00048	0.00045
Solution density	0.00215	0.00225	0.00193	0.00264	0.00170	0.00202
Solution uranium concentration	0.00172	0.00181	0.00159	0.00153	0.00177	0.00189
Solution impurities	0.00036	0.00037	0.00019	0.00030	0.00038	0.00020
Solution chemistry	0.00037	0.00037	0.00037	0.00037	0.00037	0.00037
Solution U-235	0.00018	0.00025	0.00019	0.00017	0.00017	0.00024
Tank steel impurities	0.00103	0.00096	0.00099	0.00095	0.00083	0.00076
Tank steel density	0.00047	0.00046	0.00031	0.00039	0.00029	0.00019
Tank thickness	0.00022	0.00021	0.00019	0.00023	0.00001	0.00007
Tank diameter	0.00124	0.00124	0.00120	0.00111	0.00072	0.00062
Solution annular region thickness	0.00563	0.00606	0.00549	0.00570	0.00594	0.00583
Oval tanks	0.00007	0.00013	0.00011	0.00008	0.00006	0.00014
B-free concrete water wt.%	0.00099	0.00105	0.00166	0.00117	0.00102	0.00099
1.2% B concrete water wt.%	0.00131	0.00167	-	0.00146	0.00076	0.00070
2.5% B concrete water wt.%	-	-	0.00175	-	-	-
Plaster water wt.%	0.00036	0.00036	-	0.00061	0.00022	0.00027
1.2% B concrete B wt.%	0.00034	0.00074	-	0.00074	0.00026	0.00001
2.5% B concrete B wt.%	-	-	0.00075	-	-	-
Plaster B wt.%	0.00051	0.00033	-	0.00140	0.00096	0.00093
B-free concrete density	0.00341	0.00376	0.00242	0.00217	0.00317	0.00330
1.2% B concrete density	0.00131	0.00160	-	0.00147	0.00082	0.00069
2.5% B concrete density	-	-	0.00234	-	-	-
Plaster density	0.00092	0.00048	-	0.00178	0.00139	0.00109
B-10 % abundance	0.00039	0.00053	0.00039	0.00007	0.00034	0.00042
Li-6 % abundance	0.00020	0.00028	0.00024	0.00026	0.00018	0.00027

(a) Configuration 5a is essential a repeat of configuration 3a. The results have been averaged to obtain data for Case 7.

Table 69 (cont'd). Summary of Uncertainties in k_{eff} and Total Uncertainty for Each Configuration, $\pm\Delta k_{eff}$ (1σ).

Source of Uncertainty	Conf. 1a	Conf. 1b	Conf. 1c	Conf. 1d	Conf. 2a	Conf. 2b
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Panels and floor thickness	0.00007	0.00003	0.00009	0.00007	0.00008	0.00013
Plug thickness	-	-	-	-	0.00016	0.00033
Slab thickness	-	-	-	-	-	-
Slab width	-	-	-	-	-	-
West plug moved west	-	-	-	-	0.00009	0.00013
Middle plug moved west	-	-	-	-	0.00013	0.00014
East plug moved west	-	-	-	-	0.00014	0.00044
Slabs moved south	-	-	-	-	-	-
Slabs moved north	-	-	-	-	-	-
West slab moved west	-	-	-	-	-	-
West slab moved east	-	-	-	-	-	-
East slab moved west	-	-	-	-	-	-
East slab moved east	-	-	-	-	-	-
Tank 4 moved west	0.00029	0.00000	0.00015	0.00010	0.00029	0.00029
Tank 3*moved west	0.00014	0.00065	0.00006	0.00021	0.00051	0.00117
Tank 2 moved west	0.00041	0.00034	0.00007	0.00024	0.00050	0.00040
Tanks closer/further east-west	0.00068	0.00057	0.00030	0.00054	0.00105	0.00116
East tank moved north West tank moved south	0.00007	0.00011	0.00008	0.00015	0.00010	0.00041
Temp.	0.00004	0.00004	0.00002	0.00003	0.00003	0.00003
Wood thickness	-	-	-	-	0.00005	0.00031
Wood density	-	-	-	-	0.00030	0.00019
Total	0.00841	0.00863	0.00831	0.00848	0.00863	0.00902

Table 69 (cont'd). Summary of Uncertainties in k_{eff} and Total Uncertainty for Each Configuration, $\pm\Delta k_{eff}$ (1σ).

Source of Uncertainty	Conf. 3a5a[a]	Conf. 3b	Conf. 4	Conf. 5e	Conf. 5f	Conf. 6
	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12
Panels and floor thickness	0.00013	0.00001	0.00004	0.00005	0.00010	0.00008
Plug thickness	0.00009	0.00020	0.00018	0.00021	0.00008	0.00016
Slab thickness	-	-	-	0.00080	0.00064	0.00037
Slab width	-	-	-	0.00024	0.00016	0.00006
West plug moved west	0.00024	0.00022	0.00012	0.00007	0.00017	0.00024
Middle plug moved west	0.00018	0.00008	0.00020	0.00011	-	-
East plug moved west	0.00005	0.00019	0.00018	0.00030	0.00009	0.00007
Slabs moved south/north	-	-	-	0.00009	0.00004	0.00006
West slab moved west/east	-	-	-	0.00043	0.00019	0.00011
East slab moved west/east	-	-	-	0.00003	0.00009	0.00027
Tank 4 moved west	0.00003	0.00026	0.00052	0.00014	0.00040	0.00050
Tank 3*moved west	0.00010	0.00089	0.00002	0.00045	0.00014	0.00027
Tank 2 moved west	0.00073	0.00063	0.00027	0.00068	0.00044	0.00006
Tanks closer/further east-west	0.00111	0.00089	0.00095	0.00074	0.00088	0.00071
East tank moved north West tank moved south	0.00009	0.00028	0.00017	0.00029	0.00011	0.00004
Temp.	0.00003	0.00003	0.00003	0.00003	0.00002	0.00002
Wood thickness	0.00011	0.00034	0.00026	0.00146	0.00084	0.00041
Wood density	0.00033	0.00032	0.00042	0.00086	0.00086	0.00034
Total	0.00790	0.00854	0.00807	0.00845	0.00856	0.00847

(a) Configuration 5a is essential a repeat of configuration 3a. The results have been averaged to obtain data for Case 7.

3.0 BENCHMARK SPECIFICATIONS

3.1 Description of Model

Detailed and simple models were built for each experiment setup. The important changes for the simplified model are the omission of the slope of the tank, skirt holes, rebar/steel reinforcement, and all wood. The tanks, enclosure, and surroundings were maintained in the same configuration throughout all experiments. The experiment is oriented so that west is in the +y-direction, north is in the +x-direction, and up is in the +z-direction.

Section 2 describes the difficulty encountered while trying to model the enclosure and tank placement. Average dimensions from Table 4 were used to model the enclosure and tank placement. The middle set of tanks was placed at the origin and other tanks and the enclosure were placed from there.

Details about how the models differed from the actual experiment are provided in each section hereafter where applicable.

3.1.1 Detailed Model

Solution and Tanks

The nominal values for the uranyl nitrate solution were used. These included a solution concentration of 357.4 g U/liter solution, solution density of 1.4982 g/cm^3, and 0.5751 N of free nitric acid. The uranium isotopic breakdown values are those given in Table 70, and the average elemental impurities in Table 71 were used. The total concentration of the impurities is 0.70872 μg/mm^3.

Table 70. Uranium Isotopic Composition.

Isotope	Weight Percent
^{234}U	0.982
^{235}U	93.219
^{236}U	0.432
^{238}U	5.367

Table 71. Uranyl Nitrate Solution Average Elemental Impurities.

Element	ppm by wt., relative to U wt.	Element	ppm by wt., relative to U wt.
B	4.4	Cu	81
Mg	250	Zn	230
Al	350	Mo	75
Si	43	Cd	7.8
Mn	27	Sn	280
Fe	515	Pb	44
Ni	69	Bi	6.8

All six tanks were present in each experiment, whether empty or filled with solution. They were modeled as stainless steel Type 304L, using the nominal density of 8.03 g/cm^3 and the average of the six elemental compositions given in Table 10 as shown in Table 83. The tanks were modeled as circular, using the "best" outer diameter and measured average annular-region thickness in Table 1 as shown in Figures 26–32 and in Table 76. The nominal wall thickness of 0.64 cm was used. The middle pair of tanks (2*, 3*) were placed with centers at the origin. Other tanks were placed with offset centers using the dimensions in Table 4 as guidelines and shown in Figures 18, 20, 22, 23, and 24–26 and Tables 75–76. The tank tops were modeled at an elevation of 2439 mm above the platform. The tank bottoms were modeled as sloped 2º, with the solution region midpoints at 32.28, 32.11, 31.91, and 31.65 cm above the elevated platform for tanks 1, 2 and 2*, 3 and 3*, and 4, respectively. Solution heights for each tank were level but measured up from differing solution region midpoints of each tank as given. The support skirt for each tank was modeled as a cylindrical extension of the tank inner wall, with six 25.0-cm diameter holes centered 15.25 cm above the platform floor and spaced at 60º angles. The tank interior-spacing rods were omitted. Tanks were modeled as being concentric. The tank bottoms were 0.64-mm thick.

Absorbers and Moderators

All central moderator/absorber plugs were modeled centered in the tanks in which they were placed.

The boron-free concrete, borated concrete, and borated plaster compositions were derived using nominal constituents and measured impurities as detailed in Appendix C.

The concrete and plaster plugs were modeled with steel rods and lifting anchors omitted because insufficient information was available to include them and they were a small part and assumed to have little affect of criticality. All central wooden spacer discs were omitted because there were insufficient details to be able to model them. The plugs are modeled mostly as given in Table 2 as shown in Table 77 and Figures 39–41. Plug heights were changed and made level with the tops of the tanks. This was done by increasing plug heights from 0–178 mm. This choice was based on the fact that plug heights were already close to the tops of the tanks for most cases, and both tanks and plugs were well above the top of the highest solution position, and therefore assumed to not affect criticality. This also helped to simplify the modeling.

The densities for each B-wt.% concrete should be similar since each set came from the same concrete batch. The density of the 0-wt.% B concrete plug (2.29 g/cm^3) was used for all the 0-wt.% B concrete, including the one plug used, the enclosure reflector panels, and the room walls. This was done due to a lack of information for each. For the 1.2-wt.% B plugs, the middle density, 2.22 g/cm^3, was used, which is the density of the 24 × 10 plug used in configurations 2a and 2b (Cases 5 and 6). The 2.5-wt.% B plugs used the given density of 1.94 g/cm^3. The density used for the plaster plugs was the average of the two reported in Table 2, 1.875 g/cm^3.

The 30 × 0, 1.2-wt.% B concrete plug, intended to be an annular plug, collapsed during casting and was filled as a solid plug above the collapsed portion. The dimensions the experimenters assumed, given in Figure 11, were used.

Two 1.1-wt.% boron plaster slabs were used between tanks in configurations 10 through 12. They contained the same ingredients as the plaster plugs. The location of each slab during experiments was not stated. Figure 8 in Section 1 shows the cross section of a slab. Slabs with attached wood frames were centered with the middle tank along the y-axis and placed at the mid point between tanks. These slabs were used in configurations 5e, 5f, and 6.

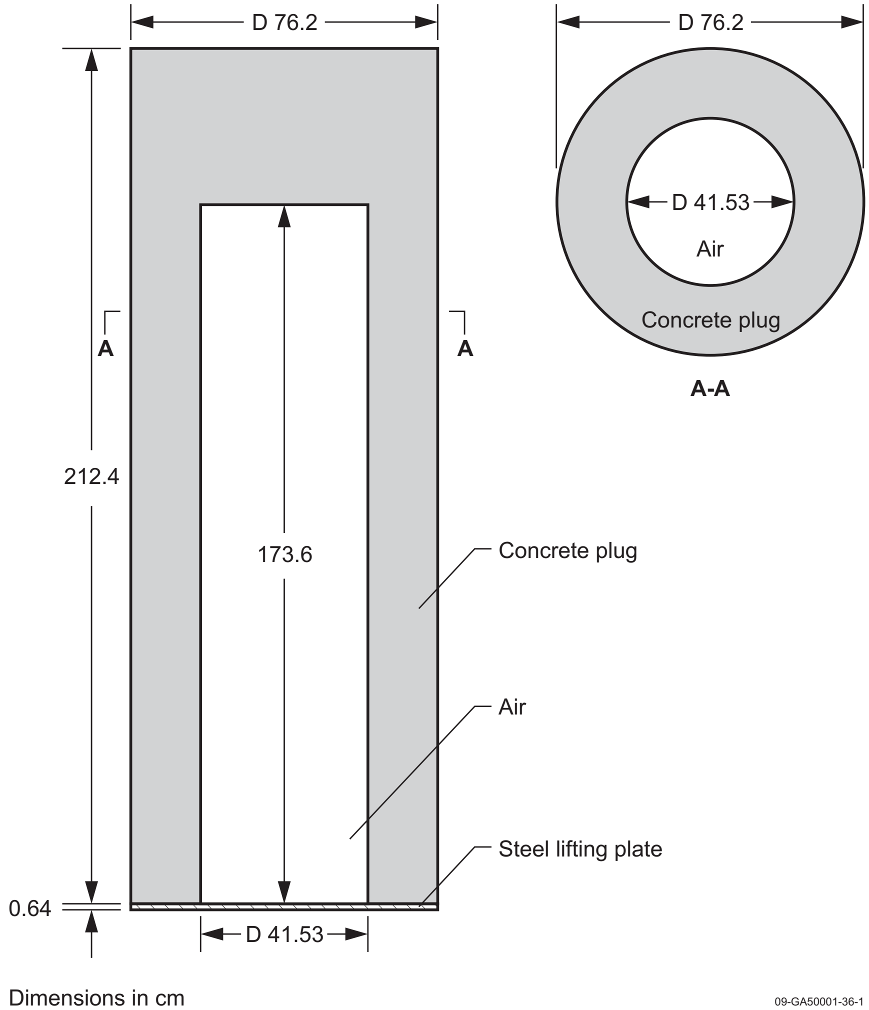

Figure 11. Vertical Cylindrical Cross Section Reported for the 30 × 0, 1.2% B Concrete Plug.
(Gray area is concrete, inner area is open cavity—inner paper not shown, steel lifting plate on bottom.)

The Sonotubes used as inner and outer plug molds were modeled as cellulose, $C_6H_{10}O_5$. Using the weights and dimensions given in Table 2, a density of 0.1854 g/cm^3 was calculated. Details about the bonding material, sodium silicate, were not given in the experiment report. It was omitted as a minor constituent. The plastic and beeswax coating thicknesses on the Sonotubes were not specified in the experiment report and were therefore omitted. Any additional bias as a result of this simplification is considered negligible.

A 0.15-cm thick commercial corrugated steel culvert stock was used in place of an inner paper Sonotube for the 30 × 18, 2.5-wt.% B concrete plug. The culvert was cut the same length as the paper tubes. The corrugation on the culvert was ignored and the average inner diameter, 46.95 cm, was used. The zinc used for galvanizing the culvert on the inside and outside was included with the rest of the culvert material components.

The plug bottom steel plates are modeled the same as the tanks, stainless steel Type 304L, using the dimensions given in Table 2 and repeated in Table 77 and shown in Figures 39–41.

The cadmium lamination placed on the 22 × 0, 0-wt.% B concrete plug was modeled using the theoretical cadmium density of 8.65 g/cm^3.[a] Since only "small daubs" of the bonding agent were used to attach the lamination to the plug (Reference 2), and details about its constituents were not provided, the bonding agent itself was omitted. The lamination was 0.159-cm thick and the height for the 22 × 0 concrete plug (level with the tanks) was used as the height of the lamination. The lamination was located on the outside of the outer paper form.

All plugs rested on wood stands (see Figure 42). The stands resembled an open square frame when viewed from above (Reference 2), but no photo or picture of the stands was provided. The overall stand dimensions were not specified. Therefore, stands were modeled with the information that was given and made in three different sizes that fit inside the nested tanks. The experiment report did not provide an analysis of the wood used and a composition was not provided. Wood ranges mostly in density and little else. All components of wood include the elements H, C, and O in various molecules. For the benchmark models, all wood was treated as cellulose with an average density of 0.6 g/cm^3. This was chosen based on various sources and other critical evaluations that modeled wood.[b] Wood was also used to frame the plaster slabs placed between tanks.

Enclosure and Room Layout

The enclosure concrete was modeled using the boron-free composition given in Table 81. Though there were eight panels used for the enclosure, the enclosure was modeled as a continuous piece of concrete without the panels extending beyond the west panel wall. Figures 18–25 show the enclosure and its surroundings as modeled. For proximity of the enclosure walls to the tanks, average spacing values from Table 4 were used as a guide and are shown in Table 76. These values were added to the outer diameter of tank 2*, then all other tanks were placed. Tank 1 was closer to the south panel than reported even after the given dimensions were followed closely. The smallest enclosure panel, at the northwest corner, was modeled level with the other panels. No air gaps in the enclosure walls were included in the model.

The elevated platform was modeled as 342.6984 cm × 159.3170 cm so that it corresponded with the enclosure wall boundaries. The room surroundings were ignored with the exception of the east and south walls immediately adjacent to the experiment enclosure. The east and south room walls were modeled extending down to the bottom of the elevated platform and up 1 m above the tops of the tanks. These wall dimensions were chosen to make the model simple and concise. The effects of adding more wall is evaluated in the room return bias.

The detailed model included the rebar in the reflector panels and room walls. The material composition for all rebar was modeled as carbon steel. The rebar reinforcement in the panels was 1.3 cm in diameter. The rebar was placed in a horizontal and vertical crossed pattern uniformly spaced in both directions in each panel and inset from the edges the same distance in the middle of each panel (10.15 cm). Vertical pieces extended from the bottom of the panels (top of the platform) to the top of the panels at a height of 244 cm.

Individual panels were not modeled but rebar was placed and spaced as if they were. The five 122-cm-wide panels each contained four vertical pieces each spaced 24.4 cm from the ends of each panel and from each other, and two for the 30-cm wide panel spaced 10 cm from the ends of the panel and each other. If modeled fully, there would have been three vertical rebar pieces for the 61-cm-wide panel spaced 15.25 cm from the ends of the panel and from each other, and three for the 91-cm-wide panel each spaced 22.75 cm from the

[a] Nuclides and Isotopes: Chart of the Nuclides, 16th edition, (2002).

[b] Magnuson, D.W., 1972, Critical Three-Dimensional Arrays of Neutron Interacting Units: Part III Arrays of U(93.2) Metal Separated by Various Materials, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant, May 1972.

ends of the panel and from each other. Because the 61- and 91-cm-wide panels were not modeled fully (compare Figure 10 to Figures 18, 20, 22, 23, and 25) only two pieces of vertical rebar were able to fit within them, giving the total number of vertical rebar in the enclosure panels to be 26.

All panels contained ten horizontal pieces of rebar that extended the length of the enclosure on each side, and spaced 22.1818 cm from the bottom, top, and from each other. Lifting and stabilizing anchors placed in the top of each panel were omitted.

The rebar in the east wall and south-east corner of the south wall had horizontal rebar that was #8 gauge (2.54 cm diameter) and the vertical rebar was #6 gauge (1.905 cm diameter) both on 30-cm centers. Two layers of rebar, each 8.0 cm in from the outer wall surfaces, was specified, but only the inner rebar was included in the model since the outer layer was far enough out to have had no effect on the system. The rebar was only placed in the portion of the walls that was exposed directly to the tank system; the rebar was not extended the length of the south wall.

There was a total of twelve pieces of horizontal rebar in the east wall. The first was placed centered with the top of the platform and the rest were spaced up from there. The horizontal rebar extended from the north side of the east wall to the point where the east wall meets the south wall, a length of 159.317 cm. A total of five vertical rebar pieces were placed in the east wall. The first was placed at the position x = 0 and spaced out north and south from there. The length of the vertical pieces was equal to the height of the modeled wall, 364.2 cm.

Horizontal rebar in the southeast corner of the south wall was placed similarly to that of the horizontal rebar in the east wall. It extended from the outside of the east wall to the point where the south enclosure panel ends on the east side, a total length of 183.9 cm. Only three vertical pieces were included in the southeast corner of the south wall. They were the same height as the vertical rebar in the east wall. The first piece was placed centered with the end of the south enclosure panel on the east side and then the other two were spaced to the east.

The placement of all rebar is shown in Figures 12–17.

3.1.2 Simplified Model - All materials were modeled identically for the simplified and detailed models. The changes between the detailed and simple model included the omission of all rebar and steel reinforcement, omission of all wood, leveling the bottoms of all tank solution regions at 31.9 cm above the platform, and not placing holes in the tank's skirt but only extending the inner walls to the top of the platform as a solid piece. All simplifications were made all at once. The effect from omitting the rebar and wood was analyzed.

Solution and Tanks

The tank bottoms were flat, horizontal, and level with one another with solution region bottoms at 31.9 cm above the platform. The tank skirt holes were omitted and the inner cylinder was extended to the floor as a solid piece, as shown in Figures 19, 21, 24, and 33–38. The solution height was measured up from a height of 31.9 mm above the platform for all tanks.

Absorbers and Moderators

There was no change to the plugs between the detailed and simple models except omitting the plug wood stands. The only change to the slabs was the removal of the wood frames.

Enclosure and Room Layout

The only change to the enclosure and room was the omission of all rebar and steel reinforcement in the reflector panels and room walls.

3.1.3 Bias from Simplification of the Model - The overall effect due to all the simplifications was evaluated. The simplified models were compared to the detailed models using MCNP5 with the ENDF/B-VI continuous-energy cross sections. The simplified models yielded higher calculated k_{eff} values than the detailed models. The uncertainty in the bias values came from taking the square root of the sum of the squares of the uncertainty in the k_{eff} values for the detailed and simple models, which was 0.00003 for each model. The bias values from simplifying the model are shown in Table 72.

Table 72. Bias Values from Simplifying the Model.

Moderators/Absorbers	Tanks with Solution	Configuration No.	Case No.	Bias
None	All	1a	1	0.00074 ± 0.00004
None	1,2,2*,3*	1b	2	0.00215 ± 0.00004
None	2*,3*	1c	3	0.00172 ± 0.00004
None	1,2,3*	1d	4	0.00185 ± 0.00004
Concrete plugs	All	2a	5	0.00090 ± 0.00004
Concrete plugs	1,2,2*,3*	2b	6	0.00080 ± 0.00004
Concrete and plaster plugs	All	3a5a	7	0.00088 ± 0.00004
Concrete and plaster plugs	1,2,2*,3*	3b	8	0.00091 ± 0.00004
Concrete plugs and Cd lamination	All	4	9	0.00103 ± 0.00004
Concrete and plaster plugs, plaster slabs	All	5e	10	0.00513 ± 0.00004
Concrete and plaster plugs, plaster slabs	All	5f	11	0.00227 ± 0.00004
Concrete and plaster plugs, plaster slabs	2*,3*,3,4	6	12	-0.00146 ± 0.00004

The bias effect of individual simplifications for excluding the wood, omitting rebar, neglecting holes in the tank skirts, and leveling the tanks were calculated. The bias calculated for the applicable cases is shown in Table 73.

Table 73. Bias Due to Individual Simplifications.

Moderators/Absorbers	Tanks with Solution	Case No.	Bias
Wood Bias			
Concrete plugs	All	5	0.00020 ± 0.00004
Concrete plugs	1,2,2*,3*	6	0.00004 ± 0.00004
Concrete and plaster plugs	All	7	0.00012 ± 0.00004
Concrete and plaster plugs	1,2,2*,3*	8	-0.00003 ± 0 00004
Concrete plugs and Cd lamination	All	9	0.00025 ± 0.00004
Concrete and plaster plugs, plaster slabs	All	10	0.00458 ± 0.00004
Concrete and plaster plugs, plaster slabs	All	11	0.00088 ± 0.00004
Concrete and plaster plugs, plaster slabs	2*,3*,3,4	12	-0.00320 ± 0.00004
Rebar Bias			
None	All	1	0.00047 ± 0.00004
None	1,2,2*,3*	2	0.00075 ± 0.00004
None	2*,3*	3	0.00021 ± 0.00004
None	1,2,3*	4	0.00047 ± 0.00004
Concrete plugs	All	5	0.00051 ± 0.00004
Concrete plugs	1,2,2*,3*	6	0.00045 ± 0.00004
Concrete and plaster plugs	All	7	0.00048 ± 0.00004
Concrete and plaster plugs	1,2,2*,3*	8	0.00042 ± 0.00004
Concrete plugs and Cd lamination	All	9	0.00045 ± 0.00004
Concrete and plaster plugs, plaster slabs	All	10	0.00043 ± 0.00004
Concrete and plaster plugs, plaster slabs	All	11	0.00020 ± 0.00004
Concrete and plaster plugs, plaster slabs	2*,3*,3,4	12	0.00022 ± 0.00004

Table 73 (cont'd). Bias Due to Individual Simplifications.

Moderators/Absorbers	Tanks with Solution	Case No.	Bias
Filled Holes in Tank Skirt Bias			
None	All	1	-0.00012 ± 0.00004
None	1,2,2*,3*	2	0.00052 ± 0.00004
None	2*,3*	3	0.00124 ± 0.00004
None	1,2,3*	4	0.00109 ± 0.00004
Concrete plugs	All	5	0.00009 ± 0.00004
Concrete plugs	1,2,2*,3*	6	0.00013 ± 0.00004
Concrete and plaster plugs	All	7	-0.00001 ± 0.00004
Concrete and plaster plugs	1,2,2*,3*	8	0.00004 ± 0 00004
Concrete plugs and Cd lamination	All	9	-0.00003 ± 0.00004
Concrete and plaster plugs, plaster slabs	All	10	0.00004 ± 0.00004
Concrete and plaster plugs, plaster slabs	All	11	0.00070 ± 0.00004
Concrete and plaster plugs, plaster slabs	2*,3*,3,4	12	0.00086 ± 0.00004
Tank Bottom Leveling Bias			
None	All	1	0.00021 ± 0.00004
None	1,2,2*,3*	2	0.00096 ± 0.00004
None	2*,3*	3	0.00015 ± 0.00004
None	1,2,3*	4	0.00018 ± 0.00004
Concrete plugs	All	5	0.00012 ± 0.00004
Concrete plugs	1,2,2*,3*	6	0.00015 ± 0.00004
Concrete and plaster plugs	All	7	0.00007 ± 0.00004
Concrete and plaster plugs	1,2,2*,3*	8	0.00017 ± 0.00004
Concrete plugs and Cd lamination	All	9	0.00002 ± 0.00004
Concrete and plaster plugs, plaster slabs	All	10	0.00003 ± 0.00004
Concrete and plaster plugs, plaster slabs	All	11	0.00013 ± 0.00004
Concrete and plaster plugs, plaster slabs	2*,3*,3,4	12	0.00027 ± 0.00004

3.1.4 Bias from Room Effects - The effect due to including more of the room was evaluated. The east and south walls were extended up to their full height above the experiment and the ceiling was included. The rebar in the walls was also extended to match the wall extension. Including anything else was decided to be not needed as there was nothing else in the room close enough to have made an effect on the system. Any neutrons that would have left the enclosure with the walls extended and ceilings included would not have been able to return to the system due to impossible angles. Additional room return effects were evaluated using MCNP5 with ENDF/B-VI continuous-energy cross sections. The bias values from room effects on the model are shown in Table 74.

Table 74. Bias Values from Room Effects.

Moderators/Absorbers	Tanks with Solution	Case No.	Bias
None	All	1	0.00039 ± 0.00013
None	1,2,2*,3*	2	0.00048 ± 0.00013
None	2*,3*	3	0.00023 ± 0.00013
None	1,2,3*	4	0.00072 ± 0.00013
Concrete plugs	All	5	-0.00007 ± 0.00013
Concrete plugs	1,2,2*,3*	6	0.00008 ± 0.00013
Concrete and plaster plugs	All	7	0.00009 ± 0.00013
Concrete and plaster plugs	1,2,2*,3*	8	0.00046 ± 0.00013
Concrete plugs and Cd lamination	All	9	0.00044 ± 0.00013
Concrete and plaster plugs, plaster slabs	All	10	0.00005 ± 0.00013
Concrete and plaster plugs, plaster slabs	All	11	0.00004 ± 0.00013
Concrete and plaster plugs, plaster slabs	2*,3*,3,4	12	0.00008 ± 0.00013

3.1.5 Solution Density Bias - The density of the solution was measured at 25ºC but the experiments were performed at approximately 20ºC. A slight correction is needed to account for the density variation. The density formula provided in Appendix B of LEU-MISC-THERM-005 was used to determine that a temperature drop of 5ºC would result in a density increase of approximately 0.0032 g/cm^3. Table 23 in Section 2.2 can be used to determine the effective bias in the benchmark model because the uncertainty in using the density formula is ±0.0032 g/cm^3. The increased uncertainty caused by using the density formula for the analysis has already been incorporated into the total benchmark model uncertainty. The solution density bias is reported in Table 75.

The impurities in the solution can form nitrate and/or oxide compounds in solution. A chemical equilibrium would exist between ions in solution and the compound forms, but the exact composition of the complex chemistry is unknown. All impurities are considered to be ions in solution and a bias is not assessed. The uncertainty has been determined in Section 2.2 and is included in the total benchmark model uncertainty.

Table 75. Bias Values from Solution Density.

Case No.	Bias
1	0.00157
2	0.00175
3	0.00163
4	0.00218
5	0.00157
6	0.00108
7	0.00192
8	0.00029
9	0.00142
10	0.00236
11	0.00151
12	0.00180

3.1.6 Bias If Impurities Were Removed - Known impurities are included for all benchmark model materials. However, calculations were performed to determine the effects on k_{eff} from omitting some of these impurities. These calculations provide bias information that enable users to omit these materials if desired. The impurity elements and isotopes omitted are given in Table 76. The resulting Δk_{eff} values are given in Table 77.

Table 76. Summary of Impurities Omitted.

Uranyl Nitrate Solution		Stainless Steel 304L		Boron-Free Concrete	
Impurity	Atom Density	Impurity	Atom Density	Impurity	Atom Density
^{11}B	7.0165×10^{-8}	O	4.3322×10^{-5}	C	8.4421×10^{-6}
Mg	2.2138×10^{-6}	Al	4.4806×10^{-6}	Na	6.3207×10^{-5}
Al	2.7919×10^{-6}	S	3.0157×10^{-6}	S	2.8290×10^{-5}
Si	3.2953×10^{-7}	Ti	1.6833×10^{-6}	V	3.4871×10^{-6}
Mn	1.0578×10^{-7}	Sn	2.0368×10^{-6}	Ni	3.0267×10^{-7}
Ni	2.5304×10^{-7}	Pb	1.9449×10^{-6}	Rb	1.7002×10^{-6}
Cu	2.7435×10^{-7}			Sr	4.0548×10^{-6}
Zn	7.5704×10^{-7}			Zr	1.9473×10^{-7}
Mo	1.6825×10^{-7}			Ba	8.7705×10^{-6}
Sn	5.0766×10^{-7}				
Pb	4.5705×10^{-8}				
Bi	7.0034×10^{-9}				
1.2-wt.% B Concrete:		2.5-wt.% B Concrete:		1.1-wt.% B Plaster	
Impurity	Atom Density	Impurity	Atom Density	Impurity	Atom Density
^{7}Li	6.0365×10^{-6}	^{7}Li	1.1565×10^{-5}	^{7}Li	4.8228×10^{-6}
C	4.6226×10^{-5}	C	8.0953×10^{-5}	K	1.6872×10^{-5}
S	3.6541×10^{-5}	S	5.1607×10^{-5}	Sr	1.5718×10^{-5}
K	1.3544×10^{-4}	K	9.6631×10^{-5}	Ba	1.7737×10^{-7}
Ti	8.4110×10^{-5}	Ti	4.0362×10^{-5}		
V	4.5043×10^{-6}	V	6.3344×10^{-6}		
Mn	1.8002×10^{-5}	Mn	1.1734×10^{-5}		
Ni	3.9096×10^{-7}	Ni	5.4981×10^{-7}		
Rb	1.4256×10^{-6}	Rb	1.1318×10^{-6}		
Sr	2.1465×10^{-5}	Sr	3.8455×10^{-5}		
Zr	2.5153×10^{-7}	Zr	3.5373×10^{-7}		
Ba	6.7555×10^{-6}	Ba	4.1797×10^{-6}		
Ta	5.4657×10^{-6}	Ta	3.5626×10^{-6}		

Table 77. Δk_{eff} Results from Omission of Material Components.

Case No.	Configuration No.	Δk_{eff}
1	1a	0.00018
2	1b	0.00011
3	1c	0.00003
4	1d	0.00032
5	2a	-0.00033
6	2b	-0.00018
7	3a5a	0.00013
8	3b	-0.00021
9	4	-0.00029
10	5e	-0.00012
11	5f	0.00024
12	6	-0.00005

3.2 Dimensions

The detailed models included rebar in the reflector panels and walls. The positions of the rebar in the detailed models are shown in Figures 12–17. Figures 18–26 illustrate the experiment setups in different views. The orientation is labeled on the figures. Figure 27 shows the proximity of the tanks to the surroundings. Figure 28 gives a top view of the nested tanks. Figures 29–34 show the tanks dimensions used in the detailed models. Figures 35–40 show tanks for the simple models, where the bottom 31.26 cm is the skirt portion. Figures 41–43 show the plugs used in the different cases. The wood stand used to rest plugs on in the detailed models is shown in Figure 44. Figure 45 provides the description of the plaster slabs used in the last three cases (detailed models). The wooden frame surrounding the slabs is not included in the simple models. Dimensions for experimental components and setup are given in Tables 78–81. All model dimensions were measured from an origin existing at the center of the middle tanks on the top side of the platform.

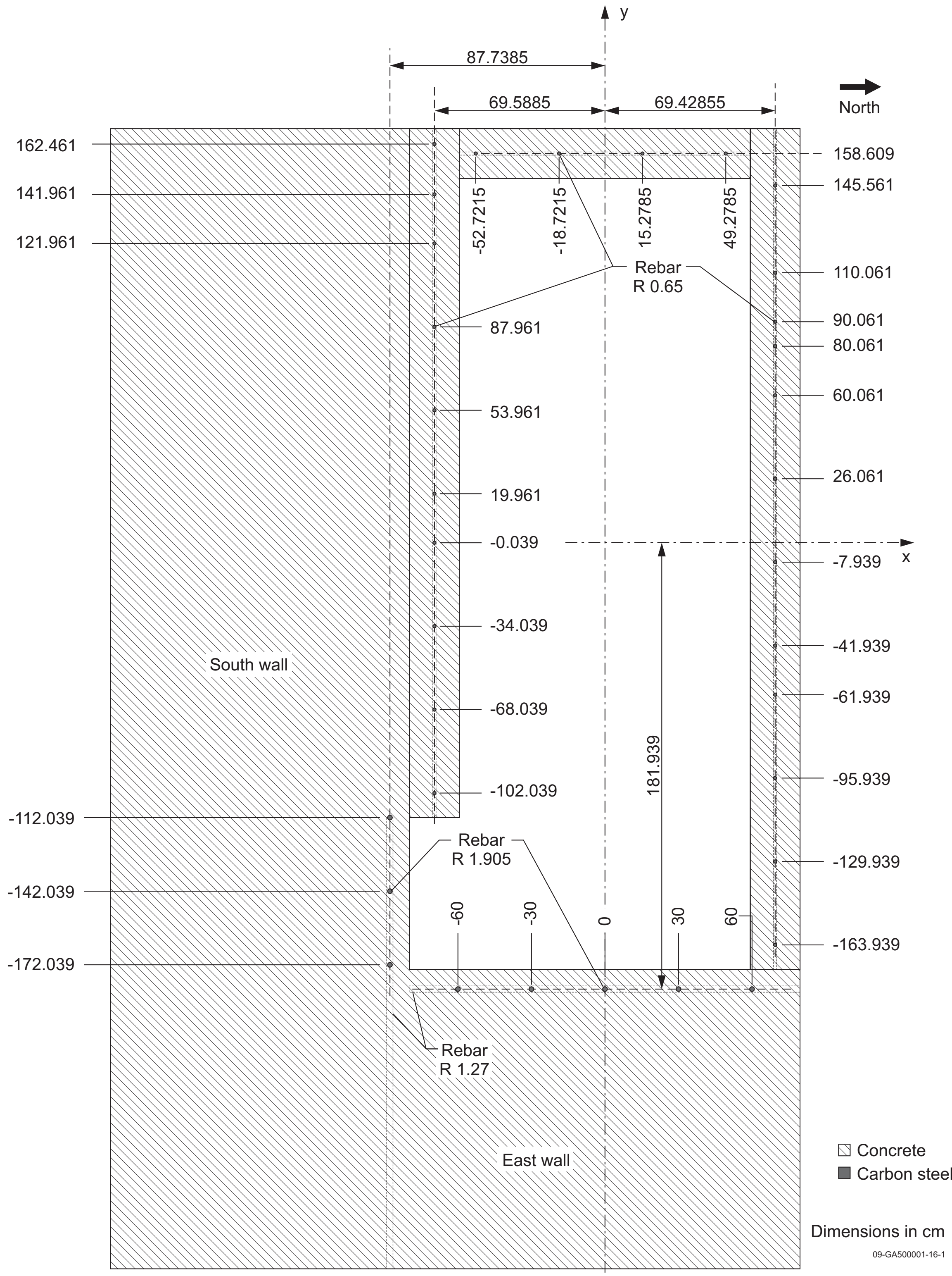

Figure 12. Detailed Model, Top View of Enclosure Showing Rebar Positions in Walls and Panels.

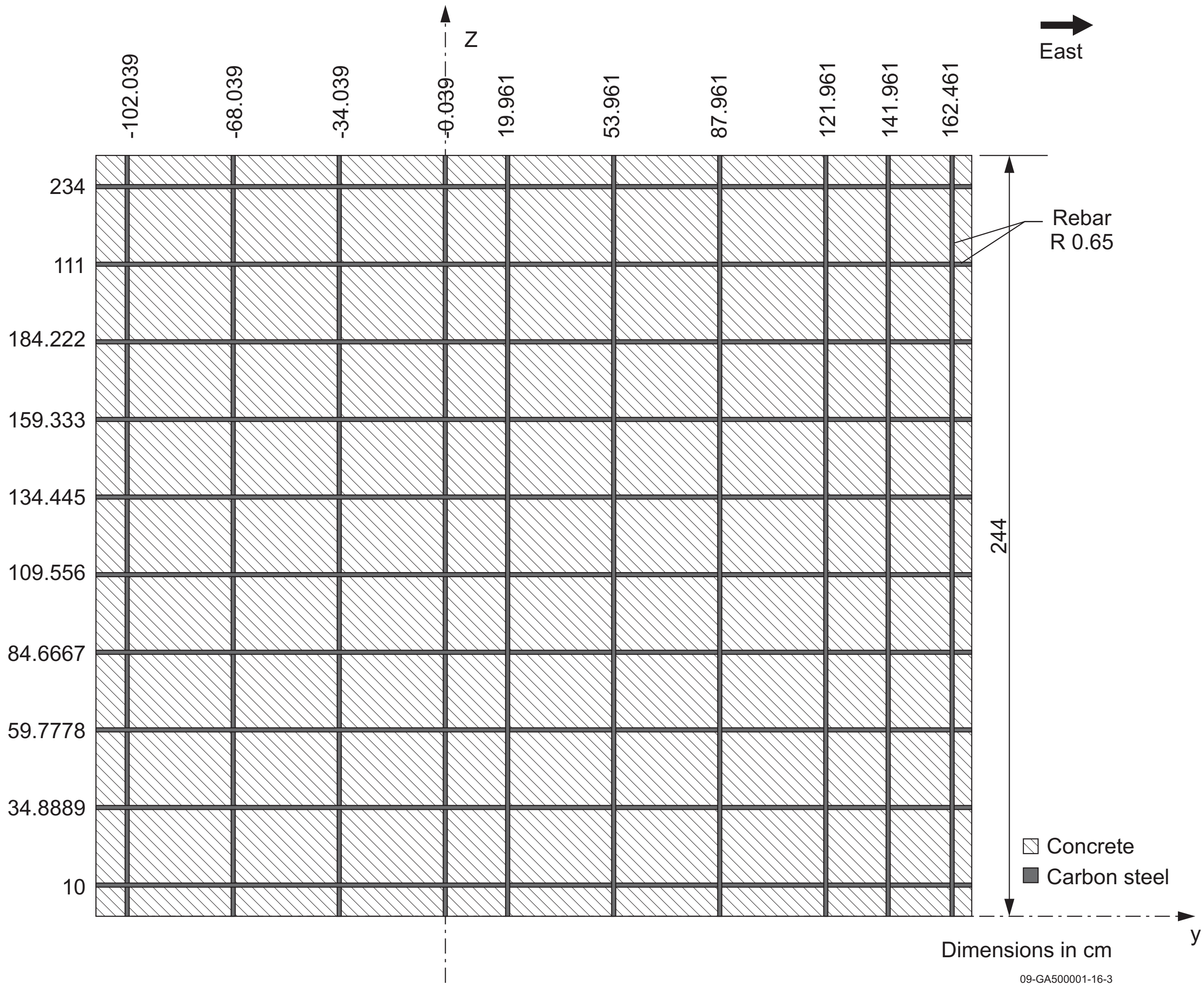

Figure 13. Detailed Model, South Side Enclosure Panel Showing Rebar Positions.

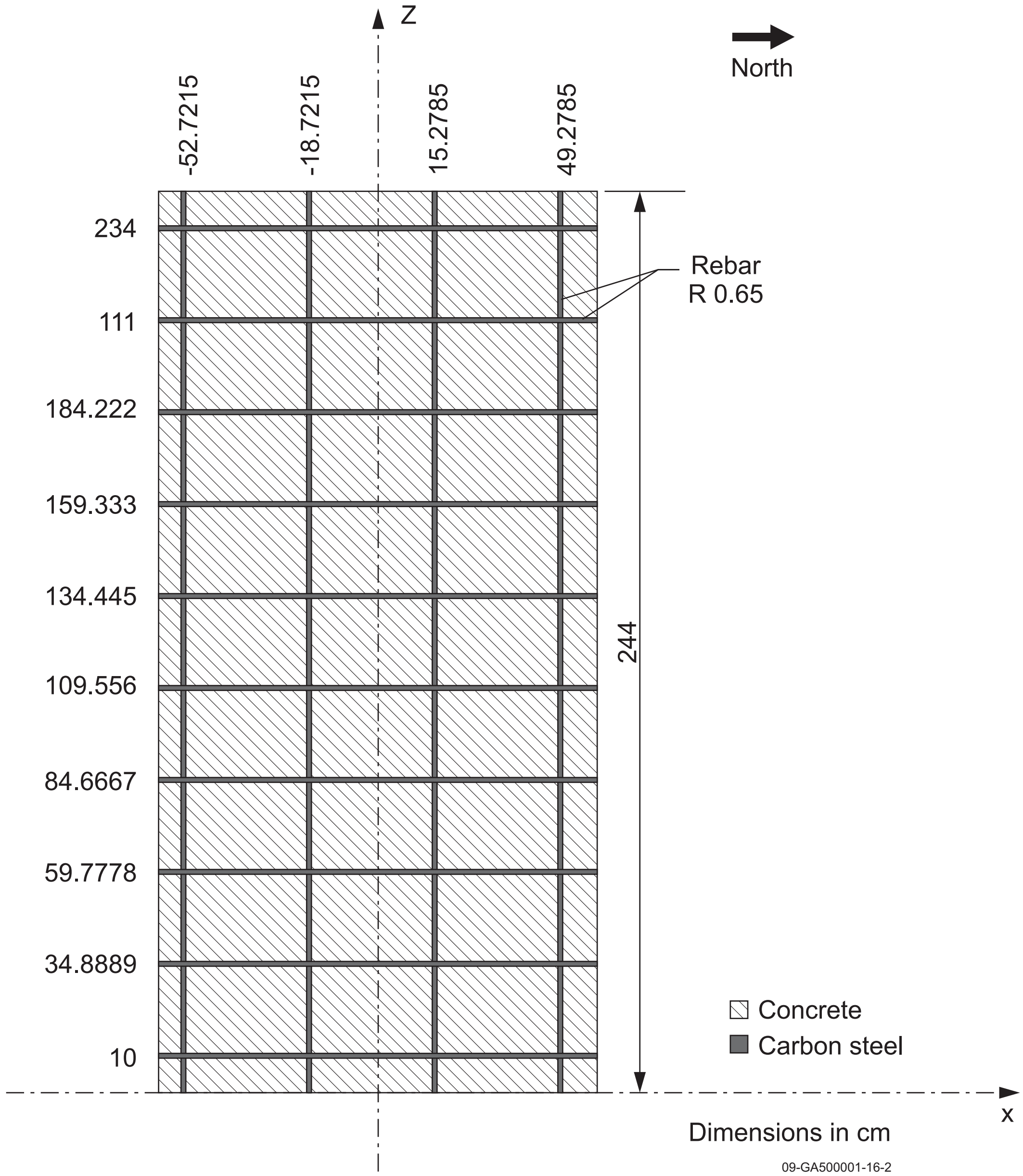

Figure 14. Detailed Model, East Side Enclosure Panel Showing Rebar Positions.

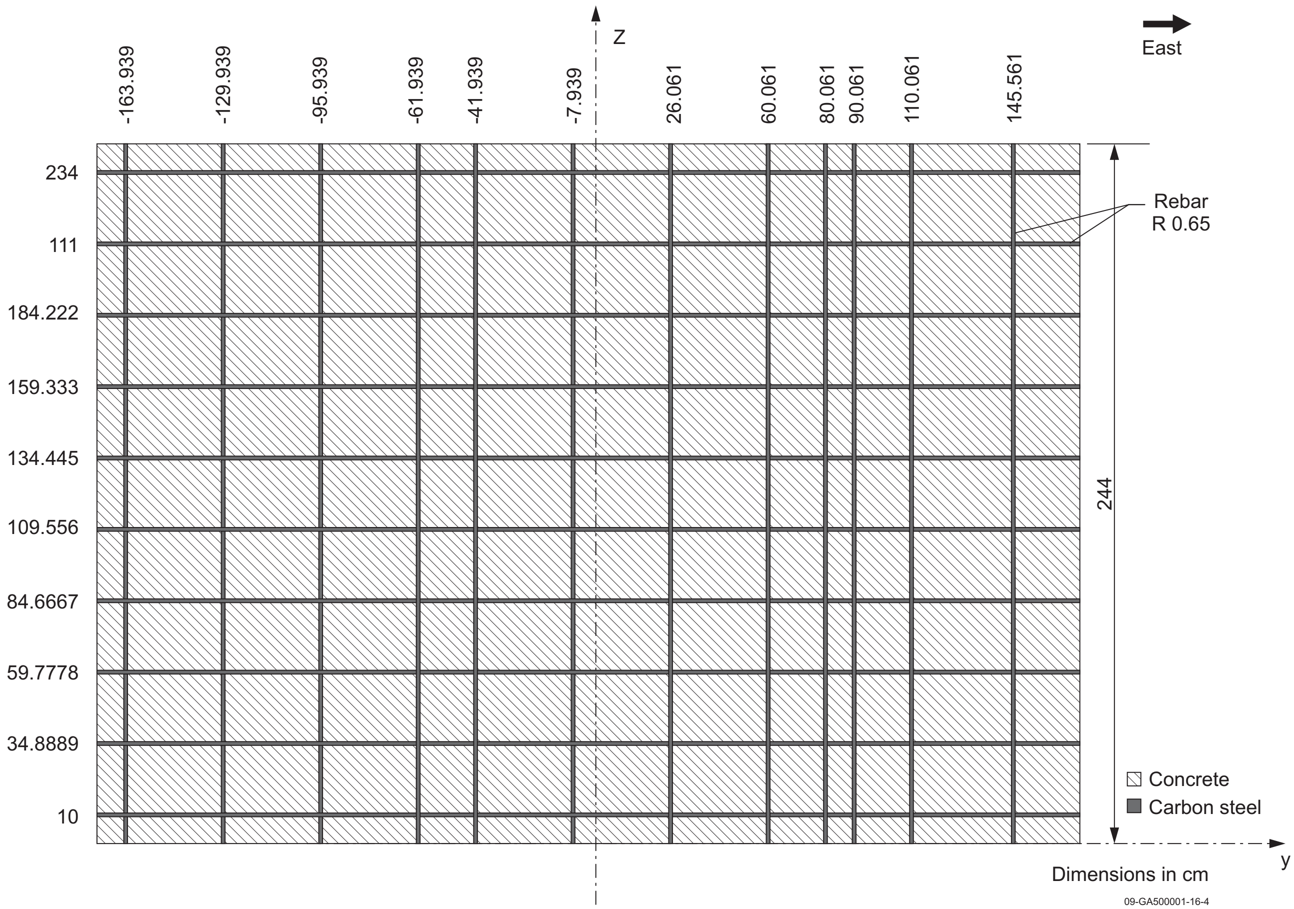

Figure 15. Detailed Model, North Side Enclosure Panel Showing Rebar Positions.

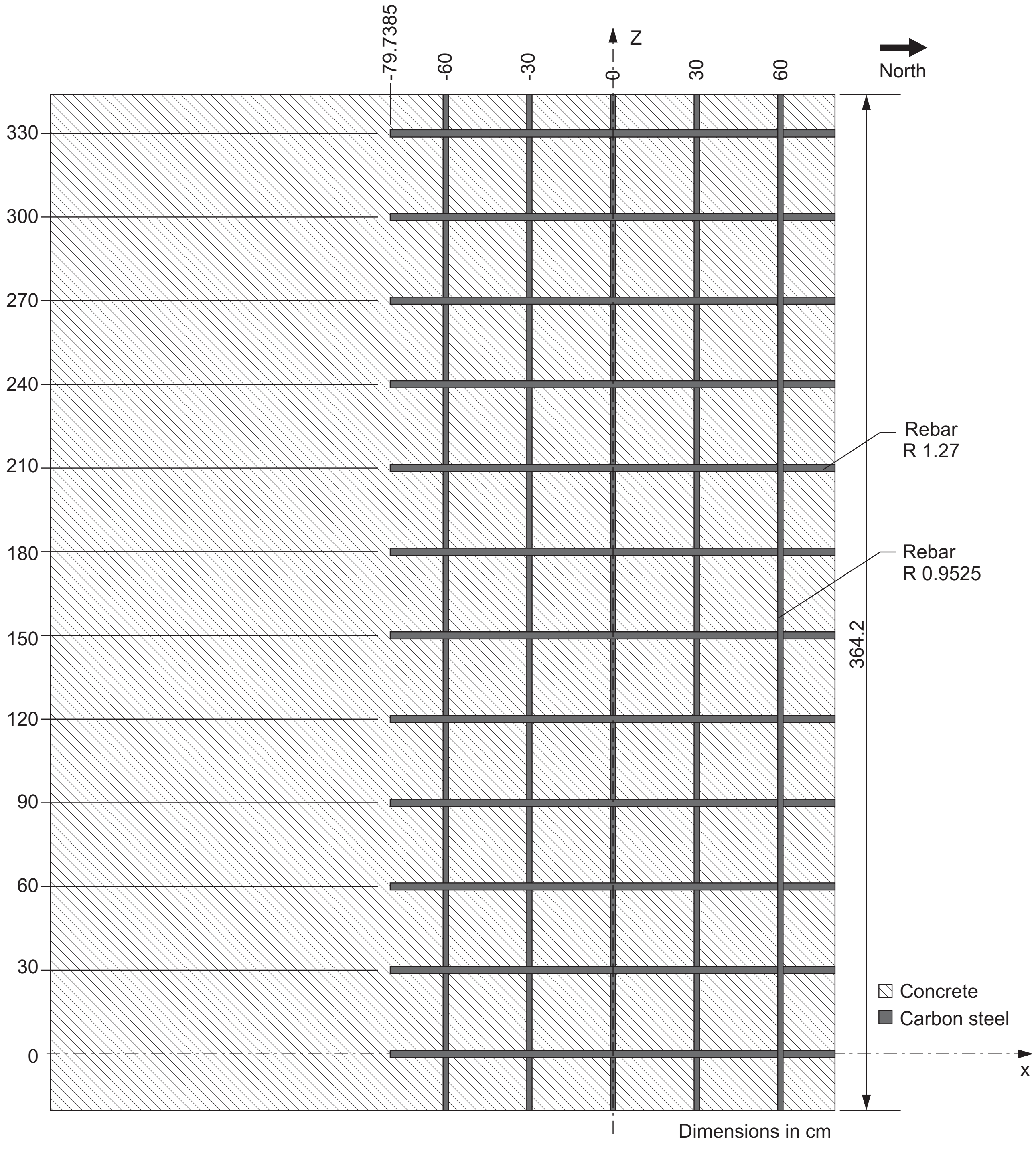

Figure 16. Detailed Model, East Wall Showing Rebar Positions.

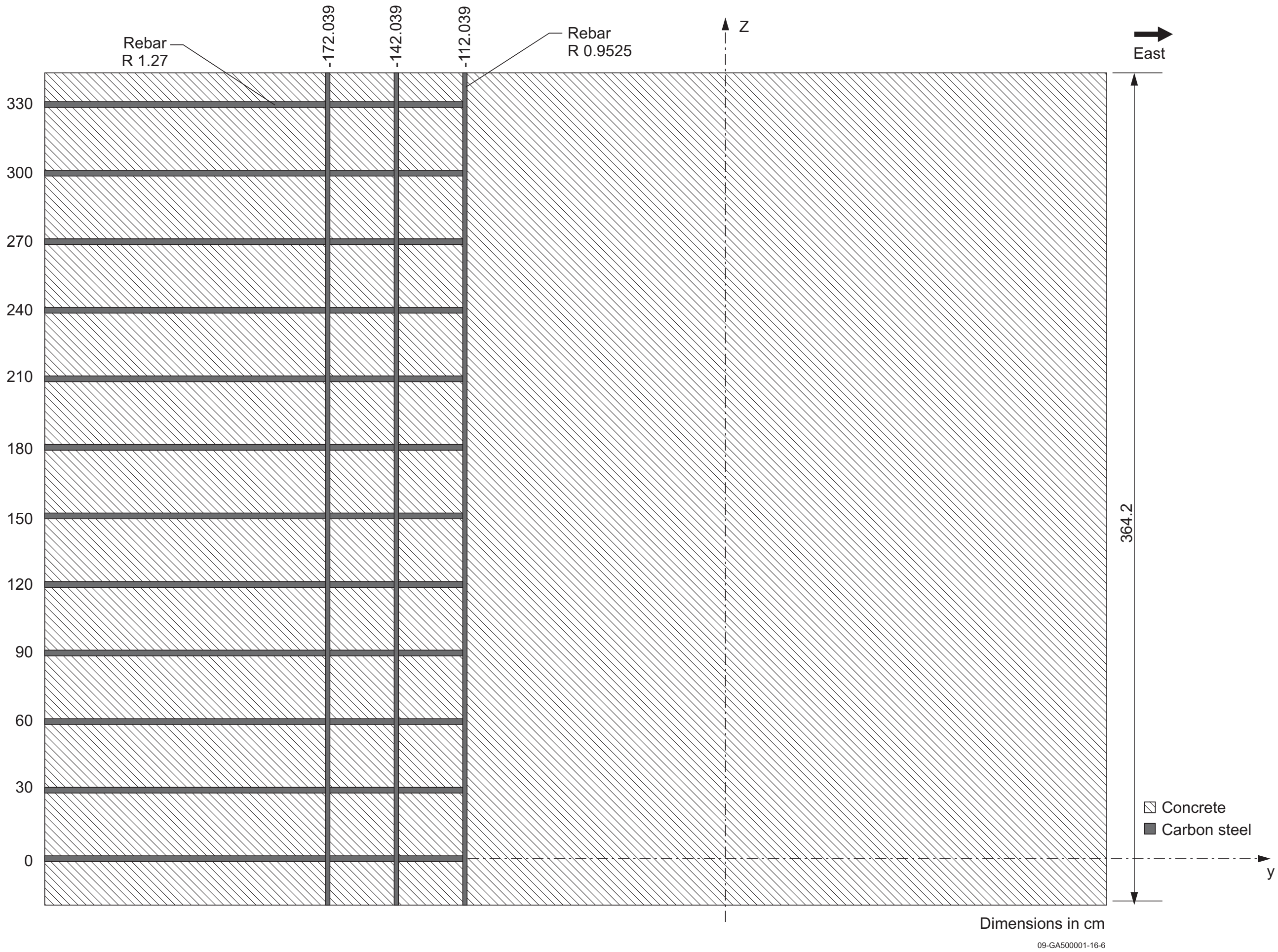

Figure 17. Detailed Model, South Wall Showing Rebar Positions.

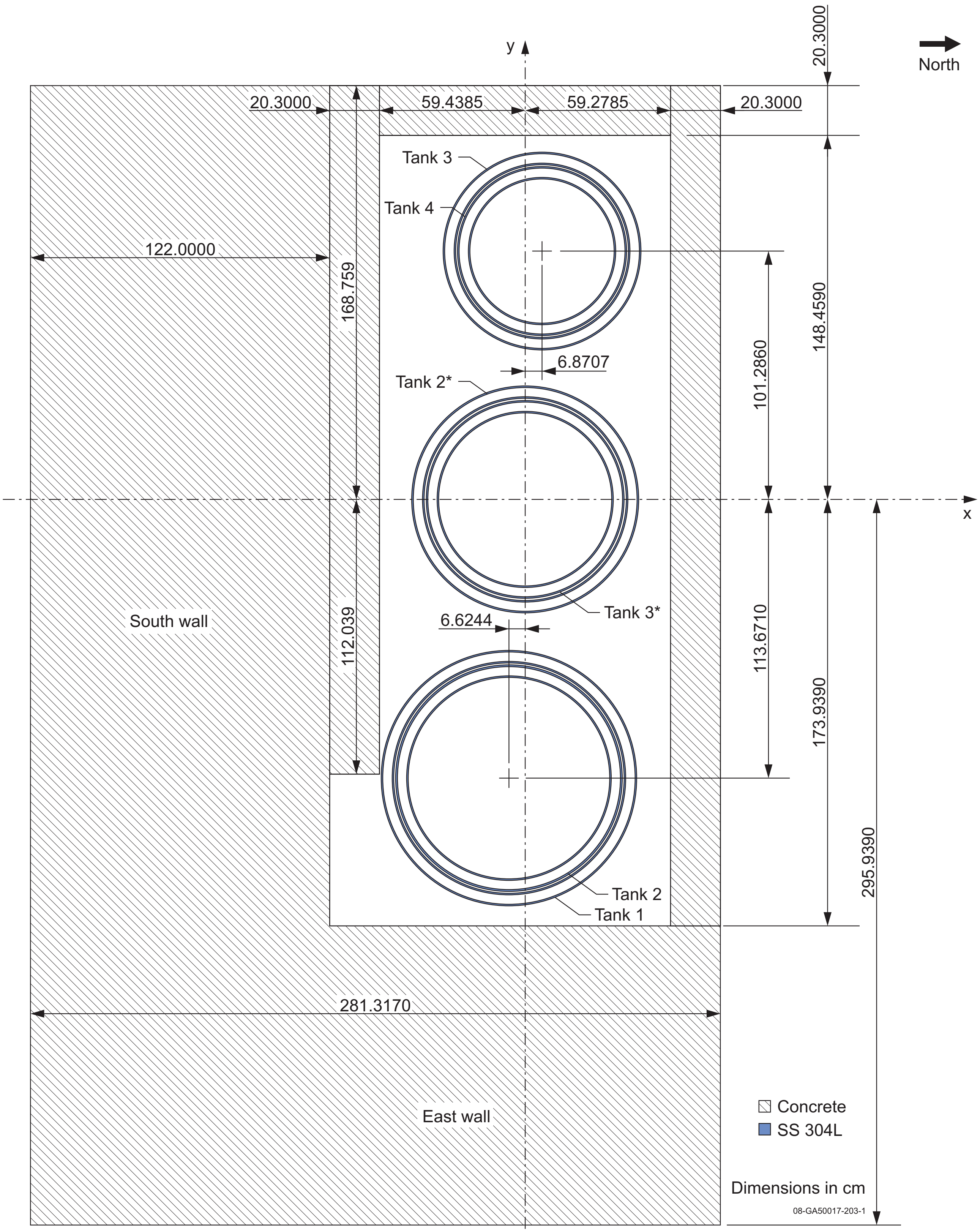

Figure 18. Cases 1–4, Configurations 1a–1d, Top View.

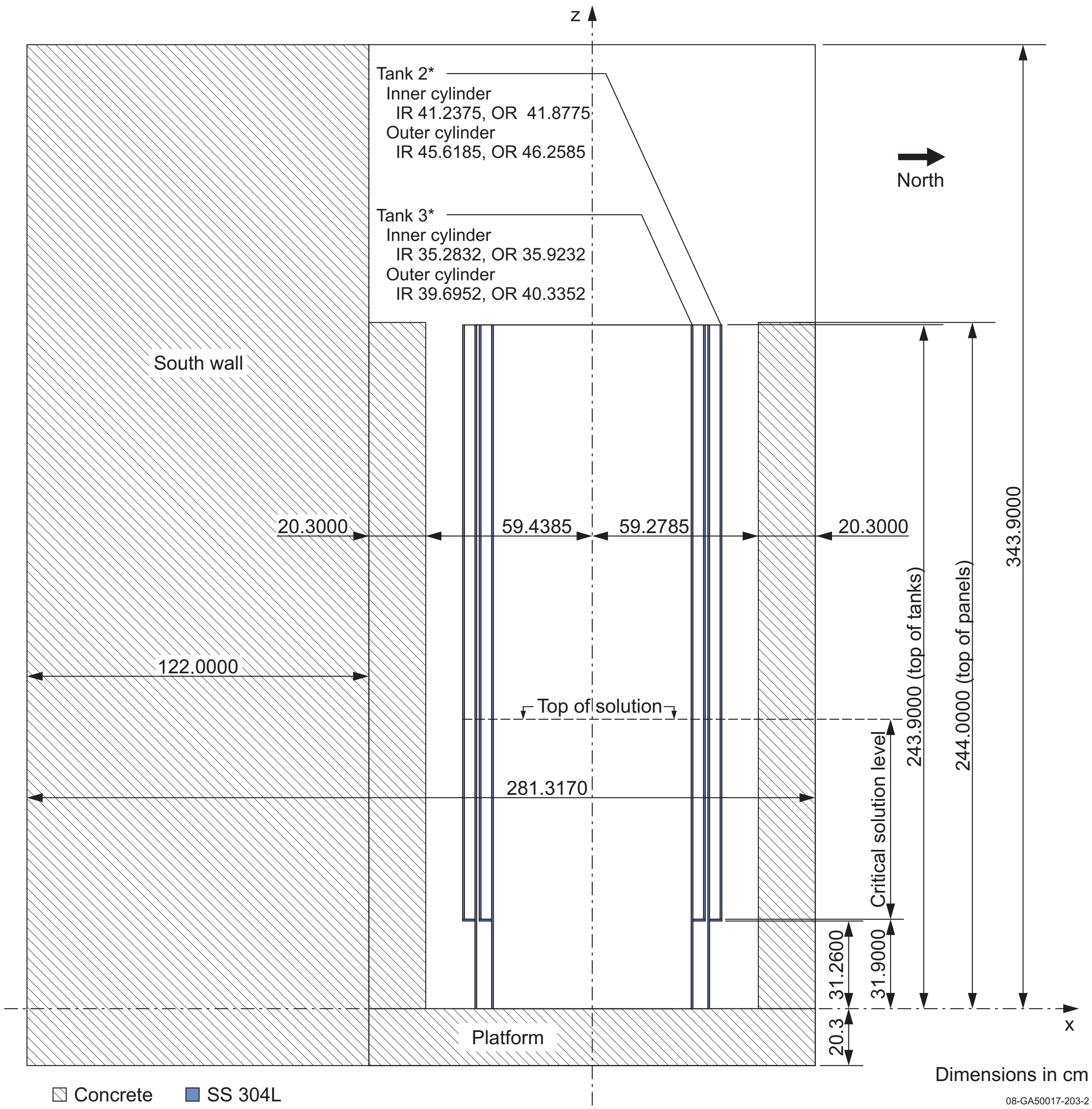

Figure 19. Cases 1–4, Configurations 1a–1d, Side View, Simple Model.

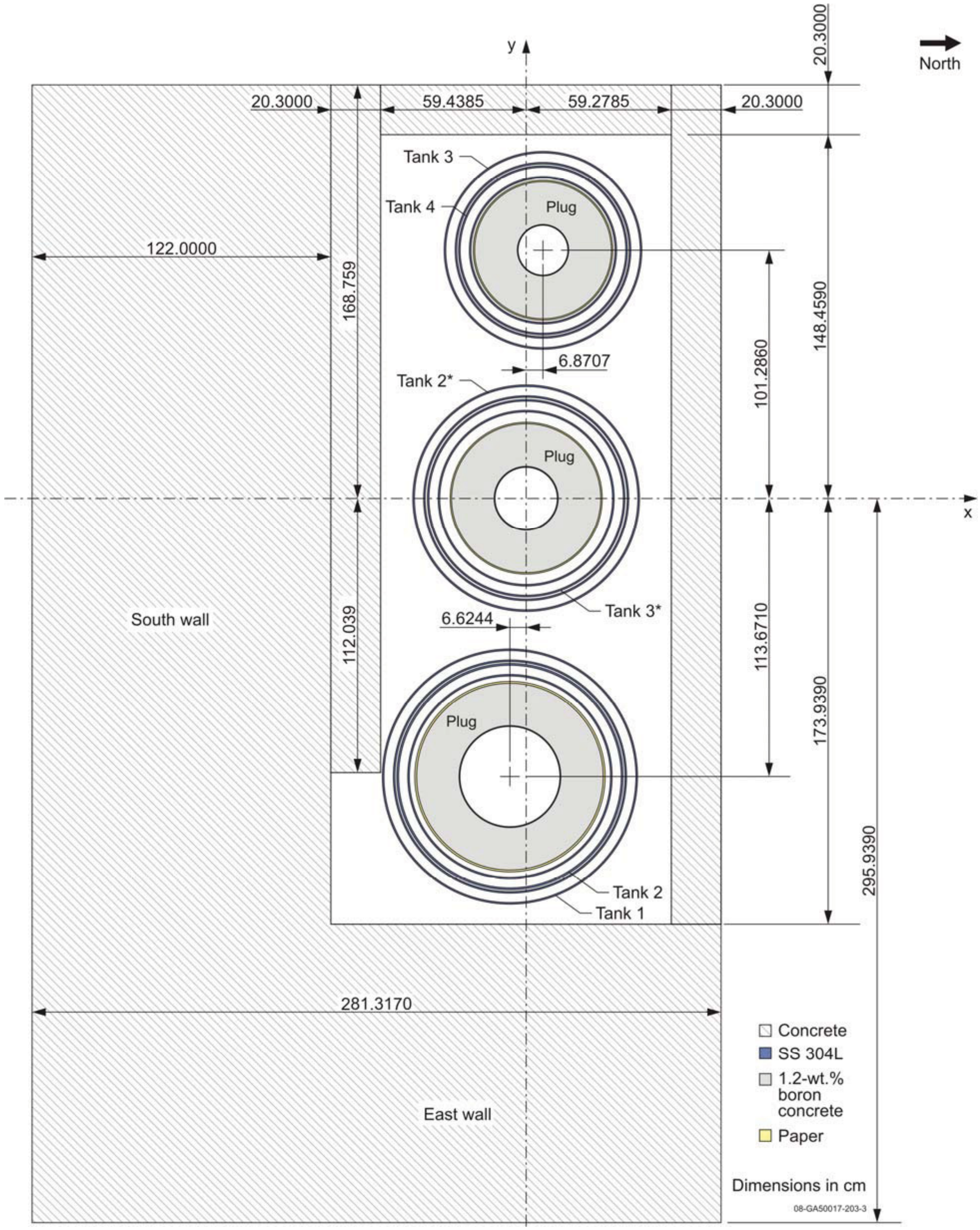

Figure 20. Cases 5–6, Configurations 2a–2b, Top View.

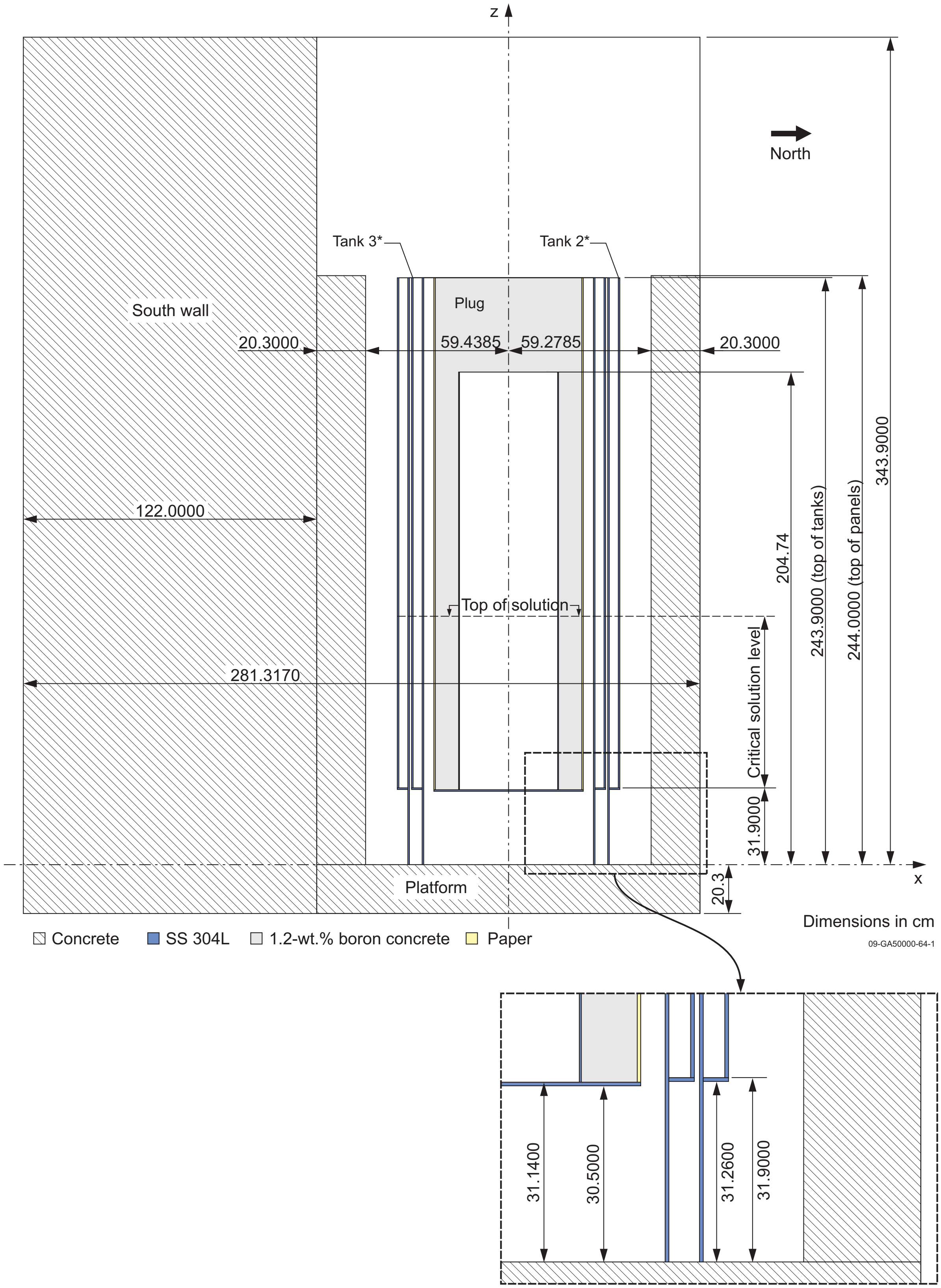

Figure 21. Cases 5–8, Configurations 2a–2b, 3a5a, and 3b, Side View, Simple Model.

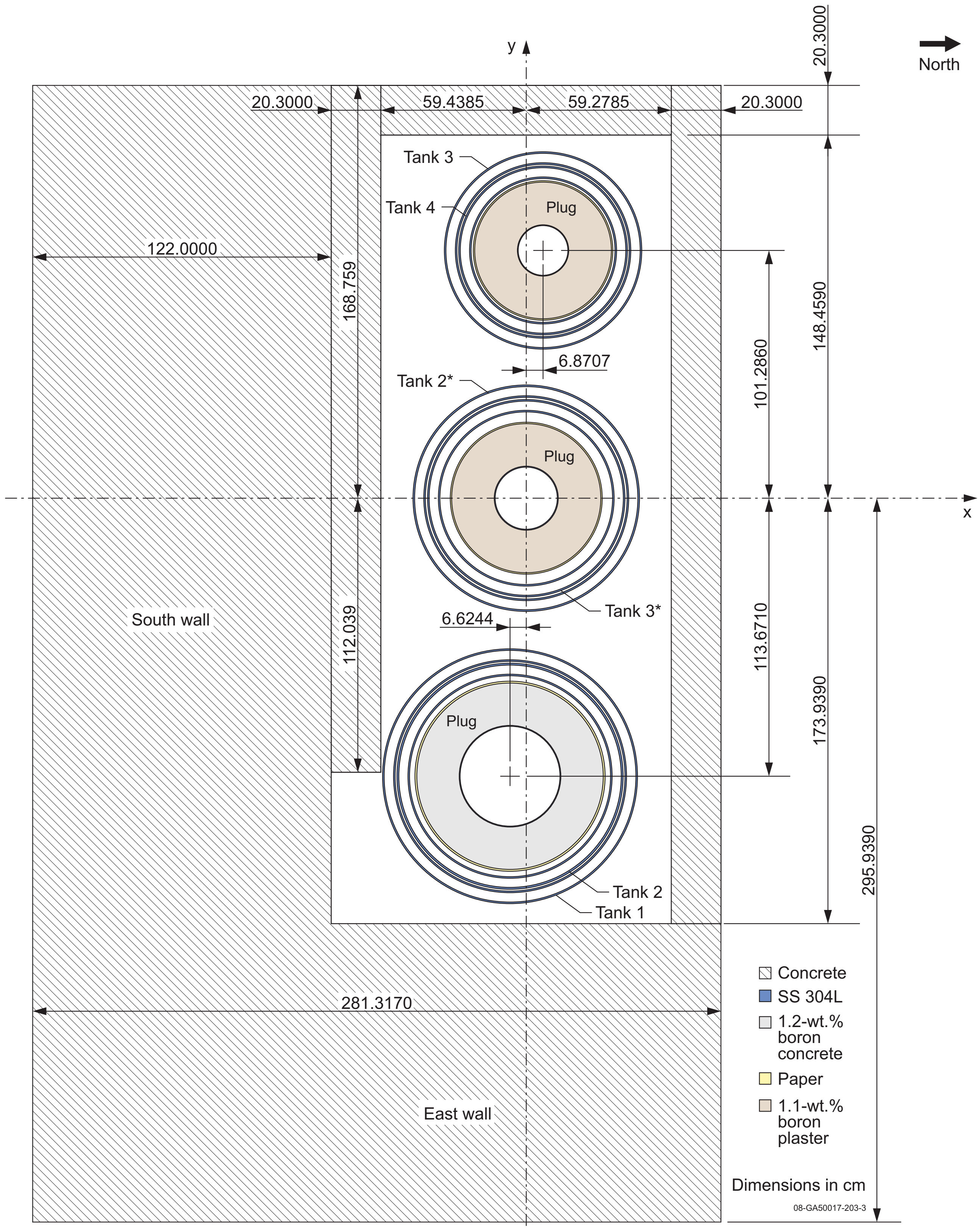

Figure 22. Cases 7–8, Configurations 3a–5a, and 3b, Top View.

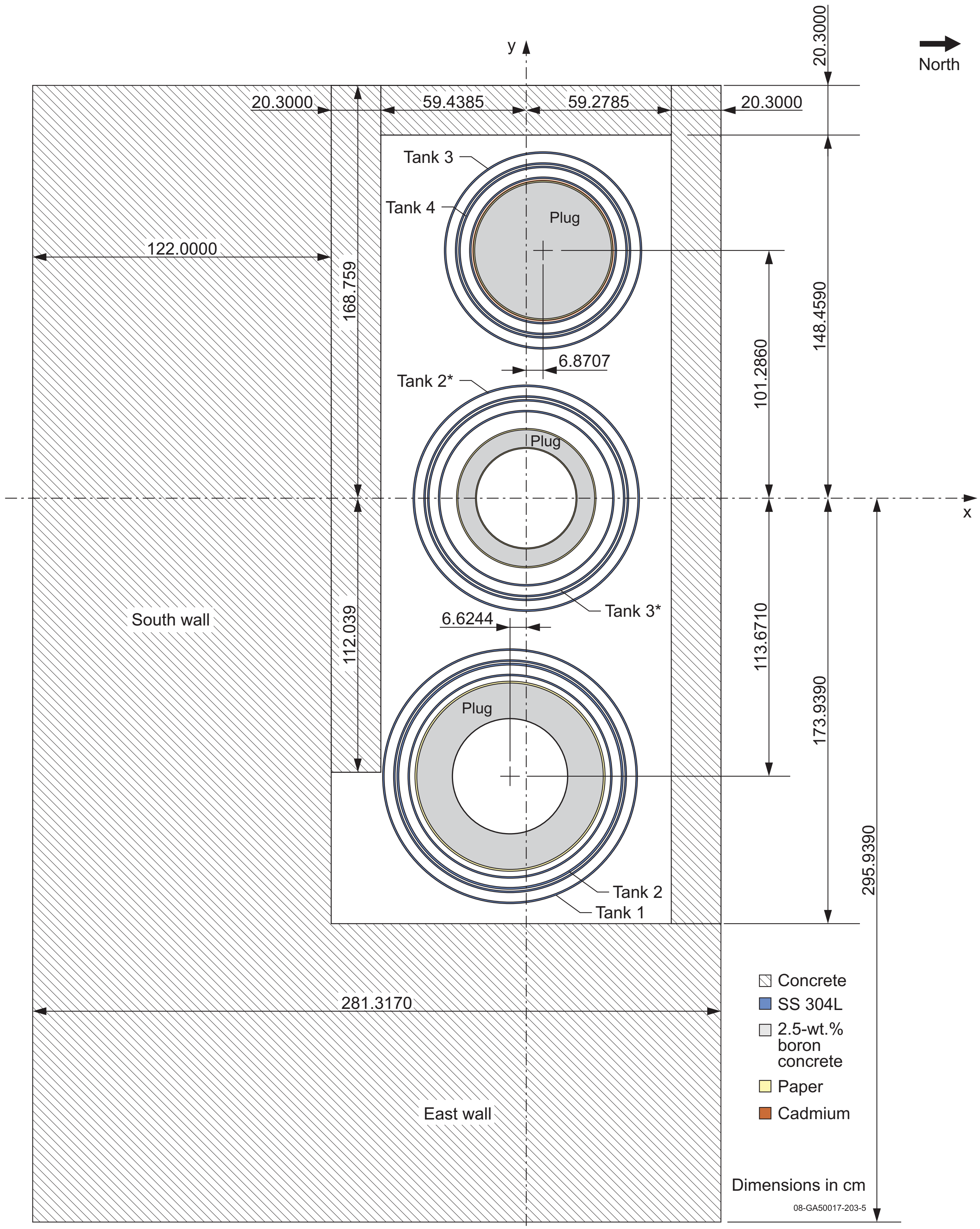

Figure 23. Case 9, Configuration 4, Top View.

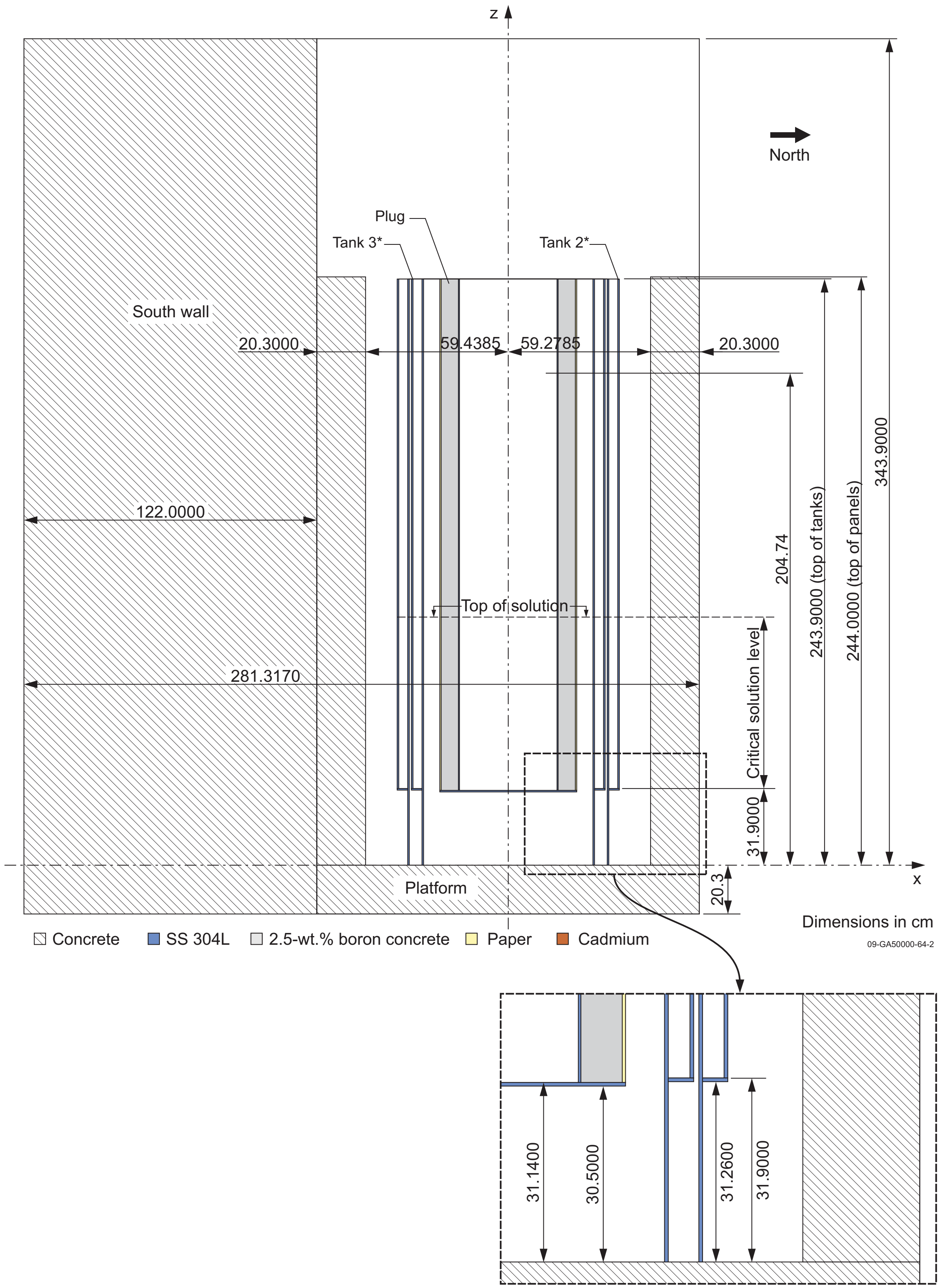

Figure 24. Case 9, Configuration 4, Side View, Simple Model.

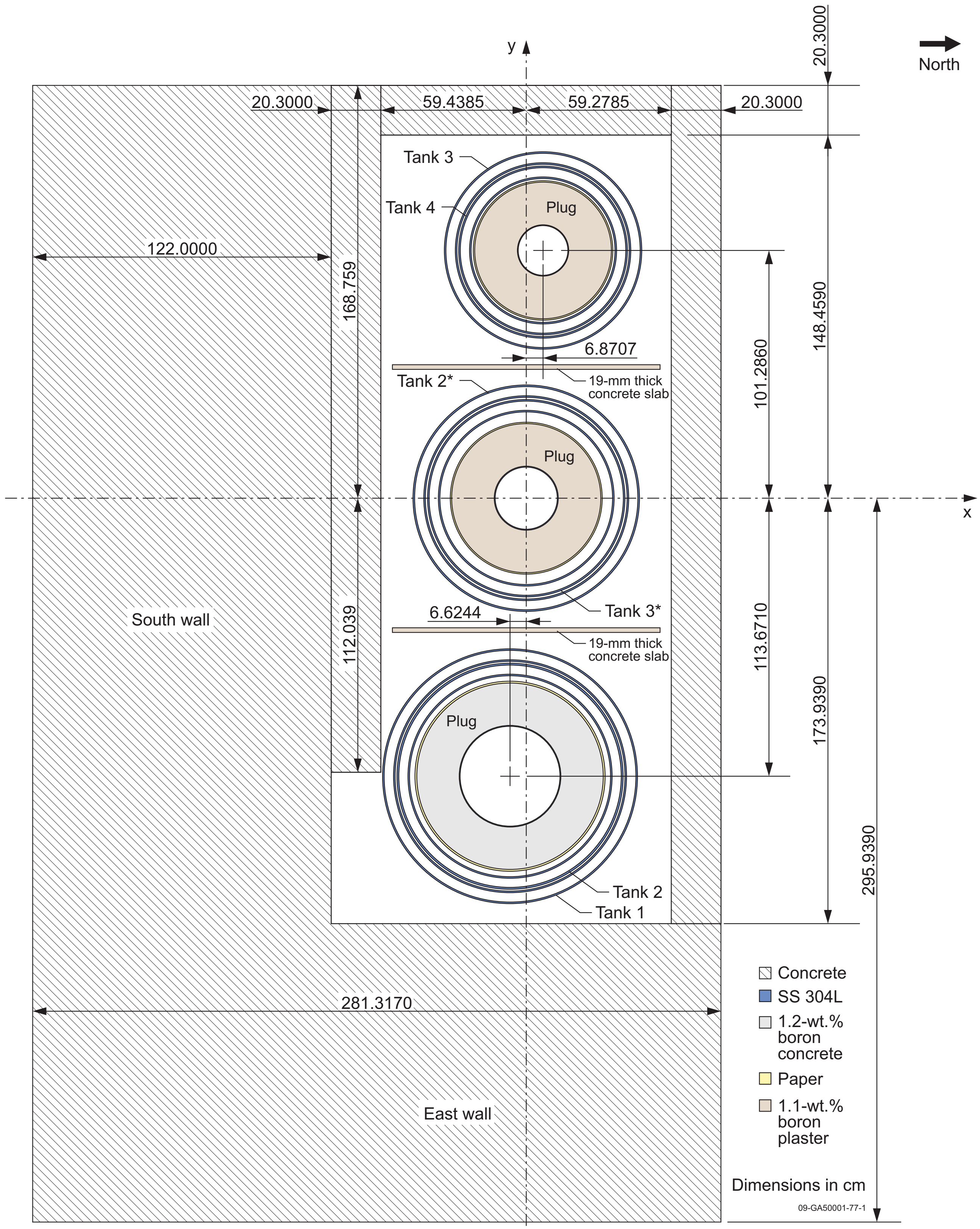

Figure 25. Case 10, Configuration 5e, Top View.

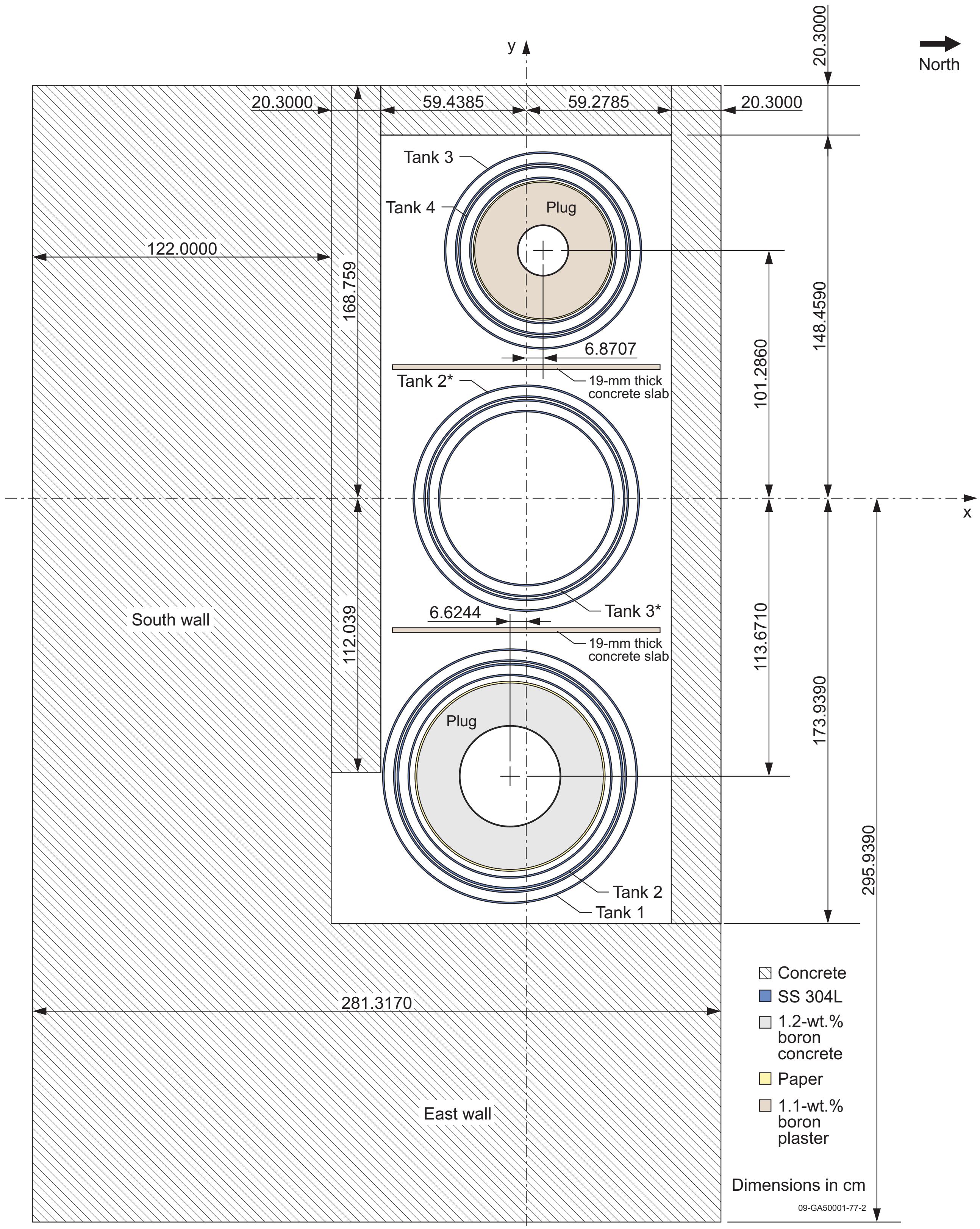

Figure 26. Cases 11 and 12, Configuration 5f and 6, Top View.

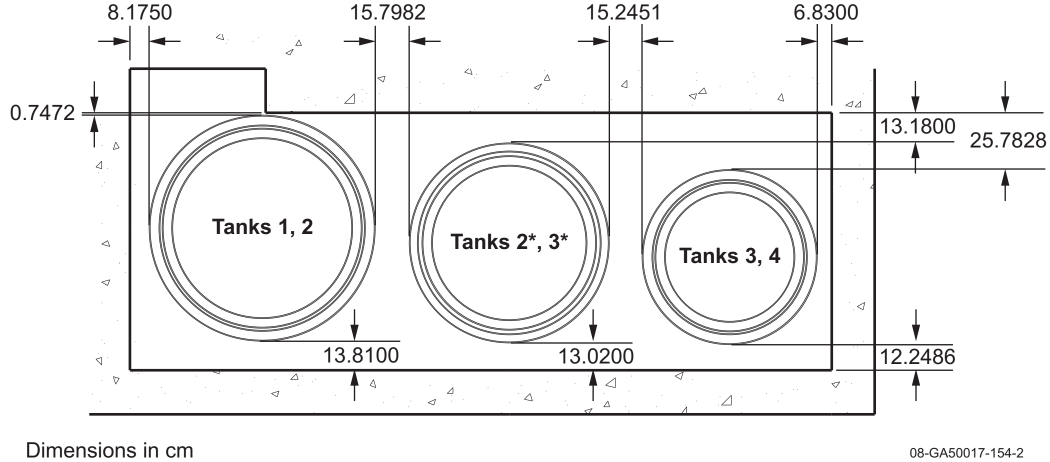

Figure 27. Enclosure Proximity to Tanks for All Cases and Configurations.

Table 78. Dimensions of Enclosure and Surroundings.

Feature	Dimension
Enclosure *See Figures 18-25 for geometry sketches*	
Tank 1 proximity	To east wall, 8.175 cm To south panel, 0.7472 cm To tank 2*, 15.7982 cm To north panel, 13.81 cm
Tank 2* proximity	To south panel, 13.18 cm To tank 3, 15.2451 cm To north panel, 13.02 cm
Tank 3 proximity	To south panel, 25.782 cm To west panel, 6.83 cm To north panel, 12.2486
Inside dimensions	322.398 × 139.017 cm (E-W) × (N-S)
North panel length outside	342.6984 cm
South panel length outside	280.798 cm
West panel length outside	159.3170 cm
Panel thickness	20.3 cm
Panel height	244.0 cm
Gap in south-east corner	61.9 cm
Surroundings *Platform and wall bottoms level with each other*	(E-W) × (N-S) × height
Platform	342.6984 × 159.3170 × 20.3 cm
South wall inside room	342.6984 × 122.0 × 343.9 cm
East wall inside room	122.0 × 159.3170 × 343.9 cm

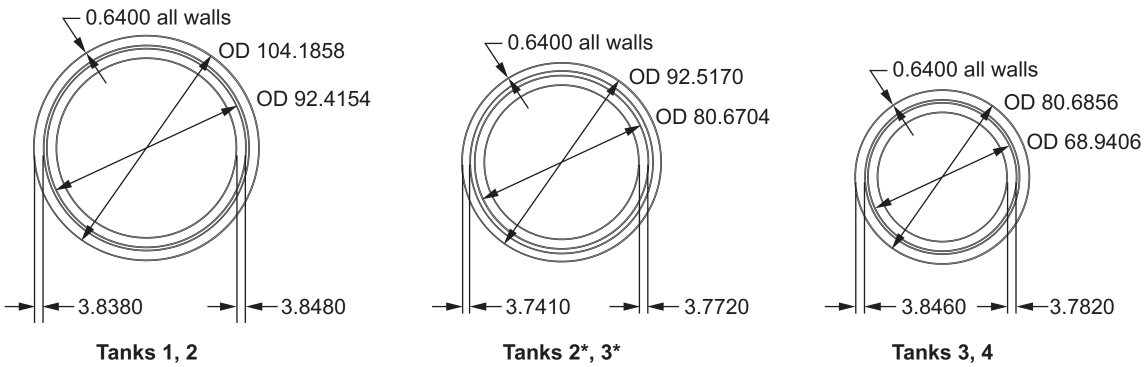

Figure 28. Top View of All Nested Tank Dimensions.

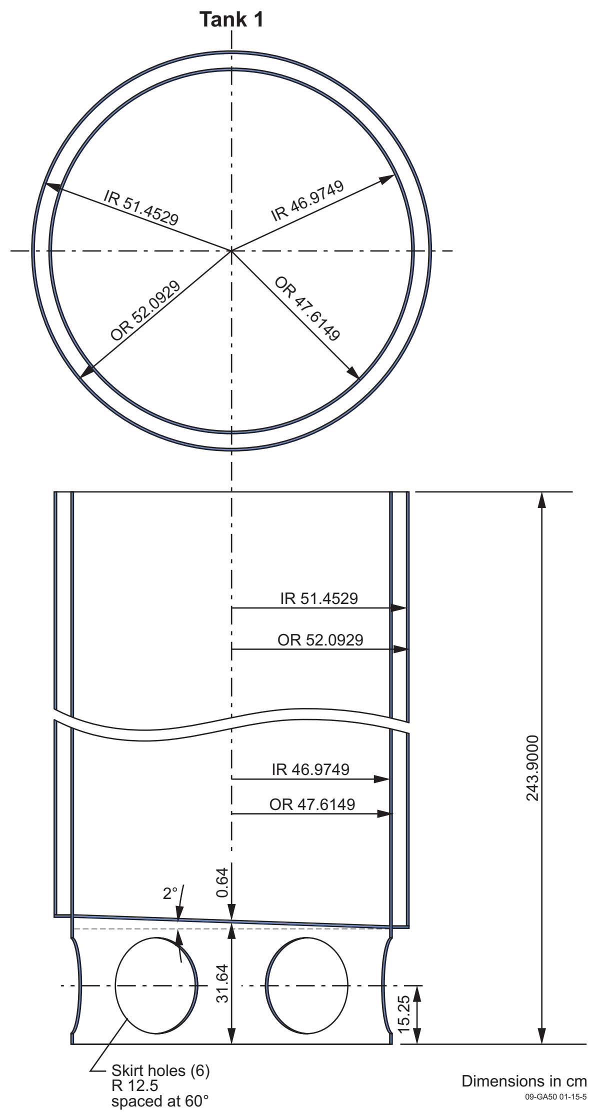

Figure 29. Tank 1 Dimensions, Detailed Model.

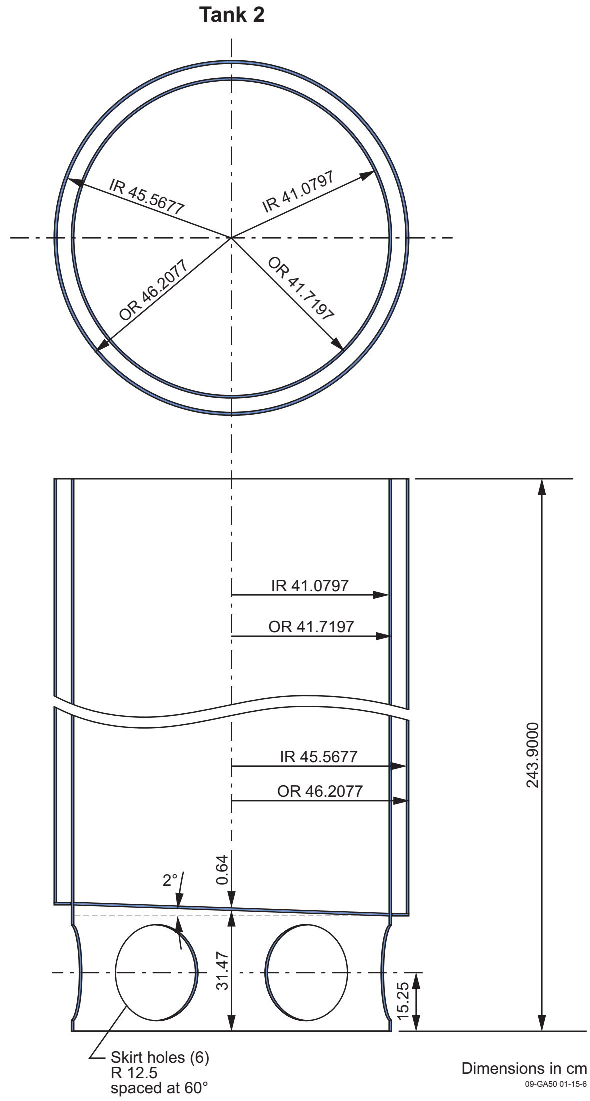

Figure 30. Tank 2 Dimensions, Detailed Model.

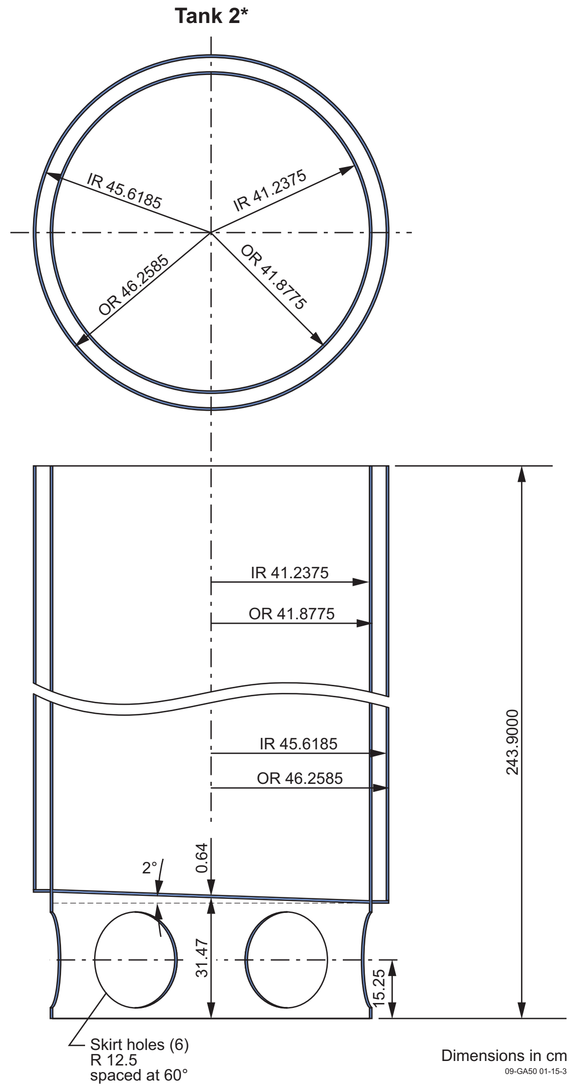

Figure 31. Tank 2* Dimensions, Detailed Model.

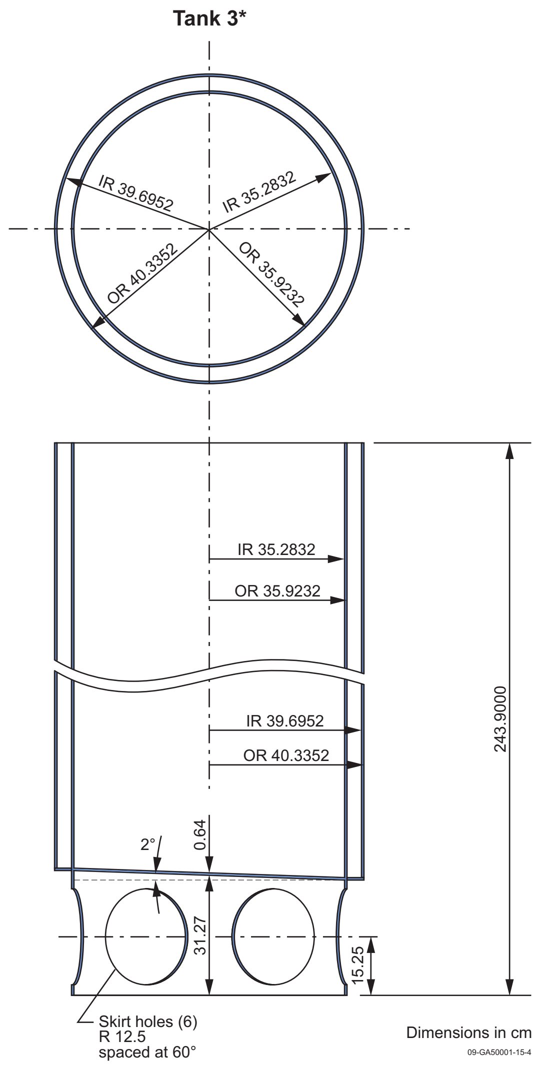

Figure 32. Tank 3* Dimensions, Detailed Model.

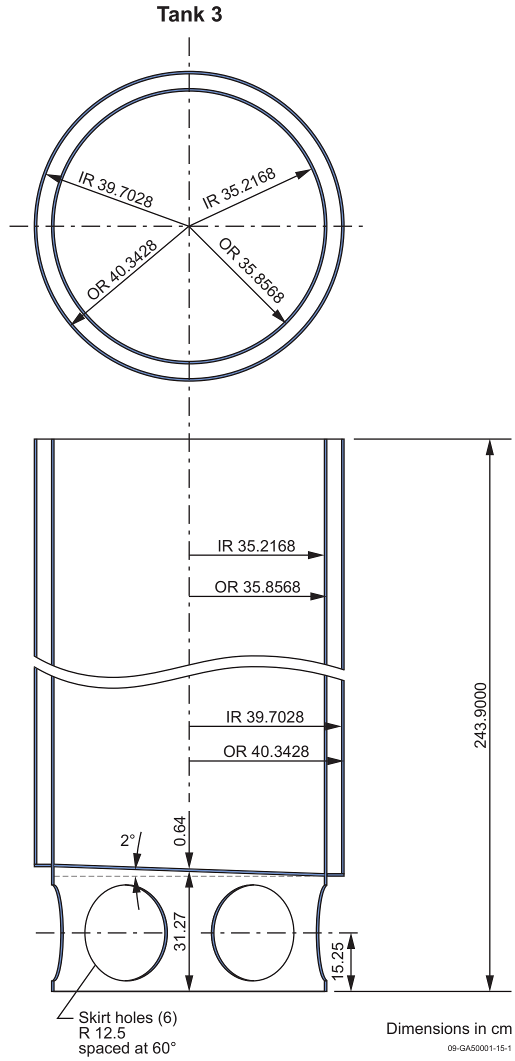

Figure 33. Tank 3 Dimensions, Detailed Model.

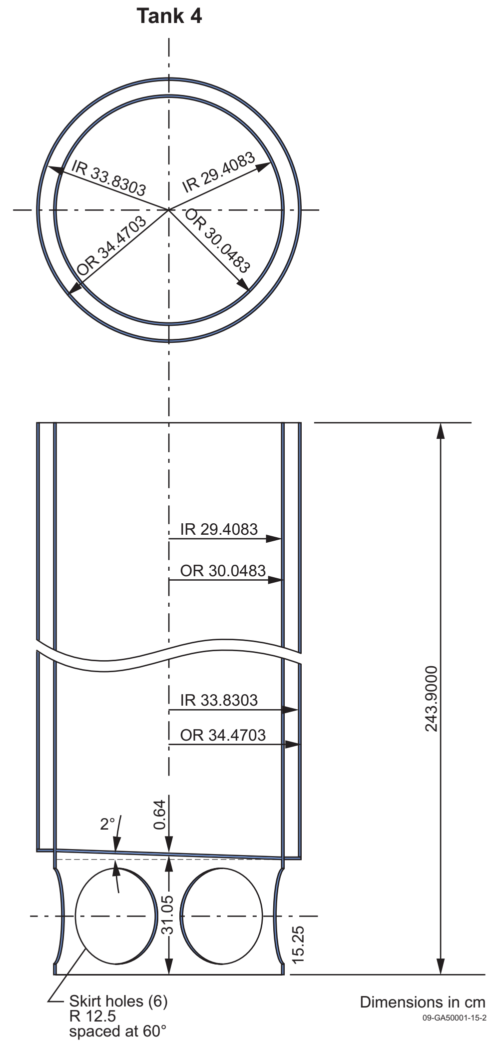

Figure 34. Tank 4 Dimensions, Detailed Model.

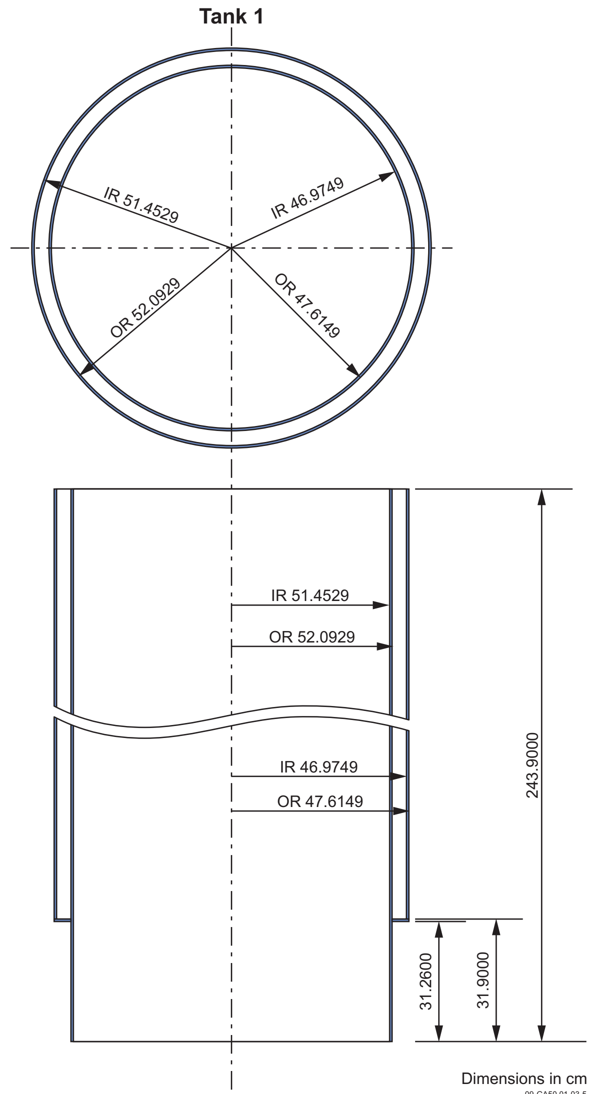

Figure 35. Tank 1 Dimensions Simple Model, Bottom 31.26 cm is the Extended Skirt.

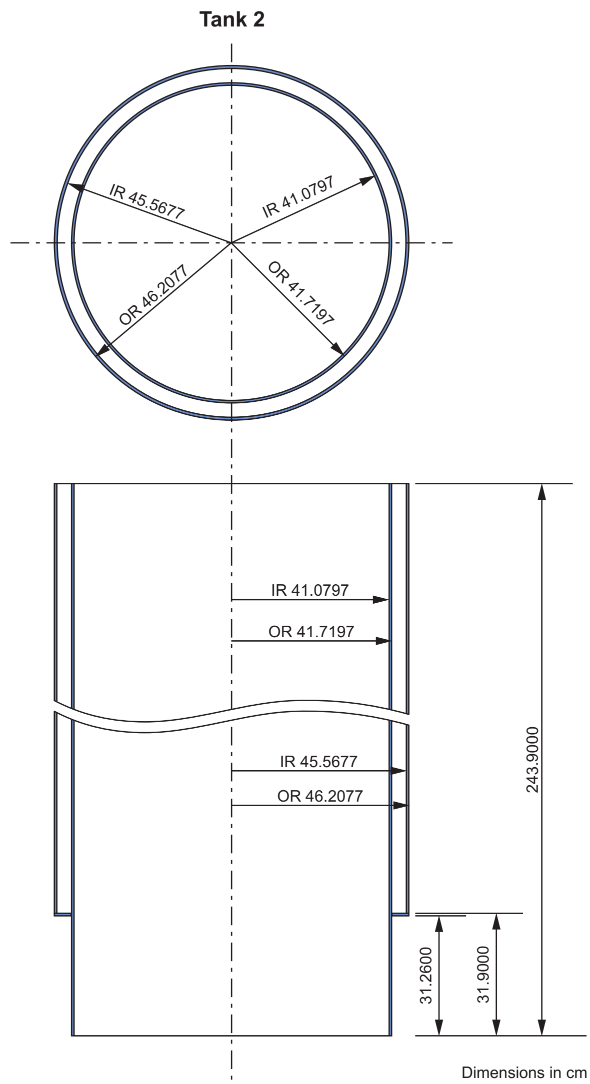

Figure 36. Tank 2 Dimensions Simple Model, Bottom 31.26 cm is the Extended Skirt.

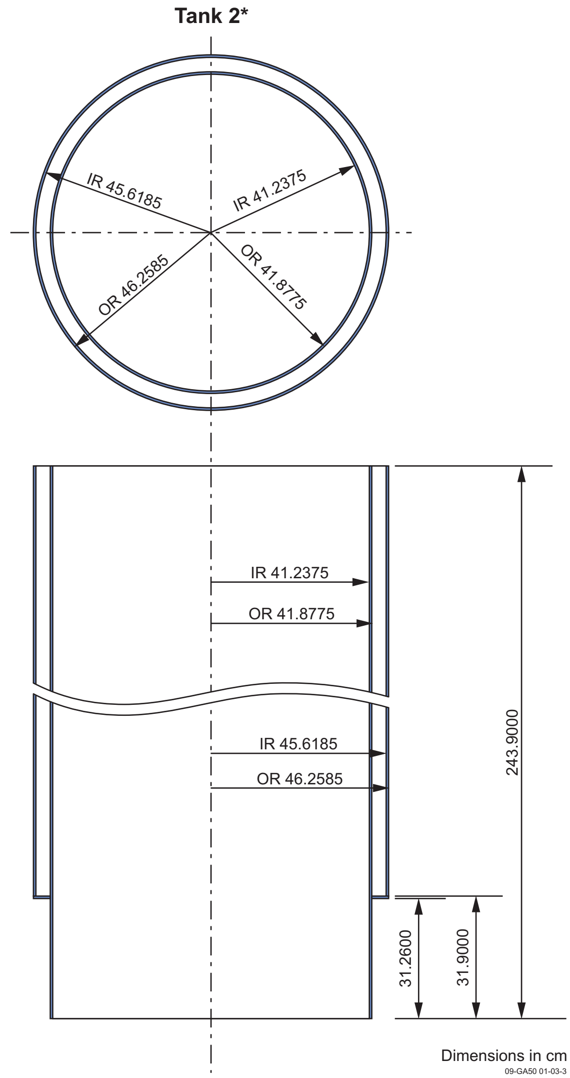

Figure 37. Tank 2* Dimensions Simple Model, Bottom 31.26 cm is the Extended Skirt.

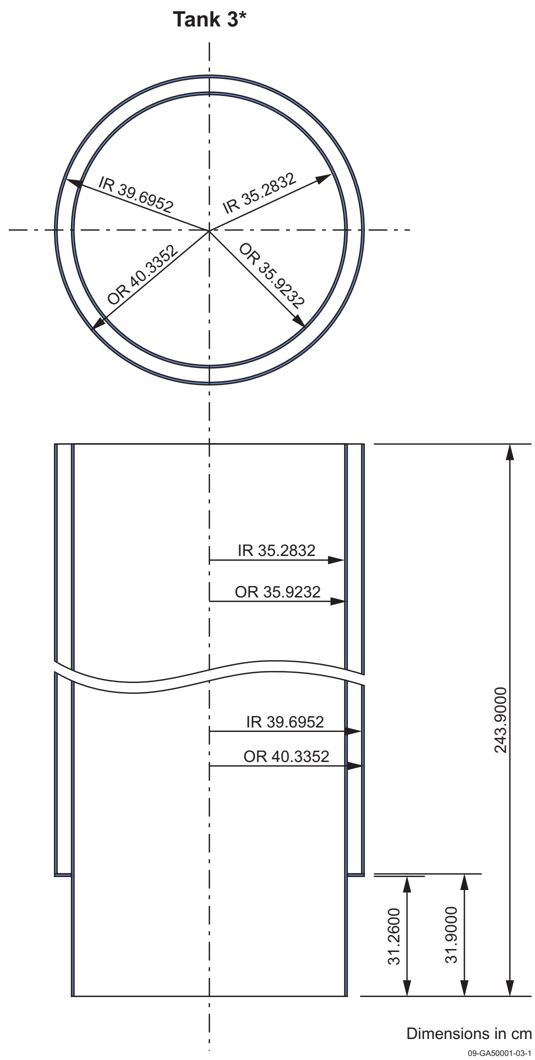

Figure 38. Tank 3* Dimensions Simple Model, Bottom 31.26 cm is the Extended Skirt.

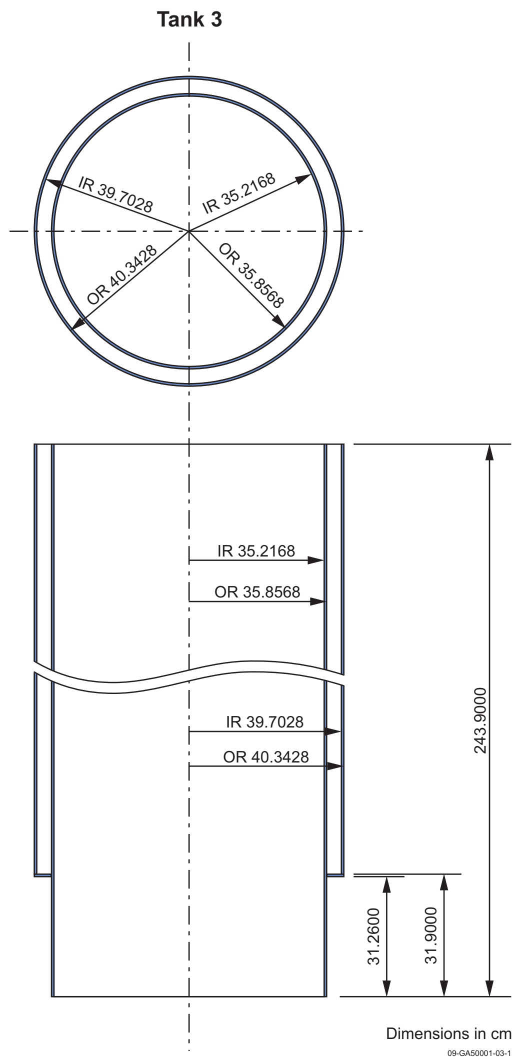

Figure 39. Tank 3 Dimensions Simple Model, Bottom 31.26 cm is the Extended Skirt.

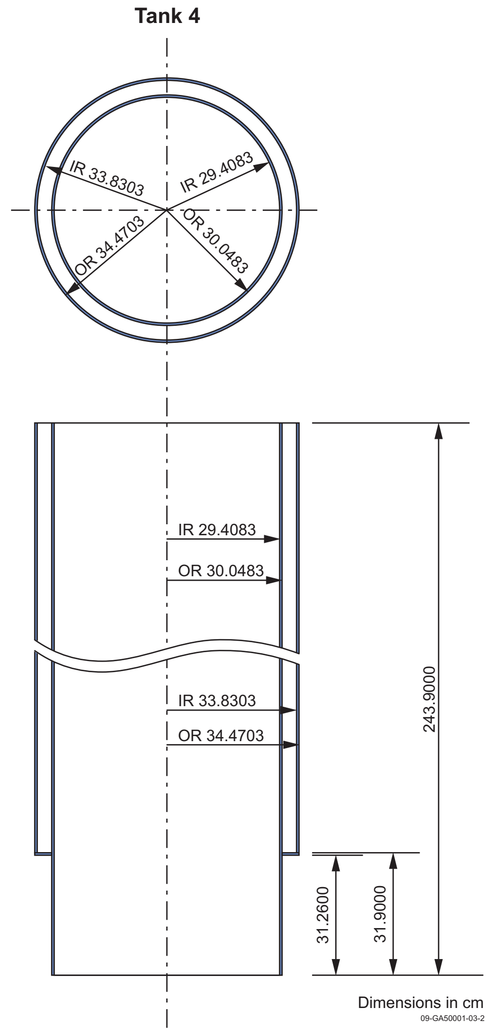

Figure 40. Tank 4 Dimensions Simple Model, bottom 31.26 cm is the Extended Skirt.

Table 79. Dimensions for Stainless Steel Tanks.

Description	Tank 1	Tank 2	Tank 2*	Tank 3*	Tank 3	Tank 4
Origin (x,y), cm	(-6.6244, -113.671)	(-6.6244, -113.671)	(0,0)	(0,0)	(6.6871,101.286)	(6.6871,101.286)
Outer diameter, cm	104.1858	92.4154	92.5170	80.6704	80.6856	68.9406
Outer wall thickness, cm	0.64	0.64	0.64	0.64	0.64	0.64
Solution annulus thickness, cm	3.838	3.848	3.741	3.772	3.846	3.782
Inner wall thickness, cm	0.64	0.64	0.64	0.64	0.64	0.64
Skirt outer diameter, cm	95.2298	83.4394	83.7550	71.8464	71.7136	60.0966
Skirt inner diameter, cm	93.9498	82.1594	82.4750	70.5664	70.4336	58.8166
Skirt height	All tanks: from platform to tank bottom.					
Tank bottom, midpoint, elevation above platform, cm[(a)]	32.28	32.11	32.11	31.91	31.91	31.69
Solution region bottom, midpoint, elevation above platform, cm	32.92	32.75	32.75	32.55	32.55	32.33
Top level of tank, elevation above platform, cm	243.9	243.9	243.9	243.9	243.9	243.9
Bottom slope[(b)]	2°	2°	2°	2°	2°	2°
Six 25.0-cm diameter holes in skirts[(c)]	All tanks: hole centers at 15.25 cm above platform, at 60° intervals around skirt.					

(a) Simple models were level at 31.9 cm.
(b) Applies to the detailed model. Lowest point of each tank is in the +y (west) direction.
(c) Applies to detailed model only.

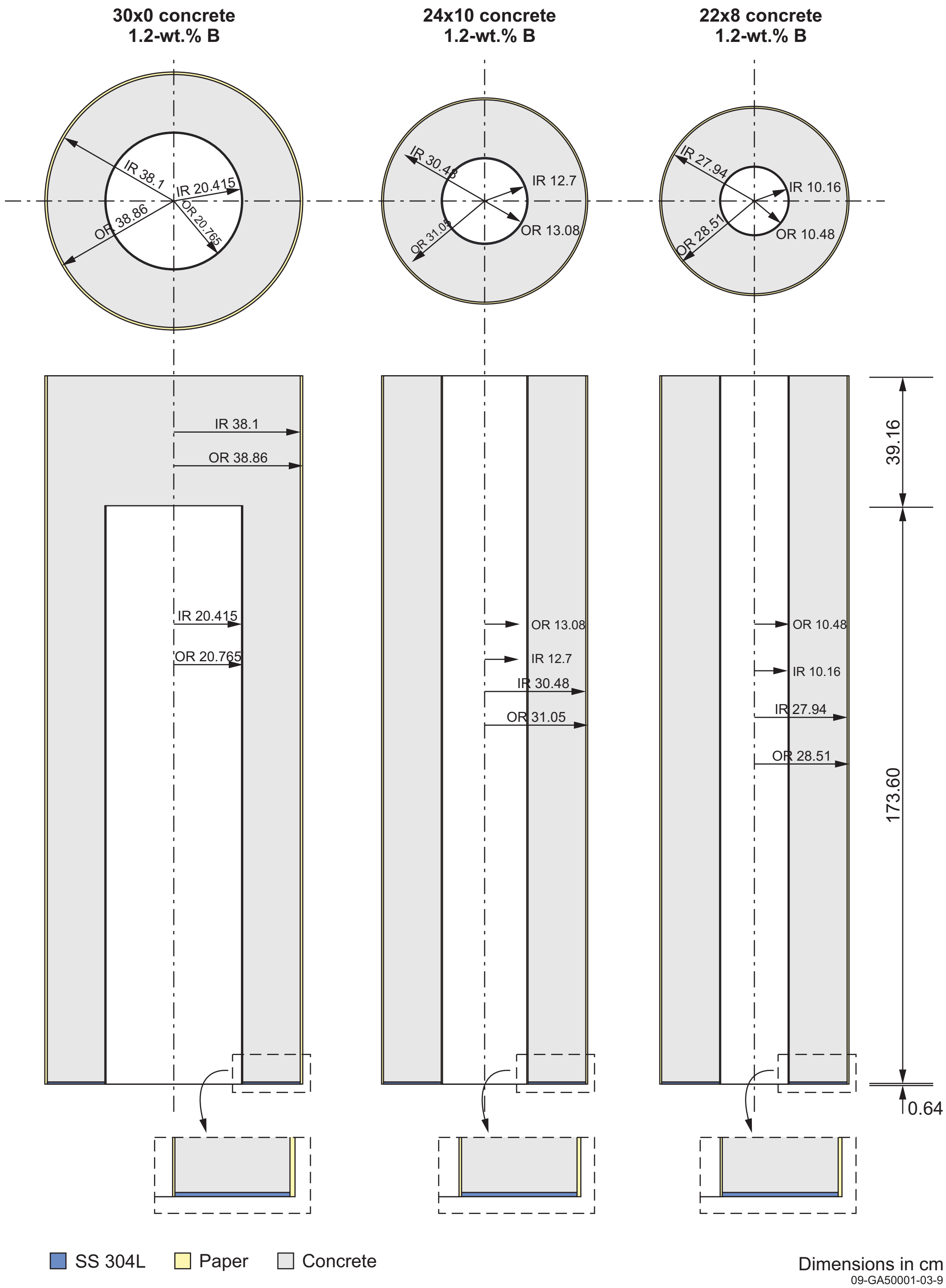

Figure 41. Plugs Used in Cases 5–6.

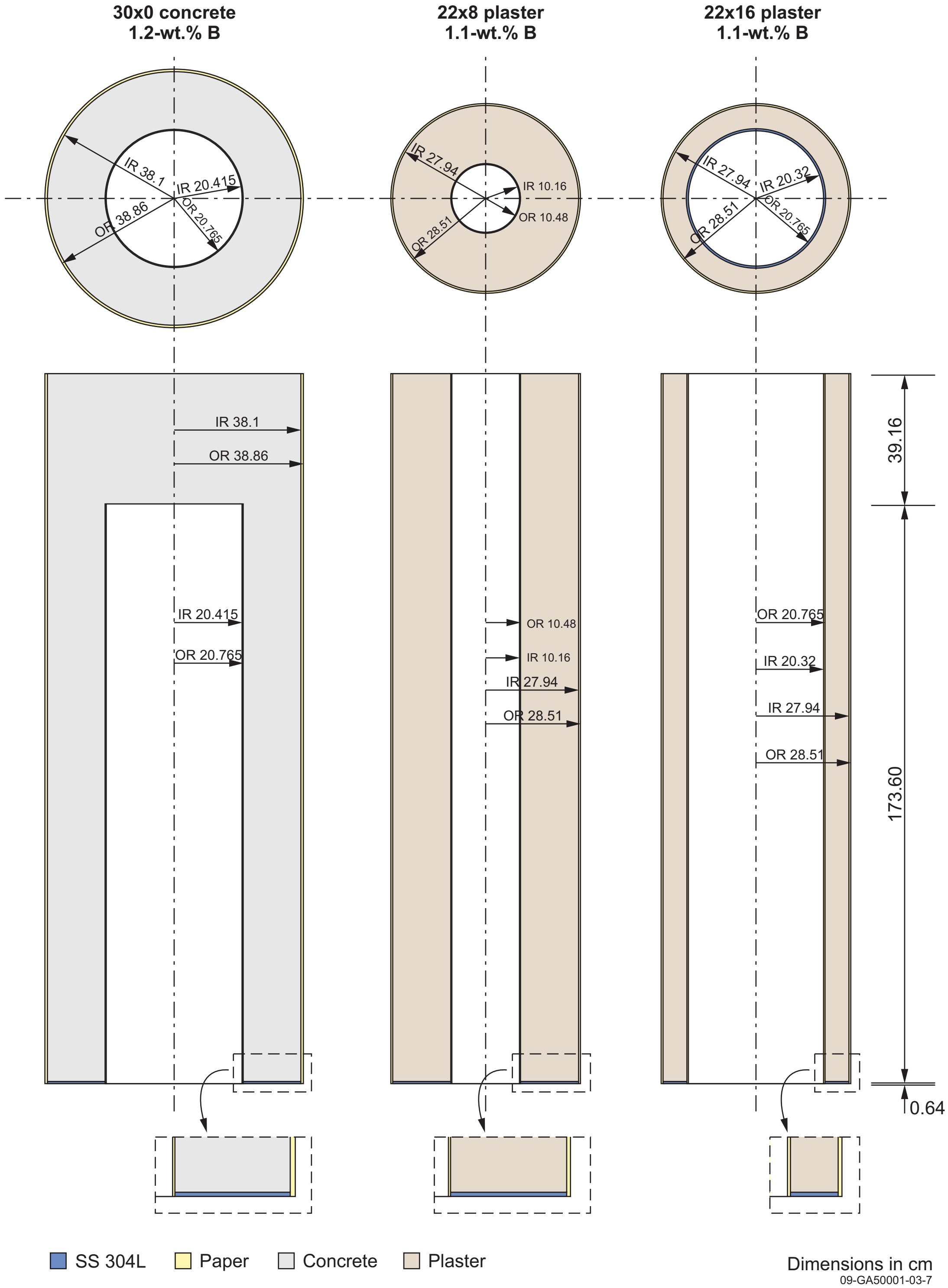

Figure 42. Plugs Used in Cases 7–8.

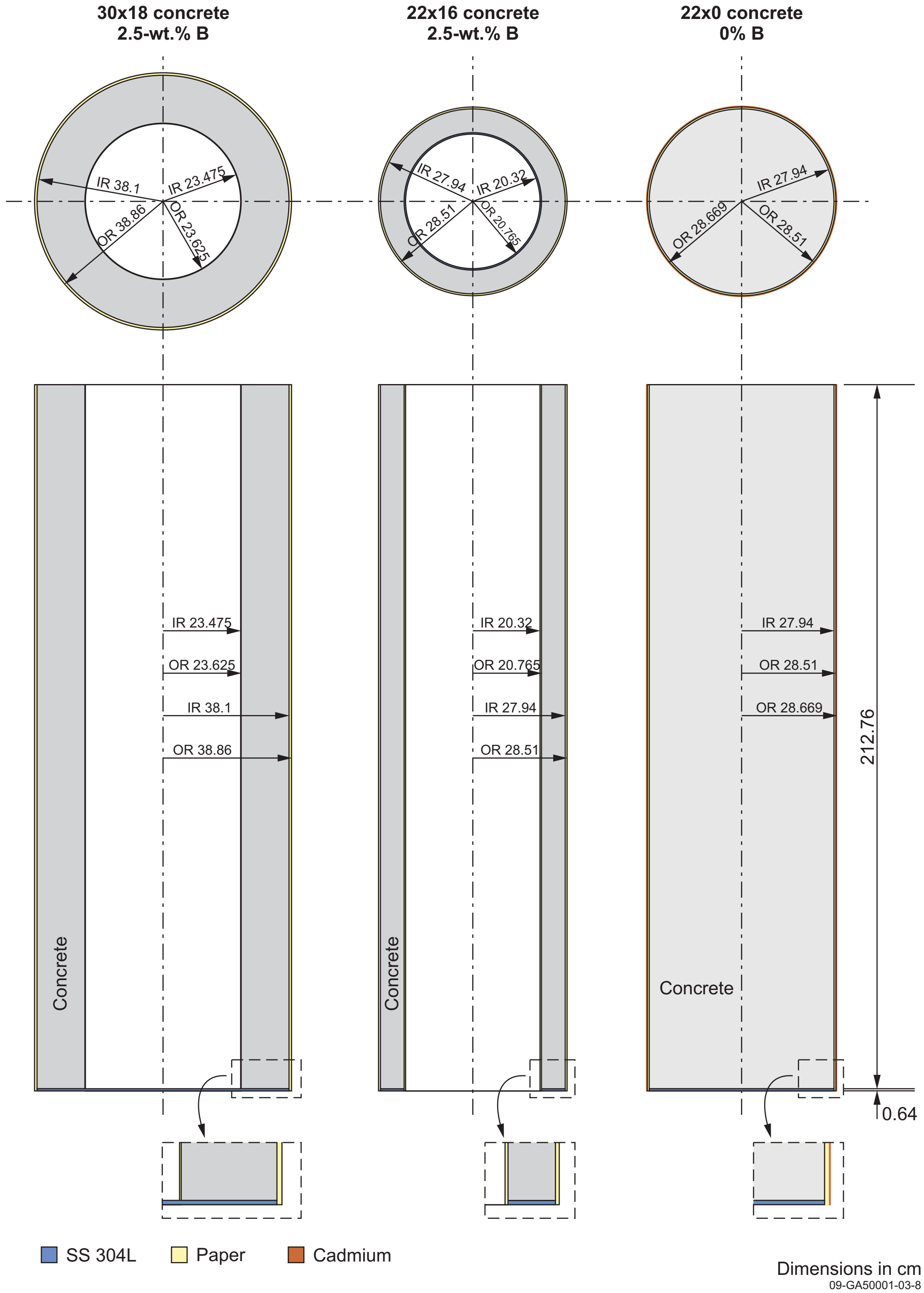

Figure 43. Plugs Used in Case 9.

Table 80. Dimensions for Central Plugs and Accessories.

Description	Height/thickness,[a] cm	Plugs, Steel OD, cm	Plugs, Steel ID, cm	Sonotubes Outer,[b] OD, cm	Sonotubes Inner,[c] ID, cm
22 × 0 concrete, 0% B	243.9	55.88	Not applicable	57.02	Not applicable
cadmium lamination	243.9	57.338	57.02	Not applicable	Not applicable
steel lifting plate	0.64	55.88	Not applicable	Not applicable	Not applicable
22 × 8 concrete, 1.2-wt.% B	243.9	55.88	20.96	57.02	20.32
steel lifting plate	0.64	55.88	20.96	Not applicable	Not applicable
24 × 10 concrete, 1.2-wt.% B	243.9	60.96	26.16	62.10	25.40
steel lifting plate	0.64	60.96	26.16	Not applicable	Not applicable
30 × 0 concrete, 1.2-wt.% B[d]	243.9	76.20	41.53	77.72	40.83
steel lifting plate	0.64	76.20	0	Not applicable	Not applicable
22 × 16 concrete, 2.5-wt.% B	243.9	55.88	41.53	57.02	40.64
steel lifting plate	0.64	55.88	41.53	Not applicable	Not applicable
30 × 18 concrete, 2.5-wt.% B	243.9	76.20	47.25	77.72	Not applicable
steel culvert	243.9	47.25	47.10	Not applicable	Not applicable
steel lifting plate	0.64	76.2	47.10	Not applicable	Not applicable
22 × 8 plaster, 1.1-wt.% B	243.9	55.88	20.96	57.02	20.32
steel lifting plate	0.64	55.88	20.96	Not applicable	Not applicable
22 × 16 plaster, 1.1-wt.% B	243.9	55.88	41.53	57.02	40.64
steel lifting plate	0.64	55.88	41.53	Not applicable	Not applicable

(a) 6.4 mm is the steel plate thickness and 243.9 cm is the height of the plugs above the platform. The bottom surface of the steel lifting plate is at 30.5 cm above platform.

(b) Outer Sonotube ID equals plug OD.

(c) Inner Sonotube OD equals plug ID.

(d) Inner Sonotube collapsed and the plug was filled above it, plug ID is for existing cavity, inner Sonotube remained inside plug.

Table 81. Critical Experiment Configurations, Critical Solution Level.

Case No.	Absorbers/Moderators	Tanks Filled with Solution	Critical Solution Level[(a)] elevation above platform (cm)
1	None	1-2-2*-3*-3-4	103.24
2	None	1-2-2*-3*	116.08
3	None	2*-3*	174.48
4	None	1-2*-3*	150.04
5	30 × 0 (1.2%B) C, 24 × 10 (1.2%B) C, 22 × 8 (1.2%B) C	1-2-2*-3*-3-4	166.54
6	30 × 0 (1.2%B) C, 24 × 10 (1.2%B) C, 22 × 8 (1.2%B) C	1-2-2*-3*	194.58
7	30 × 0 (1.2%B) C, 22 × 8 (1.1%B) P, 22 × 16 (1.1%B) P	1-2-2*-3*-3-4	164.575
8	30 × 0 (1.2%B) C, 22 × 8 (1.1%B) P, 22 × 16 (1.1%B) P	1-2-2*-3*	196.46
9	30 × 18 (2.5%B) C, 22 × 16 (2.5%B) C, 22 × 0 (Cd) C	1-2-2*-3*-3-4	158.89
10	30 × 0 (1.2%B) C, 22 × 8 (1.1%B) P, 22 × 16 (1.1%B) P, thin slabs	1-2-2*-3*-3-4	207.9
11	30 × 0 (1.2%B) C, 22 × 16 (1.1%B) P, thin slabs	1-2-2*-3*-3-4	121.41
12	30 × 0 (1.2%B) C, 22 × 16 (1.1%B) P, thin slabs	2*-3*-3-4	135.12

(a) Assuming a bottom location level at 31.9 cm for all tanks as in the simple model. The height above the platform is the same for the detailed model, the only difference is the sloped bottom and varying midpoints for each tank.

In the detailed model, all plugs rested on a wood stand 30.5-cm high. The corners of the stand were 8.9-cm-square wood pieces, joined with 1.3-cm-thick, 25.0-cm-wide plywood strips. Figure 42 gives the dimensions of a stand. The largest stand had the corner legs spaced from outer corner to outer corner 40.26 cm square. The middle size tank was 35.3554 cm square and the smallest was 31.8199 cm square. In the experiment report (Reference 2) it was stated that the plywood did not touch the platform or extend to the top of the corner legs. It was chosen to model the plywood bottom at 0.5 cm above the platform and 0.5 cm below the top of the corner legs.

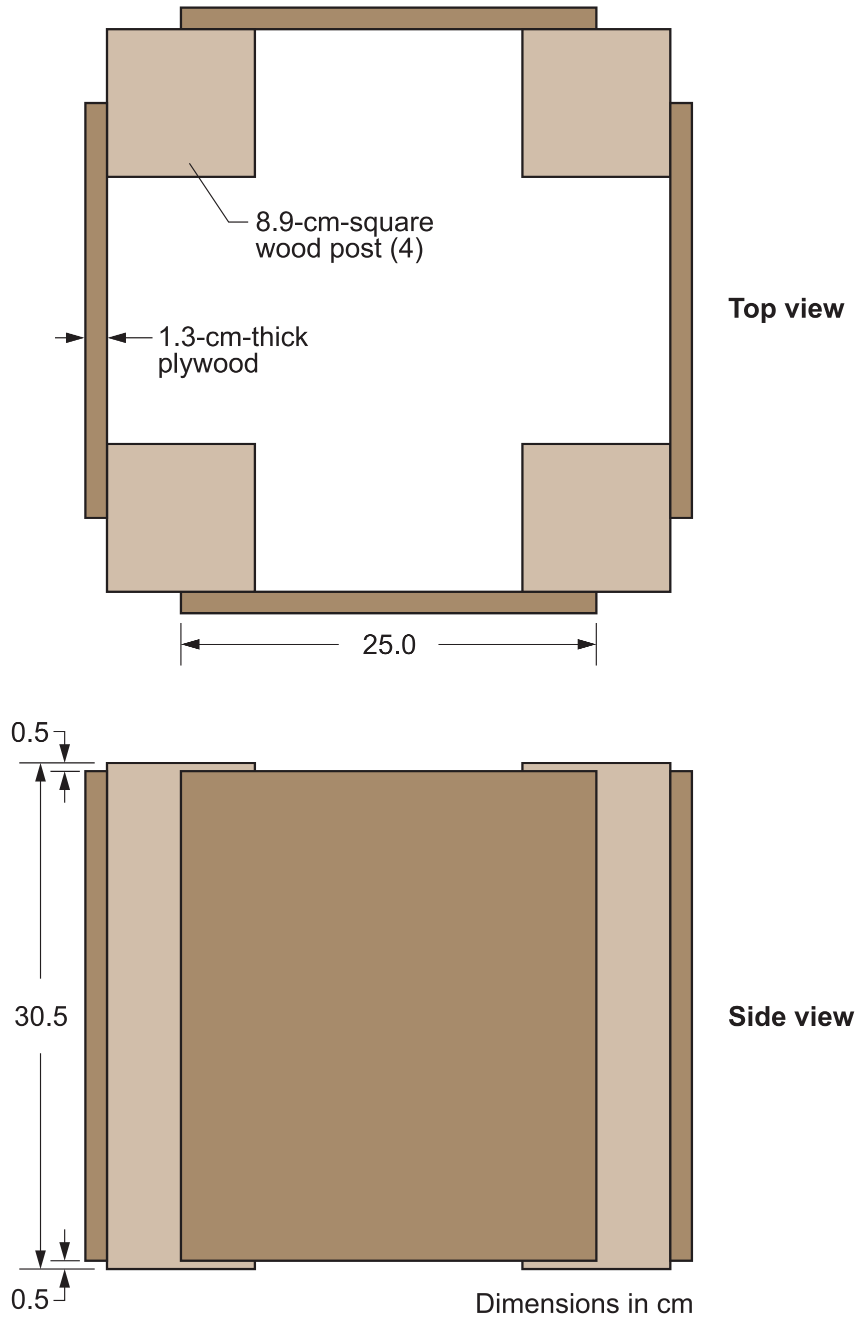

Figure 44. Wood Stands Used to Rest Plugs on in the Detailed Model.

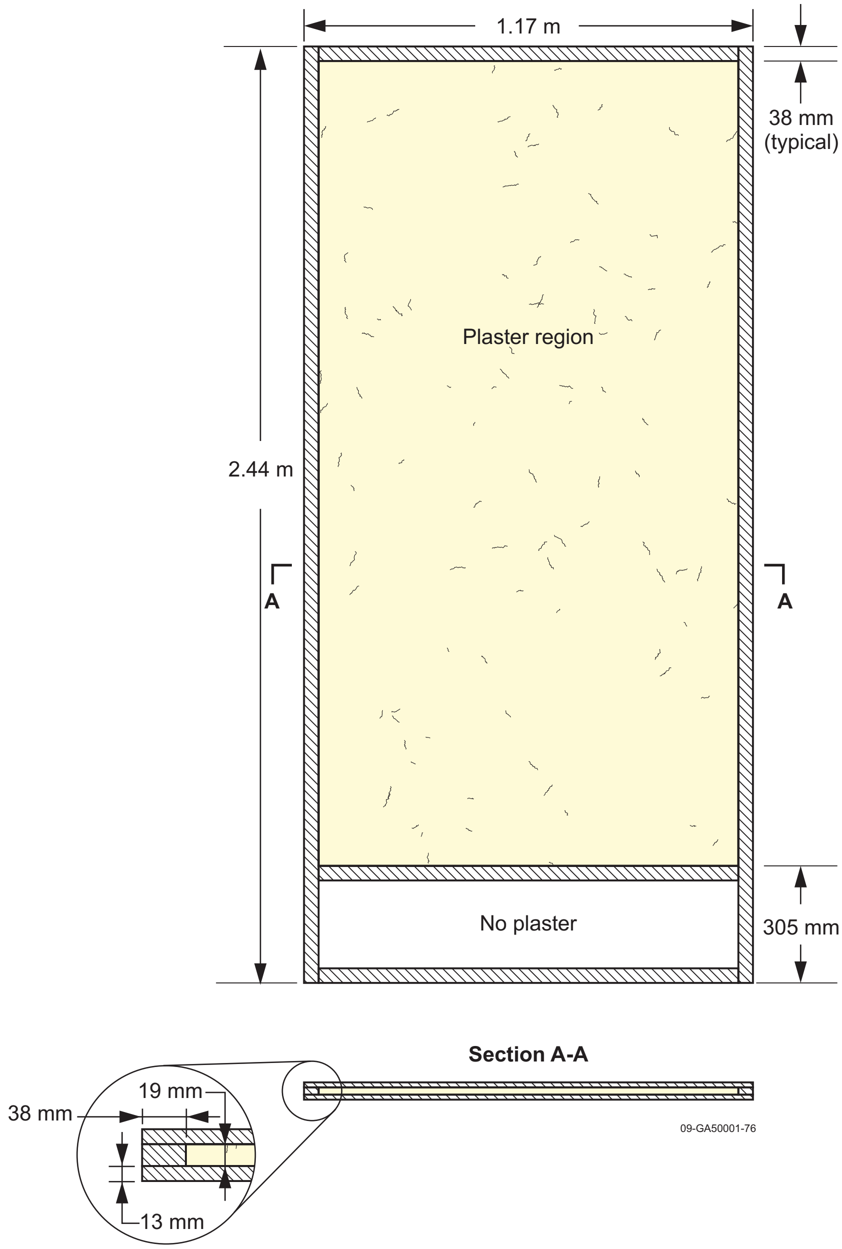

Figure 45. Plaster Slabs Used in Benchmarks Cases 10–12. Crosshatch material is wood, and it is excluded from the simplified models.

3.3 Material Data

Impurity Analysis

A rigorous analysis was conducted in the HEU-SOL-THERM-033 benchmark report to determine which impurities in the experiment materials could be omitted. The experiments in this report used the same uranyl nitrate solution, tanks, reflector panels, room and platform, and many of the same plugs. It was therefore unnecessary to repeat the same analysis. The details of the analysis are not reported here. Refer to the HEU-SOL-THERM-033 report for detailed information.

Concrete and Plaster Weight Percent Composition

The calculations for determining the weight percent composition for all the concrete and plaster are given in Appendix C. Table 82 gives the resultant calculated compositions.

Table 82. Concrete and Plaster Compositions.

Constituent	Concrete			Plaster Plugs/Slabs
	Boron-Free	1.2-wt.% Boron	2.5-wt.% Boron	1.1-wt.% Boron
	wt.%	wt.%	wt.%	wt.%
Li	0	0.0034840	0.0072881	0.0031442
B	0	1.2004	2.5012	1.0790
C	0.0070705	0.043640	0.081075	0.42483
O	44.112	41.585	36.327	34.230
Na	0.096375	0.71966	1.4161	0.60294
Mg	0.45352	0.86107	1.3367	0.49694
Al	5.9828	5.0274	3.4990	0.40754
Si	30.215	25.258	17.291	2.2276
S	0.15780	0.21759	0.33811	14.446
K	0.30451	0.28495	0.26749	0.058425
Ca	6.0722	10.565	17.481	20.183
Ti	0.29572	0.22721	0.12745	0
V	0.013041	0.017979	0.027935	0
Mn	0.037220	0.035833	0.036297	0
Fe	2.5179	2.2275	1.7956	0.15228
Ni	0.0013041	0.0017979	0.0027935	0
Zn	0.00065205	0.00089895	.0013968	
Rb	0.0054585	0.0057256	0.0066604	0
Sr	0.026082	0.14629	0.28677	0.12098
Zr	0.0013041	0.0017979	0.0027935	0
Ba	0.092746	0.076120	0.051975	0.0021438
Ta	0.069460	0.059639	0.047447	0
H_2O	9.50	11.4166	16.9847	25.566
Density	2.29	2.22	1.94	1.875

Section 3.3.1 shows how the uranyl nitrate solution atom densities (atoms/b-cm) were calculated and gives the benchmark-model atom densities in Table 83. Section 3.3.2 gives the remaining atom densities in Tables 84–89. Table 84 also provides the average weight percent used for the stainless steel 304L. Many element atom densities have been broken down into isotope atom densities in order to facilitate use with modern cross section libraries. Avogadro's number and atomic weights were taken from the ICSBEP handbook in the Document Content and Format Guide under the Nuclear Constants section.

3.3.1 Uranyl Nitrate Solution Atom Densities - The uranium isotopes are specified by weight percent in Table 7 and Table 70. The atom densities of the uranium isotopes are given by:

$$N_i = \frac{w_{f,i} \cdot \rho_U \cdot N_A}{A_{w,i}}, \quad for \;\; i = {}^{234}U,\ {}^{235}U,\ {}^{236}U,\ {}^{238}U$$

where:

$$w_{f,i} = weight\ \ fraction\ isotope\ i$$
$$\rho_U = uranium\ density,\ kg/liter\ of\ \ solution$$
$$N_A = Avogadro's\ number\ (6.0221 \times 10^{23}\ \frac{atoms}{g-mol})$$
$$A_{w,i} = atomic\ mass\ of\ \ isotope\ i$$

The concentration of the uranyl nitrate solution is given by:

$$\rho_{UO_2(NO_3)_2} = \frac{N_U \cdot M_{w,UO_2(NO_3)_2}}{N_A}$$

where:

$$N_U = N_{^{234}U} + N_{^{235}U} + N_{^{236}U} + N_{^{238}U}$$
$$M_{w,UO_2(NO_3)_2} = molecular\ weight\ of\ UO_2(NO_3)_2$$

The concentration of the excess nitric acid is given by:

$$\rho_{HNO_3} = N \cdot M_{w,HNO_3} \cdot \left(0.001 \,{}^{L}\!/_{cm^3}\right)$$

where:

$$N = Normality\ of\ \ excess\ acid,\ moles/liter$$
$$M_{w,HNO_3} = molecular\ weight\ of\ \ HNO_3$$

The impurity elements are given in Table 8 and Table 71. All impurities are used for these calculations. The concentration of each impurity element is given by:

$$\rho_{imp,i} = \rho_{imp,ppm,i} \cdot 10^{-6} \cdot \rho_U$$

where $\rho_{imp,ppm,i}$ = impurity concentration of element i, ppm by wt. relative to U wt.

The atom density of each impurity element is given by:

$$N_{imp,i} = \frac{\rho_{imp,i} \cdot N_A}{A_{w,imp,i}}$$

where $A_{w,imp,i}$ = atomic mass of impurity element i

The concentration of water is given by:

$$\rho_{H_2O} = \rho_{solution} - \rho_{UO_2(NO_3)_2} - \rho_{HNO_3} - \sum_i \rho_{imp,i} - \sum_i \rho_{imp:nitrates,i}$$

here $\sum_i \rho_{imp:nitrates,i}$ = the nitrate compounds formed by impurities in solution

The atom densities for hydrogen, nitrogen, and oxygen are given by:

$$N_H = N_A \cdot \left[\frac{2 \cdot \rho_{H_2O}}{M_{w,H_2O}} + \frac{\rho_{HNO_3}}{M_{w,HNO_3}} \right]$$

where M_{w,H_2O} = molecular weight of H_2O

$$N_N = N_A \cdot \left[\frac{2 \cdot \rho_{UO_2(NO_3)_2}}{M_{w,UO_2(NO_3)_2}} + \frac{\rho_{HNO_3}}{M_{w,HNO_3}} \right]$$

$$N_O = N_A \cdot \left[\frac{8 \cdot \rho_{UO_2(NO_3)_2}}{M_{w,UO_2(NO_3)_2}} + \frac{3 \cdot \rho_{HNO_3}}{M_{w,HNO_3}} + \frac{\rho_{H_2O}}{M_{w,H_2O}} \right]$$

Various isotopes are used in the benchmark model. Having the atom density for an element, the atom density of that element's isotopes of interest can be calculated. For example, the atom density of ^{10}B is given by:

$$N_{^{10}B} = N_B \cdot \gamma_{^{10}B}$$

where $\gamma_{^{10}B}$ = isotopic abundance of ^{10}B in atom percent

Table 83. Uranyl Nitrate Solution Atom Densities.

Element/Isotope	Atom Density	Element/Isotope	Atom Density
^{234}U	9.0307×10^{-6}	Cu	2.7435×10^{-7}
^{235}U	8.5361×10^{-4}	Zn	7.5704×10^{-7}
^{236}U	3.9390×10^{-6}	Mo	1.6825×10^{-7}
^{238}U	4.8525×10^{-5}	^{106}Cd	1.8668×10^{-10}
H	5.8296×10^{-2}	^{108}Cd	1.3292×10^{-10}
^{10}B	1.7432×10^{-8}	^{110}Cd	1.8653×10^{-9}
^{11}B	7.0165×10^{-8}	^{111}Cd	1.9116×10^{-9}
N	2.1765×10^{-3}	^{112}Cd	3.6037×10^{-9}
O	3.7335×10^{-2}	^{113}Cd	1.8250×10^{-9}
Mg	2.2138×10^{-6}	^{114}Cd	4.2907×10^{-9}
Al	2.7919×10^{-6}	^{116}Cd	1.1186×10^{-9}
Si	3.2953×10^{-7}	Sn	5.0766×10^{-7}
Mn	1.0578×10^{-7}	Pb	4.5705×10^{-8}
Fe	1.9848×10^{-6}	Bi	7.0034×10^{-9}
Ni	2.5304×10^{-7}		

3.3.2 Atom Densities for Other Materials – In order to obtain an average for the stainless steel composition, amounts given as less than a specified value were divided by 2 to obtain the average value over the possible range.

Table 84. Stainless Steel 304L Average Weight Percent and Atom Densities.

Element	Average Wt.%	Atom Density	Element	Average Wt.%	Atom Density
H	0.0004	2.0391×10^{-5}	Cr	20.00	1.8600×10^{-2}
C	0.0125	5.0326×10^{-5}	Mn	2.20	1.9365×10^{-3}
N	0.0760	2.6239×10^{-4}	Fe	66.70	5.7755×10^{-2}
O	0.0143	4.3322×10^{-5}	Co	0.1950	1.6001×10^{-4}
Al	0.0067	1.1948×10^{-5}	Ni	10.50	8.6514×10^{-3}
S	0.0020	3.0157×10^{-6}	Mo	0.1983	9.9968×10^{-5}
Ti	0.0058	5.8915×10^{-6}	Sn	0.0075	3.0552×10^{-6}
V	0.0893	8.4802×10^{-5}	Pb	0.0125	2.9173×10^{-6}

Table 85. Boron-Free Concrete Atom Densities.

Element	Atom Density	Element	Atom Density
H	1.4544×10^{-2}	V	3.5304×10^{-6}
C	8.1181×10^{-6}	Mn	9.3431×10^{-6}
O	4.5295×10^{-2}	Fe	6.2177×10^{-4}
Na	5.7811×10^{-5}	Ni	3.0643×10^{-7}
Mg	2.5732×10^{-4}	Zn	1.3752×10^{-7}
Al	3.0579×10^{-3}	Rb	6.3564×10^{-7}
Si	1.4836×10^{-2}	Sr	4.1051×10^{-6}
S	6.7855×10^{-5}	Zr	1.9714×10^{-7}
K	1.0740×10^{-4}	Ba	9.3137×10^{-6}
Ca	2.0894×10^{-3}	Ta	5.2937×10^{-6}
Ti	8.5175×10^{-5}		

Table 86. Borated Concrete Atom Densities.

Element/Isotope	Atom Density				
	1.2-wt.% B	2.5-wt.% B	Element/Isotope	1.2-wt.% B	2.5-wt.% B
H	1.6944×10^{-2}	2.2029×10^{-2}	Ca	3.5242×10^{-3}	5.0957×10^{-3}
^{6}Li	5.0933×10^{-7}	9.3108×10^{-7}	Ti	6.3443×10^{-5}	3.1098×10^{-5}
^{7}Li	6.2012×10^{-6}	1.1336×10^{-5}	V	6.3443×10^{-6}	6.4067×10^{-6}
^{10}B	2.9540×10^{-4}	5.3787×10^{-4}	Mn	8.7199×10^{-6}	7.7188×10^{-6}
^{11}B	1.1890×10^{-3}	2.1650×10^{-3}	Fe	5.3323×10^{-4}	3.7562×10^{-4}
C	4.8574×10^{-5}	8.1778×10^{-5}	Ni	7.0955×10^{-7}	5.5608×10^{-7}
O	4.3220×10^{-2}	3.7541×10^{-2}	Zn	1.8379×10^{-7}	2.4955×10^{-7}
Na	4.1850×10^{-4}	7.1963×10^{-4}	Rb	8.9561×10^{-7}	9.1043×10^{-7}
Mg	4.7364×10^{-4}	6.4254×10^{-4}	Sr	2.2321×10^{-5}	3.8237×10^{-5}
Al	2.4910×10^{-3}	1.5151×10^{-3}	Zr	2.6349×10^{-7}	3.5776×10^{-7}
Si	1.2023×10^{-2}	7.1925×10^{-3}	Ba	7.4104×10^{-6}	4.4217×10^{-6}
S	9.0706×10^{-5}	1.2317×10^{-4}	Ta	4.4063×10^{-6}	3.0634×10^{-6}
K	9.7433×10^{-5}	7.9928×10^{-5}			

Table 87. 1.1-wt.% Boron Plaster Atom Densities.

Element/Isotope	Atom Density	Element/Isotope	Atom Density
H	3.2048×10^{-2}	Al	1.7055×10^{-4}
^{6}Li	3.8822×10^{-7}	Si	8.9556×10^{-4}
^{7}Li	4.7267×10^{-6}	S	5.0862×10^{-3}
^{10}B	2.2427×10^{-4}	K	1.6873×10^{-5}
^{11}B	9.0271×10^{-4}	Ca	5.6862×10^{-3}
C	3.9938×10^{-4}	Fe	3.0789×10^{-5}
O	4.0181×10^{-2}	Sr	1.5590×10^{-5}
Na	2.9613×10^{-4}	Ba	1.7627×10^{-7}
Mg	2.3086×10^{-4}		

Table 88. Carbon Steel (Rebar) Atom Densities.

Element	Atom Density
C	1.9600×10^{-3}
Fe	8.3900×10^{-2}

Table 89. Atom Densities for Remaining Components.

Material	Element/Isotope	Atom Density
Sonotube[(a)] - cellulose	H	6.8858×10^{-3}
	C	4.1315×10^{-3}
	O	3.4429×10^{-3}
Wood-cellulose	H	2.2298×10^{-2}
	C	1.3369×10^{-2}
	O	1.1143×10^{-2}
Cadmium lamination	^{106}Cd	5.7925×10^{-4}
	^{108}Cd	4.1243×10^{-4}
	^{110}Cd	5.7879×10^{-3}
	^{111}Cd	5.9316×10^{-3}
	^{112}Cd	1.1182×10^{-2}
	^{113}Cd	5.6628×10^{-3}
	^{114}Cd	1.3314×10^{-2}
	^{116}Cd	3.4709×10^{-3}
ASTM A-444 steel (Stock Culvert)	C	1.1712×10^{-3}
	P	1.3485×10^{-4}
	S	6.0090×10^{-5}
	Fe	8.4181×10^{-2}
	Zn	1.4718×10^{-3}

(a) The HEU-SOL-THERM-033 report reported using given weights and dimensions to calculate the density of the Sonotubes. It reported a calculated density of 0.7 g/cm^3. I was not able to obtain the same result and calculated a density of 0.1854 g/cm^3.

3.4 Temperature Data

Experiments were performed at nominal room temperature. The room temperature varied seasonally between 18 and 22°C. The benchmark model temperature is 20ºC.

3.5 Experimental and Benchmark-Model k_{eff}

3.5.1 Experimental k_{eff} - Criticality was determined by interpolation between positive and negative periods, or by extrapolation from two positive periods. It was only stated that the system was critical at the specified height, and therefore the experimental k_{eff} value is equal to 1.0.

3.5.2 Benchmark-Model k_{eff}: Detailed Model - The benchmark-model k_{eff} is 1.0 plus the bias from the room return and solution density. Section 3.1.4 describes the bias introduced by benchmark model room effects for the detailed model. The uncertainty in room bias (σ_{room}) was determined by taking the square root of the sum of the squares of the uncertainties of both the detailed model and the detailed model with room return effects, which were both 0.00009. Section 2 Table 69 gives the uncertainty of k_{eff} due to uncertainties in experimental data ($\sigma_{Sec.2}$). The uncertainty in the benchmark detailed model is given by the following equation:

$$\sigma = \sqrt{\sigma_{Sec.2}^2 + \sigma_{room}^2}$$

Table 89 gives the benchmark-model k_{eff} and uncertainty for each case for the detailed model.

3.5.3 Benchmark-Model k_{eff}: Simplified Model – The benchmark model k_{eff} is 1.0 plus the bias from the simplification of the model plus the bias from the room effects and solution density. Section 3.1.3 describes the benchmark model simplifications that introduce a bias to the simplified model. The uncertainty in the benchmark simple model is the same as the detailed with the addition of the uncertainty in the simplification bias (σ_{simp}) as shown in the following equation:

$$\sigma = \sqrt{\sigma_{Sec.2}^2 + \sigma_{room}^2 + \sigma_{simp.}^2}$$

Table 90 gives the simplified benchmark-model k_{eff} and uncertainty for each case.

Table 90. Detailed and Simplified Benchmark-Model k_{eff} Values.

Case No.	Conf. No.	Absorbers/Moderators	Tanks with Solution	Detailed Model $k_{eff} \pm \sigma$	Simple Model $k_{eff} \pm \sigma$
1	1a	None	All	0.9988 ± 0.0084	0.9996 ± 0.0084
2	1b	None	1,2,2*,3*	0.9987 ± 0.0086	1.0009 ± 0.0086
3	1c	None	2*,3*	0.9986 ± 0.0083	1.0003 ± 0.0083
4	1d	None	1,2,3*	0.9985 ± 0.0085	1.0004 ± 0.0085
5	2a	30 × 0 (1.2%B) C, 24 × 10 (1.2%B) C, 22 × 8 (1.2%B) C	All	0.9984 ± 0.0086	0.9993 ± 0.0086
6	2b	30 × 0 (1.2%B) C, 24 × 10 (1.2%B) C, 22 × 8 (1.2%B) C	1,2,2*,3*	0.9990 ± 0.0090	0.9998 ± 0.0090
7	3a5a	30 × 0 (1.2%B) C, 22 × 8 (1.1%B) P, 22 × 16 (1.1%B) P	All	0.9982 ± 0.0079	0.9991 ± 0.0079
8	3b	30 × 0 (1.2%B) C, 22 × 8 (1.1%B) P, 22 × 16 (1.1%B) P	1,2,2*,3*	1.0002 ± 0.0085	1.0011 ± 0.0085
9	4	30 × 18 (2.5%B) C, 22 × 16 (2.5%B) C, 22 × 0 (Cd) C	All	0.9990 ± 0.0081	1.0001 ± 0.0081
10	5e	30 × 0 (1.2%B) C, 22 × 8 (1.1%B) P, 22 × 16 (1.1%B) P, thin slabs	All	0.9977 ± 0.0085	1.0028 ± 0.0085
11	5f	30 × 0 (1.2%B) C, 22 × 16 (1.1%B) P, thin slabs	All	0.9985 ± 0.0086	1.0008 ± 0.0086
12	6	30 × 0 (1.2%B) C, 22 × 16 (1.1%B) P, thin slabs	2*,3*,3,4	0.9982 ± 0.0085	0.9968 ± 0.0085

4.0 RESULTS OF SAMPLE CALCULATIONS

4.1 Simplified and Detailed Models

Table 91 gives the sample calculated results for the simplified and detailed benchmark models. Calculations were performed using MCNP5. ENDF/B-VI continuous-energy cross sections were used. All elements were from either the .62c or .66c libraries with the exception of Zn in the galvanized steel culvert material, which used the .42c library from LLNL. The ENDF/B-VI models do not include Sn or Sr, for which cross sections were unavailable. The ENDF/B-VII cross section library does include Zn, Sn, and Sr, and they were included in the detailed model calculations.

Results for configurations 10 through 12 are noticeably lower than the benchmark values. The primary difference between these configurations and the previous nine is the inclusion of borated plaster slabs between the annular tanks. The plaster was reported to be of the same composition as the borated plaster plugs, but no other information was available that could further detail the physical properties of the slabs or explain the lower calculated eigenvalues. Voids created during the formation of the plaster slabs might explain the difference.

Table 91. Sample Calculation Results, Simplified and Detailed Benchmark Models (United States).

Code (Cross Section Set) → Case Number ↓	Conf. No.	MCNP5 (Continuous Energy ENDF/B-VII) Detailed Model	MCNP5 (Continuous Energy ENDF/B-VI) Detailed Model	MCNP5 (Continuous Energy ENDF/B-VI) Simple Model	MCNP5 (Continuous Energy ENDF/B-V) Simple Model
1	1a	0.9984 ± 0.0001	0.9940 ± 0.0001	0.9948 ± 0.0001	0.9990 ± 0.0001
2	1b	0.9999 ± 0.0001	0.9956 ± 0.0001	0.9978 ± 0.0001	1.0017 ± 0.0001
3	1c	0.9871 ± 0.0001	0.9858 ± 0.0001	0.9874 ± 0.0001	0.9923 ± 0.0001
4	1d	0.9907 ± 0.0001	0.9879 ± 0.0001	0.9897 ± 0.0001	0.9941 ± 0.0001
5	2a	1.0047 ± 0.0001	1.0024 ± 0.0001	1.0033 ± 0.0001	1.0076 ± 0.0001
6	2b	1.0089 ± 0.0001	1.0071 ± 0.0001	1.0079 ± 0.0001	1.0124 ± 0.0001
7	3a5a	0.9933 ± 0.0001	0.9907 ± 0.0001	0.9916 ± 0.0001	0.9959 ± 0.0001
8	3b	1.0011 ± 0.0001	0.9989 ± 0.0001	0.9998 ± 0.0001	1.0041 ± 0.0001
9	4	1.0000 ± 0.0001	0.9976 ± 0.0001	0.9987 ± 0.0001	1.0036 ± 0.0001
10	5e	0.9834 ± 0.0001	0.9802 ± 0.0001	0.9854 ± 0.0001	0.9898 ± 0.0001
11	5f	0.9818 ± 0.0001	0.9785 ± 0.0001	0.9807 ± 0.0001	0.9850 ± 0.0001
12	6	0.9793 ± 0.0001	0.9760 ± 0.0001	0.9745 ± 0.0001	0.9791 ± 0.0001

5.0 REFERENCES

1. Rothe, R. E., 1981, "Criticality Safety of an Annular Tank for Fissile Solution," ANS Transactions 39, Nov. 1981, pp. 525–527.

2. Rothe, R. E., 1996, *Experimental Critical Parameters of Enriched Uranium Solution in Annular Tank Geometries*, INEL-96/0386, Idaho National Engineering Laboratory, April 1996.

APPENDIX A: TYPICAL INPUT LISTINGS FOR ACCEPTED BENCHMARKS

A.1 MCNP5 Input Listings

Simplified and Detailed Models

The MCNP calculations for all experiments used 50000 neutrons per generation and 2100 generations with 100 skipped, totaling 100,000,000 neutron histories.

ENDF/B-VI continuous-energy cross sections were used. It was necessary to break many of the elements in the materials into isotopes. All elements or isotopes were from either the .62c or .66c libraries with the exception of Zn in the galvanized steel culvert material which used the .42c library from LLNL.

MCNP5 ENDF/B-VI (Detailed Model) Input Listing for Experiment 1a of Table 91.

```
1X3 array of nested tanks, Experiment 1a Detailed
C   5                                                                      80
C      Cell Cards
C Everything but tanks and void space (all concrete)
1     1  -2.29  (-1 2 -3 4 -5 6):(4 -3 -5 12 1 -10 96 97 98 99 100 101 102 103&
                104 105 106 107 122 123 124 125 126 127 128 129 130 131):(-12 11
                -3 13 -10 1 108 109 110 111 132 133 134 135 136 137 138 139 140&
                141):(1 -10 -11 6 14 -3 112 113 114 115 116 117 118 119 120 121&
                142 143 144 145 146 147 148 149 150 151)
                imp:n=1 $platform/panels
2     1  -2.29  (2 -8 6 -5 -4 7 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79&
                80):(2 -8 -14 7 -6 9 81 82 83 84 85 86 87 88 89 90 91 92 93 94&
                 95):(2 -8 14 -3 -6 9 81):(-84 -85 -86 -87 -88 -89 -90 -91 -92
                 -93 94 95)  imp:n=1  $walls
C Tanks
3     2  -8.03  (1 -15 29 -28 46 47 48):(-52 53 28 -27):(-15 53 27 -26)
                imp:n=1  $Tank 1
4     2  -8.03  (1 -15 33 -32 46 47 48):(-54 55 32 -31):(-15 55 31 -30)
                imp:n=1  $Tank 2
5     2  -8.03  (1 -15 37 -36 49 50 51):(-60 61 36 -35):(-15 61 35 -34)
                imp:n=1  $Tank 3
6     2  -8.03  (1 -15 41 -40 49 50 51):(-62 63 40 -39):(-15 63 39 -38)
                imp:n=1  $Tank 4
7     2  -8.03  (1 -15 20 -21 43 44 45):(-56 57 21 -22):(-15 57 22 -23)
                imp:n=1  $Tank 2*
8     2  -8.03  (1 -15 16 -17 43 44 45):(-58 59 17 -18):(-15 59 18 -19)
                imp:n=1  $Tank 3*
C solution
9     3  -1.4982  -42 52 28 -27   imp:n=1  $in tank 1
10    3  -1.4982  -42 54 32 -31   imp:n=1  $in tank 2
11    3  -1.4982  -42 60 36 -35   imp:n=1  $in tank 3
12    3  -1.4982  -42 62 40 -39   imp:n=1  $in tank 4
13    3  -1.4982  -42 56 21 -22   imp:n=1  $in tank 2*
14    3  -1.4982  -42 58 17 -18   imp:n=1  $in tank 3*
C Void space
15    0  -7:-9:5:3:-2:8:(10 -8 -5 6 4 -3) imp:n=0 $Big Void outside enclosure
16    0  (4 -14 -11 6 1 -10):(15 -10 11 -12 4 -13):(1 -15 11 -12 4 -13 26 23 34)
         :(1 28 -53 -26):(1 21 -57 -23):(1 36 -61 -34) imp:n=1
         $SE corner,between tanks and panels
17    0  (1 -15 -33):(-46 -32):(-32 -47):(-48 -32) imp:n=1  $middle of tank 2
18    0  (1 -15 -16):(-43 -17):(-17 -44):(-45 -17) imp:n=1  $middle of tank 3*
19    0  (1 -15 -41):(-49 -40):(-40 -50):(-51 -40) imp:n=1  $middle of tank 4
20    0  (1 -55 32 -29):(-15 55 30 -29):(-28 29 -46):(-28 29 -47):(-28 29 -48)
         imp:n=1 $between 1 and 2 and skirt holes
21    0  (1 -59 17 -20):(-15 59 19 -20):(-21 20 -43):(-21 20 -44):(-21 20 -45)
         imp:n=1 $between 2* and 3* and skirt holes
22    0  (1 -63 40 -37):(-15 63 38 -37):(-36  37 -49):(-36 37 -50):(-36 37 -51)
         imp:n=1 $between 3 and 4 and skirt holes
23    0  42 -15 28 -27  imp:n=1  $annular void tank 1
24    0  42 -15 32 -31  imp:n=1  $annular void tank 2
25    0  42 -15 36 -35  imp:n=1  $annular void tank 3
26    0  42 -15 40 -39  imp:n=1  $annular void tank 4
27    0  42 -15 21 -22  imp:n=1  $annular void tank 2*
28    0  42 -15 17 -18  imp:n=1  $annular void tank 3*
C rebar in walls
29    4  -7.82 (-76 2 -8):(-77 2 -8):(-78 2 -8):(-79 2 -8):(-80 2 -8):(-64 -5 6)
               :(-65 -5 6):(-66 -5 6):(-67 -5 6):(-68 -5 6):(-69 -5 6)
               :(-70 -5 6):(-71 -5 6):(-72 -5 6):(-73 -5 6):(-74 -5 6)
               :(-75 -5 6) imp:n=1 $east wall rebar
30    4  -7.82 (-81 2 -8):(-82 2 -8):(-83 2 -8):(-84 7 -14):(-95 7 -14)
               :(-85 7 -14):(-86 7 -14):(-87 7 -14):(-88 7 -14):(-89 7 -14)
               :(-90 7 -14):(-91 7 -14):(-92 7 -14):(-93 7 -14):(-94 7 -14)
                imp:n=1 $south wall rebar
C rebar in panels
31    4  -7.82 (-96 1 -10):(-97 1 -10):(-98 1 -10):(-99 1 -10):(-100 1 -10)
               :(-101 1 -10):(-102 1 -10):(-103 1 -10):(-104 1 -10):(-105 1 -10)
               :(-106 1 -10):(-107 1 -10):(-122 4 -3):(-123 4 -3):(-124 4 -3)
               :(-125 4 -3):(-126 4 -3):(-127 4 -3):(-128 4 -3):(-129 4 -3)
               :(-130 4 -3):(-131 4 -3) imp:n=1 $North panels
```

```
32    4  -7.82 (-108 1 -10):(-109 1 -10):(-110 1 -10):(-111 1 -10):(-132 11 -12)
               :(-133 11 -12):(-134 11 -12):(-135 11 -12):(-136 11 -12)
               :(-137 11 -12):(-138 11 -12):(-139 11 -12):(-140 11 -12)
               :(-141 11 -12) imp:n=1 $NS panel
33    4  -7.82 (-112 1 -10):(-113 1 -10):(-114 1 -10):(-115 1 -10):(-116 1 -10)
               :(-117 1 -10):(-118 1 -10):(-119 1 -10):(-120 1 -10):(-121 1 -10)
               :(-142 14 -3):(-143 14 -3):(-144 14 -3):(-145 14 -3):(-146 14 -3)
               :(-147 14 -3):(-148 14 -3):(-149 14 -3):(-150 14 -3):(-151 14 -3)
               imp:n=1 $South panels

C      Surface Cards
1     pz    0.0    $top of platform where panels and tanks are placed on
2     pz  -20.3    $bottom of platform, bottom of east and south walls
3     py  168.759  $West end of platform and west side of panels
4     py -173.939  $East end of platform and east wall
5     px   79.5785 $North side of platform and north side of panels
6     px  -79.7385 $South side of platform and south wall
7     py -295.939  $Outer east wall
8     pz  343.9    $Top of east and south walls
9     px -201.739  $Outer south wall
10    pz  244.0    $Top of panels
11    px  -59.4385 $South inner panel wall
12    px   59.2785 $North inner panel wall
13    py  148.459  $West inner panel wall
14    py -112.039  $End of south panel on east side
15    pz  243.9    $Top of tanks
16    cz   35.2832 $Tank 3* inner cylinder inner wall
17    cz   35.9232 $Tank 3* inner cylinder outer wall
18    cz   39.6952 $Tank 3* outer cylinder inner wall
19    cz   40.3352 $Tank 3* outer cylinder outer wall
20    cz   41.2375 $Tank 2* inner cylinder inner wall
21    cz   41.8775 $Tank 2* inner cylinder outer wall
22    cz   45.6185 $Tank 2* outer cylinder inner wall
23    cz   46.2585 $Tank 2* outer cylinder outer wall
26    c/z  -6.6244 -113.671 52.0929 $Tank 1 outer cylinder outer wall
27    c/z  -6.6244 -113.671 51.4529 $Tank 1 outer cylinder inner wall
28    c/z  -6.6244 -113.671 47.6149 $Tank 1 inner cylinder outer wall
29    c/z  -6.6244 -113.671 46.9749 $Tank 1 inner cylinder inner wall
30    c/z  -6.6244 -113.671 46.2077 $Tank 2 outer cylinder outer wall
31    c/z  -6.6244 -113.671 45.5677 $Tank 2 outer cylinder inner wall
32    c/z  -6.6244 -113.671 41.7197 $Tank 2 inner cylinder outer wall
33    c/z  -6.6244 -113.671 41.0797 $Tank 2 inner cylinder inner wall
34    c/z   6.8707  101.286 40.3428 $Tank 3 outer cylinder outer wall
35    c/z   6.8707  101.286 39.7028 $Tank 3 outer cylinder inner wall
36    c/z   6.8707  101.286 35.8568 $Tank 3 inner cylinder outer wall
37    c/z   6.8707  101.286 35.2168 $Tank 3 inner cylinder inner wall
38    c/z   6.8707  101.286 34.4703 $Tank 4 outer cylinder outer wall
39    c/z   6.8707  101.286 33.8303 $Tank 4 outer cylinder inner wall
40    c/z   6.8707  101.286 30.0483 $Tank 4 inner cylinder outer wall
41    c/z   6.8707  101.286 29.4083 $Tank 4 inner cylinder inner wall
42    pz  103.24   $Top of solution level for all tanks
C Holes in tank skirt
43    c/x      0.0    15.25  12.5    $Tanks 2*,3*
44    1 c/x    0.0    15.25  12.5    $Tanks 2*,3*
45    2 c/x    0.0    15.25  12.5    $Tanks 2*,3*
46    c/x   -113.671  15.25  12.5    $Tanks 1,2
47    3 c/x    0.0    15.25  12.5    $Tanks 1,2
48    4 c/x    0.0    15.25  12.5    $Tanks 1,2
49    c/x    101.286  15.25  12.5    $Tanks 3,4
50    5 c/x    0.0    15.25  12.5    $Tanks 3,4
51    6 c/x    0.0    15.25  12.5    $Tanks 3,4
C 2 degree slope top and bottom 1-4
C 1 top then bottom
52 P -6.6244 -62.3981 30.50  6.6244 -113.671 32.28  -6.6244 -164.944 34.10
53 P -6.6244 -62.3981 29.86  6.6244 -113.671 31.64  -6.6244 -164.944 33.46
C 2 top then bottom
54 P -6.6244 -70.0273 30.50  6.6244 -113.671 32.11  -6.6244 -157.315 33.73
55 P -6.6244 -70.0273 29.86  6.6244 -113.671 31.47  -6.6244 -157.315 33.09
C 2* top then bottom
56 P 0 43.748 30.50  1 0 32.11  0 -43.748 33.73
57 P 0 43.748 29.86  1 0 31.47  0 -43.748 33.09
```

```
C 3* top then bottom
58 P 0 37.8092 30.50  1 0 31.91  0 -37.8092 33.33
59 P 0 37.8092 29.86  1 0 31.27  0 -37.8092 32.69
C 3 top then bottom
60 P 6.8707 139.066 30.50  -6.8707 101.286 31.91  6.8707 63.5062 33.33
61 P 6.8707 139.066 29.86  -6.8707 101.286 31.27  6.8707 63.5062 32.69
C 4 top then bottom
62 P 6.8707 133.225 30.50  -6.8707 101.286 31.69  6.8707 69.3467 32.87
63 P 6.8707 133.225 29.86  -6.8707 101.286 31.05  6.8707 69.3467 32.23
64 c/x -181.939 0   1.27  $Horizontal rebar in east wall
65 c/x -181.939 30  1.27
66 c/x -181.939 60  1.27
67 c/x -181.939 90  1.27
68 c/x -181.939 120 1.27
69 c/x -181.939 150 1.27
70 c/x -181.939 180 1.27
71 c/x -181.939 210 1.27
72 c/x -181.939 240 1.27
73 c/x -181.939 270 1.27
74 c/x -181.939 300 1.27
75 c/x -181.939 330 1.27
76 c/z   0 -181.939 0.9525  $Vertical rebar in east wall
77 c/z  30 -181.939 0.9525
78 c/z -30 -181.939 0.9525
79 c/z  60 -181.939 0.9525
80 c/z -60 -181.939 0.9525
81 c/z -87.7385 -112.039 0.9525 $vertical rebar in SE corner
82 c/z -87.7385 -142.039 0.9525
83 c/z -87.7385 -172.039 0.9525
84 c/y -87.7385 0 1.27 $Horizontal rebar in SE corner
85 c/y -87.7385 30 1.27
86 c/y -87.7385 60 1.27
87 c/y -87.7385 90 1.27
88 c/y -87.7385 120 1.27
89 c/y -87.7385 150 1.27
90 c/y -87.7385 180 1.27
91 c/y -87.7385 210 1.27
92 c/y -87.7385 240 1.27
93 c/y -87.7385 270 1.27
94 c/y -87.7385 300 1.27
95 c/y -87.7385 330 1.27
C rebar in reflector panels
96 c/z 69.4285  -163.939 0.65 $Vertical rebar N side panels
97 c/z 69.4285  -129.939 0.65
98 c/z 69.4285   -95.939 0.65
99 c/z 69.4285   -61.939 0.65
100 c/z 69.4285   -41.939 0.65
101 c/z 69.4285    -7.939 0.65
102 c/z 69.4285    26.061 0.65
103 c/z 69.4285    60.061 0.65
104 c/z 69.4285   80.061 0.65
105 c/z 69.4285   90.061 0.65
106 c/z 69.4285   110.061 0.65
107 c/z 69.4285   145.561 0.65
108 c/z 49.2785 158.609 0.65 $vertical rebar NS panel
109 c/z 15.2785 158.609 0.65
110 c/z -18.7215 158.609 0.65
111 c/z -52.7215 158.609 0.65
112 c/z -69.5885 -102.039 0.65 $vertical rebar S side panels
113 c/z -69.5885  -68.039 0.65
114 c/z -69.5885  -34.039 0.65
115 c/z -69.5885   -0.039 0.65
116 c/z -69.5885  19.961 0.65
117 c/z -69.5885  53.961 0.65
118 c/z -69.5885  87.961 0.65
119 c/z -69.5885 121.961 0.65
120 c/z -69.5885  141.961 0.65
121 c/z -69.5885 162.461 0.65
122 c/y 69.4285 10 0.65 $horizontal rebar north side panels
123 c/y 69.4285 34.8889 0.65
124 c/y 69.4285 59.7778 0.65
```

```
125 c/y 69.4285 84.6667 0.65
126 c/y 69.4285 109.556 0.65
127 c/y 69.4285 134.445 0.65
128 c/y 69.4285 159.333 0.65
129 c/y 69.4285 184.222 0.65
130 c/y 69.4285 209.111 0.65
131 c/y 69.4285 234 0.65
132 c/x 158.609 10 0.65 $Horizontal rebar in NS panel
133 c/x 158.609 34.8889 0.65
134 c/x 158.609 59.7778 0.65
135 c/x 158.609 84.6667 0.65
136 c/x 158.609 109.556 0.65
137 c/x 158.609 134.445 0.65
138 c/x 158.609 159.333 0.65
139 c/x 158.609 184.222 0.65
140 c/x 158.609 209.111 0.65
141 c/x 158.609 234 0.65
142 c/y -69.5885 10 0.65 $Horizontal rebar in S side panels
143 c/y -69.5885 34.8889 0.65
144 c/y -69.5885 59.7778 0.65
145 c/y -69.5885 84.6667 0.65
146 c/y -69.5885 109.556 0.65
147 c/y -69.5885 134.445 0.65
148 c/y -69.5885 159.333 0.65
149 c/y -69.5885 184.222 0.65
150 c/y -69.5885 209.111 0.65
151 c/y -69.5885 234 0.65

C      Data Cards
*tr1 0 0 0 120 30 90 210 120 90 90 90 0
*tr2 0 0 0 60 30 90 150 60 90 90 90 0
*tr3 -6.6244 -113.671 0 120 30 90 210 120 90 90 90 0
*tr4 -6.6244 -113.671 0 60 30 90 150 60 90 90 90 0
*tr5 6.8707 101.286 0 120 30 90 210 120 90 90 90 0
*tr6 6.8707 101.286 0 60 30 90 150 60 90 90 90 0
C      Materials Cards
m1     1001.62c  1.4544e-2  $Boron-free concrete
       6000.66c  8.1181e-6
       8016.62c  4.5277e-2
       8017.66c  1.7212e-5
       11023.62c 5.7811e-5
       12000.62c 2.5732e-4
       13027.62c 3.0579e-3
       14028.62c 1.3683e-2
       14029.62c 6.9480e-4
       14030.62c 4.5802e-4
       16000.62c 6.7855e-5
       19000.62c 1.0740e-4
       20000.62c 2.0894e-3
       22000.62c 8.5175e-5
       23000.62c 3.5304e-6
       25055.62c 9.3431e-6
       26054.62c 3.6343e-5
       26056.62c 5.7050e-4
       26057.62c 1.3175e-5
       26058.62c 1.7534e-6
       28058.62c 2.0861e-7
       28060.62c 8.0355e-8
       28061.62c 3.4930e-9
       28062.62c 1.1137e-8
       28064.62c 2.8363e-9
       37085.66c 6.3564e-7
       37087.66c 2.4511e-7
       40000.66c 1.9714e-7
       56138.66c 9.3137e-6
       73181.66c 5.2937e-6
m2     1001.62c  2.0391e-5 $Tank steel
       6000.66c  5.0326e-5
       7014.62c  2.6142e-4
       7015.66c  9.6558e-7
       8016.62c  4.3305e-5
```

```
        8017.66c  1.6462e-8
        13027.62c 1.1948e-5
        16000.62c 3.0157e-6
        22000.62c 5.8915e-6
        23000.62c 8.4802e-5
        24050.62c 8.0819e-4
        24052.62c 1.5585e-2
        24053.62c 1.7672e-3
        24054.62c 4.3990e-4
        25055.62c 1.9365e-3
        26054.62c 3.3758e-3
        26056.62c 5.2993e-2
        26057.62c 1.2238e-3
        26058.62c 1.6287e-4
        27059.66c 1.6001e-4
        28058.62c 5.8896e-3
        28060.62c 2.2687e-3
        28061.62c 9.8618e-5
        28062.62c 3.1444e-4
        28064.62c 8.0078e-5
        42000.66c 9.9968e-5
        82206.66c 7.0307e-7
        82207.66c 6.8557e-7
        82208.66c 1.5287e-6
m3      1001.62c  5.8296e-2 $uranyl nitrate solution
        5010.66c  1.7432e-8
        5011.66c  7.0165e-8
        7014.62c  2.1685e-3
        7015.66c  8.0096e-6
        8016.62c  3.7320e-2
        8017.66c  1.4187e-5
        12000.62c 2.2138e-6
        13027.62c 2.7919e-6
        14028.62c 3.0392e-7
        14029.62c 1.5432e-8
        14030.62c 1.0173e-8
        25055.62c 1.0578e-7
        26054.62c 1.1601e-7
        26056.62c 1.8211e-6
        26057.62c 4.2057e-8
        26058.62c 5.5970e-9
        28058.62c 1.7226e-7
        28060.62c 6.6355e-8
        28061.62c 2.8844e-9
        28062.62c 9.1967e-9
        28064.62c 2.3421e-9
        29063.62c 1.8977e-7
        29065.62c 8.4581e-8
        42000.66c 1.6825e-7
        48106.66c 1.8668e-10
        48108.66c 1.3292e-10
        48110.66c 1.8653e-9
        48111.66c 1.9116e-9
        48112.66c 3.6037e-9
        48113.66c 1.8250e-9
        48114.66c 4.2907e-9
        48116.66c 1.1186e-9
        82206.66c 1.1015e-8
        82207.66c 1.0741e-8
        82208.66c 2.3950e-8
        83209.66c 7.0034e-9
        92234.66c 9.0307e-6
        92235.66c 8.5361e-4
        92236.66c 3.9390e-6
        92238.66c 4.8525e-5
mt3     lwtr.60t
m4      6000.66c  1.9600e-3  $Rebar in walls 8.5860E-02
        26054.62c 4.9040e-3
        26056.62c 7.6982e-2
        26057.62c 1.7778e-3
        26058.62c 2.3660e-4
```

```
C      Criticality control cards
kcode 50000 1.0 100 2100
ksrc 37.8092 0 23.78  -37.8092 0 23.78
     0 37.8092 47.56  0 -37.8092 47.56
     43.748 0 47.56  -43.748 0 47.56
     0 43.748 23.78  0 -43.748 23.78
```

MCNP5 ENDF/B-VI (Detailed Model) Input Listing for Experiment 2a of Table 91.

```
1X3 array of nested tanks, Experiment 2a Detailed
C   5                                                                      80
C      Cell Cards
C Everything but tanks and void space (all concrete)
1     1  -2.29  (-1 2 -3 4 -5 6):(4 -3 -5 12 1 -10 96 97 98 99 100 101 102 103&
                104 105 106 107 122 123 124 125 126 127 128 129 130 131):(-12 11
                -3 13 -10 1 108 109 110 111 132 133 134 135 136 137 138 139 140&
                141):(1 -10 -11 6 14 -3 112 113 114 115 116 117 118 119 120 121&
                142 143 144 145 146 147 148 149 150 151)
                imp:n=1 $platform/panels
2     1  -2.29  (2 -8 6 -5 -4 7 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79&
                80):(2 -8 -14 7 -6 9 81 82 83 84 85 86 87 88 89 90 91 92 93 94&
                 95):(2 -8 14 -3 -6 9 81):(-84 -85 -86 -87 -88 -89 -90 -91 -92
                 -93 94 95)  imp:n=1  $walls
C Tanks
3     2  -8.03  (1 -15 29 -28 46 47 48):(-52 53 28 -27):(-15 53 27 -26)
                imp:n=1  $Tank 1
4     2  -8.03  (1 -15 33 -32 46 47 48):(-54 55 32 -31):(-15 55 31 -30)
                imp:n=1  $Tank 2
5     2  -8.03  (1 -15 37 -36 49 50 51):(-60 61 36 -35):(-15 61 35 -34)
                imp:n=1  $Tank 3
6     2  -8.03  (1 -15 41 -40 49 50 51):(-62 63 40 -39):(-15 63 39 -38)
                imp:n=1  $Tank 4
7     2  -8.03  (1 -15 20 -21 43 44 45):(-56 57 21 -22):(-15 57 22 -23)
                imp:n=1  $Tank 2*
8     2  -8.03  (1 -15 16 -17 43 44 45):(-58 59 17 -18):(-15 59 18 -19)
                imp:n=1  $Tank 3*
C solution
9     3  -1.4982  -42 52 28 -27   imp:n=1  $in tank 1
10    3  -1.4982  -42 54 32 -31   imp:n=1  $in tank 2
11    3  -1.4982  -42 60 36 -35   imp:n=1  $in tank 3
12    3  -1.4982  -42 62 40 -39   imp:n=1  $in tank 4
13    3  -1.4982  -42 56 21 -22   imp:n=1  $in tank 2*
14    3  -1.4982  -42 58 17 -18   imp:n=1  $in tank 3*
C Void space
15    0  -7:-9:5:3:-2:8:(10 -8 -5 6 4 -3) imp:n=0 $Big Void outside enclosure
16    0  (4 -14 -11 6 1 -10):(15 -10 11 -12 4 -13):(1 -15 11 -12 4 -13 26 23 34)
         :(1 28 -53 -26):(1 21 -57 -23):(1 36 -61 -34) imp:n=1
         $SE corner,between tanks and panels
17  0  (1 -33 -152 -204):(1 -33 -152 -208):(1 -33 -152 205):(1 -33 -152 209)
       :(152 -15 -33 157):(152 -44 47 -157):(200 -201 211 -207 204 -202):
       (200 -201 204 -212 -209 207):(200 -201 -210 206 204 -202):
       (200 -201 -206 208 204 -212):(200 -201 -206 208 213 -205):
       (200 -201 203 -205 206 -210):(200 -201 211 -207 203 -205):
       (200 -201 213 -205 207 -209):(-46 -32 -208):(-46 -32 209):
       (-32 -47 203 205):(-48 -32 203 205):(-32 -47 -202 -204)
       :(-32 -48 -202 -204):(-157 156 152 -153) imp:n=1 $between tank 2, plug, and stand
18  0  (1 -16 -152 -220):(1 -16 -152 -224):(1 -16 -152 221):(1 -16 -152 225):
       (152 -15 -16 162):(152 -44 52 -162):(200 -201 -225 223 220 -228):
       (200 -201 -223 227 220 -218):(200 -201 -226 222 220 -218):
       (200 -201 220 -228 -222 224):(200 -201 229 -221 -222 224):
       (200 -201 219 -221 222 -226):(200 -201 227 -223 219 -221):
       (200 -201 229 -221 -225 223):(-43 -17 -224):(-43 -17 225)
       :(-17 -44 221 219):(-45 -17 221 219):(-17 -44 -220 -218)
       :(-17 -45 -220 -218):(161 -162 152 -153) imp:n=1 $between tank 3*, plug, and stand
19  0  (1 -152 -41 -236):(1 -152 -41 -240):(1 -152 -41 237):(1 -152 -41 241):
       (152 -15 -41 166):(152 -44 -166 56):(200 -201 -241 239 236 -244):
       (200 -201 -239 243 236 -234):(200 -201 -242 238 236 -234):
       (200 -201 236 -244 -238 240):(200 -201 245 -237 -238 240):
       (200 -201 235 -237 -242 238):(200 -201 243 -239 235 -237):
       (200 -201 245 -237 239 -241):(-49 -40 -240):(-49 -40 241)
       :(-41 -50 235 237 245):(-51 -41 235 237 245)
       :(-41 -50 -236 -234 -244):(-41 -51 -236 -234 -244)
       :(41 -40 -50):(41 -40 -51):(165 -166 -153 152) imp:n=1 $between tank 4, plug, and stand
20    0  (1 -55 32 -29):(-15 55 30 -29):(-28 29 -46):(-28 29 -47):(-28 29 -48)
         imp:n=1 $between 1 and 2 and skirt holes
21    0  (1 -59 17 -20):(-15 59 19 -20):(-21 20 -43):(-21 20 -44):(-21 20 -45)
         imp:n=1 $between 2* and 3* and skirt holes
22    0  (1 -63 40 -37):(-15 63 38 -37):(-36  37 -49):(-36 37 -50):(-36 37 -51)
```

```
         imp:n=1 $between 3 and 4 and skirt holes
23    0  42 -15 28 -27  imp:n=1  $annular void tank 1
24    0  42 -15 32 -31  imp:n=1  $annular void tank 2
25    0  42 -15 36 -35  imp:n=1  $annular void tank 3
26    0  42 -15 40 -39  imp:n=1  $annular void tank 4
27    0  42 -15 21 -22  imp:n=1  $annular void tank 2*
28    0  42 -15 17 -18  imp:n=1  $annular void tank 3*
C rebar in walls
29    4  -7.82 (-76 2 -8):(-77 2 -8):(-78 2 -8):(-79 2 -8):(-80 2 -8):(-64 -5 6)
               :(-65 -5 6):(-66 -5 6):(-67 -5 6):(-68 -5 6):(-69 -5 6)
               :(-70 -5 6):(-71 -5 6):(-72 -5 6):(-73 -5 6):(-74 -5 6)
               :(-75 -5 6) imp:n=1 $east wall rebar
30    4  -7.82 (-81 2 -8):(-82 2 -8):(-83 2 -8):(-84 7 -14):(-95 7 -14)
               :(-85 7 -14):(-86 7 -14):(-87 7 -14):(-88 7 -14):(-89 7 -14)
               :(-90 7 -14):(-91 7 -14):(-92 7 -14):(-93 7 -14):(-94 7 -14)
                imp:n=1 $south wall rebar
C rebar in panels
31    4  -7.82 (-96 1 -10):(-97 1 -10):(-98 1 -10):(-99 1 -10):(-100 1 -10)
               :(-101 1 -10):(-102 1 -10):(-103 1 -10):(-104 1 -10):(-105 1 -10)
               :(-106 1 -10):(-107 1 -10):(-122 4 -3):(-123 4 -3):(-124 4 -3)
               :(-125 4 -3):(-126 4 -3):(-127 4 -3):(-128 4 -3):(-129 4 -3)
               :(-130 4 -3):(-131 4 -3) imp:n=1 $North panels
32    4  -7.82 (-108 1 -10):(-109 1 -10):(-110 1 -10):(-111 1 -10):(-132 11 -12)
               :(-133 11 -12):(-134 11 -12):(-135 11 -12):(-136 11 -12)
               :(-137 11 -12):(-138 11 -12):(-139 11 -12):(-140 11 -12)
               :(-141 11 -12) imp:n=1 $NS panel
33    4  -7.82 (-112 1 -10):(-113 1 -10):(-114 1 -10):(-115 1 -10):(-116 1 -10)
               :(-117 1 -10):(-118 1 -10):(-119 1 -10):(-120 1 -10):(-121 1 -10)
               :(-142 14 -3):(-143 14 -3):(-144 14 -3):(-145 14 -3):(-146 14 -3)
               :(-147 14 -3):(-148 14 -3):(-149 14 -3):(-150 14 -3):(-151 14 -3)
               imp:n=1 $South panels
C plugs
34    2  -8.03  152 -153 -156  imp:n=1  $30X0 1.2%B C steel plate
35    7  -0.1854  153 -158 154 -155  imp:n=1  $30X0 1.2%B C inner paper
36    5  -2.22  (153 -158 155 -156):(-15 158 -156)  imp:n=1  $30X0 1.2%B concrete plug
37    7  -0.1854  153 -15 -157 156 imp:n=1  $outer paper 30X0 1.2%B C
38    0  -154 153 -158  imp:n=1  $in middle of 30X0 1.2%B C plug
39    2  -8.03  152 -153 -161 159  imp:n=1  $24X10 1.2%B C steel plate
40    7  -0.1854  -15 153 160 -159 imp:n=1  $24X10 1.2%B C inner paper
41    5  -2.22  -15 153 159 -161  imp:n=1 $24X10 1.2%B concrete plug
42    7  -0.1854  -15 153 161 -162  imp:n=1  $24X10 1.2%B C outer paper
43    0  (-15 153 -160):(-153 152 -159) imp:n=1  $in middle of 24X10 1.2%B C plug
44    2  -8.03  152 -153 -165 163  imp:n=1  $22X8 1.2%B C steel plate
45    7  -0.1854  -15 153 -163 164 imp:n=1 $22X8 1.2%B C inner paper
46    5  -2.22  -15 153 163 -165  imp:n=1  $22X8 1.2%B Concrete plug
47    7  -0.1854  -15 153 165 -166  imp:n=1  $22X8 1.2%B C outer paper
48    0  (-15 153 -164):(-153 152 -163) imp:n=1 $in middle of 22X8 1.2%B Concrete plug
c wooden plug stands
100 11  -0.6 (1 -152 -216 206 202 -214):(1 -152 -216 206 -203 215)
             :(1 -152 -207 217 -203 215):(1 -152 -207 217 202 -214)
             :(200 -201 204 -202 -211 210):(200 -201 208 -206 212 -213)
             :(200 -201 203 -205 -211 210):(200 -201 -209 207 212 -213)
             :(-46 208 -206):(-46 -209 207) imp:n=1 $east plug
101 11  -0.6 (1 -152 218 -230 222 -232):(1 -152 231 -219 222 -232)
             :(1 -152 231 -219 -223 233 ):(1 -152 218 -230 -223 233 )
             :(200 -201 220 -218 226 -227):(200 -201 224 -222 228 -229):
             (200 -201 219 -221 -227 226):(200 -201 223 -225 228 -229)
             :(-43 224 -222):(-43 -225 223) imp:n=1 $middle plug
102 11  -0.6 (1 -152 234 -246 -248 238):(1 -152 247 -235 -248 238)
             :(1 -152 247 -235 -239 249):(1 -152 234 -246 -239 249)
             :(200 -201 236 -234 -243 242):(200 -201 240 -238 244 -245)
             :(200 -201 235 -237 -243 242):(200 -201 239 -241 244 -245)
             :(-49 240 -238):(-49 -241 239) imp:n=1 $west plug
103 0   (1 -152 202 -203 216 -217):(1 -152 206 -207 214 -215)
        :(-152 201 204 -202 208 -209):(-152 201 208 -206 202 -203)
        :(-152 201 203 -205 208 -209):(-152 201 207 -209 202 -203)
        :(1 -200 204 -202 208 -209):(1 -200 208 -206 202 -203)
        :(1 -200 203 -205 208 -209):(1 -200 207 -209 202 -203)
        imp:n=1 $inside east plug
104 0   (1 -152 218 -219 232 -233 ):(1 -152 222 -223 230 -231)
        :(-152 201 220 -218 224 -225):(-152 201 224 -222 220 -221)
```

```
        :(-152 201 219 -221 224 -225):(-152 201 -225 223 220 -221)
        :(1 -200 220 -218 224 -225):(1 -200 224 -222 220 -221)
        :(1 -200 219 -221 224 -225):(1 -200 -225 223 220 -221)
        imp:n=1 $inside middle plug
105 0   (1 -152 234 -235 248 -249):(1 -152 238 -239 246 -247)
        :(-152 201 236 -234 240 -241):(-152 201 240 -238 236 -237)
        :(-152 201 235 -237 240 -241):(-152 201 239 -241 236 -237)
        :(1 -200 236 -234 240 -241):(1 -200 240 -238 236 -237)
        :(1 -200 235 -237 240 -241):(1 -200 239 -241 236 -237)
        imp:n=1 $inside west plug

C      Surface Cards
1     pz    0.0    $top of platform where panels and tanks are placed on
2     pz  -20.3    $bottom of platform, bottom of east and south walls
3     py  168.759  $West end of platform and west side of panels
4     py -173.939  $East end of platform and east wall
5     px   79.5785 $North side of platform and north side of panels
6     px  -79.7385 $South side of platform and south wall
7     py -295.939  $Outer east wall
8     pz  343.9    $Top of east and south walls
9     px -201.739  $Outer south wall
10    pz  244.0    $Top of panels
11    px  -59.4385 $South inner panel wall
12    px   59.2785 $North inner panel wall
13    py  148.459  $West inner panel wall
14    py -112.039  $End of south panel on east side
15    pz  243.9    $Top of tanks
16    cz   35.2832 $Tank 3* inner cylinder inner wall
17    cz   35.9232 $Tank 3* inner cylinder outer wall
18    cz   39.6952 $Tank 3* outer cylinder inner wall
19    cz   40.3352 $Tank 3* outer cylinder outer wall
20    cz   41.2375 $Tank 2* inner cylinder inner wall
21    cz   41.8775 $Tank 2* inner cylinder outer wall
22    cz   45.6185 $Tank 2* outer cylinder inner wall
23    cz   46.2585 $Tank 2* outer cylinder outer wall
26    c/z  -6.6244 -113.671 52.0929 $Tank 1 outer cylinder outer wall
27    c/z  -6.6244 -113.671 51.4529 $Tank 1 outer cylinder inner wall
28    c/z  -6.6244 -113.671 47.6149 $Tank 1 inner cylinder outer wall
29    c/z  -6.6244 -113.671 46.9749 $Tank 1 inner cylinder inner wall
30    c/z  -6.6244 -113.671 46.2077 $Tank 2 outer cylinder outer wall
31    c/z  -6.6244 -113.671 45.5677 $Tank 2 outer cylinder inner wall
32    c/z  -6.6244 -113.671 41.7197 $Tank 2 inner cylinder outer wall
33    c/z  -6.6244 -113.671 41.0797 $Tank 2 inner cylinder inner wall
34    c/z   6.8707  101.286 40.3428 $Tank 3 outer cylinder outer wall
35    c/z   6.8707  101.286 39.7028 $Tank 3 outer cylinder inner wall
36    c/z   6.8707  101.286 35.8568 $Tank 3 inner cylinder outer wall
37    c/z   6.8707  101.286 35.2168 $Tank 3 inner cylinder inner wall
38    c/z   6.8707  101.286 34.4703 $Tank 4 outer cylinder outer wall
39    c/z   6.8707  101.286 33.8303 $Tank 4 outer cylinder inner wall
40    c/z   6.8707  101.286 30.0483 $Tank 4 inner cylinder outer wall
41    c/z   6.8707  101.286 29.4083 $Tank 4 inner cylinder inner wall
42    pz  166.54   $Top of solution level for all tanks
C Holes in tank skirt
43    c/x      0.0    15.25  12.5    $Tanks 2*,3*
44    1 c/x    0.0    15.25  12.5    $Tanks 2*,3*
45    2 c/x    0.0    15.25  12.5    $Tanks 2*,3*
46    c/x   -113.671  15.25  12.5    $Tanks 1,2
47    3 c/x    0.0    15.25  12.5    $Tanks 1,2
48    4 c/x    0.0    15.25  12.5    $Tanks 1,2
49    c/x    101.286  15.25  12.5    $Tanks 3,4
50    5 c/x    0.0    15.25  12.5    $Tanks 3,4
51    6 c/x    0.0    15.25  12.5    $Tanks 3,4
C 2 degree slope top and bottom 1-4
C 1 top then bottom
52 P -6.6244 -62.3981 30.50  6.6244 -113.671 32.28  -6.6244 -164.944 34.10
53 P -6.6244 -62.3981 29.86  6.6244 -113.671 31.64  -6.6244 -164.944 33.46
C 2 top then bottom
54 P -6.6244 -70.0273 30.50  6.6244 -113.671 32.11  -6.6244 -157.315 33.73
55 P -6.6244 -70.0273 29.86  6.6244 -113.671 31.47  -6.6244 -157.315 33.09
C 2* top then bottom
56 P 0 43.748 30.50  1 0 32.11  0 -43.748 33.73
```

```
57 P 0 43.748 29.86  1 0 31.47  0 -43.748 33.09
C 3* top then bottom
58 P 0 37.8092 30.50  1 0 31.91  0 -37.8092 33.33
59 P 0 37.8092 29.86  1 0 31.27  0 -37.8092 32.69
C 3 top then bottom
60 P 6.8707 139.066 30.50  -6.8707 101.286 31.91  6.8707 63.5062 33.33
61 P 6.8707 139.066 29.86  -6.8707 101.286 31.27  6.8707 63.5062 32.69
C 4 top then bottom
62 P 6.8707 133.225 30.50  -6.8707 101.286 31.69  6.8707 69.3467 32.87
63 P 6.8707 133.225 29.86  -6.8707 101.286 31.05  6.8707 69.3467 32.23
64 c/x -181.939 0   1.27  $Horizontal rebar in east wall
65 c/x -181.939 30  1.27
66 c/x -181.939 60  1.27
67 c/x -181.939 90  1.27
68 c/x -181.939 120 1.27
69 c/x -181.939 150 1.27
70 c/x -181.939 180 1.27
71 c/x -181.939 210 1.27
72 c/x -181.939 240 1.27
73 c/x -181.939 270 1.27
74 c/x -181.939 300 1.27
75 c/x -181.939 330 1.27
76 c/z   0 -181.939 0.9525  $Vertical rebar in east wall
77 c/z  30 -181.939 0.9525
78 c/z -30 -181.939 0.9525
79 c/z  60 -181.939 0.9525
80 c/z -60 -181.939 0.9525
81 c/z -87.7385 -112.039 0.9525 $vertical rebar in SE corner
82 c/z -87.7385 -142.039 0.9525
83 c/z -87.7385 -172.039 0.9525
84 c/y -87.7385 0 1.27 $Horizontal rebar in SE corner
85 c/y -87.7385 30 1.27
86 c/y -87.7385 60 1.27
87 c/y -87.7385 90 1.27
88 c/y -87.7385 120 1.27
89 c/y -87.7385 150 1.27
90 c/y -87.7385 180 1.27
91 c/y -87.7385 210 1.27
92 c/y -87.7385 240 1.27
93 c/y -87.7385 270 1.27
94 c/y -87.7385 300 1.27
95 c/y -87.7385 330 1.27
C rebar in reflector panels
96 c/z 69.4285  -163.939 0.65 $Vertical rebar N side panels
97 c/z 69.4285  -129.939 0.65
98 c/z 69.4285   -95.939 0.65
99 c/z 69.4285   -61.939 0.65
100 c/z 69.4285   -41.939 0.65
101 c/z 69.4285    -7.939 0.65
102 c/z 69.4285    26.061 0.65
103 c/z 69.4285    60.061 0.65
104 c/z 69.4285   80.061 0.65
105 c/z 69.4285   90.061 0.65
106 c/z 69.4285   110.061 0.65
107 c/z 69.4285   145.561 0.65
108 c/z 49.2785 158.609 0.65 $vertical rebar NS panel
109 c/z 15.2785 158.609 0.65
110 c/z -18.7215 158.609 0.65
111 c/z -52.7215 158.609 0.65
112 c/z -69.5885 -102.039 0.65 $vertical rebar S side panels
113 c/z -69.5885  -68.039 0.65
114 c/z -69.5885  -34.039 0.65
115 c/z -69.5885   -0.039 0.65
116 c/z -69.5885  19.961 0.65
117 c/z -69.5885  53.961 0.65
118 c/z -69.5885  87.961 0.65
119 c/z -69.5885 121.961 0.65
120 c/z -69.5885  141.961 0.65
121 c/z -69.5885 162.461 0.65
122 c/y 69.4285 10 0.65 $horizontal rebar north side panels
123 c/y 69.4285 34.8889 0.65
```

```
124 c/y 69.4285 59.7778 0.65
125 c/y 69.4285 84.6667 0.65
126 c/y 69.4285 109.556 0.65
127 c/y 69.4285 134.445 0.65
128 c/y 69.4285 159.333 0.65
129 c/y 69.4285 184.222 0.65
130 c/y 69.4285 209.111 0.65
131 c/y 69.4285 234 0.65
132 c/x 158.609 10 0.65 $Horizontal rebar in NS panel
133 c/x 158.609 34.8889 0.65
134 c/x 158.609 59.7778 0.65
135 c/x 158.609 84.6667 0.65
136 c/x 158.609 109.556 0.65
137 c/x 158.609 134.445 0.65
138 c/x 158.609 159.333 0.65
139 c/x 158.609 184.222 0.65
140 c/x 158.609 209.111 0.65
141 c/x 158.609 234 0.65
142 c/y -69.5885 10 0.65 $Horizontal rebar in S side panels
143 c/y -69.5885 34.8889 0.65
144 c/y -69.5885 59.7778 0.65
145 c/y -69.5885 84.6667 0.65
146 c/y -69.5885 109.556 0.65
147 c/y -69.5885 134.445 0.65
148 c/y -69.5885 159.333 0.65
149 c/y -69.5885 184.222 0.65
150 c/y -69.5885 209.111 0.65
151 c/y -69.5885 234 0.65
C plugs
152    pz    30.5   $bottom of plug steel plates
153    pz    31.14  $top of plug steel plates/bottom of plugs
154    c/z  -6.6244 -113.671 20.415 $30X0 1.2%B C inner wall inner paper
155    c/z  -6.6244 -113.671 20.765 $30X0 1.2%B C outer wall inner paper/inner plug wall
156    c/z  -6.6244 -113.671 38.1  $30X0 1.2%B C outer plug wall/outer paper inner wall/outer steel
plate
157    c/z  -6.6244 -113.671 38.86  $30X0 1.2%B C outer outer paper outer wall
158    pz  204.74  $30X0 1.2%B C top of inner portion
159    cz  13.08  $24X10 1.2%B C steel plate inner wall/outer wall inner paper/plug inner wall
160    cz  12.7   $24X10 1.2%B C inner wall inner paper
161    cz  30.48  $24X10 1.2%B C outer plug wall/outer paper inner wall/outer steel plate
162    cz  31.05  $24X10 1.2%B C outer paper outer wall
163    c/z 6.8707  101.286  10.48  $22X8 1.2%B C inner steel plate/outer inner paper wall/inner plug
wall
164    c/z 6.8707  101.286  10.16  $22X8 1.2%B C inner paper inner wall
165    c/z 6.8707  101.286  27.94  $22X8 1.2%B C outer plug wall/outer paper inner wall/outer steel
plate
166    c/z 6.8707  101.286  28.51  $22X8 1.2%B C outer paper outer wall
200  pz 0.5 $bottom of plug stand plywood
201  pz 30  $top of plug stand plywood
c East plug stand
202  py -133.801    $west face of east plywood/east side of east legs
203  py  -93.541    $east face of west plywood/west side of west legs
204  py -135.101    $east face of east plywood
205  py  -92.241    $west face of west plywood
206  px  -26.7544   $north face of south plywood/south side of south legs
207  px   13.5056   $south face of north plywood/north side of north legs
208  px  -28.0544   $south face of south plywood
209  px   14.8056   $north face of north plywood
210  px  -19.1244   $south end of plywood
211  px    5.8756   $north end of plywood
212  py -126.171    $east end of plywood
213  py -101.171    $west end of plywood
214  py -124.901    $west side of east legs
215  py -102.441    $east side of west legs
216  px  -17.8544   $north side of south legs
217  px    4.6056   $south side of north legs
c Middle plug stand
218  py -17.6777  $west face of east plywood/east side of east legs
219  py  17.6777  $east face of west plywood/west side of west legs
220  py -18.9777  $east face of east plywood
221  py  18.9777  $west face of west plywood
```

```
222  px -17.6777  $north face of south plywood/south side of south legs
223  px  17.6777  $south face of north plywood/north side of north legs
224  px -18.9777  $south face of south plywood
225  px  18.9777  $north face of north plywood
226  px -12.5     $south end of plywood
227  px  12.5     $north end of plywood
228  py -12.5     $east end of plywood
229  py  12.5     $west end of plywood
230  py -8.7777   $west side of east legs
231  py  8.7777   $east side of west legs
232  px -8.7777   $north side of south legs
233  px  8.7777   $south side of north legs
c West plug stand
234  py  85.3761  $west face of east plywood/east side of east legs
235  py 117.196   $east face of west plywood/west side of west legs
236  py  84.0761  $east face of east plywood
237  py 118.496   $west face of west plywood
238  px  -9.2228  $north face of south plywood/south side of south legs
239  px  22.597   $south face of north plywood/north side of north legs
240  px -10.5228  $south face of south plywood
241  px  23.897   $north face of north plywood
242  px  -5.8129  $south end of plywood
243  px  19.1871  $north end of plywood
244  py  88.786   $east end of plywood
245  py 113.786   $west end of plywood
246  py  94.2761  $west side of east legs
247  py 108.296   $east side of west legs
248  px  -0.3228  $north side of south legs
249  px  13.697   $south side of north legs

C      Data Cards
*tr1 0 0 0 120 30 90 210 120 90 90 90 0
*tr2 0 0 0 60 30 90 150 60 90 90 90 0
*tr3 -6.6244 -113.671 0 120 30 90 210 120 90 90 90 0
*tr4 -6.6244 -113.671 0 60 30 90 150 60 90 90 90 0
*tr5 6.8707 101.286 0 120 30 90 210 120 90 90 90 0
*tr6 6.8707 101.286 0 60 30 90 150 60 90 90 90 0
C      Materials Cards
m1     1001.62c  1.4544e-2  $Boron-free concrete
       6000.66c  8.1181e-6
       8016.62c  4.5277e-2
       8017.66c  1.7212e-5
       11023.62c 5.7811e-5
       12000.62c 2.5732e-4
       13027.62c 3.0579e-3
       14028.62c 1.3683e-2
       14029.62c 6.9480e-4
       14030.62c 4.5802e-4
       16000.62c 6.7855e-5
       19000.62c 1.0740e-4
       20000.62c 2.0894e-3
       22000.62c 8.5175e-5
       23000.62c 3.5304e-6
       25055.62c 9.3431e-6
       26054.62c 3.6343e-5
       26056.62c 5.7050e-4
       26057.62c 1.3175e-5
       26058.62c 1.7534e-6
       28058.62c 2.0861e-7
       28060.62c 8.0355e-8
       28061.62c 3.4930e-9
       28062.62c 1.1137e-8
       28064.62c 2.8363e-9
       37085.66c 6.3564e-7
       37087.66c 2.4511e-7
       40000.66c 1.9714e-7
       56138.66c 9.3137e-6
       73181.66c 5.2937e-6
m2     1001.62c  2.0391e-5 $Tank steel
       6000.66c  5.0326e-5
       7014.62c  2.6142e-4
```

```
        7015.66c  9.6558e-7
        8016.62c  4.3305e-5
        8017.66c  1.6462e-8
        13027.62c 1.1948e-5
        16000.62c 3.0157e-6
        22000.62c 5.8915e-6
        23000.62c 8.4802e-5
        24050.62c 8.0819e-4
        24052.62c 1.5585e-2
        24053.62c 1.7672e-3
        24054.62c 4.3990e-4
        25055.62c 1.9365e-3
        26054.62c 3.3758e-3
        26056.62c 5.2993e-2
        26057.62c 1.2238e-3
        26058.62c 1.6287e-4
        27059.66c 1.6001e-4
        28058.62c 5.8896e-3
        28060.62c 2.2687e-3
        28061.62c 9.8618e-5
        28062.62c 3.1444e-4
        28064.62c 8.0078e-5
        42000.66c 9.9968e-5
        82206.66c 7.0307e-7
        82207.66c 6.8557e-7
        82208.66c 1.5287e-6
m3      1001.62c  5.8296e-2 $uranyl nitrate solution
        5010.66c  1.7432e-8
        5011.66c  7.0165e-8
        7014.62c  2.1685e-3
        7015.66c  8.0096e-6
        8016.62c  3.7320e-2
        8017.66c  1.4187e-5
        12000.62c 2.2138e-6
        13027.62c 2.7919e-6
        14028.62c 3.0392e-7
        14029.62c 1.5432e-8
        14030.62c 1.0173e-8
        25055.62c 1.0578e-7
        26054.62c 1.1601e-7
        26056.62c 1.8211e-6
        26057.62c 4.2057e-8
        26058.62c 5.5970e-9
        28058.62c 1.7226e-7
        28060.62c 6.6355e-8
        28061.62c 2.8844e-9
        28062.62c 9.1967e-9
        28064.62c 2.3421e-9
        29063.62c 1.8977e-7
        29065.62c 8.4581e-8
        42000.66c 1.6825e-7
        48106.66c 1.8668e-10
        48108.66c 1.3292e-10
        48110.66c 1.8653e-9
        48111.66c 1.9116e-9
        48112.66c 3.6037e-9
        48113.66c 1.8250e-9
        48114.66c 4.2907e-9
        48116.66c 1.1186e-9
        82206.66c 1.1015e-8
        82207.66c 1.0741e-8
        82208.66c 2.3950e-8
        83209.66c 7.0034e-9
        92234.66c 9.0307e-6
        92235.66c 8.5361e-4
        92236.66c 3.9390e-6
        92238.66c 4.8525e-5
mt3     lwtr.60t
m4      6000.66c  1.9600e-3  $Rebar in walls 8.5860E-02
        26054.62c 4.9040e-3
        26056.62c 7.6982e-2
```

```
       26057.62c 1.7778e-3
       26058.62c 2.3660e-4
m5     1001.62c  1.6944e-2 $ 1.2% B concrete
       3006.66c  5.0933e-7
       3007.66c  6.2012e-6
       5010.66c  2.9540e-4
       5011.66c  1.1890e-3
       6000.66c  4.8574e-5
       8016.62c  4.3204e-2
       8017.66c  1.6424e-5
       11023.62c 4.1850e-4
       12000.62c 4.7364e-4
       13027.62c 2.4910e-3
       14028.62c 1.1089e-2
       14029.62c 5.6307e-4
       14030.62c 3.7118e-4
       16000.62c 9.0706e-5
       19000.62c 9.7433e-5
       20000.62c 3.5242e-3
       22000.62c 6.3443e-5
       23000.62c 4.7184e-6
       25055.62c 8.7199e-6
       26054.62c 3.1167e-5
       26056.62c 4.8926e-4
       26057.62c 1.1299e-5
       26058.62c 1.5037e-6
       28058.62c 2.7881e-7
       28060.62c 1.0740e-7
       28061.62c 4.6684e-9
       28062.62c 2.9770e-8
       28064.62c 3.7908e-9
       37085.66c 6.4636e-7
       37087.66c 2.4925e-7
       40000.66c 2.6349e-7
       56138.66c 7.4104e-6
       73181.66c 4.4063e-6
m7     1001.62c  6.8858e-3 $ paper sonotubes
       6000.66c  4.1315e-3
       8016.62c  3.4416e-3
       8017.66c  1.3083e-6
m11    1001.62c  2.2298e-2 $wood modeled as cellulose
       6000.66c  1.3369e-2
       8016.62c  1.1139e-2
       8017.66c  4.2343e-6
C      Criticality control cards
kcode 50000 1.0 100 2100
ksrc 37.8092 0 23.78  -37.8092 0 23.78
     0 37.8092 47.56  0 -37.8092 47.56
     43.748 0 47.56  -43.748 0 47.56
     0 43.748 23.78  0 -43.748 23.78
```

MCNP5 ENDF/B-VI (Detailed Model) Input Listing for Experiment 3a5a of Table 91.

```
1X3 array of nested tanks,Experiment 3a and 5a average Detailed
C   5                                                                    80
C      Cell Cards
C Everything but tanks and void space (all conrete)
1     1  -2.29  (-1 2 -3 4 -5 6):(4 -3 -5 12 1 -10 96 97 98 99 100 101 102 103&
                104 105 106 107 122 123 124 125 126 127 128 129 130 131):(-12 11
                -3 13 -10 1 108 109 110 111 132 133 134 135 136 137 138 139 140&
                141):(1 -10 -11 6 14 -3 112 113 114 115 116 117 118 119 120 121&
                142 143 144 145 146 147 148 149 150 151)
                imp:n=1 $platform/panels
2     1  -2.29  (2 -8 6 -5 -4 7 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79&
                80):(2 -8 -14 7 -6 9 81 82 83 84 85 86 87 88 89 90 91 92 93 94&
                 95):(2 -8 14 -3 -6 9 81):(-84 -85 -86 -87 -88 -89 -90 -91 -92
                 -93 94 95)  imp:n=1  $walls
C Tanks
3     2  -8.03  (1 -15 29 -28 46 47 48):(-52 53 28 -27):(-15 53 27 -26)
                imp:n=1  $Tank 1
4     2  -8.03  (1 -15 33 -32 46 47 48):(-54 55 32 -31):(-15 55 31 -30)
                imp:n=1  $Tank 2
5     2  -8.03  (1 -15 37 -36 49 50 51):(-60 61 36 -35):(-15 61 35 -34)
                imp:n=1  $Tank 3
6     2  -8.03  (1 -15 41 -40 49 50 51):(-62 63 40 -39):(-15 63 39 -38)
                imp:n=1  $Tank 4
7     2  -8.03  (1 -15 20 -21 43 44 45):(-56 57 21 -22):(-15 57 22 -23)
                imp:n=1  $Tank 2*
8     2  -8.03  (1 -15 16 -17 43 44 45):(-58 59 17 -18):(-15 59 18 -19)
                imp:n=1  $Tank 3*
C solution
9     3  -1.4982  -42 52 28 -27   imp:n=1  $in tank 1
10    3  -1.4982  -42 54 32 -31   imp:n=1  $in tank 2
11    3  -1.4982  -42 60 36 -35   imp:n=1  $in tank 3
12    3  -1.4982  -42 62 40 -39   imp:n=1  $in tank 4
13    3  -1.4982  -42 56 21 -22   imp:n=1  $in tank 2*
14    3  -1.4982  -42 58 17 -18   imp:n=1  $in tank 3*
C Void space
15    0  -7:-9:5:3:-2:8:(10 -8 -5 6 4 -3) imp:n=0 $Big Void outside enclosure
16    0  (4 -14 -11 6 1 -10):(15 -10 11 -12 4 -13):(1 -15 11 -12 4 -13 26 23 34)
         :(1 28 -53 -26):(1 21 -57 -23):(1 36 -61 -34) imp:n=1
         $SE corner,between tanks and panels
17  0  (1 -33 -152 -204):(1 -33 -152 -208):(1 -33 -152 205):(1 -33 -152 209)
       :(152 -15 -33 157):(152 -44 47 -157):(200 -201 211 -207 204 -202):
       (200 -201 204 -212 -209 207):(200 -201 -210 206 204 -202):
       (200 -201 -206 208 204 -212):(200 -201 -206 208 213 -205):
       (200 -201 203 -205 206 -210):(200 -201 211 -207 203 -205):
       (200 -201 213 -205 207 -209):(-46 -32 -208):(-46 -32 209):
       (-32 -47 203 205):(-48 -32 203 205):(-32 -47 -202 -204)
       :(-32 -48 -202 -204):(-157 156 152 -153) imp:n=1 $between tank 2, plug, and stand
18  0  (1 -16 -152 -220):(1 -16 -152 -224):(1 -16 -152 221):(1 -16 -152 225):
       (152 -15 -16 162):(152 -44 52 -162):(200 -201 -225 223 220 -228):
       (200 -201 -223 227 220 -218):(200 -201 -226 222 220 -218):
       (200 -201 220 -228 -222 224):(200 -201 229 -221 -222 224):
       (200 -201 219 -221 222 -226):(200 -201 227 -223 219 -221):
       (200 -201 229 -221 -225 223):(-43 -17 -224):(-43 -17 225)
       :(-17 -44 221 219):(-45 -17 221 219):(-17 -44 -220 -218)
       :(-17 -45 -220 -218):(161 -162 152 -153) imp:n=1 $between tank 3*, plug, and stand
19  0  (1 -152 -41 -236):(1 -152 -41 -240):(1 -152 -41 237):(1 -152 -41 241):
       (152 -15 -41 166):(152 -44 -166 56):(200 -201 -241 239 236 -244):
       (200 -201 -239 243 236 -234):(200 -201 -242 238 236 -234):
       (200 -201 236 -244 -238 240):(200 -201 245 -237 -238 240):
       (200 -201 235 -237 -242 238):(200 -201 243 -239 235 -237):
       (200 -201 245 -237 239 -241):(-49 -40 -240):(-49 -40 241)
       :(-41 -50 235 237 245):(-51 -41 235 237 245)
       :(-41 -50 -236 -234 -244):(-41 -51 -236 -234 -244)
       :(41 -40 -50):(41 -40 -51):(165 -166 -153 152) imp:n=1 $between tank 4, plug, and stand
20    0  (1 -55 32 -29):(-15 55 30 -29):(-28 29 -46):(-28 29 -47):(-28 29 -48)
           imp:n=1 $between 1 and 2 and skirt holes
21    0  (1 -59 17 -20):(-15 59 19 -20):(-21 20 -43):(-21 20 -44):(-21 20 -45)
           imp:n=1 $between 2* and 3* and skirt holes
22    0  (1 -63 40 -37):(-15 63 38 -37):(-36  37 -49):(-36 37 -50):(-36 37 -51)
```

```
         imp:n=1 $between 3 and 4 and skirt holes
23    0  42 -15 28 -27  imp:n=1  $annular void tank 1
24    0  42 -15 32 -31  imp:n=1  $annular void tank 2
25    0  42 -15 36 -35  imp:n=1  $annular void tank 3
26    0  42 -15 40 -39  imp:n=1  $annular void tank 4
27    0  42 -15 21 -22  imp:n=1  $annular void tank 2*
28    0  42 -15 17 -18  imp:n=1  $annular void tank 3*
C rebar in walls
29    4  -7.82 (-76 2 -8):(-77 2 -8):(-78 2 -8):(-79 2 -8):(-80 2 -8):(-64 -5 6)
               :(-65 -5 6):(-66 -5 6):(-67 -5 6):(-68 -5 6):(-69 -5 6)
               :(-70 -5 6):(-71 -5 6):(-72 -5 6):(-73 -5 6):(-74 -5 6)
               :(-75 -5 6) imp:n=1 $east wall rebar
30    4  -7.82 (-81 2 -8):(-82 2 -8):(-83 2 -8):(-84 7 -14):(-95 7 -14)
               :(-85 7 -14):(-86 7 -14):(-87 7 -14):(-88 7 -14):(-89 7 -14)
               :(-90 7 -14):(-91 7 -14):(-92 7 -14):(-93 7 -14):(-94 7 -14)
                imp:n=1 $south wall rebar
C rebar in panels
31    4  -7.82 (-96 1 -10):(-97 1 -10):(-98 1 -10):(-99 1 -10):(-100 1 -10)
               :(-101 1 -10):(-102 1 -10):(-103 1 -10):(-104 1 -10):(-105 1 -10)
               :(-106 1 -10):(-107 1 -10):(-122 4 -3):(-123 4 -3):(-124 4 -3)
               :(-125 4 -3):(-126 4 -3):(-127 4 -3):(-128 4 -3):(-129 4 -3)
               :(-130 4 -3):(-131 4 -3) imp:n=1 $North panels
32    4  -7.82 (-108 1 -10):(-109 1 -10):(-110 1 -10):(-111 1 -10):(-132 11 -12)
               :(-133 11 -12):(-134 11 -12):(-135 11 -12):(-136 11 -12)
               :(-137 11 -12):(-138 11 -12):(-139 11 -12):(-140 11 -12)
               :(-141 11 -12) imp:n=1 $NS panel
33    4  -7.82 (-112 1 -10):(-113 1 -10):(-114 1 -10):(-115 1 -10):(-116 1 -10)
               :(-117 1 -10):(-118 1 -10):(-119 1 -10):(-120 1 -10):(-121 1 -10)
               :(-142 14 -3):(-143 14 -3):(-144 14 -3):(-145 14 -3):(-146 14 -3)
               :(-147 14 -3):(-148 14 -3):(-149 14 -3):(-150 14 -3):(-151 14 -3)
               imp:n=1 $South panels
C plugs
34    2  -8.03  152 -153 -156        imp:n=1  $30X0 1.2%B C steel plate
35    7  -0.1854  153 -158 154 -155  imp:n=1  $30X0 1.2%B C inner paper
36    5  -2.22  (153 -158 155 -156):(-15 158 -156)  imp:n=1  $30X0 1.2%B concrete plug
37    7  -0.1854  153 -15 -157 156                  imp:n=1  $outer paper 30X0 1.2%B C
38    0  -154 153 -158               imp:n=1  $in middle of 30X0 1.2%B C plug
39    2  -8.03  152 -153 -161 159       imp:n=1  $22x8 1.1%B P steel plate
40    7  -0.1854  -15 153 160 -159      imp:n=1  $22x8 1.1%B P inner paper
41    8  -1.875  -15 153 159 -161        imp:n=1  $22x8 1.1%B Plaster plug
42    7  -0.1854  -15 153 161 -162      imp:n=1  $22x8 1.1%B P outer paper
43    0  (-15 153 -160):(-153 152 -159) imp:n=1  $in middle of 22x8 1.1%B P plug
44    2  -8.03  152 -153 -165 163       imp:n=1 $22X16 1.1%B P steel plate
45    7  -0.1854  -15 153 -163 164      imp:n=1 $22X16 1.1%B P inner paper
46    8  -1.875  -15 153 163 -165        imp:n=1 $22X16 1.1%B Plaster plug
47    7  -0.1854  -15 153 165 -166      imp:n=1 $22X16 1.1%B P outer paper
48    0  (-15 153 -164):(-153 152 -163) imp:n=1 $in middle of 22X16 1.1%B Plaster plug
c wooden plug stands
100 11  -0.6 (1 -152 -216 206 202 -214):(1 -152 -216 206 -203 215)
             :(1 -152 -207 217 -203 215):(1 -152 -207 217 202 -214)
             :(200 -201 204 -202 -211 210):(200 -201 208 -206 212 -213)
             :(200 -201 203 -205 -211 210):(200 -201 -209 207 212 -213)
             :(-46 208 -206):(-46 -209 207) imp:n=1 $east plug
101 11  -0.6 (1 -152 218 -230 222 -232):(1 -152 231 -219 222 -232)
             :(1 -152 231 -219 -223 233 ):(1 -152 218 -230 -223 233 )
             :(200 -201 220 -218 226 -227):(200 -201 224 -222 228 -229):
             (200 -201 219 -221 -227 226):(200 -201 223 -225 228 -229)
             :(-43 224 -222):(-43 -225 223) imp:n=1 $middle plug
102 11  -0.6 (1 -152 234 -246 -248 238):(1 -152 247 -235 -248 238)
             :(1 -152 247 -235 -239 249):(1 -152 234 -246 -239 249)
             :(200 -201 236 -234 -243 242):(200 -201 240 -238 244 -245)
             :(200 -201 235 -237 -243 242):(200 -201 239 -241 244 -245)
             :(-49 240 -238):(-49 -241 239) imp:n=1 $west plug
103 0   (1 -152 202 -203 216 -217):(1 -152 206 -207 214 -215)
        :(-152 201 204 -202 208 -209):(-152 201 208 -206 202 -203)
        :(-152 201 203 -205 208 -209):(-152 201 207 -209 202 -203)
        :(1 -200 204 -202 208 -209):(1 -200 208 -206 202 -203)
        :(1 -200 203 -205 208 -209):(1 -200 207 -209 202 -203)
        imp:n=1 $inside east plug
104 0   (1 -152 218 -219 232 -233 ):(1 -152 222 -223 230 -231)
        :(-152 201 220 -218 224 -225):(-152 201 224 -222 220 -221)
```

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        :(-152 201 219 -221 224 -225):(-152 201 -225 223 220 -221)
        :(1 -200 220 -218 224 -225):(1 -200 224 -222 220 -221)
        :(1 -200 219 -221 224 -225):(1 -200 -225 223 220 -221)
        imp:n=1 $inside middle plug
105 0   (1 -152 234 -235 248 -249):(1 -152 238 -239 246 -247)
        :(-152 201 236 -234 240 -241):(-152 201 240 -238 236 -237)
        :(-152 201 235 -237 240 -241):(-152 201 239 -241 236 -237)
        :(1 -200 236 -234 240 -241):(1 -200 240 -238 236 -237)
        :(1 -200 235 -237 240 -241):(1 -200 239 -241 236 -237)
        imp:n=1 $inside west plug

C      Surface Cards
1     pz    0.0    $top of platform where panels and tanks are placed on
2     pz  -20.3    $bottom of platform, bottom of east and south walls
3     py  168.759  $West end of platform and west side of panels
4     py -173.939  $East end of platform and east wall
5     px   79.5785 $North side of platform and north side of panels
6     px  -79.7385 $South side of platform and south wall
7     py -295.939  $Outer east wall
8     pz  343.9    $Top of east and south walls
9     px -201.739  $Outer south wall
10    pz  244.0    $Top of panels
11    px  -59.4385 $South inner panel wall
12    px   59.2785 $North inner panel wall
13    py  148.459  $West inner panel wall
14    py -112.039  $End of south panel on east side
15    pz  243.9    $Top of tanks
16    cz   35.2832 $Tank 3* inner cylinder inner wall
17    cz   35.9232 $Tank 3* inner cylinder outer wall
18    cz   39.6952 $Tank 3* outer cylinder inner wall
19    cz   40.3352 $Tank 3* outer cylinder outer wall
20    cz   41.2375 $Tank 2* inner cylinder inner wall
21    cz   41.8775 $Tank 2* inner cylinder outer wall
22    cz   45.6185 $Tank 2* outer cylinder inner wall
23    cz   46.2585 $Tank 2* outer cylinder outer wall
26    c/z  -6.6244 -113.671 52.0929 $Tank 1 outer cylinder outer wall
27    c/z  -6.6244 -113.671 51.4529 $Tank 1 outer cylinder inner wall
28    c/z  -6.6244 -113.671 47.6149 $Tank 1 inner cylinder outer wall
29    c/z  -6.6244 -113.671 46.9749 $Tank 1 inner cylinder inner wall
30    c/z  -6.6244 -113.671 46.2077 $Tank 2 outer cylinder outer wall
31    c/z  -6.6244 -113.671 45.5677 $Tank 2 outer cylinder inner wall
32    c/z  -6.6244 -113.671 41.7197 $Tank 2 inner cylinder outer wall
33    c/z  -6.6244 -113.671 41.0797 $Tank 2 inner cylinder inner wall
34    c/z   6.8707  101.286 40.3428 $Tank 3 outer cylinder outer wall
35    c/z   6.8707  101.286 39.7028 $Tank 3 outer cylinder inner wall
36    c/z   6.8707  101.286 35.8568 $Tank 3 inner cylinder outer wall
37    c/z   6.8707  101.286 35.2168 $Tank 3 inner cylinder inner wall
38    c/z   6.8707  101.286 34.4703 $Tank 4 outer cylinder outer wall
39    c/z   6.8707  101.286 33.8303 $Tank 4 outer cylinder inner wall
40    c/z   6.8707  101.286 30.0483 $Tank 4 inner cylinder outer wall
41    c/z   6.8707  101.286 29.4083 $Tank 4 inner cylinder inner wall
42    pz  164.575   $Top of solution level for all tanks
C Holes in tank skirt
43    c/x      0.0    15.25  12.5    $Tanks 2*,3*
44    1 c/x    0.0    15.25  12.5    $Tanks 2*,3*
45    2 c/x    0.0    15.25  12.5    $Tanks 2*,3*
46    c/x   -113.671  15.25  12.5    $Tanks 1,2
47    3 c/x    0.0    15.25  12.5    $Tanks 1,2
48    4 c/x    0.0    15.25  12.5    $Tanks 1,2
49    c/x    101.286  15.25  12.5    $Tanks 3,4
50    5 c/x    0.0    15.25  12.5    $Tanks 3,4
51    6 c/x    0.0    15.25  12.5    $Tanks 3,4
C 2 degree slope top and bottom 1-4
C 1 top then bottom
52 P -6.6244 -62.3981 30.50  6.6244 -113.671 32.28  -6.6244 -164.944 34.10
53 P -6.6244 -62.3981 29.86  6.6244 -113.671 31.64  -6.6244 -164.944 33.46
C 2 top then bottom
54 P -6.6244 -70.0273 30.50  6.6244 -113.671 32.11  -6.6244 -157.315 33.73
55 P -6.6244 -70.0273 29.86  6.6244 -113.671 31.47  -6.6244 -157.315 33.09
C 2* top then bottom
56 P 0 43.748 30.50  1 0 32.11  0 -43.748 33.73
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57 P 0 43.748 29.86  1 0 31.47  0 -43.748 33.09
C 3* top then bottom
58 P 0 37.8092 30.50  1 0 31.91  0 -37.8092 33.33
59 P 0 37.8092 29.86  1 0 31.27  0 -37.8092 32.69
C 3 top then bottom
60 P 6.8707 139.066 30.50  -6.8707 101.286 31.91  6.8707 63.5062 33.33
61 P 6.8707 139.066 29.86  -6.8707 101.286 31.27  6.8707 63.5062 32.69
C 4 top then bottom
62 P 6.8707 133.225 30.50  -6.8707 101.286 31.69  6.8707 69.3467 32.87
63 P 6.8707 133.225 29.86  -6.8707 101.286 31.05  6.8707 69.3467 32.23
64 c/x -181.939 0   1.27  $Horizontal rebar in east wall
65 c/x -181.939 30  1.27
66 c/x -181.939 60  1.27
67 c/x -181.939 90  1.27
68 c/x -181.939 120 1.27
69 c/x -181.939 150 1.27
70 c/x -181.939 180 1.27
71 c/x -181.939 210 1.27
72 c/x -181.939 240 1.27
73 c/x -181.939 270 1.27
74 c/x -181.939 300 1.27
75 c/x -181.939 330 1.27
76 c/z   0 -181.939 0.9525  $Vertical rebar in east wall
77 c/z  30 -181.939 0.9525
78 c/z -30 -181.939 0.9525
79 c/z  60 -181.939 0.9525
80 c/z -60 -181.939 0.9525
81 c/z -87.7385 -112.039 0.9525 $vertical rebar in SE corner
82 c/z -87.7385 -142.039 0.9525
83 c/z -87.7385 -172.039 0.9525
84 c/y -87.7385 0 1.27 $Horizontal rebar in SE corner
85 c/y -87.7385 30 1.27
86 c/y -87.7385 60 1.27
87 c/y -87.7385 90 1.27
88 c/y -87.7385 120 1.27
89 c/y -87.7385 150 1.27
90 c/y -87.7385 180 1.27
91 c/y -87.7385 210 1.27
92 c/y -87.7385 240 1.27
93 c/y -87.7385 270 1.27
94 c/y -87.7385 300 1.27
95 c/y -87.7385 330 1.27
C rebar in reflector panels
96 c/z 69.4285  -163.939 0.65 $Vertical rebar N side panels
97 c/z 69.4285  -129.939 0.65
98 c/z 69.4285   -95.939 0.65
99 c/z 69.4285   -61.939 0.65
100 c/z 69.4285   -41.939 0.65
101 c/z 69.4285    -7.939 0.65
102 c/z 69.4285    26.061 0.65
103 c/z 69.4285    60.061 0.65
104 c/z 69.4285   80.061 0.65
105 c/z 69.4285   90.061 0.65
106 c/z 69.4285   110.061 0.65
107 c/z 69.4285   145.561 0.65
108 c/z 49.2785 158.609 0.65 $vertical rebar NS panel
109 c/z 15.2785 158.609 0.65
110 c/z -18.7215 158.609 0.65
111 c/z -52.7215 158.609 0.65
112 c/z -69.5885 -102.039 0.65 $vertical rebar S side panels
113 c/z -69.5885  -68.039 0.65
114 c/z -69.5885  -34.039 0.65
115 c/z -69.5885   -0.039 0.65
116 c/z -69.5885  19.961 0.65
117 c/z -69.5885  53.961 0.65
118 c/z -69.5885  87.961 0.65
119 c/z -69.5885 121.961 0.65
120 c/z -69.5885  141.961 0.65
121 c/z -69.5885 162.461 0.65
122 c/y 69.4285 10 0.65 $horizontal rebar north side panels
123 c/y 69.4285 34.8889 0.65
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124 c/y 69.4285 59.7778 0.65
125 c/y 69.4285 84.6667 0.65
126 c/y 69.4285 109.556 0.65
127 c/y 69.4285 134.445 0.65
128 c/y 69.4285 159.333 0.65
129 c/y 69.4285 184.222 0.65
130 c/y 69.4285 209.111 0.65
131 c/y 69.4285 234 0.65
132 c/x 158.609 10 0.65 $Horizontal rebar in NS panel
133 c/x 158.609 34.8889 0.65
134 c/x 158.609 59.7778 0.65
135 c/x 158.609 84.6667 0.65
136 c/x 158.609 109.556 0.65
137 c/x 158.609 134.445 0.65
138 c/x 158.609 159.333 0.65
139 c/x 158.609 184.222 0.65
140 c/x 158.609 209.111 0.65
141 c/x 158.609 234 0.65
142 c/y -69.5885 10 0.65 $Horizontal rebar in S side panels
143 c/y -69.5885 34.8889 0.65
144 c/y -69.5885 59.7778 0.65
145 c/y -69.5885 84.6667 0.65
146 c/y -69.5885 109.556 0.65
147 c/y -69.5885 134.445 0.65
148 c/y -69.5885 159.333 0.65
149 c/y -69.5885 184.222 0.65
150 c/y -69.5885 209.111 0.65
151 c/y -69.5885 234 0.65
C plugs
152    pz    30.5   $bottom of plug steel plates
153    pz    31.14  $top of plug steel plates/bottom of plugs
154    c/z  -6.6244 -113.671 20.415 $30X0 1.2%B C inner wall inner paper
155    c/z  -6.6244 -113.671 20.765 $30X0 1.2%B C outer wall inner paper/inner plug wall
156    c/z  -6.6244 -113.671 38.1   $30X0 1.2%B C outer plug wall/outer paper inner wall/outer steel
plate
157    c/z  -6.6244 -113.671 38.86  $30X0 1.2%B C outer outer paper outer wall
158    pz  204.74                   $30X0 1.2%B C top of inner portion
159    cz  10.48  $22x8 1.1%B P steel plate inner wall/outer wall inner paper/plug inner wall
160    cz  10.16  $22x8 1.1%B P inner wall inner paper
161    cz  27.94  $22x8 1.1%B P outer plug wall/outer paper inner wall/outer steel plate
162    cz  28.51  $22x8 1.1%B P outer paper outer wall
163    c/z 6.8707  101.286  20.765  $22X16 1.1%B P inner steel plate/outer inner paper wall/inner
plug wall
164    c/z 6.8707  101.286  20.32  $22X16 1.1%B P inner paper inner wall
165    c/z 6.8707  101.286  27.94  $22X16 1.1%B P outer plug wall/outer paper inner wall/outer steel
plate
166    c/z 6.8707  101.286  28.51  $22X16 1.1%B P outer paper outer wall
200  pz 0.5 $bottom of plug stand plywood
201  pz 30  $top of plug stand plywood
c East plug stand
202  py -133.801    $west face of east plywood/east side of east legs
203  py  -93.541    $east face of west plywood/west side of west legs
204  py -135.101    $east face of east plywood
205  py  -92.241    $west face of west plywood
206  px  -26.7544   $north face of south plywood/south side of south legs
207  px   13.5056   $south face of north plywood/north side of north legs
208  px  -28.0544   $south face of south plywood
209  px   14.8056   $north face of north plywood
210  px  -19.1244   $south end of plywood
211  px    5.8756   $north end of plywood
212  py -126.171    $east end of plywood
213  py -101.171    $west end of plywood
214  py -124.901    $west side of east legs
215  py -102.441    $east side of west legs
216  px  -17.8544   $north side of south legs
217  px    4.6056   $south side of north legs
c Middle plug stand
218  py -17.6777  $west face of east plywood/east side of east legs
219  py  17.6777  $east face of west plywood/west side of west legs
220  py -18.9777  $east face of east plywood
221  py  18.9777  $west face of west plywood
```

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222  px -17.6777  $north face of south plywood/south side of south legs
223  px  17.6777  $south face of north plywood/north side of north legs
224  px -18.9777  $south face of south plywood
225  px  18.9777  $north face of north plywood
226  px -12.5     $south end of plywood
227  px  12.5     $north end of plywood
228  py -12.5     $east end of plywood
229  py  12.5     $west end of plywood
230  py -8.7777   $west side of east legs
231  py  8.7777   $east side of west legs
232  px -8.7777   $north side of south legs
233  px  8.7777   $south side of north legs
c West plug stand
234  py  85.3761  $west face of east plywood/east side of east legs
235  py 117.196   $east face of west plywood/west side of west legs
236  py  84.0761  $east face of east plywood
237  py 118.496   $west face of west plywood
238  px  -9.2228  $north face of south plywood/south side of south legs
239  px  22.597   $south face of north plywood/north side of north legs
240  px -10.5228  $south face of south plywood
241  px  23.897   $north face of north plywood
242  px  -5.8129  $south end of plywood
243  px  19.1871  $north end of plywood
244  py  88.786   $east end of plywood
245  py 113.786   $west end of plywood
246  py  94.2761  $west side of east legs
247  py 108.296   $east side of west legs
248  px  -0.3228  $north side of south legs
249  px  13.697   $south side of north legs

C      Data Cards
*tr1 0 0 0 120 30 90 210 120 90 90 90 0
*tr2 0 0 0 60 30 90 150 60 90 90 90 0
*tr3 -6.6244 -113.671 0 120 30 90 210 120 90 90 90 0
*tr4 -6.6244 -113.671 0 60 30 90 150 60 90 90 90 0
*tr5 6.8707 101.286 0 120 30 90 210 120 90 90 90 0
*tr6 6.8707 101.286 0 60 30 90 150 60 90 90 90 0
C      Materials Cards
m1     1001.62c  1.4544e-2  $Boron-free concrete
       6000.66c  8.1181e-6
       8016.62c  4.5277e-2
       8017.66c  1.7212e-5
       11023.62c 5.7811e-5
       12000.62c 2.5732e-4
       13027.62c 3.0579e-3
       14028.62c 1.3683e-2
       14029.62c 6.9480e-4
       14030.62c 4.5802e-4
       16000.62c 6.7855e-5
       19000.62c 1.0740e-4
       20000.62c 2.0894e-3
       22000.62c 8.5175e-5
       23000.62c 3.5304e-6
       25055.62c 9.3431e-6
       26054.62c 3.6343e-5
       26056.62c 5.7050e-4
       26057.62c 1.3175e-5
       26058.62c 1.7534e-6
       28058.62c 2.0861e-7
       28060.62c 8.0355e-8
       28061.62c 3.4930e-9
       28062.62c 1.1137e-8
       28064.62c 2.8363e-9
       37085.66c 6.3564e-7
       37087.66c 2.4511e-7
       40000.66c 1.9714e-7
       56138.66c 9.3137e-6
       73181.66c 5.2937e-6
m2     1001.62c  2.0391e-5 $Tank steel
       6000.66c  5.0326e-5
       7014.62c  2.6142e-4
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        7015.66c  9.6558e-7
        8016.62c  4.3305e-5
        8017.66c  1.6462e-8
        13027.62c 1.1948e-5
        16000.62c 3.0157e-6
        22000.62c 5.8915e-6
        23000.62c 8.4802e-5
        24050.62c 8.0819e-4
        24052.62c 1.5585e-2
        24053.62c 1.7672e-3
        24054.62c 4.3990e-4
        25055.62c 1.9365e-3
        26054.62c 3.3758e-3
        26056.62c 5.2993e-2
        26057.62c 1.2238e-3
        26058.62c 1.6287e-4
        27059.66c 1.6001e-4
        28058.62c 5.8896e-3
        28060.62c 2.2687e-3
        28061.62c 9.8618e-5
        28062.62c 3.1444e-4
        28064.62c 8.0078e-5
        42000.66c 9.9968e-5
        82206.66c 7.0307e-7
        82207.66c 6.8557e-7
        82208.66c 1.5287e-6
m3      1001.62c  5.8296e-2 $uranyl nitrate solution
        5010.66c  1.7432e-8
        5011.66c  7.0165e-8
        7014.62c  2.1685e-3
        7015.66c  8.0096e-6
        8016.62c  3.7320e-2
        8017.66c  1.4187e-5
        12000.62c 2.2138e-6
        13027.62c 2.7919e-6
        14028.62c 3.0392e-7
        14029.62c 1.5432e-8
        14030.62c 1.0173e-8
        25055.62c 1.0578e-7
        26054.62c 1.1601e-7
        26056.62c 1.8211e-6
        26057.62c 4.2057e-8
        26058.62c 5.5970e-9
        28058.62c 1.7226e-7
        28060.62c 6.6355e-8
        28061.62c 2.8844e-9
        28062.62c 9.1967e-9
        28064.62c 2.3421e-9
        29063.62c 1.8977e-7
        29065.62c 8.4581e-8
        42000.66c 1.6825e-7
        48106.66c 1.8668e-10
        48108.66c 1.3292e-10
        48110.66c 1.8653e-9
        48111.66c 1.9116e-9
        48112.66c 3.6037e-9
        48113.66c 1.8250e-9
        48114.66c 4.2907e-9
        48116.66c 1.1186e-9
        82206.66c 1.1015e-8
        82207.66c 1.0741e-8
        82208.66c 2.3950e-8
        83209.66c 7.0034e-9
        92234.66c 9.0307e-6
        92235.66c 8.5361e-4
        92236.66c 3.9390e-6
        92238.66c 4.8525e-5
mt3     lwtr.60t
m4      6000.66c  1.9600e-3  $Rebar in walls 8.5860E-02
        26054.62c 4.9040e-3
        26056.62c 7.6982e-2
```

```
       26057.62c 1.7778e-3
       26058.62c 2.3660e-4
m5     1001.62c  1.6944e-2 $ 1.2% B concrete
       3006.66c  5.0933e-7
       3007.66c  6.2012e-6
       5010.66c  2.9540e-4
       5011.66c  1.1890e-3
       6000.66c  4.8574e-5
       8016.62c  4.3204e-2
       8017.66c  1.6424e-5
       11023.62c 4.1850e-4
       12000.62c 4.7364e-4
       13027.62c 2.4910e-3
       14028.62c 1.1089e-2
       14029.62c 5.6307e-4
       14030.62c 3.7118e-4
       16000.62c 9.0706e-5
       19000.62c 9.7433e-5
       20000.62c 3.5242e-3
       22000.62c 6.3443e-5
       23000.62c 4.7184e-6
       25055.62c 8.7199e-6
       26054.62c 3.1167e-5
       26056.62c 4.8926e-4
       26057.62c 1.1299e-5
       26058.62c 1.5037e-6
       28058.62c 2.7881e-7
       28060.62c 1.0740e-7
       28061.62c 4.6684e-9
       28062.62c 2.9770e-8
       28064.62c 3.7908e-9
       37085.66c 6.4636e-7
       37087.66c 2.4925e-7
       40000.66c 2.6349e-7
       56138.66c 7.4104e-6
       73181.66c 4.4063e-6
m7     1001.62c  6.8858e-3 $ paper sonotubes
       6000.66c  4.1315e-3
       8016.62c  3.4416e-3
       8017.66c  1.3083e-6
m8     1001.62c  3.2048e-2 $ 1.1% B plaster
       3006.66c  3.8822e-7
       3007.66c  4.7267e-6
       5010.66c  2.2427e-4
       5011.66c  9.0271e-4
       6000.66c  3.9938e-4
       8016.62c  4.0166e-2
       8017.66c  1.5269e-5
       11023.62c 2.9613e-4
       12000.62c 2.3086e-4
       13027.62c 1.7055e-4
       14028.62c 8.2598e-4
       14029.62c 4.1941e-5
       14030.62c 2.7648e-5
       16000.62c 5.0862e-3
       19000.62c 1.6873e-5
       20000.62c 5.6862e-3
       26054.62c 1.7996e-6
       26056.62c 2.8250e-5
       26057.62c 6.5243e-7
       26058.62c 8.6826e-8
       56138.66c 1.7627e-7
m11    1001.62c  2.2298e-2 $wood modeled as cellulose
       6000.66c  1.3369e-2
       8016.62c  1.1139e-2
       8017.66c  4.2343e-6
C      Criticality control cards
kcode 50000 1.0 100 2100
ksrc 37.8092 0 23.78  -37.8092 0 23.78
     0 37.8092 47.56  0 -37.8092 47.56
     43.748 0 47.56  -43.748 0 47.56
```

```
0 43.748 23.78  0 -43.748 23.78
```

MCNP5 ENDF/B-VI (Detailed Model) Input Listing for Experiment 4 of Table 91.

```
1X3 array of nested tanks, Experiment 4 Detailed
C   5                                                                          80
C      Cell Cards
C Everything but tanks and void space (all concrete)
1     1  -2.29  (-1 2 -3 4 -5 6):(4 -3 -5 12 1 -10 96 97 98 99 100 101 102 103&
                104 105 106 107 122 123 124 125 126 127 128 129 130 131):(-12 11
                -3 13 -10 1 108 109 110 111 132 133 134 135 136 137 138 139 140&
                141):(1 -10 -11 6 14 -3 112 113 114 115 116 117 118 119 120 121&
                142 143 144 145 146 147 148 149 150 151)
                imp:n=1 $platform/panels
2     1  -2.29  (2 -8 6 -5 -4 7 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79&
                80):(2 -8 -14 7 -6 9 81 82 83 84 85 86 87 88 89 90 91 92 93 94&
                 95):(2 -8 14 -3 -6 9 81):(-84 -85 -86 -87 -88 -89 -90 -91 -92
                 -93 94 95)  imp:n=1  $walls
C Tanks
3     2  -8.03  (1 -15 29 -28 46 47 48):(-52 53 28 -27):(-15 53 27 -26)
                imp:n=1  $Tank 1
4     2  -8.03  (1 -15 33 -32 46 47 48):(-54 55 32 -31):(-15 55 31 -30)
                imp:n=1  $Tank 2
5     2  -8.03  (1 -15 37 -36 49 50 51):(-60 61 36 -35):(-15 61 35 -34)
                imp:n=1  $Tank 3
6     2  -8.03  (1 -15 41 -40 49 50 51):(-62 63 40 -39):(-15 63 39 -38)
                imp:n=1  $Tank 4
7     2  -8.03  (1 -15 20 -21 43 44 45):(-56 57 21 -22):(-15 57 22 -23)
                imp:n=1  $Tank 2*
8     2  -8.03  (1 -15 16 -17 43 44 45):(-58 59 17 -18):(-15 59 18 -19)
                imp:n=1  $Tank 3*
C solution
9     3  -1.4982  -42 52 28 -27   imp:n=1  $in tank 1
10    3  -1.4982  -42 54 32 -31   imp:n=1  $in tank 2
11    3  -1.4982  -42 60 36 -35   imp:n=1  $in tank 3
12    3  -1.4982  -42 62 40 -39   imp:n=1  $in tank 4
13    3  -1.4982  -42 56 21 -22   imp:n=1  $in tank 2*
14    3  -1.4982  -42 58 17 -18   imp:n=1  $in tank 3*
C Void space
15    0  -7:-9:5:3:-2:8:(10 -8 -5 6 4 -3) imp:n=0 $Big Void outside enclosure
16    0  (4 -14 -11 6 1 -10):(15 -10 11 -12 4 -13):(1 -15 11 -12 4 -13 26 23 34)
         :(1 28 -53 -26):(1 21 -57 -23):(1 36 -61 -34) imp:n=1
         $SE corner,between tanks and panels
17  0  (1 -33 -152 -204):(1 -33 -152 -208):(1 -33 -152 205):(1 -33 -152 209)
       :(152 -15 -33 157):(152 -44 47 -157):(200 -201 211 -207 204 -202):
       (200 -201 204 -212 -209 207):(200 -201 -210 206 204 -202):
       (200 -201 -206 208 204 -212):(200 -201 -206 208 213 -205):
       (200 -201 203 -205 206 -210):(200 -201 211 -207 203 -205):
       (200 -201 213 -205 207 -209):(-46 -32 -208):(-46 -32 209):
       (-32 -47 203 205):(-48 -32 203 205):(-32 -47 -202 -204)
       :(-32 -48 -202 -204):(-157 156 152 -153) imp:n=1 $between tank 2, plug, and stand
18  0  (1 -16 -152 -220):(1 -16 -152 -224):(1 -16 -152 221):(1 -16 -152 225):
       (152 -15 -16 162):(152 -44 52 -162):(200 -201 -225 223 220 -228):
       (200 -201 -223 227 220 -218):(200 -201 -226 222 220 -218):
       (200 -201 220 -228 -222 224):(200 -201 229 -221 -222 224):
       (200 -201 219 -221 222 -226):(200 -201 227 -223 219 -221):
       (200 -201 229 -221 -225 223):(-43 -17 -224):(-43 -17 225)
       :(-17 -44 221 219):(-45 -17 221 219):(-17 -44 -220 -218)
       :(-17 -45 -220 -218):(161 -162 152 -153) imp:n=1 $between tank 3*, plug, and stand
19  0  (1 -152 -41 -236):(1 -152 -41 -240):(1 -152 -41 237):(1 -152 -41 241):
       (152 -15 -41 168):(152 -44 -168 56):(200 -201 -241 239 236 -244):
       (200 -201 -239 243 236 -234):(200 -201 -242 238 236 -234):
       (200 -201 236 -244 -238 240):(200 -201 245 -237 -238 240):
       (200 -201 235 -237 -242 238):(200 -201 243 -239 235 -237):
       (200 -201 245 -237 239 -241):(-49 -40 -240):(-49 -40 241)
       :(-41 -50 235 237 245):(-51 -41 235 237 245)
       :(-41 -50 -236 -234 -244):(-41 -51 -236 -234 -244)
       :(41 -40 -50):(41 -40 -51):(165 -168 -153 152) imp:n=1 $between tank 4, plug, and stand
20    0  (1 -55 32 -29):(-15 55 30 -29):(-28 29 -46):(-28 29 -47):(-28 29 -48)
         imp:n=1 $between 1 and 2 and skirt holes
21    0  (1 -59 17 -20):(-15 59 19 -20):(-21 20 -43):(-21 20 -44):(-21 20 -45)
         imp:n=1 $between 2* and 3* and skirt holes
22    0  (1 -63 40 -37):(-15 63 38 -37):(-36  37 -49):(-36 37 -50):(-36 37 -51)
```

```
         imp:n=1 $between 3 and 4 and skirt holes
23    0  42 -15 28 -27  imp:n=1  $annular void tank 1
24    0  42 -15 32 -31  imp:n=1  $annular void tank 2
25    0  42 -15 36 -35  imp:n=1  $annular void tank 3
26    0  42 -15 40 -39  imp:n=1  $annular void tank 4
27    0  42 -15 21 -22  imp:n=1  $annular void tank 2*
28    0  42 -15 17 -18  imp:n=1  $annular void tank 3*
C rebar in walls
29    4  -7.82 (-76 2 -8):(-77 2 -8):(-78 2 -8):(-79 2 -8):(-80 2 -8):(-64 -5 6)
               :(-65 -5 6):(-66 -5 6):(-67 -5 6):(-68 -5 6):(-69 -5 6)
               :(-70 -5 6):(-71 -5 6):(-72 -5 6):(-73 -5 6):(-74 -5 6)
               :(-75 -5 6) imp:n=1 $east wall rebar
30    4  -7.82 (-81 2 -8):(-82 2 -8):(-83 2 -8):(-84 7 -14):(-95 7 -14)
               :(-85 7 -14):(-86 7 -14):(-87 7 -14):(-88 7 -14):(-89 7 -14)
               :(-90 7 -14):(-91 7 -14):(-92 7 -14):(-93 7 -14):(-94 7 -14)
                imp:n=1 $south wall rebar
C rebar in panels
31    4  -7.82 (-96 1 -10):(-97 1 -10):(-98 1 -10):(-99 1 -10):(-100 1 -10)
               :(-101 1 -10):(-102 1 -10):(-103 1 -10):(-104 1 -10):(-105 1 -10)
               :(-106 1 -10):(-107 1 -10):(-122 4 -3):(-123 4 -3):(-124 4 -3)
               :(-125 4 -3):(-126 4 -3):(-127 4 -3):(-128 4 -3):(-129 4 -3)
               :(-130 4 -3):(-131 4 -3) imp:n=1 $North panels
32    4  -7.82 (-108 1 -10):(-109 1 -10):(-110 1 -10):(-111 1 -10):(-132 11 -12)
               :(-133 11 -12):(-134 11 -12):(-135 11 -12):(-136 11 -12)
               :(-137 11 -12):(-138 11 -12):(-139 11 -12):(-140 11 -12)
               :(-141 11 -12) imp:n=1 $NS panel
33    4  -7.82 (-112 1 -10):(-113 1 -10):(-114 1 -10):(-115 1 -10):(-116 1 -10)
               :(-117 1 -10):(-118 1 -10):(-119 1 -10):(-120 1 -10):(-121 1 -10)
               :(-142 14 -3):(-143 14 -3):(-144 14 -3):(-145 14 -3):(-146 14 -3)
               :(-147 14 -3):(-148 14 -3):(-149 14 -3):(-150 14 -3):(-151 14 -3)
               imp:n=1 $South panels
C plugs
34    2  -8.03  152 -153 -156 155        imp:n=1  $30X18 2.5%B C steel plate
35    10 -8  153 -15 154 -155            imp:n=1  $30X18 2.5%B C culvert
36    6  -1.94  -15 153 -156 155         imp:n=1  $30X18 2.5%B concrete plug
37    7  -0.1854  153 -15 -157 156       imp:n=1  $outer paper 30X18 2.5%B C
38    0  (-154 153 -15):(152 -153 -155)  imp:n=1  $in middle of 30X18 2.5%B C plug
39    2  -8.03  152 -153 -161 159  imp:n=1  $22X16 2.5%B C steel plate
40    7  -0.1854  -15 153 160 -159 imp:n=1  $22X16 2.5%B C inner paper
41    6  -1.94  -15 153 159 -161   imp:n=1  $22X16 2.5%B concrete plug
42    7  -0.1854  -15 153 161 -162 imp:n=1  $22X16 2.5%B C outer paper
43    0  (-15 153 -160):(-153 152 -159) imp:n=1  $in middle of 22X16 2.5%B C plug
44    2  -8.03  152 -153 -165       imp:n=1  $22X0 0%B C steel plate
46    1  -2.29  -15 153 -165        imp:n=1  $22X0 0%B Concrete plug
47    7  -0.1854  -15 153 165 -166  imp:n=1  $22X0 0%B C outer paper
48    9  -8.65 -15 153 166 -168  imp:n=1  $cadmium lamination
c wooden plug stands
100 11  -0.6 (1 -152 -216 206 202 -214):(1 -152 -216 206 -203 215)
             :(1 -152 -207 217 -203 215):(1 -152 -207 217 202 -214)
             :(200 -201 204 -202 -211 210):(200 -201 208 -206 212 -213)
             :(200 -201 203 -205 -211 210):(200 -201 -209 207 212 -213)
             :(-46 208 -206):(-46 -209 207) imp:n=1 $east plug
101 11  -0.6 (1 -152 218 -230 222 -232):(1 -152 231 -219 222 -232)
             :(1 -152 231 -219 -223 233 ):(1 -152 218 -230 -223 233 )
             :(200 -201 220 -218 226 -227):(200 -201 224 -222 228 -229):
             (200 -201 219 -221 -227 226):(200 -201 223 -225 228 -229)
             :(-43 224 -222):(-43 -225 223) imp:n=1 $middle plug
102 11  -0.6 (1 -152 234 -246 -248 238):(1 -152 247 -235 -248 238)
             :(1 -152 247 -235 -239 249):(1 -152 234 -246 -239 249)
             :(200 -201 236 -234 -243 242):(200 -201 240 -238 244 -245)
             :(200 -201 235 -237 -243 242):(200 -201 239 -241 244 -245)
             :(-49 240 -238):(-49 -241 239) imp:n=1 $west plug
103 0   (1 -152 202 -203 216 -217):(1 -152 206 -207 214 -215)
        :(-152 201 204 -202 208 -209):(-152 201 208 -206 202 -203)
        :(-152 201 203 -205 208 -209):(-152 201 207 -209 202 -203)
        :(1 -200 204 -202 208 -209):(1 -200 208 -206 202 -203)
        :(1 -200 203 -205 208 -209):(1 -200 207 -209 202 -203)
        imp:n=1 $inside east plug
104 0   (1 -152 218 -219 232 -233 ):(1 -152 222 -223 230 -231)
        :(-152 201 220 -218 224 -225):(-152 201 224 -222 220 -221)
        :(-152 201 219 -221 224 -225):(-152 201 -225 223 220 -221)
```

```
        :(1 -200 220 -218 224 -225):(1 -200 224 -222 220 -221)
        :(1 -200 219 -221 224 -225):(1 -200 -225 223 220 -221)
        imp:n=1 $inside middle plug
105 0   (1 -152 234 -235 248 -249):(1 -152 238 -239 246 -247)
        :(-152 201 236 -234 240 -241):(-152 201 240 -238 236 -237)
        :(-152 201 235 -237 240 -241):(-152 201 239 -241 236 -237)
        :(1 -200 236 -234 240 -241):(1 -200 240 -238 236 -237)
        :(1 -200 235 -237 240 -241):(1 -200 239 -241 236 -237)
        imp:n=1 $inside west plug

C      Surface Cards
1     pz    0.0    $top of platform where panels and tanks are placed on
2     pz  -20.3    $bottom of platform, bottom of east and south walls
3     py  168.759  $West end of platform and west side of panels
4     py -173.939  $East end of platform and east wall
5     px   79.5785 $North side of platform and north side of panels
6     px  -79.7385 $South side of platform and south wall
7     py -295.939  $Outer east wall
8     pz  343.9    $Top of east and south walls
9     px -201.739  $Outer south wall
10    pz  244.0    $Top of panels
11    px  -59.4385 $South inner panel wall
12    px   59.2785 $North inner panel wall
13    py  148.459  $West inner panel wall
14    py -112.039  $End of south panel on east side
15    pz  243.9    $Top of tanks
16    cz   35.2832 $Tank 3* inner cylinder inner wall
17    cz   35.9232 $Tank 3* inner cylinder outer wall
18    cz   39.6952 $Tank 3* outer cylinder inner wall
19    cz   40.3352 $Tank 3* outer cylinder outer wall
20    cz   41.2375 $Tank 2* inner cylinder inner wall
21    cz   41.8775 $Tank 2* inner cylinder outer wall
22    cz   45.6185 $Tank 2* outer cylinder inner wall
23    cz   46.2585 $Tank 2* outer cylinder outer wall
26    c/z  -6.6244 -113.671 52.0929 $Tank 1 outer cylinder outer wall
27    c/z  -6.6244 -113.671 51.4529 $Tank 1 outer cylinder inner wall
28    c/z  -6.6244 -113.671 47.6149 $Tank 1 inner cylinder outer wall
29    c/z  -6.6244 -113.671 46.9749 $Tank 1 inner cylinder inner wall
30    c/z  -6.6244 -113.671 46.2077 $Tank 2 outer cylinder outer wall
31    c/z  -6.6244 -113.671 45.5677 $Tank 2 outer cylinder inner wall
32    c/z  -6.6244 -113.671 41.7197 $Tank 2 inner cylinder outer wall
33    c/z  -6.6244 -113.671 41.0797 $Tank 2 inner cylinder inner wall
34    c/z   6.8707  101.286 40.3428 $Tank 3 outer cylinder outer wall
35    c/z   6.8707  101.286 39.7028 $Tank 3 outer cylinder inner wall
36    c/z   6.8707  101.286 35.8568 $Tank 3 inner cylinder outer wall
37    c/z   6.8707  101.286 35.2168 $Tank 3 inner cylinder inner wall
38    c/z   6.8707  101.286 34.4703 $Tank 4 outer cylinder outer wall
39    c/z   6.8707  101.286 33.8303 $Tank 4 outer cylinder inner wall
40    c/z   6.8707  101.286 30.0483 $Tank 4 inner cylinder outer wall
41    c/z   6.8707  101.286 29.4083 $Tank 4 inner cylinder inner wall
42    pz  158.89   $Top of solution level for all tanks
C Holes in tank skirt
43    c/x      0.0    15.25  12.5    $Tanks 2*,3*
44    1 c/x    0.0    15.25  12.5    $Tanks 2*,3*
45    2 c/x    0.0    15.25  12.5    $Tanks 2*,3*
46    c/x   -113.671  15.25  12.5    $Tanks 1,2
47    3 c/x    0.0    15.25  12.5    $Tanks 1,2
48    4 c/x    0.0    15.25  12.5    $Tanks 1,2
49    c/x    101.286  15.25  12.5    $Tanks 3,4
50    5 c/x    0.0    15.25  12.5    $Tanks 3,4
51    6 c/x    0.0    15.25  12.5    $Tanks 3,4
C 2 degree slope top and bottom 1-4
C 1 top then bottom
52 P -6.6244 -62.3981 30.50  6.6244 -113.671 32.28  -6.6244 -164.944 34.10
53 P -6.6244 -62.3981 29.86  6.6244 -113.671 31.64  -6.6244 -164.944 33.46
C 2 top then bottom
54 P -6.6244 -70.0273 30.50  6.6244 -113.671 32.11  -6.6244 -157.315 33.73
55 P -6.6244 -70.0273 29.86  6.6244 -113.671 31.47  -6.6244 -157.315 33.09
C 2* top then bottom
56 P 0 43.748 30.50  1 0 32.11  0 -43.748 33.73
57 P 0 43.748 29.86  1 0 31.47  0 -43.748 33.09
```

```
C 3* top then bottom
58 P 0 37.8092 30.50  1 0 31.91  0 -37.8092 33.33
59 P 0 37.8092 29.86  1 0 31.27  0 -37.8092 32.69
C 3 top then bottom
60 P 6.8707 139.066 30.50  -6.8707 101.286 31.91  6.8707 63.5062 33.33
61 P 6.8707 139.066 29.86  -6.8707 101.286 31.27  6.8707 63.5062 32.69
C 4 top then bottom
62 P 6.8707 133.225 30.50  -6.8707 101.286 31.69  6.8707 69.3467 32.87
63 P 6.8707 133.225 29.86  -6.8707 101.286 31.05  6.8707 69.3467 32.23
64 c/x -181.939 0   1.27  $Horizontal rebar in east wall
65 c/x -181.939 30  1.27
66 c/x -181.939 60  1.27
67 c/x -181.939 90  1.27
68 c/x -181.939 120 1.27
69 c/x -181.939 150 1.27
70 c/x -181.939 180 1.27
71 c/x -181.939 210 1.27
72 c/x -181.939 240 1.27
73 c/x -181.939 270 1.27
74 c/x -181.939 300 1.27
75 c/x -181.939 330 1.27
76 c/z   0 -181.939 0.9525  $Vertical rebar in east wall
77 c/z  30 -181.939 0.9525
78 c/z -30 -181.939 0.9525
79 c/z  60 -181.939 0.9525
80 c/z -60 -181.939 0.9525
81 c/z -87.7385 -112.039 0.9525 $vertical rebar in SE corner
82 c/z -87.7385 -142.039 0.9525
83 c/z -87.7385 -172.039 0.9525
84 c/y -87.7385 0 1.27 $Horizontal rebar in SE corner
85 c/y -87.7385 30 1.27
86 c/y -87.7385 60 1.27
87 c/y -87.7385 90 1.27
88 c/y -87.7385 120 1.27
89 c/y -87.7385 150 1.27
90 c/y -87.7385 180 1.27
91 c/y -87.7385 210 1.27
92 c/y -87.7385 240 1.27
93 c/y -87.7385 270 1.27
94 c/y -87.7385 300 1.27
95 c/y -87.7385 330 1.27
C rebar in reflector panels
96 c/z 69.4285  -163.939 0.65 $Vertical rebar N side panels
97 c/z 69.4285  -129.939 0.65
98 c/z 69.4285   -95.939 0.65
99 c/z 69.4285   -61.939 0.65
100 c/z 69.4285   -41.939 0.65
101 c/z 69.4285    -7.939 0.65
102 c/z 69.4285    26.061 0.65
103 c/z 69.4285    60.061 0.65
104 c/z 69.4285   80.061 0.65
105 c/z 69.4285   90.061 0.65
106 c/z 69.4285   110.061 0.65
107 c/z 69.4285   145.561 0.65
108 c/z 49.2785 158.609 0.65 $vertical rebar NS panel
109 c/z 15.2785 158.609 0.65
110 c/z -18.7215 158.609 0.65
111 c/z -52.7215 158.609 0.65
112 c/z -69.5885 -102.039 0.65 $vertical rebar S side panels
113 c/z -69.5885  -68.039 0.65
114 c/z -69.5885  -34.039 0.65
115 c/z -69.5885   -0.039 0.65
116 c/z -69.5885  19.961 0.65
117 c/z -69.5885  53.961 0.65
118 c/z -69.5885  87.961 0.65
119 c/z -69.5885 121.961 0.65
120 c/z -69.5885  141.961 0.65
121 c/z -69.5885 162.461 0.65
122 c/y 69.4285 10 0.65 $horizontal rebar north side panels
123 c/y 69.4285 34.8889 0.65
124 c/y 69.4285 59.7778 0.65
```

```
125 c/y 69.4285 84.6667 0.65
126 c/y 69.4285 109.556 0.65
127 c/y 69.4285 134.445 0.65
128 c/y 69.4285 159.333 0.65
129 c/y 69.4285 184.222 0.65
130 c/y 69.4285 209.111 0.65
131 c/y 69.4285 234 0.65
132 c/x 158.609 10 0.65 $Horizontal rebar in NS panel
133 c/x 158.609 34.8889 0.65
134 c/x 158.609 59.7778 0.65
135 c/x 158.609 84.6667 0.65
136 c/x 158.609 109.556 0.65
137 c/x 158.609 134.445 0.65
138 c/x 158.609 159.333 0.65
139 c/x 158.609 184.222 0.65
140 c/x 158.609 209.111 0.65
141 c/x 158.609 234 0.65
142 c/y -69.5885 10 0.65 $Horizontal rebar in S side panels
143 c/y -69.5885 34.8889 0.65
144 c/y -69.5885 59.7778 0.65
145 c/y -69.5885 84.6667 0.65
146 c/y -69.5885 109.556 0.65
147 c/y -69.5885 134.445 0.65
148 c/y -69.5885 159.333 0.65
149 c/y -69.5885 184.222 0.65
150 c/y -69.5885 209.111 0.65
151 c/y -69.5885 234 0.65
C plugs
152    pz    30.5   $bottom of plug steel plates
153    pz    31.14  $top of plug steel plates/bottom of plugs
154    c/z  -6.6244 -113.671 23.475 $30X18 2.5%B C inner wall of culvert
155    c/z  -6.6244 -113.671 23.625 $30X18 2.5%B C outer wall of culvert/inner plug wall/inner steel
plate
156    c/z  -6.6244 -113.671 38.1  $30X18 2.5%B C outer plug wall/outer paper inner wall/outer steel
plate
157    c/z  -6.6244 -113.671 38.86  $30X18 2.5%B C outer paper outer wall
159    cz  20.765  $22X16 2.5%B C steel plate inner wall/outer wall inner paper/plug inner wall
160    cz  20.32   $22X16 2.5%B C inner wall inner paper
161    cz  27.94   $22X16 2.5%B C outer plug wall/outer paper inner wall/outer steel plate
162    cz  28.51   $22X16 2.5%B C outer paper outer wall
165    c/z 6.8707  101.286  27.94  $22X0 0%B C outer plug wall/outer paper inner wall/outer steel
plate
166    c/z 6.8707  101.286  28.51  $22X0 0%B C outer paper outer wall
168    c/z 6.8707  101.286  28.669  $cadmium lamination outer wall
200  pz 0.5 $bottom of plug stand plywood
201  pz 30  $top of plug stand plywood
c East plug stand
202  py -133.801    $west face of east plywood/east side of east legs
203  py  -93.541    $east face of west plywood/west side of west legs
204  py -135.101    $east face of east plywood
205  py  -92.241    $west face of west plywood
206  px  -26.7544   $north face of south plywood/south side of south legs
207  px   13.5056   $south face of north plywood/north side of north legs
208  px  -28.0544   $south face of south plywood
209  px   14.8056   $north face of north plywood
210  px  -19.1244   $south end of plywood
211  px    5.8756   $north end of plywood
212  py -126.171    $east end of plywood
213  py -101.171    $west end of plywood
214  py -124.901    $west side of east legs
215  py -102.441    $east side of west legs
216  px  -17.8544   $north side of south legs
217  px    4.6056   $south side of north legs
c Middle plug stand
218  py -17.6777  $west face of east plywood/east side of east legs
219  py  17.6777  $east face of west plywood/west side of west legs
220  py -18.9777  $east face of east plywood
221  py  18.9777  $west face of west plywood
222  px -17.6777  $north face of south plywood/south side of south legs
223  px  17.6777  $south face of north plywood/north side of north legs
224  px -18.9777  $south face of south plywood
```

```
225  px  18.9777  $north face of north plywood
226  px -12.5     $south end of plywood
227  px  12.5     $north end of plywood
228  py -12.5     $east end of plywood
229  py  12.5     $west end of plywood
230  py -8.7777   $west side of east legs
231  py  8.7777   $east side of west legs
232  px -8.7777   $north side of south legs
233  px  8.7777   $south side of north legs
c West plug stand
234  py  85.3761  $west face of east plywood/east side of east legs
235  py 117.196   $east face of west plywood/west side of west legs
236  py  84.0761  $east face of east plywood
237  py 118.496   $west face of west plywood
238  px  -9.2228  $north face of south plywood/south side of south legs
239  px  22.597   $south face of north plywood/north side of north legs
240  px -10.5228  $south face of south plywood
241  px  23.897   $north face of north plywood
242  px  -5.8129  $south end of plywood
243  px  19.1871  $north end of plywood
244  py  88.786   $east end of plywood
245  py 113.786   $west end of plywood
246  py  94.2761  $west side of east legs
247  py 108.296   $east side of west legs
248  px  -0.3228  $north side of south legs
249  px  13.697   $south side of north legs

C      Data Cards
*tr1 0 0 0 120 30 90 210 120 90 90 90 0
*tr2 0 0 0 60 30 90 150 60 90 90 90 0
*tr3 -6.6244 -113.671 0 120 30 90 210 120 90 90 90 0
*tr4 -6.6244 -113.671 0 60 30 90 150 60 90 90 90 0
*tr5 6.8707 101.286 0 120 30 90 210 120 90 90 90 0
*tr6 6.8707 101.286 0 60 30 90 150 60 90 90 90 0
C      Materials Cards
m1     1001.62c  1.4544e-2  $Boron-free concrete
       6000.66c  8.1181e-6
       8016.62c  4.5277e-2
       8017.66c  1.7212e-5
       11023.62c 5.7811e-5
       12000.62c 2.5732e-4
       13027.62c 3.0579e-3
       14028.62c 1.3683e-2
       14029.62c 6.9480e-4
       14030.62c 4.5802e-4
       16000.62c 6.7855e-5
       19000.62c 1.0740e-4
       20000.62c 2.0894e-3
       22000.62c 8.5175e-5
       23000.62c 3.5304e-6
       25055.62c 9.3431e-6
       26054.62c 3.6343e-5
       26056.62c 5.7050e-4
       26057.62c 1.3175e-5
       26058.62c 1.7534e-6
       28058.62c 2.0861e-7
       28060.62c 8.0355e-8
       28061.62c 3.4930e-9
       28062.62c 1.1137e-8
       28064.62c 2.8363e-9
       37085.66c 6.3564e-7
       37087.66c 2.4511e-7
       40000.66c 1.9714e-7
       56138.66c 9.3137e-6
       73181.66c 5.2937e-6
m2     1001.62c  2.0391e-5 $Tank steel
       6000.66c  5.0326e-5
       7014.62c  2.6142e-4
       7015.66c  9.6558e-7
       8016.62c  4.3305e-5
       8017.66c  1.6462e-8
```

```
        13027.62c 1.1948e-5
        16000.62c 3.0157e-6
        22000.62c 5.8915e-6
        23000.62c 8.4802e-5
        24050.62c 8.0819e-4
        24052.62c 1.5585e-2
        24053.62c 1.7672e-3
        24054.62c 4.3990e-4
        25055.62c 1.9365e-3
        26054.62c 3.3758e-3
        26056.62c 5.2993e-2
        26057.62c 1.2238e-3
        26058.62c 1.6287e-4
        27059.66c 1.6001e-4
        28058.62c 5.8896e-3
        28060.62c 2.2687e-3
        28061.62c 9.8618e-5
        28062.62c 3.1444e-4
        28064.62c 8.0078e-5
        42000.66c 9.9968e-5
        82206.66c 7.0307e-7
        82207.66c 6.8557e-7
        82208.66c 1.5287e-6
m3      1001.62c  5.8296e-2 $uranyl nitrate solution
        5010.66c  1.7432e-8
        5011.66c  7.0165e-8
        7014.62c  2.1685e-3
        7015.66c  8.0096e-6
        8016.62c  3.7320e-2
        8017.66c  1.4187e-5
        12000.62c 2.2138e-6
        13027.62c 2.7919e-6
        14028.62c 3.0392e-7
        14029.62c 1.5432e-8
        14030.62c 1.0173e-8
        25055.62c 1.0578e-7
        26054.62c 1.1601e-7
        26056.62c 1.8211e-6
        26057.62c 4.2057e-8
        26058.62c 5.5970e-9
        28058.62c 1.7226e-7
        28060.62c 6.6355e-8
        28061.62c 2.8844e-9
        28062.62c 9.1967e-9
        28064.62c 2.3421e-9
        29063.62c 1.8977e-7
        29065.62c 8.4581e-8
        42000.66c 1.6825e-7
        48106.66c 1.8668e-10
        48108.66c 1.3292e-10
        48110.66c 1.8653e-9
        48111.66c 1.9116e-9
        48112.66c 3.6037e-9
        48113.66c 1.8250e-9
        48114.66c 4.2907e-9
        48116.66c 1.1186e-9
        82206.66c 1.1015e-8
        82207.66c 1.0741e-8
        82208.66c 2.3950e-8
        83209.66c 7.0034e-9
        92234.66c 9.0307e-6
        92235.66c 8.5361e-4
        92236.66c 3.9390e-6
        92238.66c 4.8525e-5
mt3     lwtr.60t
m4      6000.66c  1.9600e-3  $Rebar in walls 8.5860E-02
        26054.62c 4.9040e-3
        26056.62c 7.6982e-2
        26057.62c 1.7778e-3
        26058.62c 2.3660e-4
m6      1001.62c  2.2029e-2 $ 2.5% B concrete
```

```
       3006.66c  9.3108e-7
       3007.66c  1.1336e-5
       5010.66c  5.3787e-4
       5011.66c  2.1650e-3
       6000.66c  8.1778e-5
       8016.62c  3.7527e-2
       8017.66c  1.4266e-5
       11023.62c 7.1963e-4
       12000.62c 6.4254e-4
       13027.62c 1.5151e-3
       14028.62c 6.6336e-3
       14029.62c 3.3684e-4
       14030.62c 2.2205e-4
       16000.62c 1.2317e-4
       19000.62c 7.9928e-5
       20000.62c 5.0957e-3
       22000.62c 3.1098e-5
       23000.62c 6.4067e-6
       25055.62c 7.7188e-6
       26054.62c 2.1955e-5
       26056.62c 3.4465e-4
       26057.62c 7.9594e-6
       26058.62c 1.0592e-6
       28058.62c 3.7856e-7
       28060.62c 1.4582e-7
       28061.62c 6.3388e-9
       28062.62c 2.0211e-8
       28064.62c 5.1471e-9
       37085.66c 6.5706e-7
       37087.66c 2.5337e-7
       40000.66c 3.5779e-7
       56138.66c 4.4217e-6
       73181.66c 3.0634e-6
m7     1001.62c  6.8858e-3 $ paper sonotubes
       6000.66c  4.1315e-3
       8016.62c  3.4416e-3
       8017.66c  1.3083e-6
m9     48106.66c 5.7925e-4 $cadmium lamination 4.6340E-02
       48108.66c 4.1243e-4
       48110.66c 5.7879e-3
       48111.66c 5.9316e-3
       48112.66c 1.1182e-2
       48113.66c 5.6628e-3
       48114.66c 1.3314e-2
       48116.66c 3.4709e-3
m10    6000.66c  1.1712e-3 $steel culvert
       15031.66c 1.3485e-4
       16000.62c 6.0090e-5
       26054.62c 4.9204e-3
       26056.62c 7.7240e-2
       26057.62c 1.7838e-3
       26058.62c 2.3739e-4
       30000.42c 1.4718e-3
m11    1001.62c  2.2298e-2 $wood modeled as cellulose
       6000.66c  1.3369e-2
       8016.62c  1.1139e-2
       8017.66c  4.2343e-6
C      Criticality control cards
kcode 50000 1.0 100 2100
ksrc 37.8092 0 23.78  -37.8092 0 23.78  0 37.8092 47.56  0 -37.8092 47.56
     43.748 0 47.56  -43.748 0 47.56  0 43.748 23.78  0 -43.748 23.78
```

MCNP5 ENDF/B-VI (Detailed Model) Input Listing for Experiment 5e of Table 91.

```
1X3 array of nested tanks,Experiment 5e Detailed
C   5                                                                    80
C      Cell Cards
C Everything but tanks and void space (all conrete)
1     1  -2.29  (-1 2 -3 4 -5 6):(4 -3 -5 12 1 -10 96 97 98 99 100 101 102 103&
                104 105 106 107 122 123 124 125 126 127 128 129 130 131):(-12 11
                -3 13 -10 1 108 109 110 111 132 133 134 135 136 137 138 139 140&
                141):(1 -10 -11 6 14 -3 112 113 114 115 116 117 118 119 120 121&
                142 143 144 145 146 147 148 149 150 151)
                imp:n=1 $platform/panels
2     1  -2.29  (2 -8 6 -5 -4 7 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79&
                80):(2 -8 -14 7 -6 9 81 82 83 84 85 86 87 88 89 90 91 92 93 94&
                 95):(2 -8 14 -3 -6 9 81):(-84 -85 -86 -87 -88 -89 -90 -91 -92
                 -93 94 95)  imp:n=1  $walls
C Tanks
3     2  -8.03  (1 -15 29 -28 46 47 48):(-52 53 28 -27):(-15 53 27 -26)
                imp:n=1  $Tank 1
4     2  -8.03  (1 -15 33 -32 46 47 48):(-54 55 32 -31):(-15 55 31 -30)
                imp:n=1  $Tank 2
5     2  -8.03  (1 -15 37 -36 49 50 51):(-60 61 36 -35):(-15 61 35 -34)
                imp:n=1  $Tank 3
6     2  -8.03  (1 -15 41 -40 49 50 51):(-62 63 40 -39):(-15 63 39 -38)
                imp:n=1  $Tank 4
7     2  -8.03  (1 -15 20 -21 43 44 45):(-56 57 21 -22):(-15 57 22 -23)
                imp:n=1  $Tank 2*
8     2  -8.03  (1 -15 16 -17 43 44 45):(-58 59 17 -18):(-15 59 18 -19)
                imp:n=1  $Tank 3*
C solution
9     3  -1.4982  -42 52 28 -27   imp:n=1  $in tank 1
10    3  -1.4982  -42 54 32 -31   imp:n=1  $in tank 2
11    3  -1.4982  -42 60 36 -35   imp:n=1  $in tank 3
12    3  -1.4982  -42 62 40 -39   imp:n=1  $in tank 4
13    3  -1.4982  -42 56 21 -22   imp:n=1  $in tank 2*
14    3  -1.4982  -42 58 17 -18   imp:n=1  $in tank 3*
C Void space
15    0  -7:-9:5:3:-2:8:(10 -8 -5 6 4 -3) imp:n=0 $Big Void outside enclosure
16    0  (4 -14 -11 6 1 -10):(15 -10 11 -12 4 -13):(1 28 -53 -26)
         :(1 21 -57 -23):(1 36 -61 -34)
         :(-43 1 26 23 34 -12 11 -13 4 -300 301 306 -307):
         (-300 1 -15 26 4 -12 11):(301 -307 23 1 -15 -12 11):
         (306 -13 -12 11 -15 1 34):(1 -15 -302 11 4 -13 26):
         (1 -15 303 -12 4 -13) imp:n=1 $SE corner,between tanks and panels
17  0  (1 -33 -152 -204):(1 -33 -152 -208):(1 -33 -152 205):(1 -33 -152 209)
       :(152 -15 -33 157):(152 -44 47 -157):(200 -201 211 -207 204 -202):
       (200 -201 204 -212 -209 207):(200 -201 -210 206 204 -202):
       (200 -201 -206 208 204 -212):(200 -201 -206 208 213 -205):
       (200 -201 203 -205 206 -210):(200 -201 211 -207 203 -205):
       (200 -201 213 -205 207 -209):(-46 -32 -208):(-46 -32 209):
       (-32 -47 203 205):(-48 -32 203 205):(-32 -47 -202 -204)
       :(-32 -48 -202 -204):(-157 156 152 -153) imp:n=1 $between tank 2, plug, and stand
18  0  (1 -16 -152 -220):(1 -16 -152 -224):(1 -16 -152 221):(1 -16 -152 225):
       (152 -15 -16 162):(152 -44 52 -162):(200 -201 -225 223 220 -228):
       (200 -201 -223 227 220 -218):(200 -201 -226 222 220 -218):
       (200 -201 220 -228 -222 224):(200 -201 229 -221 -222 224):
       (200 -201 219 -221 222 -226):(200 -201 227 -223 219 -221):
       (200 -201 229 -221 -225 223):(-43 -17 -224):(-43 -17 225)
       :(-17 -44 221 219):(-45 -17 221 219):(-17 -44 -220 -218)
       :(-17 -45 -220 -218):(161 -162 152 -153) imp:n=1 $between tank 3*, plug, and stand
19  0  (1 -152 -41 -236):(1 -152 -41 -240):(1 -152 -41 237):(1 -152 -41 241):
       (152 -15 -41 166):(152 -44 -166 56):(200 -201 -241 239 236 -244):
       (200 -201 -239 243 236 -234):(200 -201 -242 238 236 -234):
       (200 -201 236 -244 -238 240):(200 -201 245 -237 -238 240):
       (200 -201 235 -237 -242 238):(200 -201 243 -239 235 -237):
       (200 -201 245 -237 239 -241):(-49 -40 -240):(-49 -40 241)
       :(-41 -50 235 237 245):(-51 -41 235 237 245)
       :(-41 -50 -236 -234 -244):(-41 -51 -236 -234 -244)
       :(41 -40 -50):(41 -40 -51):(165 -166 -153 152) imp:n=1 $between tank 4, plug, and stand
20    0  (1 -55 32 -29):(-15 55 30 -29):(-28 29 -46):(-28 29 -47):(-28 29 -48)
           imp:n=1 $between 1 and 2 and skirt holes
```

```
21    0  (1 -59 17 -20):(-15 59 19 -20):(-21 20 -43):(-21 20 -44):(-21 20 -45)
           imp:n=1 $between 2* and 3* and skirt holes
22    0  (1 -63 40 -37):(-15 63 38 -37):(-36  37 -49):(-36 37 -50):(-36 37 -51)
         imp:n=1 $between 3 and 4 and skirt holes
23    0  42 -15 28 -27  imp:n=1  $annular void tank 1
24    0  42 -15 32 -31  imp:n=1  $annular void tank 2
25    0  42 -15 36 -35  imp:n=1  $annular void tank 3
26    0  42 -15 40 -39  imp:n=1  $annular void tank 4
27    0  42 -15 21 -22  imp:n=1  $annular void tank 2*
28    0  42 -15 17 -18  imp:n=1  $annular void tank 3*
C rebar in walls
29    4  -7.82 (-76 2 -8):(-77 2 -8):(-78 2 -8):(-79 2 -8):(-80 2 -8):(-64 -5 6)
               :(-65 -5 6):(-66 -5 6):(-67 -5 6):(-68 -5 6):(-69 -5 6)
               :(-70 -5 6):(-71 -5 6):(-72 -5 6):(-73 -5 6):(-74 -5 6)
               :(-75 -5 6) imp:n=1 $east wall rebar
30    4  -7.82 (-81 2 -8):(-82 2 -8):(-83 2 -8):(-84 7 -14):(-95 7 -14)
               :(-85 7 -14):(-86 7 -14):(-87 7 -14):(-88 7 -14):(-89 7 -14)
               :(-90 7 -14):(-91 7 -14):(-92 7 -14):(-93 7 -14):(-94 7 -14)
                imp:n=1 $south wall rebar
C rebar in panels
31    4  -7.82 (-96 1 -10):(-97 1 -10):(-98 1 -10):(-99 1 -10):(-100 1 -10)
               :(-101 1 -10):(-102 1 -10):(-103 1 -10):(-104 1 -10):(-105 1 -10)
               :(-106 1 -10):(-107 1 -10):(-122 4 -3):(-123 4 -3):(-124 4 -3)
               :(-125 4 -3):(-126 4 -3):(-127 4 -3):(-128 4 -3):(-129 4 -3)
               :(-130 4 -3):(-131 4 -3) imp:n=1 $North panels
32    4  -7.82 (-108 1 -10):(-109 1 -10):(-110 1 -10):(-111 1 -10):(-132 11 -12)
               :(-133 11 -12):(-134 11 -12):(-135 11 -12):(-136 11 -12)
               :(-137 11 -12):(-138 11 -12):(-139 11 -12):(-140 11 -12)
               :(-141 11 -12) imp:n=1 $NS panel
33    4  -7.82 (-112 1 -10):(-113 1 -10):(-114 1 -10):(-115 1 -10):(-116 1 -10)
               :(-117 1 -10):(-118 1 -10):(-119 1 -10):(-120 1 -10):(-121 1 -10)
               :(-142 14 -3):(-143 14 -3):(-144 14 -3):(-145 14 -3):(-146 14 -3)
               :(-147 14 -3):(-148 14 -3):(-149 14 -3):(-150 14 -3):(-151 14 -3)
               imp:n=1 $South panels
C plugs
34    2  -8.03  152 -153 -156        imp:n=1  $30X0 1.2%B C steel plate
35    7  -0.1854  153 -158 154 -155  imp:n=1  $30X0 1.2%B C inner paper
36    5  -2.22  (153 -158 155 -156):(-15 158 -156)  imp:n=1  $30X0 1.2%B concrete plug
37    7  -0.1854  153 -15 -157 156                  imp:n=1  $outer paper 30X0 1.2%B C
38    0  -154 153 -158               imp:n=1  $in middle of 30X0 1.2%B C plug
39    2  -8.03  152 -153 -161 159       imp:n=1  $22x8 1.1%B P steel plate
40    7  -0.1854  -15 153 160 -159      imp:n=1  $22x8 1.1%B P inner paper
41    8  -1.875  -15 153 159 -161       imp:n=1  $22x8 1.1%B Plaster plug
42    7  -0.1854  -15 153 161 -162      imp:n=1  $22x8 1.1%B P outer paper
43    0  (-15 153 -160):(-153 152 -159) imp:n=1  $in middle of 22x8 1.1%B P plug
44    2  -8.03  152 -153 -165 163       imp:n=1 $22X16 1.1%B P steel plate
45    7  -0.1854  -15 153 -163 164      imp:n=1 $22X16 1.1%B P inner paper
46    8  -1.875  -15 153 163 -165       imp:n=1 $22X16 1.1%B Plaster plug
47    7  -0.1854  -15 153 165 -166      imp:n=1 $22X16 1.1%B P outer paper
48    0  (-15 153 -164):(-153 152 -163) imp:n=1 $in middle of 22X16 1.1%B Plaster plug
C Slabs
49    8  -1.875 152 -169 -170 171 -173 172 imp:n=1 $east slab
50    8  -1.875 152 -169 -170 171 -174 175 imp:n=1 $west slab
c wooden plug stands
100 11  -0.6 (1 -152 -216 206 202 -214):(1 -152 -216 206 -203 215)
             :(1 -152 -207 217 -203 215):(1 -152 -207 217 202 -214)
             :(200 -201 204 -202 -211 210):(200 -201 208 -206 212 -213)
             :(200 -201 203 -205 -211 210):(200 -201 -209 207 212 -213)
             :(-46 208 -206):(-46 -209 207) imp:n=1 $east plug
101 11  -0.6 (1 -152 218 -230 222 -232):(1 -152 231 -219 222 -232)
             :(1 -152 231 -219 -223 233 ):(1 -152 218 -230 -223 233 )
             :(200 -201 220 -218 226 -227):(200 -201 224 -222 228 -229):
             (200 -201 219 -221 -227 226):(200 -201 223 -225 228 -229)
             :(-43 224 -222):(-43 -225 223) imp:n=1 $middle plug
102 11  -0.6 (1 -152 234 -246 -248 238):(1 -152 247 -235 -248 238)
             :(1 -152 247 -235 -239 249):(1 -152 234 -246 -239 249)
             :(200 -201 236 -234 -243 242):(200 -201 240 -238 244 -245)
             :(200 -201 235 -237 -243 242):(200 -201 239 -241 244 -245)
             :(-49 240 -238):(-49 -241 239) imp:n=1 $west plug
103 0   (1 -152 202 -203 216 -217):(1 -152 206 -207 214 -215)
        :(-152 201 204 -202 208 -209):(-152 201 208 -206 202 -203)
```

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        :(-152 201 203 -205 208 -209):(-152 201 207 -209 202 -203)
        :(1 -200 204 -202 208 -209):(1 -200 208 -206 202 -203)
        :(1 -200 203 -205 208 -209):(1 -200 207 -209 202 -203)
        imp:n=1 $inside east plug
104 0   (1 -152 218 -219 232 -233 ):(1 -152 222 -223 230 -231)
        :(-152 201 220 -218 224 -225):(-152 201 224 -222 220 -221)
        :(-152 201 219 -221 224 -225):(-152 201 -225 223 220 -221)
        :(1 -200 220 -218 224 -225):(1 -200 224 -222 220 -221)
        :(1 -200 219 -221 224 -225):(1 -200 -225 223 220 -221)
        imp:n=1 $inside middle plug
105 0   (1 -152 234 -235 248 -249):(1 -152 238 -239 246 -247)
        :(-152 201 236 -234 240 -241):(-152 201 240 -238 236 -237)
        :(-152 201 235 -237 240 -241):(-152 201 239 -241 236 -237)
        :(1 -200 236 -234 240 -241):(1 -200 240 -238 236 -237)
        :(1 -200 235 -237 240 -241):(1 -200 239 -241 236 -237)
        imp:n=1 $inside west plug
c slab wood frame
200   11    -0.6 (1 -304 172 -173 171 -170):(171 -170 305 -152 172 -173)
                 :(-15 169 -170 171 172 -173):(-171 302 172 -173 -15 1)
                 :(1 -15 172 -173 170 -303):(1 -15 -172 300 302 -303)
                 :(1 -15 302 -303 173 -301) imp:n=1 $east slab frame
201   11    -0.6 (1 -304 -170 171 -174 175):(305 -152 -170 171 -174 175)
                 :(-15 169 -170 171 -174 175):(-171 302 175 -174 1 -15)
                 :(1 -15 175 -174 170 -303):(1 -15 302 -303 -175 307)
                 :(1 -15 302 -303 -306 174) imp:n=1 $west slab frame
202    0         304 -305 171 -170 172 -173  imp:n=1 $void part of slab frame east slab
203    0         304 -305 171 -170 -174 175  imp:n=1 $void part of slab frame west slab

C      Surface Cards
1     pz    0.0    $top of platform where panels and tanks are placed on
2     pz  -20.3    $bottom of platform, bottom of east and south walls
3     py  168.759  $West end of platform and west side of panels
4     py -173.939  $East end of platform and east wall
5     px   79.5785 $North side of platform and north side of panels
6     px  -79.7385 $South side of platform and south wall
7     py -295.939  $Outer east wall
8     pz  343.9    $Top of east and south walls
9     px -201.739  $Outer south wall
10    pz  244.0    $Top of panels
11    px  -59.4385 $South inner panel wall
12    px   59.2785 $North inner panel wall
13    py  148.459  $West inner panel wall
14    py -112.039  $End of south panel on east side
15    pz  243.9    $Top of tanks
16    cz   35.2832 $Tank 3* inner cylinder inner wall
17    cz   35.9232 $Tank 3* inner cylinder outer wall
18    cz   39.6952 $Tank 3* outer cylinder inner wall
19    cz   40.3352 $Tank 3* outer cylinder outer wall
20    cz   41.2375 $Tank 2* inner cylinder inner wall
21    cz   41.8775 $Tank 2* inner cylinder outer wall
22    cz   45.6185 $Tank 2* outer cylinder inner wall
23    cz   46.2585 $Tank 2* outer cylinder outer wall
26    c/z  -6.6244 -113.671 52.0929 $Tank 1 outer cylinder outer wall
27    c/z  -6.6244 -113.671 51.4529 $Tank 1 outer cylinder inner wall
28    c/z  -6.6244 -113.671 47.6149 $Tank 1 inner cylinder outer wall
29    c/z  -6.6244 -113.671 46.9749 $Tank 1 inner cylinder inner wall
30    c/z  -6.6244 -113.671 46.2077 $Tank 2 outer cylinder outer wall
31    c/z  -6.6244 -113.671 45.5677 $Tank 2 outer cylinder inner wall
32    c/z  -6.6244 -113.671 41.7197 $Tank 2 inner cylinder outer wall
33    c/z  -6.6244 -113.671 41.0797 $Tank 2 inner cylinder inner wall
34    c/z   6.8707  101.286 40.3428 $Tank 3 outer cylinder outer wall
35    c/z   6.8707  101.286 39.7028 $Tank 3 outer cylinder inner wall
36    c/z   6.8707  101.286 35.8568 $Tank 3 inner cylinder outer wall
37    c/z   6.8707  101.286 35.2168 $Tank 3 inner cylinder inner wall
38    c/z   6.8707  101.286 34.4703 $Tank 4 outer cylinder outer wall
39    c/z   6.8707  101.286 33.8303 $Tank 4 outer cylinder inner wall
40    c/z   6.8707  101.286 30.0483 $Tank 4 inner cylinder outer wall
41    c/z   6.8707  101.286 29.4083 $Tank 4 inner cylinder inner wall
42    pz  207.9   $Top of solution level for all tanks
C Holes in tank skirt
43    c/x      0.0    15.25  12.5    $Tanks 2*,3*
```

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44    1 c/x    0.0    15.25  12.5    $Tanks 2*,3*
45    2 c/x    0.0    15.25  12.5    $Tanks 2*,3*
46    c/x   -113.671  15.25  12.5    $Tanks 1,2
47    3 c/x    0.0    15.25  12.5    $Tanks 1,2
48    4 c/x    0.0    15.25  12.5    $Tanks 1,2
49    c/x    101.286  15.25  12.5    $Tanks 3,4
50    5 c/x    0.0    15.25  12.5    $Tanks 3,4
51    6 c/x    0.0    15.25  12.5    $Tanks 3,4
C 2 degree slope top and bottom 1-4
C 1 top then bottom
52 P -6.6244 -62.3981 30.50  6.6244 -113.671 32.28  -6.6244 -164.944 34.10
53 P -6.6244 -62.3981 29.86  6.6244 -113.671 31.64  -6.6244 -164.944 33.46
C 2 top then bottom
54 P -6.6244 -70.0273 30.50  6.6244 -113.671 32.11  -6.6244 -157.315 33.73
55 P -6.6244 -70.0273 29.86  6.6244 -113.671 31.47  -6.6244 -157.315 33.09
C 2* top then bottom
56 P 0 43.748 30.50  1 0 32.11  0 -43.748 33.73
57 P 0 43.748 29.86  1 0 31.47  0 -43.748 33.09
C 3* top then bottom
58 P 0 37.8092 30.50  1 0 31.91  0 -37.8092 33.33
59 P 0 37.8092 29.86  1 0 31.27  0 -37.8092 32.69
C 3 top then bottom
60 P 6.8707 139.066 30.50  -6.8707 101.286 31.91  6.8707 63.5062 33.33
61 P 6.8707 139.066 29.86  -6.8707 101.286 31.27  6.8707 63.5062 32.69
C 4 top then bottom
62 P 6.8707 133.225 30.50  -6.8707 101.286 31.69  6.8707 69.3467 32.87
63 P 6.8707 133.225 29.86  -6.8707 101.286 31.05  6.8707 69.3467 32.23
64 c/x -181.939 0   1.27  $Horizontal rebar in east wall
65 c/x -181.939 30  1.27
66 c/x -181.939 60  1.27
67 c/x -181.939 90  1.27
68 c/x -181.939 120 1.27
69 c/x -181.939 150 1.27
70 c/x -181.939 180 1.27
71 c/x -181.939 210 1.27
72 c/x -181.939 240 1.27
73 c/x -181.939 270 1.27
74 c/x -181.939 300 1.27
75 c/x -181.939 330 1.27
76 c/z   0 -181.939 0.9525  $Vertical rebar in east wall
77 c/z  30 -181.939 0.9525
78 c/z -30 -181.939 0.9525
79 c/z  60 -181.939 0.9525
80 c/z -60 -181.939 0.9525
81 c/z -87.7385 -112.039 0.9525 $vertical rebar in SE corner
82 c/z -87.7385 -142.039 0.9525
83 c/z -87.7385 -172.039 0.9525
84 c/y -87.7385 0 1.27 $Horizontal rebar in SE corner
85 c/y -87.7385 30 1.27
86 c/y -87.7385 60 1.27
87 c/y -87.7385 90 1.27
88 c/y -87.7385 120 1.27
89 c/y -87.7385 150 1.27
90 c/y -87.7385 180 1.27
91 c/y -87.7385 210 1.27
92 c/y -87.7385 240 1.27
93 c/y -87.7385 270 1.27
94 c/y -87.7385 300 1.27
95 c/y -87.7385 330 1.27
C rebar in reflector panels
96 c/z 69.4285  -163.939 0.65 $Vertical rebar N side panels
97 c/z 69.4285  -129.939 0.65
98 c/z 69.4285   -95.939 0.65
99 c/z 69.4285   -61.939 0.65
100 c/z 69.4285   -41.939 0.65
101 c/z 69.4285    -7.939 0.65
102 c/z 69.4285    26.061 0.65
103 c/z 69.4285    60.061 0.65
104 c/z 69.4285   80.061 0.65
105 c/z 69.4285   90.061 0.65
106 c/z 69.4285   110.061 0.65
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107 c/z 69.4285   145.561 0.65
108 c/z 49.2785 158.609 0.65 $vertical rebar NS panel
109 c/z 15.2785 158.609 0.65
110 c/z -18.7215 158.609 0.65
111 c/z -52.7215 158.609 0.65
112 c/z -69.5885 -102.039 0.65 $vertical rebar S side panels
113 c/z -69.5885  -68.039 0.65
114 c/z -69.5885  -34.039 0.65
115 c/z -69.5885   -0.039 0.65
116 c/z -69.5885  19.961 0.65
117 c/z -69.5885  53.961 0.65
118 c/z -69.5885  87.961 0.65
119 c/z -69.5885 121.961 0.65
120 c/z -69.5885  141.961 0.65
121 c/z -69.5885 162.461 0.65
122 c/y 69.4285 10 0.65 $horizontal rebar north side panels
123 c/y 69.4285 34.8889 0.65
124 c/y 69.4285 59.7778 0.65
125 c/y 69.4285 84.6667 0.65
126 c/y 69.4285 109.556 0.65
127 c/y 69.4285 134.445 0.65
128 c/y 69.4285 159.333 0.65
129 c/y 69.4285 184.222 0.65
130 c/y 69.4285 209.111 0.65
131 c/y 69.4285 234 0.65
132 c/x 158.609 10 0.65 $Horizontal rebar in NS panel
133 c/x 158.609 34.8889 0.65
134 c/x 158.609 59.7778 0.65
135 c/x 158.609 84.6667 0.65
136 c/x 158.609 109.556 0.65
137 c/x 158.609 134.445 0.65
138 c/x 158.609 159.333 0.65
139 c/x 158.609 184.222 0.65
140 c/x 158.609 209.111 0.65
141 c/x 158.609 234 0.65
142 c/y -69.5885 10 0.65 $Horizontal rebar in S side panels
143 c/y -69.5885 34.8889 0.65
144 c/y -69.5885 59.7778 0.65
145 c/y -69.5885 84.6667 0.65
146 c/y -69.5885 109.556 0.65
147 c/y -69.5885 134.445 0.65
148 c/y -69.5885 159.333 0.65
149 c/y -69.5885 184.222 0.65
150 c/y -69.5885 209.111 0.65
151 c/y -69.5885 234 0.65
C plugs
152    pz    30.5   $bottom of plug steel plates/bottom of slabs
153    pz    31.14  $top of plug steel plates/bottom of plugs
154    c/z  -6.6244 -113.671 20.415 $30X0 1.2%B C inner wall inner paper
155    c/z  -6.6244 -113.671 20.765 $30X0 1.2%B C outer wall inner paper/inner plug wall
156    c/z  -6.6244 -113.671 38.1   $30X0 1.2%B C outer plug wall/outer paper inner wall/outer steel
plate
157    c/z  -6.6244 -113.671 38.86  $30X0 1.2%B C outer outer paper outer wall
158    pz  204.74                   $30X0 1.2%B C top of inner portion
159    cz  10.48  $22x8 1.1%B P steel plate inner wall/outer wall inner paper/plug inner wall
160    cz  10.16  $22x8 1.1%B P inner wall inner paper
161    cz  27.94  $22x8 1.1%B P outer plug wall/outer paper inner wall/outer steel plate
162    cz  28.51  $22x8 1.1%B P outer paper outer wall
163    c/z 6.8707  101.286  20.765  $22X16 1.1%B P inner steel plate/outer inner paper wall/inner
plug wall
164    c/z 6.8707  101.286  20.32  $22X16 1.1%B P inner paper inner wall
165    c/z 6.8707  101.286  27.94  $22X16 1.1%B P outer plug wall/outer paper inner wall/outer steel
plate
166    c/z 6.8707  101.286  28.51  $22X16 1.1%B P outer paper outer wall
169    pz  240.2  $top of slabs
170    px  54.5   $North edge of slabs
171    px -54.5   $South edge of slabs
172    py -54.8685 $east face of east slab
173    py -52.9685 $west face of east slab
174    py  54.551  $west face of west slab
175    py  52.651  $east face of west slab
```

```
c slab wood frame
300       py -56.1685  $east face of east slab frame of east slab
301       py -51.6685  $west face of west slab frame of east slab
302       px -58.3  $south end of slab frames
303       px  58.3  $north end of slab frames
304       pz   3.8  $top of bottom of frames
305       pz  26.7  $bottom of middle frame piece
306       py  55.851  $west face of west slab frame of west slab
307       py  51.351  $east face of east slab frame of west slab
200  pz 0.5 $bottom of plug stand plywood
201  pz 30  $top of plug stand plywood
c East plug stand
202  py -133.801    $west face of east plywood/east side of east legs
203  py  -93.541    $east face of west plywood/west side of west legs
204  py -135.101    $east face of east plywood
205  py  -92.241    $west face of west plywood
206  px  -26.7544   $north face of south plywood/south side of south legs
207  px   13.5056   $south face of north plywood/north side of north legs
208  px  -28.0544   $south face of south plywood
209  px   14.8056   $north face of north plywood
210  px  -19.1244   $south end of plywood
211  px    5.8756   $north end of plywood
212  py -126.171    $east end of plywood
213  py -101.171    $west end of plywood
214  py -124.901    $west side of east legs
215  py -102.441    $east side of west legs
216  px  -17.8544   $north side of south legs
217  px    4.6056   $south side of north legs
c Middle plug stand
218  py -17.6777  $west face of east plywood/east side of east legs
219  py  17.6777  $east face of west plywood/west side of west legs
220  py -18.9777  $east face of east plywood
221  py  18.9777  $west face of west plywood
222  px -17.6777  $north face of south plywood/south side of south legs
223  px  17.6777  $south face of north plywood/north side of north legs
224  px -18.9777  $south face of south plywood
225  px  18.9777  $north face of north plywood
226  px -12.5     $south end of plywood
227  px  12.5     $north end of plywood
228  py -12.5     $east end of plywood
229  py  12.5     $west end of plywood
230  py -8.7777   $west side of east legs
231  py  8.7777   $east side of west legs
232  px -8.7777   $north side of south legs
233  px  8.7777   $south side of north legs
c West plug stand
234  py  85.3761  $west face of east plywood/east side of east legs
235  py 117.196   $east face of west plywood/west side of west legs
236  py  84.0761  $east face of east plywood
237  py 118.496   $west face of west plywood
238  px  -9.2228  $north face of south plywood/south side of south legs
239  px  22.597   $south face of north plywood/north side of north legs
240  px -10.5228  $south face of south plywood
241  px  23.897   $north face of north plywood
242  px  -5.8129  $south end of plywood
243  px  19.1871  $north end of plywood
244  py  88.786   $east end of plywood
245  py 113.786   $west end of plywood
246  py  94.2761  $west side of east legs
247  py 108.296   $east side of west legs
248  px  -0.3228  $north side of south legs
249  px  13.697   $south side of north legs

C      Data Cards
*tr1 0 0 0 120 30 90 210 120 90 90 90 0
*tr2 0 0 0 60 30 90 150 60 90 90 90 0
*tr3 -6.6244 -113.671 0 120 30 90 210 120 90 90 90 0
*tr4 -6.6244 -113.671 0 60 30 90 150 60 90 90 90 0
*tr5 6.8707 101.286 0 120 30 90 210 120 90 90 90 0
*tr6 6.8707 101.286 0 60 30 90 150 60 90 90 90 0
C      Materials Cards
```

```
m1      1001.62c  1.4544e-2  $Boron-free concrete
        6000.66c  8.1181e-6
        8016.62c  4.5277e-2
        8017.66c  1.7212e-5
        11023.62c 5.7811e-5
        12000.62c 2.5732e-4
        13027.62c 3.0579e-3
        14028.62c 1.3683e-2
        14029.62c 6.9480e-4
        14030.62c 4.5802e-4
        16000.62c 6.7855e-5
        19000.62c 1.0740e-4
        20000.62c 2.0894e-3
        22000.62c 8.5175e-5
        23000.62c 3.5304e-6
        25055.62c 9.3431e-6
        26054.62c 3.6343e-5
        26056.62c 5.7050e-4
        26057.62c 1.3175e-5
        26058.62c 1.7534e-6
        28058.62c 2.0861e-7
        28060.62c 8.0355e-8
        28061.62c 3.4930e-9
        28062.62c 1.1137e-8
        28064.62c 2.8363e-9
        37085.66c 6.3564e-7
        37087.66c 2.4511e-7
        40000.66c 1.9714e-7
        56138.66c 9.3137e-6
        73181.66c 5.2937e-6
m2      1001.62c  2.0391e-5 $Tank steel
        6000.66c  5.0326e-5
        7014.62c  2.6142e-4
        7015.66c  9.6558e-7
        8016.62c  4.3305e-5
        8017.66c  1.6462e-8
        13027.62c 1.1948e-5
        16000.62c 3.0157e-6
        22000.62c 5.8915e-6
        23000.62c 8.4802e-5
        24050.62c 8.0819e-4
        24052.62c 1.5585e-2
        24053.62c 1.7672e-3
        24054.62c 4.3990e-4
        25055.62c 1.9365e-3
        26054.62c 3.3758e-3
        26056.62c 5.2993e-2
        26057.62c 1.2238e-3
        26058.62c 1.6287e-4
        27059.66c 1.6001e-4
        28058.62c 5.8896e-3
        28060.62c 2.2687e-3
        28061.62c 9.8618e-5
        28062.62c 3.1444e-4
        28064.62c 8.0078e-5
        42000.66c 9.9968e-5
        82206.66c 7.0307e-7
        82207.66c 6.8557e-7
        82208.66c 1.5287e-6
m3      1001.62c  5.8296e-2 $uranyl nitrate solution
        5010.66c  1.7432e-8
        5011.66c  7.0165e-8
        7014.62c  2.1685e-3
        7015.66c  8.0096e-6
        8016.62c  3.7320e-2
        8017.66c  1.4187e-5
        12000.62c 2.2138e-6
        13027.62c 2.7919e-6
        14028.62c 3.0392e-7
        14029.62c 1.5432e-8
        14030.62c 1.0173e-8
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        25055.62c 1.0578e-7
        26054.62c 1.1601e-7
        26056.62c 1.8211e-6
        26057.62c 4.2057e-8
        26058.62c 5.5970e-9
        28058.62c 1.7226e-7
        28060.62c 6.6355e-8
        28061.62c 2.8844e-9
        28062.62c 9.1967e-9
        28064.62c 2.3421e-9
        29063.62c 1.8977e-7
        29065.62c 8.4581e-8
        42000.66c 1.6825e-7
        48106.66c 1.8668e-10
        48108.66c 1.3292e-10
        48110.66c 1.8653e-9
        48111.66c 1.9116e-9
        48112.66c 3.6037e-9
        48113.66c 1.8250e-9
        48114.66c 4.2907e-9
        48116.66c 1.1186e-9
        82206.66c 1.1015e-8
        82207.66c 1.0741e-8
        82208.66c 2.3950e-8
        83209.66c 7.0034e-9
        92234.66c 9.0307e-6
        92235.66c 8.5361e-4
        92236.66c 3.9390e-6
        92238.66c 4.8525e-5
mt3     lwtr.60t
m4      6000.66c  1.9600e-3  $Rebar in walls 8.5860E-02
        26054.62c 4.9040e-3
        26056.62c 7.6982e-2
        26057.62c 1.7778e-3
        26058.62c 2.3660e-4
m5      1001.62c  1.6944e-2 $ 1.2% B concrete
        3006.66c  5.0933e-7
        3007.66c  6.2012e-6
        5010.66c  2.9540e-4
        5011.66c  1.1890e-3
        6000.66c  4.8574e-5
        8016.62c  4.3204e-2
        8017.66c  1.6424e-5
        11023.62c 4.1850e-4
        12000.62c 4.7364e-4
        13027.62c 2.4910e-3
        14028.62c 1.1089e-2
        14029.62c 5.6307e-4
        14030.62c 3.7118e-4
        16000.62c 9.0706e-5
        19000.62c 9.7433e-5
        20000.62c 3.5242e-3
        22000.62c 6.3443e-5
        23000.62c 4.7184e-6
        25055.62c 8.7199e-6
        26054.62c 3.1167e-5
        26056.62c 4.8926e-4
        26057.62c 1.1299e-5
        26058.62c 1.5037e-6
        28058.62c 2.7881e-7
        28060.62c 1.0740e-7
        28061.62c 4.6684e-9
        28062.62c 2.9770e-8
        28064.62c 3.7908e-9
        37085.66c 6.4636e-7
        37087.66c 2.4925e-7
        40000.66c 2.6349e-7
        56138.66c 7.4104e-6
        73181.66c 4.4063e-6
m7      1001.62c  6.8858e-3 $ paper sonotubes
        6000.66c  4.1315e-3
```

```
       8016.62c  3.4416e-3
       8017.66c  1.3083e-6
m8     1001.62c  3.2048e-2 $ 1.1% B plaster
       3006.66c  3.8822e-7
       3007.66c  4.7267e-6
       5010.66c  2.2427e-4
       5011.66c  9.0271e-4
       6000.66c  3.9938e-4
       8016.62c  4.0166e-2
       8017.66c  1.5269e-5
       11023.62c 2.9613e-4
       12000.62c 2.3086e-4
       13027.62c 1.7055e-4
       14028.62c 8.2598e-4
       14029.62c 4.1941e-5
       14030.62c 2.7648e-5
       16000.62c 5.0862e-3
       19000.62c 1.6873e-5
       20000.62c 5.6862e-3
       26054.62c 1.7996e-6
       26056.62c 2.8250e-5
       26057.62c 6.5243e-7
       26058.62c 8.6826e-8
       56138.66c 1.7627e-7
m11    1001.62c  2.2298e-2 $wood modeled as cellulose
       6000.66c  1.3369e-2
       8016.62c  1.1139e-2
       8017.66c  4.2343e-6
C      Criticality control cards
kcode 50000 1.0 100 2100
ksrc 37.8092 0 23.78  -37.8092 0 23.78
     0 37.8092 47.56  0 -37.8092 47.56
     43.748 0 47.56  -43.748 0 47.56
     0 43.748 23.78  0 -43.748 23.78
```

MCNP5 ENDF/B-VI (Detailed Model) Input Listing for Experiment 6 of Table 91.

```
1X3 array of nested tanks,Experiment 6 Detailed
C   5                                                                      80
C      Cell Cards
C Everything but tanks and void space (all conrete)
1     1  -2.29  (-1 2 -3 4 -5 6):(4 -3 -5 12 1 -10 96 97 98 99 100 101 102 103&
                104 105 106 107 122 123 124 125 126 127 128 129 130 131):(-12 11
                -3 13 -10 1 108 109 110 111 132 133 134 135 136 137 138 139 140&
                141):(1 -10 -11 6 14 -3 112 113 114 115 116 117 118 119 120 121&
                142 143 144 145 146 147 148 149 150 151)
                imp:n=1 $platform/panels
2     1  -2.29  (2 -8 6 -5 -4 7 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79&
                80):(2 -8 -14 7 -6 9 81 82 83 84 85 86 87 88 89 90 91 92 93 94&
                 95):(2 -8 14 -3 -6 9 81):(-84 -85 -86 -87 -88 -89 -90 -91 -92
                 -93 94 95)  imp:n=1  $walls
C Tanks
3     2  -8.03  (1 -15 29 -28 46 47 48):(-52 53 28 -27):(-15 53 27 -26)
                imp:n=1  $Tank 1
4     2  -8.03  (1 -15 33 -32 46 47 48):(-54 55 32 -31):(-15 55 31 -30)
                imp:n=1  $Tank 2
5     2  -8.03  (1 -15 37 -36 49 50 51):(-60 61 36 -35):(-15 61 35 -34)
                imp:n=1  $Tank 3
6     2  -8.03  (1 -15 41 -40 49 50 51):(-62 63 40 -39):(-15 63 39 -38)
                imp:n=1  $Tank 4
7     2  -8.03  (1 -15 20 -21 43 44 45):(-56 57 21 -22):(-15 57 22 -23)
                imp:n=1  $Tank 2*
8     2  -8.03  (1 -15 16 -17 43 44 45):(-58 59 17 -18):(-15 59 18 -19)
                imp:n=1  $Tank 3*
C solution
11    3  -1.4982  -42 60 36 -35   imp:n=1  $in tank 3
12    3  -1.4982  -42 62 40 -39   imp:n=1  $in tank 4
13    3  -1.4982  -42 56 21 -22   imp:n=1  $in tank 2*
14    3  -1.4982  -42 58 17 -18   imp:n=1  $in tank 3*
C Void space
15    0  -7:-9:5:3:-2:8:(10 -8 -5 6 4 -3) imp:n=0 $Big Void outside enclosure
16    0  (4 -14 -11 6 1 -10):(15 -10 11 -12 4 -13):(1 28 -53 -26)
         :(1 21 -57 -23):(1 36 -61 -34)
         :(-43 1 26 23 34 -12 11 -13 4 -300 301 306 -307):
         (-300 1 -15 26 4 -12 11):(301 -307 23 1 -15 -12 11):
         (306 -13 -12 11 -15 1 34):(1 -15 -302 11 4 -13 26):
         (1 -15 303 -12 4 -13) imp:n=1 $SE corner,between tanks and panels
17  0  (1 -33 -152 -204):(1 -33 -152 -208):(1 -33 -152 205):(1 -33 -152 209)
       :(152 -15 -33 157):(152 -44 47 -157):(200 -201 211 -207 204 -202):
       (200 -201 204 -212 -209 207):(200 -201 -210 206 204 -202):
       (200 -201 -206 208 204 -212):(200 -201 -206 208 213 -205):
       (200 -201 203 -205 206 -210):(200 -201 211 -207 203 -205):
       (200 -201 213 -205 207 -209):(-46 -32 -208):(-46 -32 209):
       (-32 -47 203 205):(-48 -32 203 205):(-32 -47 -202 -204)
       :(-32 -48 -202 -204):(-157 156 152 -153) imp:n=1 $between tank 2, plug, and stand
18  0  (1 -16 -152 -220):(1 -16 -152 -224):(1 -16 -152 221):(1 -16 -152 225):
       (152 -15 -16):(200 -201 -225 223 220 -228):
       (200 -201 -223 227 220 -218):(200 -201 -226 222 220 -218):
       (200 -201 220 -228 -222 224):(200 -201 229 -221 -222 224):
       (200 -201 219 -221 222 -226):(200 -201 227 -223 219 -221):
       (200 -201 229 -221 -225 223):(-43 -17 -224):(-43 -17 225)
       :(-17 -44 221 219):(-45 -17 221 219):(-17 -44 -220 -218)
       :(-17 -45 -220 -218) imp:n=1 $between tank 3*, plug, and stand
19  0  (1 -152 -41 -236):(1 -152 -41 -240):(1 -152 -41 237):(1 -152 -41 241):
       (152 -15 -41 166):(152 -44 -166 56):(200 -201 -241 239 236 -244):
       (200 -201 -239 243 236 -234):(200 -201 -242 238 236 -234):
       (200 -201 236 -244 -238 240):(200 -201 245 -237 -238 240):
       (200 -201 235 -237 -242 238):(200 -201 243 -239 235 -237):
       (200 -201 245 -237 239 -241):(-49 -40 -240):(-49 -40 241)
       :(-41 -50 235 237 245):(-51 -41 235 237 245)
       :(-41 -50 -236 -234 -244):(-41 -51 -236 -234 -244)
       :(41 -40 -50):(41 -40 -51):(165 -166 -153 152) imp:n=1 $between tank 4, plug, and stand
20    0  (1 -55 32 -29):(-15 55 30 -29):(-28 29 -46):(-28 29 -47):(-28 29 -48)
           imp:n=1 $between 1 and 2 and skirt holes
21    0  (1 -59 17 -20):(-15 59 19 -20):(-21 20 -43):(-21 20 -44):(-21 20 -45)
           imp:n=1 $between 2* and 3* and skirt holes
```

```
22    0  (1 -63 40 -37):(-15 63 38 -37):(-36  37 -49):(-36 37 -50):(-36 37 -51)
         imp:n=1 $between 3 and 4 and skirt holes
23    0  52 -15 28 -27  imp:n=1  $annular void tank 1
24    0  54 -15 32 -31  imp:n=1  $annular void tank 2
25    0  42 -15 36 -35  imp:n=1  $annular void tank 3
26    0  42 -15 40 -39  imp:n=1  $annular void tank 4
27    0  42 -15 21 -22  imp:n=1  $annular void tank 2*
28    0  42 -15 17 -18  imp:n=1  $annular void tank 3*
C rebar in walls
29    4  -7.82 (-76 2 -8):(-77 2 -8):(-78 2 -8):(-79 2 -8):(-80 2 -8):(-64 -5 6)
               :(-65 -5 6):(-66 -5 6):(-67 -5 6):(-68 -5 6):(-69 -5 6)
               :(-70 -5 6):(-71 -5 6):(-72 -5 6):(-73 -5 6):(-74 -5 6)
               :(-75 -5 6) imp:n=1 $east wall rebar
30    4  -7.82 (-81 2 -8):(-82 2 -8):(-83 2 -8):(-84 7 -14):(-95 7 -14)
               :(-85 7 -14):(-86 7 -14):(-87 7 -14):(-88 7 -14):(-89 7 -14)
               :(-90 7 -14):(-91 7 -14):(-92 7 -14):(-93 7 -14):(-94 7 -14)
                imp:n=1 $south wall rebar
C rebar in panels
31    4  -7.82 (-96 1 -10):(-97 1 -10):(-98 1 -10):(-99 1 -10):(-100 1 -10)
               :(-101 1 -10):(-102 1 -10):(-103 1 -10):(-104 1 -10):(-105 1 -10)
               :(-106 1 -10):(-107 1 -10):(-122 4 -3):(-123 4 -3):(-124 4 -3)
               :(-125 4 -3):(-126 4 -3):(-127 4 -3):(-128 4 -3):(-129 4 -3)
               :(-130 4 -3):(-131 4 -3) imp:n=1 $North panels
32    4  -7.82 (-108 1 -10):(-109 1 -10):(-110 1 -10):(-111 1 -10):(-132 11 -12)
               :(-133 11 -12):(-134 11 -12):(-135 11 -12):(-136 11 -12)
               :(-137 11 -12):(-138 11 -12):(-139 11 -12):(-140 11 -12)
               :(-141 11 -12) imp:n=1 $NS panel
33    4  -7.82 (-112 1 -10):(-113 1 -10):(-114 1 -10):(-115 1 -10):(-116 1 -10)
               :(-117 1 -10):(-118 1 -10):(-119 1 -10):(-120 1 -10):(-121 1 -10)
               :(-142 14 -3):(-143 14 -3):(-144 14 -3):(-145 14 -3):(-146 14 -3)
               :(-147 14 -3):(-148 14 -3):(-149 14 -3):(-150 14 -3):(-151 14 -3)
               imp:n=1 $South panels
C plugs
34    2  -8.03  152 -153 -156        imp:n=1  $30X0 1.2%B C steel plate
35    7  -0.1854  153 -158 154 -155  imp:n=1  $30X0 1.2%B C inner paper
36    5  -2.22  (153 -158 155 -156):(-15 158 -156)  imp:n=1  $30X0 1.2%B concrete plug
37    7  -0.1854  153 -15 -157 156                 imp:n=1  $outer paper 30X0 1.2%B C
38    0  -154 153 -158               imp:n=1  $in middle of 30X0 1.2%B C plug
44    2  -8.03  152 -153 -165 163       imp:n=1 $22X16 1.1%B P steel plate
45    7  -0.1854  -15 153 -163 164      imp:n=1 $22X16 1.1%B P inner paper
46    8  -1.875  -15 153 163 -165       imp:n=1 $22X16 1.1%B Plaster plug
47    7  -0.1854  -15 153 165 -166      imp:n=1 $22X16 1.1%B P outer paper
48    0  (-15 153 -164):(-153 152 -163) imp:n=1 $in middle of 22X16 1.1%B Plaster plug
C Slabs
49    8  -1.875 152 -169 -170 171 -173 172 imp:n=1 $east slab
50    8  -1.875 152 -169 -170 171 -174 175 imp:n=1 $west slab
c wooden plug stands
100 11  -0.6 (1 -152 -216 206 202 -214):(1 -152 -216 206 -203 215)
             :(1 -152 -207 217 -203 215):(1 -152 -207 217 202 -214)
             :(200 -201 204 -202 -211 210):(200 -201 208 -206 212 -213)
             :(200 -201 203 -205 -211 210):(200 -201 -209 207 212 -213)
             :(-46 208 -206):(-46 -209 207) imp:n=1 $east plug
101 11  -0.6 (1 -152 218 -230 222 -232):(1 -152 231 -219 222 -232)
             :(1 -152 231 -219 -223 233 ):(1 -152 218 -230 -223 233 )
             :(200 -201 220 -218 226 -227):(200 -201 224 -222 228 -229):
             (200 -201 219 -221 -227 226):(200 -201 223 -225 228 -229)
             :(-43 224 -222):(-43 -225 223) imp:n=1 $middle plug
102 11  -0.6 (1 -152 234 -246 -248 238):(1 -152 247 -235 -248 238)
             :(1 -152 247 -235 -239 249):(1 -152 234 -246 -239 249)
             :(200 -201 236 -234 -243 242):(200 -201 240 -238 244 -245)
             :(200 -201 235 -237 -243 242):(200 -201 239 -241 244 -245)
             :(-49 240 -238):(-49 -241 239) imp:n=1 $west plug
103 0   (1 -152 202 -203 216 -217):(1 -152 206 -207 214 -215)
        :(-152 201 204 -202 208 -209):(-152 201 208 -206 202 -203)
        :(-152 201 203 -205 208 -209):(-152 201 207 -209 202 -203)
        :(1 -200 204 -202 208 -209):(1 -200 208 -206 202 -203)
        :(1 -200 203 -205 208 -209):(1 -200 207 -209 202 -203)
        imp:n=1 $inside east plug
104 0   (1 -152 218 -219 232 -233 ):(1 -152 222 -223 230 -231)
        :(-152 201 220 -218 224 -225):(-152 201 224 -222 220 -221)
        :(-152 201 219 -221 224 -225):(-152 201 -225 223 220 -221)
```

```
        :(1 -200 220 -218 224 -225):(1 -200 224 -222 220 -221)
        :(1 -200 219 -221 224 -225):(1 -200 -225 223 220 -221)
        imp:n=1 $inside middle plug
105 0   (1 -152 234 -235 248 -249):(1 -152 238 -239 246 -247)
        :(-152 201 236 -234 240 -241):(-152 201 240 -238 236 -237)
        :(-152 201 235 -237 240 -241):(-152 201 239 -241 236 -237)
        :(1 -200 236 -234 240 -241):(1 -200 240 -238 236 -237)
        :(1 -200 235 -237 240 -241):(1 -200 239 -241 236 -237)
        imp:n=1 $inside west plug
c slab wood frame
200   11    -0.6 (1 -304 172 -173 171 -170):(171 -170 305 -152 172 -173)
                 :(-15 169 -170 171 172 -173):(-171 302 172 -173 -15 1)
                 :(1 -15 172 -173 170 -303):(1 -15 -172 300 302 -303)
                 :(1 -15 302 -303 173 -301) imp:n=1 $east slab frame
201   11    -0.6 (1 -304 -170 171 -174 175):(305 -152 -170 171 -174 175)
                 :(-15 169 -170 171 -174 175):(-171 302 175 -174 1 -15)
                 :(1 -15 175 -174 170 -303):(1 -15 302 -303 -175 307)
                 :(1 -15 302 -303 -306 174) imp:n=1 $west slab frame
202    0         304 -305 171 -170 172 -173  imp:n=1 $void part of slab frame east slab
203    0         304 -305 171 -170 -174 175  imp:n=1 $void part of slab frame west slab

C      Surface Cards
1      pz    0.0    $top of platform where panels and tanks are placed on
2      pz  -20.3    $bottom of platform, bottom of east and south walls
3      py  168.759  $West end of platform and west side of panels
4      py -173.939  $East end of platform and east wall
5      px   79.5785 $North side of platform and north side of panels
6      px  -79.7385 $South side of platform and south wall
7      py -295.939  $Outer east wall
8      pz  343.9    $Top of east and south walls
9      px -201.739  $Outer south wall
10     pz  244.0    $Top of panels
11     px  -59.4385 $South inner panel wall
12     px   59.2785 $North inner panel wall
13     py  148.459  $West inner panel wall
14     py -112.039  $End of south panel on east side
15     pz  243.9    $Top of tanks
16     cz   35.2832 $Tank 3* inner cylinder inner wall
17     cz   35.9232 $Tank 3* inner cylinder outer wall
18     cz   39.6952 $Tank 3* outer cylinder inner wall
19     cz   40.3352 $Tank 3* outer cylinder outer wall
20     cz   41.2375 $Tank 2* inner cylinder inner wall
21     cz   41.8775 $Tank 2* inner cylinder outer wall
22     cz   45.6185 $Tank 2* outer cylinder inner wall
23     cz   46.2585 $Tank 2* outer cylinder outer wall
26     c/z  -6.6244 -113.671 52.0929 $Tank 1 outer cylinder outer wall
27     c/z  -6.6244 -113.671 51.4529 $Tank 1 outer cylinder inner wall
28     c/z  -6.6244 -113.671 47.6149 $Tank 1 inner cylinder outer wall
29     c/z  -6.6244 -113.671 46.9749 $Tank 1 inner cylinder inner wall
30     c/z  -6.6244 -113.671 46.2077 $Tank 2 outer cylinder outer wall
31     c/z  -6.6244 -113.671 45.5677 $Tank 2 outer cylinder inner wall
32     c/z  -6.6244 -113.671 41.7197 $Tank 2 inner cylinder outer wall
33     c/z  -6.6244 -113.671 41.0797 $Tank 2 inner cylinder inner wall
34     c/z   6.8707  101.286 40.3428 $Tank 3 outer cylinder outer wall
35     c/z   6.8707  101.286 39.7028 $Tank 3 outer cylinder inner wall
36     c/z   6.8707  101.286 35.8568 $Tank 3 inner cylinder outer wall
37     c/z   6.8707  101.286 35.2168 $Tank 3 inner cylinder inner wall
38     c/z   6.8707  101.286 34.4703 $Tank 4 outer cylinder outer wall
39     c/z   6.8707  101.286 33.8303 $Tank 4 outer cylinder inner wall
40     c/z   6.8707  101.286 30.0483 $Tank 4 inner cylinder outer wall
41     c/z   6.8707  101.286 29.4083 $Tank 4 inner cylinder inner wall
42     pz  135.12   $Top of solution level for all tanks
C Holes in tank skirt
43     c/x      0.0    15.25  12.5    $Tanks 2*,3*
44     1 c/x    0.0    15.25  12.5    $Tanks 2*,3*
45     2 c/x    0.0    15.25  12.5    $Tanks 2*,3*
46     c/x   -113.671  15.25  12.5    $Tanks 1,2
47     3 c/x    0.0    15.25  12.5    $Tanks 1,2
48     4 c/x    0.0    15.25  12.5    $Tanks 1,2
49     c/x    101.286  15.25  12.5    $Tanks 3,4
50     5 c/x    0.0    15.25  12.5    $Tanks 3,4
```

```
51    6 c/x    0.0    15.25  12.5    $Tanks 3,4
C 2 degree slope top and bottom 1-4
C 1 top then bottom
52 P -6.6244 -62.3981 30.50  6.6244 -113.671 32.28  -6.6244 -164.944 34.10
53 P -6.6244 -62.3981 29.86  6.6244 -113.671 31.64  -6.6244 -164.944 33.46
C 2 top then bottom
54 P -6.6244 -70.0273 30.50  6.6244 -113.671 32.11  -6.6244 -157.315 33.73
55 P -6.6244 -70.0273 29.86  6.6244 -113.671 31.47  -6.6244 -157.315 33.09
C 2* top then bottom
56 P 0 43.748 30.50  1 0 32.11  0 -43.748 33.73
57 P 0 43.748 29.86  1 0 31.47  0 -43.748 33.09
C 3* top then bottom
58 P 0 37.8092 30.50  1 0 31.91  0 -37.8092 33.33
59 P 0 37.8092 29.86  1 0 31.27  0 -37.8092 32.69
C 3 top then bottom
60 P 6.8707 139.066 30.50  -6.8707 101.286 31.91  6.8707 63.5062 33.33
61 P 6.8707 139.066 29.86  -6.8707 101.286 31.27  6.8707 63.5062 32.69
C 4 top then bottom
62 P 6.8707 133.225 30.50  -6.8707 101.286 31.69  6.8707 69.3467 32.87
63 P 6.8707 133.225 29.86  -6.8707 101.286 31.05  6.8707 69.3467 32.23
64 c/x -181.939 0   1.27  $Horizontal rebar in east wall
65 c/x -181.939 30  1.27
66 c/x -181.939 60  1.27
67 c/x -181.939 90  1.27
68 c/x -181.939 120 1.27
69 c/x -181.939 150 1.27
70 c/x -181.939 180 1.27
71 c/x -181.939 210 1.27
72 c/x -181.939 240 1.27
73 c/x -181.939 270 1.27
74 c/x -181.939 300 1.27
75 c/x -181.939 330 1.27
76 c/z   0 -181.939 0.9525  $Vertical rebar in east wall
77 c/z  30 -181.939 0.9525
78 c/z -30 -181.939 0.9525
79 c/z  60 -181.939 0.9525
80 c/z -60 -181.939 0.9525
81 c/z -87.7385 -112.039 0.9525 $vertical rebar in SE corner
82 c/z -87.7385 -142.039 0.9525
83 c/z -87.7385 -172.039 0.9525
84 c/y -87.7385 0 1.27 $Horizontal rebar in SE corner
85 c/y -87.7385 30 1.27
86 c/y -87.7385 60 1.27
87 c/y -87.7385 90 1.27
88 c/y -87.7385 120 1.27
89 c/y -87.7385 150 1.27
90 c/y -87.7385 180 1.27
91 c/y -87.7385 210 1.27
92 c/y -87.7385 240 1.27
93 c/y -87.7385 270 1.27
94 c/y -87.7385 300 1.27
95 c/y -87.7385 330 1.27
C rebar in reflector panels
96 c/z 69.4285  -163.939 0.65 $Vertical rebar N side panels
97 c/z 69.4285  -129.939 0.65
98 c/z 69.4285   -95.939 0.65
99 c/z 69.4285   -61.939 0.65
100 c/z 69.4285   -41.939 0.65
101 c/z 69.4285    -7.939 0.65
102 c/z 69.4285    26.061 0.65
103 c/z 69.4285    60.061 0.65
104 c/z 69.4285   80.061 0.65
105 c/z 69.4285   90.061 0.65
106 c/z 69.4285   110.061 0.65
107 c/z 69.4285   145.561 0.65
108 c/z 49.2785 158.609 0.65 $vertical rebar NS panel
109 c/z 15.2785 158.609 0.65
110 c/z -18.7215 158.609 0.65
111 c/z -52.7215 158.609 0.65
112 c/z -69.5885 -102.039 0.65 $vertical rebar S side panels
113 c/z -69.5885  -68.039 0.65
```

```
114 c/z -69.5885  -34.039 0.65
115 c/z -69.5885   -0.039 0.65
116 c/z -69.5885  19.961 0.65
117 c/z -69.5885  53.961 0.65
118 c/z -69.5885  87.961 0.65
119 c/z -69.5885 121.961 0.65
120 c/z -69.5885  141.961 0.65
121 c/z -69.5885 162.461 0.65
122 c/y 69.4285 10 0.65 $horizontal rebar north side panels
123 c/y 69.4285 34.8889 0.65
124 c/y 69.4285 59.7778 0.65
125 c/y 69.4285 84.6667 0.65
126 c/y 69.4285 109.556 0.65
127 c/y 69.4285 134.445 0.65
128 c/y 69.4285 159.333 0.65
129 c/y 69.4285 184.222 0.65
130 c/y 69.4285 209.111 0.65
131 c/y 69.4285 234 0.65
132 c/x 158.609 10 0.65 $Horizontal rebar in NS panel
133 c/x 158.609 34.8889 0.65
134 c/x 158.609 59.7778 0.65
135 c/x 158.609 84.6667 0.65
136 c/x 158.609 109.556 0.65
137 c/x 158.609 134.445 0.65
138 c/x 158.609 159.333 0.65
139 c/x 158.609 184.222 0.65
140 c/x 158.609 209.111 0.65
141 c/x 158.609 234 0.65
142 c/y -69.5885 10 0.65 $Horizontal rebar in S side panels
143 c/y -69.5885 34.8889 0.65
144 c/y -69.5885 59.7778 0.65
145 c/y -69.5885 84.6667 0.65
146 c/y -69.5885 109.556 0.65
147 c/y -69.5885 134.445 0.65
148 c/y -69.5885 159.333 0.65
149 c/y -69.5885 184.222 0.65
150 c/y -69.5885 209.111 0.65
151 c/y -69.5885 234 0.65
C plugs
152    pz    30.5   $bottom of plug steel plates/bottom of slabs
153    pz    31.14  $top of plug steel plates/bottom of plugs
154    c/z  -6.6244 -113.671 20.415 $30X0 1.2%B C inner wall inner paper
155    c/z  -6.6244 -113.671 20.765 $30X0 1.2%B C outer wall inner paper/inner plug wall
156    c/z  -6.6244 -113.671 38.1   $30X0 1.2%B C outer plug wall/outer paper inner wall/outer steel
plate
157    c/z  -6.6244 -113.671 38.86  $30X0 1.2%B C outer outer paper outer wall
158    pz  204.74                   $30X0 1.2%B C top of inner portion
163    c/z 6.8707  101.286  20.765  $22X16 1.1%B P inner steel plate/outer inner paper wall/inner
plug wall
164    c/z 6.8707  101.286  20.32  $22X16 1.1%B P inner paper inner wall
165    c/z 6.8707  101.286  27.94  $22X16 1.1%B P outer plug wall/outer paper inner wall/outer steel
plate
166    c/z 6.8707  101.286  28.51  $22X16 1.1%B P outer paper outer wall
169    pz  240.2  $top of slabs
170    px  54.5   $North edge of slabs
171    px -54.5   $South edge of slabs
172    py -54.8685 $east face of east slab
173    py -52.9685 $west face of east slab
174    py  54.551  $west face of west slab
175    py  52.651  $east face of west slab
c slab wood frame
300        py -56.1685  $east face of east slab frame of east slab
301        py -51.6685  $west face of west slab frame of east slab
302        px -58.3  $south end of slab frames
303        px  58.3  $north end of slab frames
304        pz   3.8  $top of bottom of frames
305        pz  26.7  $bottom of middle frame piece
306        py  55.851  $west face of west slab frame of west slab
307        py  51.351  $east face of east slab frame of west slab
200  pz 0.5 $bottom of plug stand plywood
201  pz 30  $top of plug stand plywood
```

```
c East plug stand
202  py -133.801    $west face of east plywood/east side of east legs
203  py  -93.541    $east face of west plywood/west side of west legs
204  py -135.101    $east face of east plywood
205  py  -92.241    $west face of west plywood
206  px  -26.7544   $north face of south plywood/south side of south legs
207  px   13.5056   $south face of north plywood/north side of north legs
208  px  -28.0544   $south face of south plywood
209  px   14.8056   $north face of north plywood
210  px  -19.1244   $south end of plywood
211  px    5.8756   $north end of plywood
212  py -126.171    $east end of plywood
213  py -101.171    $west end of plywood
214  py -124.901    $west side of east legs
215  py -102.441    $east side of west legs
216  px  -17.8544   $north side of south legs
217  px    4.6056   $south side of north legs
c Middle plug stand
218  py -17.6777  $west face of east plywood/east side of east legs
219  py  17.6777  $east face of west plywood/west side of west legs
220  py -18.9777  $east face of east plywood
221  py  18.9777  $west face of west plywood
222  px -17.6777  $north face of south plywood/south side of south legs
223  px  17.6777  $south face of north plywood/north side of north legs
224  px -18.9777  $south face of south plywood
225  px  18.9777  $north face of north plywood
226  px -12.5     $south end of plywood
227  px  12.5     $north end of plywood
228  py -12.5     $east end of plywood
229  py  12.5     $west end of plywood
230  py -8.7777   $west side of east legs
231  py  8.7777   $east side of west legs
232  px -8.7777   $north side of south legs
233  px  8.7777   $south side of north legs
c West plug stand
234  py  85.3761  $west face of east plywood/east side of east legs
235  py 117.196   $east face of west plywood/west side of west legs
236  py  84.0761  $east face of east plywood
237  py 118.496   $west face of west plywood
238  px  -9.2228  $north face of south plywood/south side of south legs
239  px  22.597   $south face of north plywood/north side of north legs
240  px -10.5228  $south face of south plywood
241  px  23.897   $north face of north plywood
242  px  -5.8129  $south end of plywood
243  px  19.1871  $north end of plywood
244  py  88.786   $east end of plywood
245  py 113.786   $west end of plywood
246  py  94.2761  $west side of east legs
247  py 108.296   $east side of west legs
248  px  -0.3228  $north side of south legs
249  px  13.697   $south side of north legs

C      Data Cards
*tr1 0 0 0 120 30 90 210 120 90 90 90 0
*tr2 0 0 0 60 30 90 150 60 90 90 90 0
*tr3 -6.6244 -113.671 0 120 30 90 210 120 90 90 90 0
*tr4 -6.6244 -113.671 0 60 30 90 150 60 90 90 90 0
*tr5 6.8707 101.286 0 120 30 90 210 120 90 90 90 0
*tr6 6.8707 101.286 0 60 30 90 150 60 90 90 90 0
C      Materials Cards
m1     1001.62c  1.4544e-2  $Boron-free concrete
       6000.66c  8.1181e-6
       8016.62c  4.5277e-2
       8017.66c  1.7212e-5
       11023.62c 5.7811e-5
       12000.62c 2.5732e-4
       13027.62c 3.0579e-3
       14028.62c 1.3683e-2
       14029.62c 6.9480e-4
       14030.62c 4.5802e-4
       16000.62c 6.7855e-5
```

```
        19000.62c 1.0740e-4
        20000.62c 2.0894e-3
        22000.62c 8.5175e-5
        23000.62c 3.5304e-6
        25055.62c 9.3431e-6
        26054.62c 3.6343e-5
        26056.62c 5.7050e-4
        26057.62c 1.3175e-5
        26058.62c 1.7534e-6
        28058.62c 2.0861e-7
        28060.62c 8.0355e-8
        28061.62c 3.4930e-9
        28062.62c 1.1137e-8
        28064.62c 2.8363e-9
        37085.66c 6.3564e-7
        37087.66c 2.4511e-7
        40000.66c 1.9714e-7
        56138.66c 9.3137e-6
        73181.66c 5.2937e-6
m2      1001.62c  2.0391e-5 $Tank steel
        6000.66c  5.0326e-5
        7014.62c  2.6142e-4
        7015.66c  9.6558e-7
        8016.62c  4.3305e-5
        8017.66c  1.6462e-8
        13027.62c 1.1948e-5
        16000.62c 3.0157e-6
        22000.62c 5.8915e-6
        23000.62c 8.4802e-5
        24050.62c 8.0819e-4
        24052.62c 1.5585e-2
        24053.62c 1.7672e-3
        24054.62c 4.3990e-4
        25055.62c 1.9365e-3
        26054.62c 3.3758e-3
        26056.62c 5.2993e-2
        26057.62c 1.2238e-3
        26058.62c 1.6287e-4
        27059.66c 1.6001e-4
        28058.62c 5.8896e-3
        28060.62c 2.2687e-3
        28061.62c 9.8618e-5
        28062.62c 3.1444e-4
        28064.62c 8.0078e-5
        42000.66c 9.9968e-5
        82206.66c 7.0307e-7
        82207.66c 6.8557e-7
        82208.66c 1.5287e-6
m3      1001.62c  5.8296e-2 $uranyl nitrate solution
        5010.66c  1.7432e-8
        5011.66c  7.0165e-8
        7014.62c  2.1685e-3
        7015.66c  8.0096e-6
        8016.62c  3.7320e-2
        8017.66c  1.4187e-5
        12000.62c 2.2138e-6
        13027.62c 2.7919e-6
        14028.62c 3.0392e-7
        14029.62c 1.5432e-8
        14030.62c 1.0173e-8
        25055.62c 1.0578e-7
        26054.62c 1.1601e-7
        26056.62c 1.8211e-6
        26057.62c 4.2057e-8
        26058.62c 5.5970e-9
        28058.62c 1.7226e-7
        28060.62c 6.6355e-8
        28061.62c 2.8844e-9
        28062.62c 9.1967e-9
        28064.62c 2.3421e-9
        29063.62c 1.8977e-7
```

```
        29065.62c 8.4581e-8
        42000.66c 1.6825e-7
        48106.66c 1.8668e-10
        48108.66c 1.3292e-10
        48110.66c 1.8653e-9
        48111.66c 1.9116e-9
        48112.66c 3.6037e-9
        48113.66c 1.8250e-9
        48114.66c 4.2907e-9
        48116.66c 1.1186e-9
        82206.66c 1.1015e-8
        82207.66c 1.0741e-8
        82208.66c 2.3950e-8
        83209.66c 7.0034e-9
        92234.66c 9.0307e-6
        92235.66c 8.5361e-4
        92236.66c 3.9390e-6
        92238.66c 4.8525e-5
mt3     lwtr.60t
m4      6000.66c  1.9600e-3  $Rebar in walls 8.5860E-02
        26054.62c 4.9040e-3
        26056.62c 7.6982e-2
        26057.62c 1.7778e-3
        26058.62c 2.3660e-4
m5      1001.62c  1.6944e-2 $ 1.2% B concrete
        3006.66c  5.0933e-7
        3007.66c  6.2012e-6
        5010.66c  2.9540e-4
        5011.66c  1.1890e-3
        6000.66c  4.8574e-5
        8016.62c  4.3204e-2
        8017.66c  1.6424e-5
        11023.62c 4.1850e-4
        12000.62c 4.7364e-4
        13027.62c 2.4910e-3
        14028.62c 1.1089e-2
        14029.62c 5.6307e-4
        14030.62c 3.7118e-4
        16000.62c 9.0706e-5
        19000.62c 9.7433e-5
        20000.62c 3.5242e-3
        22000.62c 6.3443e-5
        23000.62c 4.7184e-6
        25055.62c 8.7199e-6
        26054.62c 3.1167e-5
        26056.62c 4.8926e-4
        26057.62c 1.1299e-5
        26058.62c 1.5037e-6
        28058.62c 2.7881e-7
        28060.62c 1.0740e-7
        28061.62c 4.6684e-9
        28062.62c 2.9770e-8
        28064.62c 3.7908e-9
        37085.66c 6.4636e-7
        37087.66c 2.4925e-7
        40000.66c 2.6349e-7
        56138.66c 7.4104e-6
        73181.66c 4.4063e-6
m7      1001.62c  6.8858e-3 $ paper sonotubes
        6000.66c  4.1315e-3
        8016.62c  3.4416e-3
        8017.66c  1.3083e-6
m8      1001.62c  3.2048e-2 $ 1.1% B plaster
        3006.66c  3.8822e-7
        3007.66c  4.7267e-6
        5010.66c  2.2427e-4
        5011.66c  9.0271e-4
        6000.66c  3.9938e-4
        8016.62c  4.0166e-2
        8017.66c  1.5269e-5
        11023.62c 2.9613e-4
```

```
       12000.62c 2.3086e-4
       13027.62c 1.7055e-4
       14028.62c 8.2598e-4
       14029.62c 4.1941e-5
       14030.62c 2.7648e-5
       16000.62c 5.0862e-3
       19000.62c 1.6873e-5
       20000.62c 5.6862e-3
       26054.62c 1.7996e-6
       26056.62c 2.8250e-5
       26057.62c 6.5243e-7
       26058.62c 8.6826e-8
       56138.66c 1.7627e-7
m11    1001.62c  2.2298e-2 $wood modeled as cellulose
       6000.66c  1.3369e-2
       8016.62c  1.1139e-2
       8017.66c  4.2343e-6
C      Criticality control cards
kcode 50000 1.0 100 2100
ksrc 37.8092 0 23.78  -37.8092 0 23.78
     0 37.8092 47.56  0 -37.8092 47.56
     43.748 0 47.56  -43.748 0 47.56
     0 43.748 23.78  0 -43.748 23.78
```

MCNP5 ENDF/B-VI (Simple Model) Input Listing for Experiment 1a of Table 91.

```
1X3 array of nested tanks,Experiment 1a Simple
C      Cell Cards
C Everything but tanks and void space
1     1  -2.29  (-1 2 -3 4 -5 6):(4 -3 -5 12 1 -10):(-12 11 -3 13 -10 1):(1 -10
                -11 6 14 -3) imp:n=1 $platform/panels
2     1  -2.29  (2 -8 6 -5 -4 7):(2 -8 -3 7 -6 9) imp:n=1  $walls
C Tanks
3     2  -8.03  (1 -15 29 -28):(-25 24 28 -27):(-15 24 27 -26) imp:n=1  $Tank 1
4     2  -8.03  (1 -15 33 -32):(-25 24 32 -31):(-15 24 31 -30) imp:n=1  $Tank 2
5     2  -8.03  (1 -15 37 -36):(-25 24 36 -35):(-15 24 35 -34) imp:n=1  $Tank 3
6     2  -8.03  (1 -15 41 -40):(-25 24 40 -39):(-15 24 39 -38) imp:n=1  $Tank 4
7     2  -8.03  (1 -15 20 -21):(-25 24 21 -22):(-15 24 22 -23) imp:n=1  $Tank 2*
8     2  -8.03  (1 -15 16 -17):(-25 24 17 -18):(-15 24 18 -19) imp:n=1  $Tank 3*
C solution
9     3  -1.4982  -42 25 28 -27   imp:n=1  $in tank 1
10    3  -1.4982  -42 25 32 -31   imp:n=1  $in tank 2
11    3  -1.4982  -42 25 36 -35   imp:n=1  $in tank 3
12    3  -1.4982  -42 25 40 -39   imp:n=1  $in tank 4
13    3  -1.4982  -42 25 21 -22   imp:n=1  $in tank 2*
14    3  -1.4982  -42 25 17 -18   imp:n=1  $in tank 3*
C Void space
15    0  -7:-9:5:3:-2:8:(10 -8 -5 6 4 -3) imp:n=0 $Big Void outside enclosure
16    0  (4 -14 -11 6 1 -10):(15 -10 11 -12 4 -13):(1 -15 11 -12 4 -13 26 23 34)
         :(1 28 -24 -26):(1 21 -24 -23):(1 36 -24 -34) imp:n=1 $SE corner,between tanks and panels
17    0  1 -15 -33 imp:n=1  $middle of tank 2
18    0  1 -15 -16 imp:n=1  $middle of tank 3*
19    0  1 -15 -41 imp:n=1  $middle of tank 4
20    0  (1 -24 32 -29):(-15 24 30 -29)  imp:n=1  $between tanks 1 and 2
21    0  (1 -24 17 -20):(-15 24 19 -20)  imp:n=1  $between tanks 2* and 3*
22    0  (1 -24 40 -37):(-15 24 38 -37)  imp:n=1  $between tanks 3 and 4
23    0  42 -15 28 -27  imp:n=1  $annular void tank 1
24    0  42 -15 32 -31  imp:n=1  $annular void tank 2
25    0  42 -15 36 -35  imp:n=1  $annular void tank 3
26    0  42 -15 40 -39  imp:n=1  $annular void tank 4
27    0  42 -15 21 -22  imp:n=1  $annular void tank 2*
28    0  42 -15 17 -18  imp:n=1  $annular void tank 3*

C      Surface Cards
1     pz    0.0    $top of platform where panels and tanks are placed on
2     pz  -20.3    $bottom of platform, bottom of east and south walls
3     py  168.759  $West end of platform and west side of panels
4     py -173.939  $East end of platform and east wall
5     px   79.5785 $North side of platform and north side of panels
6     px  -79.7385 $South side of platform and south wall
7     py -295.939  $Outer east wall
8     pz  343.9    $Top of east and south walls
9     px -201.739  $Outer south wall
10    pz  244.0    $Top of panels
11    px  -59.4385 $South inner panel wall
12    px   59.2785 $North inner panel wall
13    py  148.459  $West inner panel wall
14    py -112.039  $End of south panel on east side
15    pz  243.9    $Top of tanks
16    cz   35.2832 $Tank 3* inner cylinder inner wall
17    cz   35.9232 $Tank 3* inner cylinder outer wall
18    cz   39.6952 $Tank 3* outer cylinder inner wall
19    cz   40.3352 $Tank 3* outer cylinder outer wall
20    cz   41.2375 $Tank 2* inner cylinder inner wall
21    cz   41.8775 $Tank 2* inner cylinder outer wall
22    cz   45.6185 $Tank 2* outer cylinder inner wall
23    cz   46.2585 $Tank 2* outer cylinder outer wall
24    pz   31.26   $New position for tank bottoms
25    pz   31.90   $Top of tank bottom steel union piece/bottom of solution
26    c/z  -6.6244 -113.671 52.0929 $Tank 1 outer cylinder outer wall
27    c/z  -6.6244 -113.671 51.4529 $Tank 1 outer cylinder inner wall
28    c/z  -6.6244 -113.671 47.6149 $Tank 1 inner cylinder outer wall
29    c/z  -6.6244 -113.671 46.9749 $Tank 1 inner cylinder inner wall
30    c/z  -6.6244 -113.671 46.2077 $Tank 2 outer cylinder outer wall
31    c/z  -6.6244 -113.671 45.5677 $Tank 2 outer cylinder inner wall
```

```
32    c/z  -6.6244 -113.671 41.7197 $Tank 2 inner cylinder outer wall
33    c/z  -6.6244 -113.671 41.0797 $Tank 2 inner cylinder inner wall
34    c/z   6.8707  101.286 40.3428 $Tank 3 outer cylinder outer wall
35    c/z   6.8707  101.286 39.7028 $Tank 3 outer cylinder inner wall
36    c/z   6.8707  101.286 35.8568 $Tank 3 inner cylinder outer wall
37    c/z   6.8707  101.286 35.2168 $Tank 3 inner cylinder inner wall
38    c/z   6.8707  101.286 34.4703 $Tank 4 outer cylinder outer wall
39    c/z   6.8707  101.286 33.8303 $Tank 4 outer cylinder inner wall
40    c/z   6.8707  101.286 30.0483 $Tank 4 inner cylinder outer wall
41    c/z   6.8707  101.286 29.4083 $Tank 4 inner cylinder inner wall
42    pz  103.24   $Top of solution level for all tanks

C      Data Cards
C      Materials Cards
m1     1001.62c  1.4544e-2  $Boron-free concrete
       6000.66c  8.1181e-6
       8016.62c  4.5277e-2
       8017.66c  1.7212e-5
       11023.62c 5.7811e-5
       12000.62c 2.5732e-4
       13027.62c 3.0579e-3
       14028.62c 1.3683e-2
       14029.62c 6.9480e-4
       14030.62c 4.5802e-4
       16000.62c 6.7855e-5
       19000.62c 1.0740e-4
       20000.62c 2.0894e-3
       22000.62c 8.5175e-5
       23000.62c 3.5304e-6
       25055.62c 9.3431e-6
       26054.62c 3.6343e-5
       26056.62c 5.7050e-4
       26057.62c 1.3175e-5
       26058.62c 1.7534e-6
       28058.62c 2.0861e-7
       28060.62c 8.0355e-8
       28061.62c 3.4930e-9
       28062.62c 1.1137e-8
       28064.62c 2.8363e-9
       37085.66c 6.3564e-7
       37087.66c 2.4511e-7
       40000.66c 1.9714e-7
       56138.66c 9.3137e-6
       73181.66c 5.2937e-6
m2     1001.62c  2.0391e-5 $Tank steel
       6000.66c  5.0326e-5
       7014.62c  2.6142e-4
       7015.66c  9.6558e-7
       8016.62c  4.3305e-5
       8017.66c  1.6462e-8
       13027.62c 1.1948e-5
       16000.62c 3.0157e-6
       22000.62c 5.8915e-6
       23000.62c 8.4802e-5
       24050.62c 8.0819e-4
       24052.62c 1.5585e-2
       24053.62c 1.7672e-3
       24054.62c 4.3990e-4
       25055.62c 1.9365e-3
       26054.62c 3.3758e-3
       26056.62c 5.2993e-2
       26057.62c 1.2238e-3
       26058.62c 1.6287e-4
       27059.66c 1.6001e-4
       28058.62c 5.8896e-3
       28060.62c 2.2687e-3
       28061.62c 9.8618e-5
       28062.62c 3.1444e-4
       28064.62c 8.0078e-5
       42000.66c 9.9968e-5
       82206.66c 7.0307e-7
```

```
       82207.66c 6.8557e-7
       82208.66c 1.5287e-6
m3     1001.62c  5.8296e-2 $uranyl nitrate solution
       5010.66c  1.7432e-8
       5011.66c  7.0165e-8
       7014.62c  2.1685e-3
       7015.66c  8.0096e-6
       8016.62c  3.7320e-2
       8017.66c  1.4187e-5
       12000.62c 2.2138e-6
       13027.62c 2.7919e-6
       14028.62c 3.0392e-7
       14029.62c 1.5432e-8
       14030.62c 1.0173e-8
       25055.62c 1.0578e-7
       26054.62c 1.1601e-7
       26056.62c 1.8211e-6
       26057.62c 4.2057e-8
       26058.62c 5.5970e-9
       28058.62c 1.7226e-7
       28060.62c 6.6355e-8
       28061.62c 2.8844e-9
       28062.62c 9.1967e-9
       28064.62c 2.3421e-9
       29063.62c 1.8977e-7
       29065.62c 8.4581e-8
       42000.66c 1.6825e-7
       48106.66c 1.8668e-10
       48108.66c 1.3292e-10
       48110.66c 1.8653e-9
       48111.66c 1.9116e-9
       48112.66c 3.6037e-9
       48113.66c 1.8250e-9
       48114.66c 4.2907e-9
       48116.66c 1.1186e-9
       82206.66c 1.1015e-8
       82207.66c 1.0741e-8
       82208.66c 2.3950e-8
       83209.66c 7.0034e-9
       92234.66c 9.0307e-6
       92235.66c 8.5361e-4
       92236.66c 3.9390e-6
       92238.66c 4.8525e-5
mt3    lwtr.60t
C      Criticality control cards
kcode 50000 1.0 100 2100
ksrc 37.8092 0 23.78  -37.8092 0 23.78
     0 37.8092 47.56  0 -37.8092 47.56
     43.748 0 47.56  -43.748 0 47.56
     0 43.748 23.78  0 -43.748 23.78
```

MCNP5 ENDF/B-VI (Simple Model) Input Listing for Experiment 2a of Table 91.

```
1X3 array of nested tanks, Experiment 2a Simple
C   5                                                                       80
C      Cell Cards
C Everything but tanks and void space
1     1  -2.29  (-1 2 -3 4 -5 6):(4 -3 -5 12 1 -10):(-12 11 -3 13 -10 1):(1 -10
                -11 6 14 -3) imp:n=1 $platform/panels
2     1  -2.29  (2 -8 6 -5 -4 7):(2 -8 -3 7 -6 9) imp:n=1  $walls
C Tanks
3     2  -8.03  (1 -15 29 -28):(-25 24 28 -27):(-15 24 27 -26) imp:n=1  $Tank 1
4     2  -8.03  (1 -15 33 -32):(-25 24 32 -31):(-15 24 31 -30) imp:n=1  $Tank 2
5     2  -8.03  (1 -15 37 -36):(-25 24 36 -35):(-15 24 35 -34) imp:n=1  $Tank 3
6     2  -8.03  (1 -15 41 -40):(-25 24 40 -39):(-15 24 39 -38) imp:n=1  $Tank 4
7     2  -8.03  (1 -15 20 -21):(-25 24 21 -22):(-15 24 22 -23) imp:n=1  $Tank 2*
8     2  -8.03  (1 -15 16 -17):(-25 24 17 -18):(-15 24 18 -19) imp:n=1  $Tank 3*
C solution
9     3  -1.4982  -42 25 28 -27   imp:n=1  $in tank 1
10    3  -1.4982  -42 25 32 -31   imp:n=1  $in tank 2
11    3  -1.4982  -42 25 36 -35   imp:n=1  $in tank 3
12    3  -1.4982  -42 25 40 -39   imp:n=1  $in tank 4
13    3  -1.4982  -42 25 21 -22   imp:n=1  $in tank 2*
14    3  -1.4982  -42 25 17 -18   imp:n=1  $in tank 3*
C Void space
15    0  -7:-9:5:3:-2:8:(10 -8 -5 6 4 -3) imp:n=0 $Big Void outside enclosure
16    0  (4 -14 -11 6 1 -10):(15 -10 11 -12 4 -13):(1 -15 11 -12 4 -13 26 23 34)
         :(1 28 -24 -26):(1 21 -24 -23):(1 36 -24 -34) imp:n=1 $SE corner,between tanks and panels
17    0  (1 -33 -43):(43 -15 -33 48):(43 -44 47 -48) imp:n=1  $betweeb tank 2 and plug
18    0  (1 -16 -43):(43 -15 -16 53):(43 -44 52 -53) imp:n=1  $between tank 3* and plug
19    0  (1 -43 -41):(43 -15 -41 57):(43 -44 -57 56) imp:n=1  $betweeb tank 4 and plug
20    0  (1 -24 32 -29):(-15 24 30 -29)  imp:n=1  $between tanks 1 and 2
21    0  (1 -24 17 -20):(-15 24 19 -20)  imp:n=1  $between tanks 2* and 3*
22    0  (1 -24 40 -37):(-15 24 38 -37)  imp:n=1  $between tanks 3 and 4
23    0  42 -15 28 -27  imp:n=1  $annular void tank 1
24    0  42 -15 32 -31  imp:n=1  $annular void tank 2
25    0  42 -15 36 -35  imp:n=1  $annular void tank 3
26    0  42 -15 40 -39  imp:n=1  $annular void tank 4
27    0  42 -15 21 -22  imp:n=1  $annular void tank 2*
28    0  42 -15 17 -18  imp:n=1  $annular void tank 3*
C plugs
29    2  -8.03  43 -44 -47  imp:n=1  $30X0 1.2%B C steel plate
30    7  -0.1854  44 -49 45 -46  imp:n=1  $30X0 1.2%B C inner paper
31    5  -2.22  (44 -49 46 -47):(-15 49 -47)  imp:n=1  $30X0 1.2%B concrete plug
32    7  -0.1854  44 -15 -48 47 imp:n=1  $outer paper 30X0 1.2%B C
33    0  -45 44 -49  imp:n=1  $in middle of 30X0 1.2%B C plug
34    2  -8.03  43 -44 -52 50  imp:n=1  $24X10 1.2%B C steel plate
35    7  -0.1854  -15 44 51 -50 imp:n=1  $24X10 1.2%B C inner paper
36    5  -2.22  -15 44 50 -52  imp:n=1 $24X10 1.2%B concrete plug
37    7  -0.1854  -15 44 52 -53  imp:n=1  $24X10 1.2%B C outer paper
38    0  (-15 44 -51):(-44 43 -50) imp:n=1  $in middle of 24X10 1.2%B C plug
39    2  -8.03  43 -44 -56 54  imp:n=1  $22X8 1.2%B C steel plate
40    7  -0.1854  -15 44 -54 55 imp:n=1 $22X8 1.2%B C inner paper
41    5  -2.22  -15 44 54 -56  imp:n=1  $22X8 1.2%B Concrete plug
42    7  -0.1854  -15 44 56 -57  imp:n=1  $22X8 1.2%B C outer paper
43    0  (-15 44 -55):(-44 43 -54) imp:n=1 $in middle of 22X8 1.2%B Concrete plug

C      Surface Cards
1      pz    0.0    $top of platform where panels and tanks are placed on
2      pz  -20.3    $bottom of platform, bottom of east and south walls
3      py  168.759  $West end of platform and west side of panels
4      py -173.939  $East end of platform and east wall
5      px   79.5785 $North side of platform and north side of panels
6      px  -79.7385 $South side of platform and south wall
7      py -295.939  $Outer east wall
8      pz  343.9    $Top of east and south walls
9      px -201.739  $Outer south wall
10     pz  244.0    $Top of panels
11     px  -59.4385 $South inner panel wall
12     px   59.2785 $North inner panel wall
13     py  148.459  $West inner panel wall
14     py -112.039  $End of south panel on east side
```

```
15    pz  243.9    $Top of tanks
16    cz   35.2832 $Tank 3* inner cylinder inner wall
17    cz   35.9232 $Tank 3* inner cylinder outer wall
18    cz   39.6952 $Tank 3* outer cylinder inner wall
19    cz   40.3352 $Tank 3* outer cylinder outer wall
20    cz   41.2375 $Tank 2* inner cylinder inner wall
21    cz   41.8775 $Tank 2* inner cylinder outer wall
22    cz   45.6185 $Tank 2* outer cylinder inner wall
23    cz   46.2585 $Tank 2* outer cylinder outer wall
24    pz   31.26   $New position for tank bottoms
25    pz   31.90   $Top of tank bottom steel union piece/bottom of solution
26    c/z  -6.6244 -113.671 52.0929 $Tank 1 outer cylinder outer wall
27    c/z  -6.6244 -113.671 51.4529 $Tank 1 outer cylinder inner wall
28    c/z  -6.6244 -113.671 47.6149 $Tank 1 inner cylinder outer wall
29    c/z  -6.6244 -113.671 46.9749 $Tank 1 inner cylinder inner wall
30    c/z  -6.6244 -113.671 46.2077 $Tank 2 outer cylinder outer wall
31    c/z  -6.6244 -113.671 45.5677 $Tank 2 outer cylinder inner wall
32    c/z  -6.6244 -113.671 41.7197 $Tank 2 inner cylinder outer wall
33    c/z  -6.6244 -113.671 41.0797 $Tank 2 inner cylinder inner wall
34    c/z   6.8707  101.286 40.3428 $Tank 3 outer cylinder outer wall
35    c/z   6.8707  101.286 39.7028 $Tank 3 outer cylinder inner wall
36    c/z   6.8707  101.286 35.8568 $Tank 3 inner cylinder outer wall
37    c/z   6.8707  101.286 35.2168 $Tank 3 inner cylinder inner wall
38    c/z   6.8707  101.286 34.4703 $Tank 4 outer cylinder outer wall
39    c/z   6.8707  101.286 33.8303 $Tank 4 outer cylinder inner wall
40    c/z   6.8707  101.286 30.0483 $Tank 4 inner cylinder outer wall
41    c/z   6.8707  101.286 29.4083 $Tank 4 inner cylinder inner wall
42    pz  166.54   $Top of solution level for all tanks
43    pz    30.5   $bottom of plug steel plates
44    pz    31.14  $top of plug steel plates/bottom of plugs
45    c/z  -6.6244 -113.671 20.415 $30X0 1.2%B C inner wall inner paper
46    c/z  -6.6244 -113.671 20.765 $30X0 1.2%B C outer wall inner paper/inner plug wall
47    c/z  -6.6244 -113.671 38.1  $30X0 1.2%B C outer plug wall/outer paper inner wall/outer steel
plate
48    c/z  -6.6244 -113.671 38.86  $30X0 1.2%B C outer outer paper outer wall
49    pz  204.74  $30X0 1.2%B C top of inner portion
50    cz  13.08  $24X10 1.2%B C steel plate inner wall/outer wall inner paper/plug inner wall
51    cz  12.7   $24X10 1.2%B C inner wall inner paper
52    cz  30.48  $24X10 1.2%B C outer plug wall/outer paper inner wall/outer steel plate
53    cz  31.05  $24X10 1.2%B C outer paper outer wall
54    c/z 6.8707  101.286  10.48  $22X8 1.2%B C inner steel plate/outer inner paper wall/inner plug
wall
55    c/z 6.8707  101.286  10.16  $22X8 1.2%B C inner paper inner wall
56    c/z 6.8707  101.286  27.94  $22X8 1.2%B C outer plug wall/outer paper inner wall/outer steel
plate
57    c/z 6.8707  101.286  28.51  $22X8 1.2%B C outer paper outer wall

C      Data Cards
C      Materials Cards
m1     1001.62c  1.4544e-2  $Boron-free concrete
       6000.66c  8.1181e-6
       8016.62c  4.5277e-2
       8017.66c  1.7212e-5
       11023.62c 5.7811e-5
       12000.62c 2.5732e-4
       13027.62c 3.0579e-3
       14028.62c 1.3683e-2
       14029.62c 6.9480e-4
       14030.62c 4.5802e-4
       16000.62c 6.7855e-5
       19000.62c 1.0740e-4
       20000.62c 2.0894e-3
       22000.62c 8.5175e-5
       23000.62c 3.5304e-6
       25055.62c 9.3431e-6
       26054.62c 3.6343e-5
       26056.62c 5.7050e-4
       26057.62c 1.3175e-5
       26058.62c 1.7534e-6
       28058.62c 2.0861e-7
       28060.62c 8.0355e-8
```

```
        28061.62c 3.4930e-9
        28062.62c 1.1137e-8
        28064.62c 2.8363e-9
        37085.66c 6.3564e-7
        37087.66c 2.4511e-7
        40000.66c 1.9714e-7
        56138.66c 9.3137e-6
        73181.66c 5.2937e-6
m2      1001.62c  2.0391e-5 $Tank steel
        6000.66c  5.0326e-5
        7014.62c  2.6142e-4
        7015.66c  9.6558e-7
        8016.62c  4.3305e-5
        8017.66c  1.6462e-8
        13027.62c 1.1948e-5
        16000.62c 3.0157e-6
        22000.62c 5.8915e-6
        23000.62c 8.4802e-5
        24050.62c 8.0819e-4
        24052.62c 1.5585e-2
        24053.62c 1.7672e-3
        24054.62c 4.3990e-4
        25055.62c 1.9365e-3
        26054.62c 3.3758e-3
        26056.62c 5.2993e-2
        26057.62c 1.2238e-3
        26058.62c 1.6287e-4
        27059.66c 1.6001e-4
        28058.62c 5.8896e-3
        28060.62c 2.2687e-3
        28061.62c 9.8618e-5
        28062.62c 3.1444e-4
        28064.62c 8.0078e-5
        42000.66c 9.9968e-5
        82206.66c 7.0307e-7
        82207.66c 6.8557e-7
        82208.66c 1.5287e-6
m3      1001.62c  5.8296e-2 $uranyl nitrate solution
        5010.66c  1.7432e-8
        5011.66c  7.0165e-8
        7014.62c  2.1685e-3
        7015.66c  8.0096e-6
        8016.62c  3.7320e-2
        8017.66c  1.4187e-5
        12000.62c 2.2138e-6
        13027.62c 2.7919e-6
        14028.62c 3.0392e-7
        14029.62c 1.5432e-8
        14030.62c 1.0173e-8
        25055.62c 1.0578e-7
        26054.62c 1.1601e-7
        26056.62c 1.8211e-6
        26057.62c 4.2057e-8
        26058.62c 5.5970e-9
        28058.62c 1.7226e-7
        28060.62c 6.6355e-8
        28061.62c 2.8844e-9
        28062.62c 9.1967e-9
        28064.62c 2.3421e-9
        29063.62c 1.8977e-7
        29065.62c 8.4581e-8
        42000.66c 1.6825e-7
        48106.66c 1.8668e-10
        48108.66c 1.3292e-10
        48110.66c 1.8653e-9
        48111.66c 1.9116e-9
        48112.66c 3.6037e-9
        48113.66c 1.8250e-9
        48114.66c 4.2907e-9
        48116.66c 1.1186e-9
        82206.66c 1.1015e-8
```

```
        82207.66c 1.0741e-8
        82208.66c 2.3950e-8
        83209.66c 7.0034e-9
        92234.66c 9.0307e-6
        92235.66c 8.5361e-4
        92236.66c 3.9390e-6
        92238.66c 4.8525e-5
mt3     lwtr.60t
m5      1001.62c  1.6944e-2 $ 1.2% B concrete
        3006.66c  5.0933e-7
        3007.66c  6.2012e-6
        5010.66c  2.9540e-4
        5011.66c  1.1890e-3
        6000.66c  4.8574e-5
        8016.62c  4.3204e-2
        8017.66c  1.6424e-5
        11023.62c 4.1850e-4
        12000.62c 4.7364e-4
        13027.62c 2.4910e-3
        14028.62c 1.1089e-2
        14029.62c 5.6307e-4
        14030.62c 3.7118e-4
        16000.62c 9.0706e-5
        19000.62c 9.7433e-5
        20000.62c 3.5242e-3
        22000.62c 6.3443e-5
        23000.62c 4.7184e-6
        25055.62c 8.7199e-6
        26054.62c 3.1167e-5
        26056.62c 4.8926e-4
        26057.62c 1.1299e-5
        26058.62c 1.5037e-6
        28058.62c 2.7881e-7
        28060.62c 1.0740e-7
        28061.62c 4.6684e-9
        28062.62c 2.9770e-8
        28064.62c 3.7908e-9
        37085.66c 6.4636e-7
        37087.66c 2.4925e-7
        40000.66c 2.6349e-7
        56138.66c 7.4104e-6
        73181.66c 4.4063e-6
m7      1001.62c  6.8858e-3 $ paper sonotubes
        6000.66c  4.1315e-3
        8016.62c  3.4416e-3
        8017.66c  1.3083e-6
C       Criticality control cards
kcode 50000 1.0 100 2100
ksrc 37.8092 0 23.78  -37.8092 0 23.78
     0 37.8092 47.56  0 -37.8092 47.56
     43.748 0 47.56  -43.748 0 47.56
     0 43.748 23.78  0 -43.748 23.78
```

MCNP5 ENDF/B-VI (Simple Model) Input Listing for Experiment 3a5a of Table 91.

```
1X3 array of nested tanks,Experiment 3a and 5a average Simple
C   5                                                                    80
C      Cell Cards
C Everything but tanks and void space
1     1  -2.29  (-1 2 -3 4 -5 6):(4 -3 -5 12 1 -10):(-12 11 -3 13 -10 1):(1 -10
                -11 6 14 -3) imp:n=1 $platform/panels
2     1  -2.29  (2 -8 6 -5 -4 7):(2 -8 -3 7 -6 9) imp:n=1  $walls
C Tanks
3     2  -8.03  (1 -15 29 -28):(-25 24 28 -27):(-15 24 27 -26) imp:n=1  $Tank 1
4     2  -8.03  (1 -15 33 -32):(-25 24 32 -31):(-15 24 31 -30) imp:n=1  $Tank 2
5     2  -8.03  (1 -15 37 -36):(-25 24 36 -35):(-15 24 35 -34) imp:n=1  $Tank 3
6     2  -8.03  (1 -15 41 -40):(-25 24 40 -39):(-15 24 39 -38) imp:n=1  $Tank 4
7     2  -8.03  (1 -15 20 -21):(-25 24 21 -22):(-15 24 22 -23) imp:n=1  $Tank 2*
8     2  -8.03  (1 -15 16 -17):(-25 24 17 -18):(-15 24 18 -19) imp:n=1  $Tank 3*
C solution
9     3  -1.4982  -42 25 28 -27   imp:n=1  $in tank 1
10    3  -1.4982  -42 25 32 -31   imp:n=1  $in tank 2
11    3  -1.4982  -42 25 36 -35   imp:n=1  $in tank 3
12    3  -1.4982  -42 25 40 -39   imp:n=1  $in tank 4
13    3  -1.4982  -42 25 21 -22   imp:n=1  $in tank 2*
14    3  -1.4982  -42 25 17 -18   imp:n=1  $in tank 3*
C Void space
15    0  -7:-9:5:3:-2:8:(10 -8 -5 6 4 -3) imp:n=0 $Big Void outside enclosure
16    0  (4 -14 -11 6 1 -10):(15 -10 11 -12 4 -13):(1 -15 11 -12 4 -13 26 23 34)
         :(1 28 -24 -26):(1 21 -24 -23):(1 36 -24 -34) imp:n=1 $SE corner,between tanks and panels
17    0  (1 -33 -43):(43 -15 -33 48):(43 -44 47 -48) imp:n=1  $betweeb tank 2 and plug
18    0  (1 -16 -43):(43 -15 -16 53):(43 -44 52 -53) imp:n=1  $between tank 3* and plug
19    0  (1 -43 -41):(43 -15 -41 57):(43 -44 -57 56) imp:n=1  $betweeb tank 4 and plug
20    0  (1 -24 32 -29):(-15 24 30 -29)  imp:n=1  $between tanks 1 and 2
21    0  (1 -24 17 -20):(-15 24 19 -20)  imp:n=1  $between tanks 2* and 3*
22    0  (1 -24 40 -37):(-15 24 38 -37)  imp:n=1  $between tanks 3 and 4
23    0  42 -15 28 -27  imp:n=1  $annular void tank 1
24    0  42 -15 32 -31  imp:n=1  $annular void tank 2
25    0  42 -15 36 -35  imp:n=1  $annular void tank 3
26    0  42 -15 40 -39  imp:n=1  $annular void tank 4
27    0  42 -15 21 -22  imp:n=1  $annular void tank 2*
28    0  42 -15 17 -18  imp:n=1  $annular void tank 3*
C plugs
29    2  -8.03  43 -44 -47       imp:n=1  $30X0 1.2%B C steel plate
30    7  -0.1854  44 -49 45 -46  imp:n=1  $30X0 1.2%B C inner paper
31    5  -2.22  (44 -49 46 -47):(-15 49 -47)  imp:n=1  $30X0 1.2%B concrete plug
32    7  -0.1854  44 -15 -48 47  imp:n=1  $outer paper 30X0 1.2%B C
33    0  -45 44 -49              imp:n=1  $in middle of 30X0 1.2%B C plug
34    2  -8.03  43 -44 -52 50      imp:n=1  $22x8 1.1%B P steel plate
35    7  -0.1854  -15 44 51 -50    imp:n=1  $22x8 1.1%B P inner paper
36    8  -1.875  -15 44 50 -52      imp:n=1  $22x8 1.1%B Plaster plug
37    7  -0.1854  -15 44 52 -53    imp:n=1  $22x8 1.1%B P outer paper
38    0  (-15 44 -51):(-44 43 -50) imp:n=1  $in middle of 22x8 1.1%B P plug
39    2  -8.03  43 -44 -56 54       imp:n=1  $22X16 1.1%B P steel plate
40    7  -0.1854  -15 44 -54 55     imp:n=1  $22X16 1.1%B P inner paper
41    8  -1.875  -15 44 54 -56       imp:n=1  $22X16 1.1%B Plaster plug
42    7  -0.1854  -15 44 56 -57     imp:n=1  $22X16 1.1%B P outer paper
43    0  (-15 44 -55):(-44 43 -54)  imp:n=1  $in middle of 22X16 1.1%B P Concrete plug

C      Surface Cards
1      pz    0.0    $top of platform where panels and tanks are placed on
2      pz  -20.3    $bottom of platform, bottom of east and south walls
3      py  168.759  $West end of platform and west side of panels
4      py -173.939  $East end of platform and east wall
5      px   79.5785 $North side of platform and north side of panels
6      px  -79.7385 $South side of platform and south wall
7      py -295.939  $Outer east wall
8      pz  343.9    $Top of east and south walls
9      px -201.739  $Outer south wall
10     pz  244.0    $Top of panels
11     px  -59.4385 $South inner panel wall
12     px   59.2785 $North inner panel wall
13     py  148.459  $West inner panel wall
14     py -112.039  $End of south panel on east side
```

```
15    pz  243.9    $Top of tanks
16    cz   35.2832 $Tank 3* inner cylinder inner wall
17    cz   35.9232 $Tank 3* inner cylinder outer wall
18    cz   39.6952 $Tank 3* outer cylinder inner wall
19    cz   40.3352 $Tank 3* outer cylinder outer wall
20    cz   41.2375 $Tank 2* inner cylinder inner wall
21    cz   41.8775 $Tank 2* inner cylinder outer wall
22    cz   45.6185 $Tank 2* outer cylinder inner wall
23    cz   46.2585 $Tank 2* outer cylinder outer wall
24    pz   31.26   $New position for tank bottoms
25    pz   31.90   $Top of tank bottom steel union piece/bottom of solution
26    c/z  -6.6244 -113.671 52.0929 $Tank 1 outer cylinder outer wall
27    c/z  -6.6244 -113.671 51.4529 $Tank 1 outer cylinder inner wall
28    c/z  -6.6244 -113.671 47.6149 $Tank 1 inner cylinder outer wall
29    c/z  -6.6244 -113.671 46.9749 $Tank 1 inner cylinder inner wall
30    c/z  -6.6244 -113.671 46.2077 $Tank 2 outer cylinder outer wall
31    c/z  -6.6244 -113.671 45.5677 $Tank 2 outer cylinder inner wall
32    c/z  -6.6244 -113.671 41.7197 $Tank 2 inner cylinder outer wall
33    c/z  -6.6244 -113.671 41.0797 $Tank 2 inner cylinder inner wall
34    c/z   6.8707  101.286 40.3428 $Tank 3 outer cylinder outer wall
35    c/z   6.8707  101.286 39.7028 $Tank 3 outer cylinder inner wall
36    c/z   6.8707  101.286 35.8568 $Tank 3 inner cylinder outer wall
37    c/z   6.8707  101.286 35.2168 $Tank 3 inner cylinder inner wall
38    c/z   6.8707  101.286 34.4703 $Tank 4 outer cylinder outer wall
39    c/z   6.8707  101.286 33.8303 $Tank 4 outer cylinder inner wall
40    c/z   6.8707  101.286 30.0483 $Tank 4 inner cylinder outer wall
41    c/z   6.8707  101.286 29.4083 $Tank 4 inner cylinder inner wall
42    pz  164.575   $Top of solution level for all tanks
43    pz    30.5   $bottom of plug steel plates
44    pz    31.14  $top of plug steel plates/bottom of plugs
45    c/z  -6.6244 -113.671 20.415 $30X0 1.2%B C inner wall inner paper
46    c/z  -6.6244 -113.671 20.765 $30X0 1.2%B C outer wall inner paper/inner plug wall
47    c/z  -6.6244 -113.671 38.1   $30X0 1.2%B C outer plug wall/outer paper inner wall/outer steel
plate
48    c/z  -6.6244 -113.671 38.86  $30X0 1.2%B C outer outer paper outer wall
49    pz  204.74                   $30X0 1.2%B C top of inner portion
50    cz  10.48  $22x8 1.1%B P steel plate inner wall/outer wall inner paper/plug inner wall
51    cz  10.16  $22x8 1.1%B P inner wall inner paper
52    cz  27.94  $22x8 1.1%B P outer plug wall/outer paper inner wall/outer steel plate
53    cz  28.51  $22x8 1.1%B P outer paper outer wall
54    c/z 6.8707  101.286  20.765  $22X16 1.1%B P inner steel plate/outer inner paper wall/inner
plug wall
55    c/z 6.8707  101.286  20.32   $22X16 1.1%B P inner paper inner wall
56    c/z 6.8707  101.286  27.94   $22X16 1.1%B P outer plug wall/outer paper inner wall
57    c/z 6.8707  101.286  28.51   $22X16 1.1%B P outer paper outer wall

C      Data Cards
C      Materials Cards
m1     1001.62c  1.4544e-2  $Boron-free concrete
       6000.66c  8.1181e-6
       8016.62c  4.5277e-2
       8017.66c  1.7212e-5
       11023.62c 5.7811e-5
       12000.62c 2.5732e-4
       13027.62c 3.0579e-3
       14028.62c 1.3683e-2
       14029.62c 6.9480e-4
       14030.62c 4.5802e-4
       16000.62c 6.7855e-5
       19000.62c 1.0740e-4
       20000.62c 2.0894e-3
       22000.62c 8.5175e-5
       23000.62c 3.5304e-6
       25055.62c 9.3431e-6
       26054.62c 3.6343e-5
       26056.62c 5.7050e-4
       26057.62c 1.3175e-5
       26058.62c 1.7534e-6
       28058.62c 2.0861e-7
       28060.62c 8.0355e-8
       28061.62c 3.4930e-9
```

```
        28062.62c 1.1137e-8
        28064.62c 2.8363e-9
        37085.66c 6.3564e-7
        37087.66c 2.4511e-7
        40000.66c 1.9714e-7
        56138.66c 9.3137e-6
        73181.66c 5.2937e-6
m2      1001.62c  2.0391e-5 $Tank steel
        6000.66c  5.0326e-5
        7014.62c  2.6142e-4
        7015.66c  9.6558e-7
        8016.62c  4.3305e-5
        8017.66c  1.6462e-8
        13027.62c 1.1948e-5
        16000.62c 3.0157e-6
        22000.62c 5.8915e-6
        23000.62c 8.4802e-5
        24050.62c 8.0819e-4
        24052.62c 1.5585e-2
        24053.62c 1.7672e-3
        24054.62c 4.3990e-4
        25055.62c 1.9365e-3
        26054.62c 3.3758e-3
        26056.62c 5.2993e-2
        26057.62c 1.2238e-3
        26058.62c 1.6287e-4
        27059.66c 1.6001e-4
        28058.62c 5.8896e-3
        28060.62c 2.2687e-3
        28061.62c 9.8618e-5
        28062.62c 3.1444e-4
        28064.62c 8.0078e-5
        42000.66c 9.9968e-5
        82206.66c 7.0307e-7
        82207.66c 6.8557e-7
        82208.66c 1.5287e-6
m3      1001.62c  5.8296e-2 $uranyl nitrate solution
        5010.66c  1.7432e-8
        5011.66c  7.0165e-8
        7014.62c  2.1685e-3
        7015.66c  8.0096e-6
        8016.62c  3.7320e-2
        8017.66c  1.4187e-5
        12000.62c 2.2138e-6
        13027.62c 2.7919e-6
        14028.62c 3.0392e-7
        14029.62c 1.5432e-8
        14030.62c 1.0173e-8
        25055.62c 1.0578e-7
        26054.62c 1.1601e-7
        26056.62c 1.8211e-6
        26057.62c 4.2057e-8
        26058.62c 5.5970e-9
        28058.62c 1.7226e-7
        28060.62c 6.6355e-8
        28061.62c 2.8844e-9
        28062.62c 9.1967e-9
        28064.62c 2.3421e-9
        29063.62c 1.8977e-7
        29065.62c 8.4581e-8
        42000.66c 1.6825e-7
        48106.66c 1.8668e-10
        48108.66c 1.3292e-10
        48110.66c 1.8653e-9
        48111.66c 1.9116e-9
        48112.66c 3.6037e-9
        48113.66c 1.8250e-9
        48114.66c 4.2907e-9
        48116.66c 1.1186e-9
        82206.66c 1.1015e-8
        82207.66c 1.0741e-8
```

```
       82208.66c 2.3950e-8
       83209.66c 7.0034e-9
       92234.66c 9.0307e-6
       92235.66c 8.5361e-4
       92236.66c 3.9390e-6
       92238.66c 4.8525e-5
mt3    lwtr.60t
m5     1001.62c  1.6944e-2 $ 1.2% B concrete
       3006.66c  5.0933e-7
       3007.66c  6.2012e-6
       5010.66c  2.9540e-4
       5011.66c  1.1890e-3
       6000.66c  4.8574e-5
       8016.62c  4.3204e-2
       8017.66c  1.6424e-5
       11023.62c 4.1850e-4
       12000.62c 4.7364e-4
       13027.62c 2.4910e-3
       14028.62c 1.1089e-2
       14029.62c 5.6307e-4
       14030.62c 3.7118e-4
       16000.62c 9.0706e-5
       19000.62c 9.7433e-5
       20000.62c 3.5242e-3
       22000.62c 6.3443e-5
       23000.62c 4.7184e-6
       25055.62c 8.7199e-6
       26054.62c 3.1167e-5
       26056.62c 4.8926e-4
       26057.62c 1.1299e-5
       26058.62c 1.5037e-6
       28058.62c 2.7881e-7
       28060.62c 1.0740e-7
       28061.62c 4.6684e-9
       28062.62c 2.9770e-8
       28064.62c 3.7908e-9
       37085.66c 6.4636e-7
       37087.66c 2.4925e-7
       40000.66c 2.6349e-7
       56138.66c 7.4104e-6
       73181.66c 4.4063e-6
m7     1001.62c  6.8858e-3 $ paper sonotubes
       6000.66c  4.1315e-3
       8016.62c  3.4416e-3
       8017.66c  1.3083e-6
m8     1001.62c  3.2048e-2 $ 1.1% B plaster
       3006.66c  3.8822e-7
       3007.66c  4.7267e-6
       5010.66c  2.2427e-4
       5011.66c  9.0271e-4
       6000.66c  3.9938e-4
       8016.62c  4.0166e-2
       8017.66c  1.5269e-5
       11023.62c 2.9613e-4
       12000.62c 2.3086e-4
       13027.62c 1.7055e-4
       14028.62c 8.2598e-4
       14029.62c 4.1941e-5
       14030.62c 2.7648e-5
       16000.62c 5.0862e-3
       19000.62c 1.6873e-5
       20000.62c 5.6862e-3
       26054.62c 1.7996e-6
       26056.62c 2.8250e-5
       26057.62c 6.5243e-7
       26058.62c 8.6826e-8
       56138.66c 1.7627e-7
C      Criticality control cards
kcode 50000 1.0 100 2100
ksrc 37.8092 0 23.78  -37.8092 0 23.78
     0 37.8092 47.56  0 -37.8092 47.56
```

```
43.748 0 47.56  -43.748 0 47.56
0 43.748 23.78  0 -43.748 23.78
```

MCNP5 ENDF/B-VI (Simple Model) Input Listing for Experiment 4 of Table 91.

```
1X3 array of nested tanks,Experiment 4 Simple
C   5                                                                        80
C      Cell Cards
C Concrete
1     1  -2.29  (-1 2 -3 4 -5 6):(4 -3 -5 12 1 -10):(-12 11 -3 13 -10 1):(1 -10
                -11 6 14 -3) imp:n=1 $platform/panels
2     1  -2.29  (2 -8 6 -5 -4 7):(2 -8 -3 7 -6 9) imp:n=1  $walls
C Tanks
3     2  -8.03  (1 -15 29 -28):(-25 24 28 -27):(-15 24 27 -26) imp:n=1  $Tank 1
4     2  -8.03  (1 -15 33 -32):(-25 24 32 -31):(-15 24 31 -30) imp:n=1  $Tank 2
5     2  -8.03  (1 -15 37 -36):(-25 24 36 -35):(-15 24 35 -34) imp:n=1  $Tank 3
6     2  -8.03  (1 -15 41 -40):(-25 24 40 -39):(-15 24 39 -38) imp:n=1  $Tank 4
7     2  -8.03  (1 -15 20 -21):(-25 24 21 -22):(-15 24 22 -23) imp:n=1  $Tank 2*
8     2  -8.03  (1 -15 16 -17):(-25 24 17 -18):(-15 24 18 -19) imp:n=1  $Tank 3*
C solution
9     3  -1.4982  -42 25 28 -27   imp:n=1  $in tank 1
10    3  -1.4982  -42 25 32 -31   imp:n=1  $in tank 2
11    3  -1.4982  -42 25 36 -35   imp:n=1  $in tank 3
12    3  -1.4982  -42 25 40 -39   imp:n=1  $in tank 4
13    3  -1.4982  -42 25 21 -22   imp:n=1  $in tank 2*
14    3  -1.4982  -42 25 17 -18   imp:n=1  $in tank 3*
C Void space
15    0  -7:-9:5:3:-2:8:(10 -8 -5 6 4 -3) imp:n=0 $Big Void outside enclosure
16    0  (4 -14 -11 6 1 -10):(15 -10 11 -12 4 -13):(1 -15 11 -12 4 -13 26 23 34)
         :(1 28 -24 -26):(1 21 -24 -23):(1 36 -24 -34) imp:n=1 $SE corner,between tanks and panels
17    0  (1 -33 -43):(43 -15 -33 48):(43 -44 47 -48) imp:n=1  $betweeb tank 2 and plug
18    0  (1 -16 -43):(43 -15 -16 53):(43 -44 52 -53) imp:n=1  $between tank 3* and plug
19    0  (1 -43 -41):(43 -15 -41 58):(43 -44 -58 56) imp:n=1  $betweeb tank 4 and plug
20    0  (1 -24 32 -29):(-15 24 30 -29)  imp:n=1  $between tanks 1 and 2
21    0  (1 -24 17 -20):(-15 24 19 -20)  imp:n=1  $between tanks 2* and 3*
22    0  (1 -24 40 -37):(-15 24 38 -37)  imp:n=1  $between tanks 3 and 4
23    0  42 -15 28 -27  imp:n=1  $annular void tank 1
24    0  42 -15 32 -31  imp:n=1  $annular void tank 2
25    0  42 -15 36 -35  imp:n=1  $annular void tank 3
26    0  42 -15 40 -39  imp:n=1  $annular void tank 4
27    0  42 -15 21 -22  imp:n=1  $annular void tank 2*
28    0  42 -15 17 -18  imp:n=1  $annular void tank 3*
C plugs
29    2  -8.03  43 -44 -47 46 imp:n=1  $30X18 2.5%B C steel plate
30    10  -8  44 -15 45 -46  imp:n=1  $30X18 2.5%B C culvert
31    6  -1.94  44 -15 46 -47  imp:n=1  $30X18 2.5%B concrete plug
32    7  -0.1854  44 -15 -48 47 imp:n=1  $outer paper 30X18 2.5%B C
33    0  (-45 44 -15):(43 -44 -46)  imp:n=1  $in middle of 30X18 2.5%B C plug
34    2  -8.03  43 -44 -52 50  imp:n=1  $22X16 2.5%B C steel plate
35    7  -0.1854  -15 44 51 -50 imp:n=1  $22X16 2.5%B C inner paper
36    6  -1.94  -15 44 50 -52  imp:n=1 $22X16 2.5%B concrete plug
37    7  -0.1854  -15 44 52 -53  imp:n=1  $22X16 2.5%B C outer paper
38    0  (-15 44 -51):(-44 43 -50) imp:n=1  $in middle of 22X16 2.5%B C plug
39    2  -8.03  43 -44 -56  imp:n=1  $22X0 0% C w/Cd steel plate
41    1  -2.29  -15 44 -56  imp:n=1  $22X0 0% w/Cd Concrete plug
42    7  -0.1854  -15 44 56 -57  imp:n=1  $22X0 0% C w/Cd outer paper
43    9  -8.65  -15 44 -58 57  imp:n=1 $cadmium lamination

C      Surface Cards
1     pz    0.0    $top of platform where panels and tanks are placed on
2     pz  -20.3    $bottom of platform, bottom of east and south walls
3     py  168.759  $West end of platform and west side of panels
4     py -173.939  $East end of platform and east wall
5     px   79.5785 $North side of platform and north side of panels
6     px  -79.7385 $South side of platform and south wall
7     py -295.939  $Outer east wall
8     pz  343.9    $Top of east and south walls
9     px -201.739  $Outer south wall
10    pz  244.0    $Top of panels
11    px  -59.4385 $South inner panel wall
12    px   59.2785 $North inner panel wall
13    py  148.459  $West inner panel wall
14    py -112.039  $End of south panel on east side
15    pz  243.9    $Top of tanks
```

```
16    cz   35.2832 $Tank 3* inner cylinder inner wall
17    cz   35.9232 $Tank 3* inner cylinder outer wall
18    cz   39.6952 $Tank 3* outer cylinder inner wall
19    cz   40.3352 $Tank 3* outer cylinder outer wall
20    cz   41.2375 $Tank 2* inner cylinder inner wall
21    cz   41.8775 $Tank 2* inner cylinder outer wall
22    cz   45.6185 $Tank 2* outer cylinder inner wall
23    cz   46.2585 $Tank 2* outer cylinder outer wall
24    pz   31.26   $New position for tank bottoms
25    pz   31.90   $Top of tank bottom steel union piece/bottom of solution
26    c/z  -6.6244 -113.671 52.0929 $Tank 1 outer cylinder outer wall
27    c/z  -6.6244 -113.671 51.4529 $Tank 1 outer cylinder inner wall
28    c/z  -6.6244 -113.671 47.6149 $Tank 1 inner cylinder outer wall
29    c/z  -6.6244 -113.671 46.9749 $Tank 1 inner cylinder inner wall
30    c/z  -6.6244 -113.671 46.2077 $Tank 2 outer cylinder outer wall
31    c/z  -6.6244 -113.671 45.5677 $Tank 2 outer cylinder inner wall
32    c/z  -6.6244 -113.671 41.7197 $Tank 2 inner cylinder outer wall
33    c/z  -6.6244 -113.671 41.0797 $Tank 2 inner cylinder inner wall
34    c/z   6.8707  101.286 40.3428 $Tank 3 outer cylinder outer wall
35    c/z   6.8707  101.286 39.7028 $Tank 3 outer cylinder inner wall
36    c/z   6.8707  101.286 35.8568 $Tank 3 inner cylinder outer wall
37    c/z   6.8707  101.286 35.2168 $Tank 3 inner cylinder inner wall
38    c/z   6.8707  101.286 34.4703 $Tank 4 outer cylinder outer wall
39    c/z   6.8707  101.286 33.8303 $Tank 4 outer cylinder inner wall
40    c/z   6.8707  101.286 30.0483 $Tank 4 inner cylinder outer wall
41    c/z   6.8707  101.286 29.4083 $Tank 4 inner cylinder inner wall
42    pz  158.89   $Top of solution level for all tanks
43    pz    30.5   $bottom of plug steel plates
44    pz    31.14  $top of plug steel plates/bottom of plugs
45    c/z  -6.6244 -113.671 23.475 $30X18 2.5%B C inner wall of culvert
46    c/z  -6.6244 -113.671 23.625  $30X18 2.5%B C outer wall of culvert/inner plug wall/inner steel
plate
47    c/z  -6.6244 -113.671 38.1   $30X18 2.5%B C outer plug wall/outer paper inner wall/outer steel
plate
48    c/z  -6.6244 -113.671 38.86  $30X18 2.5%B C outer outer paper outer wall
50    cz  20.765  $22X16 2.5%B C steel plate inner wall/outer wall inner paper/plug inner wall
51    cz  20.32   $22X16 2.5%B C inner wall inner paper
52    cz  27.94   $22X16 2.5%B C outer plug wall/outer paper inner wall/outer steel plate
53    cz  28.51   $22X16 2.5%B C outer paper outer wall
56    c/z 6.8707  101.286  27.94  $22X0 C w/Cd outer plug wall/outer paper inner wall/outer steel
plate
57    c/z 6.8707  101.286  28.51  $22X0 C w/Cd outer paper outer wall
58    c/z 6.8707  101.286  28.669  $cadmium lamination

C      Data Cards
C      Materials Cards
m1     1001.62c  1.4544e-2  $Boron-free concrete
       6000.66c  8.1181e-6
       8016.62c  4.5277e-2
       8017.66c  1.7212e-5
       11023.62c 5.7811e-5
       12000.62c 2.5732e-4
       13027.62c 3.0579e-3
       14028.62c 1.3683e-2
       14029.62c 6.9480e-4
       14030.62c 4.5802e-4
       16000.62c 6.7855e-5
       19000.62c 1.0740e-4
       20000.62c 2.0894e-3
       22000.62c 8.5175e-5
       23000.62c 3.5304e-6
       25055.62c 9.3431e-6
       26054.62c 3.6343e-5
       26056.62c 5.7050e-4
       26057.62c 1.3175e-5
       26058.62c 1.7534e-6
       28058.62c 2.0861e-7
       28060.62c 8.0355e-8
       28061.62c 3.4930e-9
       28062.62c 1.1137e-8
       28064.62c 2.8363e-9
```

```
        37085.66c 6.3564e-7
        37087.66c 2.4511e-7
        40000.66c 1.9714e-7
        56138.66c 9.3137e-6
        73181.66c 5.2937e-6
m2      1001.62c  2.0391e-5 $Tank steel
        6000.66c  5.0326e-5
        7014.62c  2.6142e-4
        7015.66c  9.6558e-7
        8016.62c  4.3305e-5
        8017.66c  1.6462e-8
        13027.62c 1.1948e-5
        16000.62c 3.0157e-6
        22000.62c 5.8915e-6
        23000.62c 8.4802e-5
        24050.62c 8.0819e-4
        24052.62c 1.5585e-2
        24053.62c 1.7672e-3
        24054.62c 4.3990e-4
        25055.62c 1.9365e-3
        26054.62c 3.3758e-3
        26056.62c 5.2993e-2
        26057.62c 1.2238e-3
        26058.62c 1.6287e-4
        27059.66c 1.6001e-4
        28058.62c 5.8896e-3
        28060.62c 2.2687e-3
        28061.62c 9.8618e-5
        28062.62c 3.1444e-4
        28064.62c 8.0078e-5
        42000.66c 9.9968e-5
        82206.66c 7.0307e-7
        82207.66c 6.8557e-7
        82208.66c 1.5287e-6
m3      1001.62c  5.8296e-2 $uranyl nitrate solution
        5010.66c  1.7432e-8
        5011.66c  7.0165e-8
        7014.62c  2.1685e-3
        7015.66c  8.0096e-6
        8016.62c  3.7320e-2
        8017.66c  1.4187e-5
        12000.62c 2.2138e-6
        13027.62c 2.7919e-6
        14028.62c 3.0392e-7
        14029.62c 1.5432e-8
        14030.62c 1.0173e-8
        25055.62c 1.0578e-7
        26054.62c 1.1601e-7
        26056.62c 1.8211e-6
        26057.62c 4.2057e-8
        26058.62c 5.5970e-9
        28058.62c 1.7226e-7
        28060.62c 6.6355e-8
        28061.62c 2.8844e-9
        28062.62c 9.1967e-9
        28064.62c 2.3421e-9
        29063.62c 1.8977e-7
        29065.62c 8.4581e-8
        42000.66c 1.6825e-7
        48106.66c 1.8668e-10
        48108.66c 1.3292e-10
        48110.66c 1.8653e-9
        48111.66c 1.9116e-9
        48112.66c 3.6037e-9
        48113.66c 1.8250e-9
        48114.66c 4.2907e-9
        48116.66c 1.1186e-9
        82206.66c 1.1015e-8
        82207.66c 1.0741e-8
        82208.66c 2.3950e-8
        83209.66c 7.0034e-9
```

```
       92234.66c 9.0307e-6
       92235.66c 8.5361e-4
       92236.66c 3.9390e-6
       92238.66c 4.8525e-5
mt3    lwtr.60t
m6     1001.62c  2.2029e-2 $ 2.5% B concrete
       3006.66c  9.3108e-7
       3007.66c  1.1336e-5
       5010.66c  5.3787e-4
       5011.66c  2.1650e-3
       6000.66c  8.1778e-5
       8016.62c  3.7527e-2
       8017.66c  1.4266e-5
       11023.62c 7.1963e-4
       12000.62c 6.4254e-4
       13027.62c 1.5151e-3
       14028.62c 6.6336e-3
       14029.62c 3.3684e-4
       14030.62c 2.2205e-4
       16000.62c 1.2317e-4
       19000.62c 7.9928e-5
       20000.62c 5.0957e-3
       22000.62c 3.1098e-5
       23000.62c 6.4067e-6
       25055.62c 7.7188e-6
       26054.62c 2.1955e-5
       26056.62c 3.4465e-4
       26057.62c 7.9594e-6
       26058.62c 1.0592e-6
       28058.62c 3.7856e-7
       28060.62c 1.4582e-7
       28061.62c 6.3388e-9
       28062.62c 2.0211e-8
       28064.62c 5.1471e-9
       37085.66c 6.5706e-7
       37087.66c 2.5337e-7
       40000.66c 3.5779e-7
       56138.66c 4.4217e-6
       73181.66c 3.0634e-6
m7     1001.62c  6.8858e-3 $ paper sonotubes
       6000.66c  4.1315e-3
       8016.62c  3.4416e-3
       8017.66c  1.3083e-6
m9     48106.66c 5.7925e-4 $cadmium lamination 4.6340E-02
       48108.66c 4.1243e-4
       48110.66c 5.7879e-3
       48111.66c 5.9316e-3
       48112.66c 1.1182e-2
       48113.66c 5.6628e-3
       48114.66c 1.3314e-2
       48116.66c 3.4709e-3
m10    6000.66c  1.1712e-3 $steel culvert
       15031.66c 1.3485e-4
       16000.62c 6.0090e-5
       26054.62c 4.9204e-3
       26056.62c 7.7240e-2
       26057.62c 1.7838e-3
       26058.62c 2.3739e-4
       30000.42c 1.4718e-3
C      Criticality control cards
kcode 50000 1.0 100 2100
ksrc 37.8092 0 23.78  -37.8092 0 23.78
     0 37.8092 47.56  0 -37.8092 47.56
     43.748 0 47.56  -43.748 0 47.56
     0 43.748 23.78  0 -43.748 23.78
```

MCNP5 ENDF/B-VI (Simple Model) Input Listing for Experiment 5e of Table 91.

```
1X3 array of nested tanks,Experiment 5e Simple
C   5                                                                    80
C      Cell Cards
C Concrete
1     1  -2.29  (-1 2 -3 4 -5 6):(4 -3 -5 12 1 -10):(-12 11 -3 13 -10 1):(1 -10
                -11 6 14 -3) imp:n=1 $platform/panels
2     1  -2.29  (2 -8 6 -5 -4 7):(2 -8 -3 7 -6 9) imp:n=1  $walls
C Tanks
3     2  -8.03  (1 -15 29 -28):(-25 24 28 -27):(-15 24 27 -26) imp:n=1  $Tank 1
4     2  -8.03  (1 -15 33 -32):(-25 24 32 -31):(-15 24 31 -30) imp:n=1  $Tank 2
5     2  -8.03  (1 -15 37 -36):(-25 24 36 -35):(-15 24 35 -34) imp:n=1  $Tank 3
6     2  -8.03  (1 -15 41 -40):(-25 24 40 -39):(-15 24 39 -38) imp:n=1  $Tank 4
7     2  -8.03  (1 -15 20 -21):(-25 24 21 -22):(-15 24 22 -23) imp:n=1  $Tank 2*
8     2  -8.03  (1 -15 16 -17):(-25 24 17 -18):(-15 24 18 -19) imp:n=1  $Tank 3*
C solution
9     3  -1.4982  -42 25 28 -27   imp:n=1  $in tank 1
10    3  -1.4982  -42 25 32 -31   imp:n=1  $in tank 2
11    3  -1.4982  -42 25 36 -35   imp:n=1  $in tank 3
12    3  -1.4982  -42 25 40 -39   imp:n=1  $in tank 4
13    3  -1.4982  -42 25 21 -22   imp:n=1  $in tank 2*
14    3  -1.4982  -42 25 17 -18   imp:n=1  $in tank 3*
C Void space
15    0  -7:-9:5:3:-2:8:(10 -8 -5 6 4 -3) imp:n=0 $Big Void outside enclosure
16    0  (4 -14 -11 6 1 -10):(15 -10 11 -12 4 -13):(1 28 -24 -26):(1 21 -24 -23)
         :(1 36 -24 -34):(-43 1 26 23 34 -12 11 -13 4)
         :(60 -15 26 23 34 -12 11 -13 4):(-63 43 -60 26 4 -12 11)
         :(64 -66 23 43 -60 -12 11):(65 -13 -12 11 -60 43 34)
         :(1 -15 -62 11 4 -13 26):(1 -15 61 -12 4 -13) imp:n=1 $SE corner,between tanks and panels
17    0  (1 -33 -43):(43 -15 -33 48):(43 -44 47 -48) imp:n=1  $betweeb tank 2 and plug
18    0  (1 -16 -43):(43 -15 -16 53):(43 -44 52 -53) imp:n=1  $between tank 3* and plug
19    0  (1 -43 -41):(43 -15 -41 57):(43 -44 -57 56) imp:n=1  $betweeb tank 4 and plug
20    0  (1 -24 32 -29):(-15 24 30 -29)  imp:n=1  $between tanks 1 and 2
21    0  (1 -24 17 -20):(-15 24 19 -20)  imp:n=1  $between tanks 2* and 3*
22    0  (1 -24 40 -37):(-15 24 38 -37)  imp:n=1  $between tanks 3 and 4
23    0  42 -15 28 -27  imp:n=1  $annular void tank 1
24    0  42 -15 32 -31  imp:n=1  $annular void tank 2
25    0  42 -15 36 -35  imp:n=1  $annular void tank 3
26    0  42 -15 40 -39  imp:n=1  $annular void tank 4
27    0  42 -15 21 -22  imp:n=1  $annular void tank 2*
28    0  42 -15 17 -18  imp:n=1  $annular void tank 3*
C plugs
29    2  -8.03  43 -44 -47       imp:n=1  $30X0 1.2%B C steel plate
30    7  -0.1854  44 -49 45 -46  imp:n=1  $30X0 1.2%B C inner paper
31    5  -2.22  (44 -49 46 -47):(-15 49 -47)  imp:n=1  $30X0 1.2%B concrete plug
32    7  -0.1854  44 -15 -48 47  imp:n=1  $outer paper 30X0 1.2%B C
33    0  -45 44 -49              imp:n=1  $in middle of 30X0 1.2%B C plug
34    2  -8.03  43 -44 -52 50      imp:n=1  $22x8 1.1%B P steel plate
35    7  -0.1854  -15 44 51 -50    imp:n=1  $22x8 1.1%B P inner paper
36    8  -1.875  -15 44 50 -52     imp:n=1  $22x8 1.1%B Plaster plug
37    7  -0.1854  -15 44 52 -53    imp:n=1  $22x8 1.1%B P outer paper
38    0  (-15 44 -51):(-44 43 -50) imp:n=1  $in middle of 22x8 1.1%B P plug
39    2  -8.03  43 -44 -56 54       imp:n=1  $22X16 1.1%B P steel plate
40    7  -0.1854  -15 44 -54 55     imp:n=1  $22X16 1.1%B P inner paper
41    8  -1.875  -15 44 54 -56      imp:n=1  $22X16 1.1%B Plaster plug
42    7  -0.1854  -15 44 56 -57     imp:n=1  $22X16 1.1%B P outer paper
43    0  (-15 44 -55):(-44 43 -54)  imp:n=1  $in middle of 22X16 1.1%B P Concrete plug
C Slabs
44    8  -1.875 43 -60 -61 62 -64 63 imp:n=1 $east slab
45    8  -1.875 43 -60 -61 62 -65 66 imp:n=1 $west slab

C      Surface Cards
1      pz    0.0    $top of platform where panels and tanks are placed on
2      pz  -20.3    $bottom of platform, bottom of east and south walls
3      py  168.759  $West end of platform and west side of panels
4      py -173.939  $East end of platform and east wall
5      px   79.5785 $North side of platform and north side of panels
6      px  -79.7385 $South side of platform and south wall
7      py -295.939  $Outer east wall
8      pz  343.9    $Top of east and south walls
```

```
9     px -201.739  $Outer south wall
10    pz  244.0    $Top of panels
11    px  -59.4385 $South inner panel wall
12    px   59.2785 $North inner panel wall
13    py  148.459  $West inner panel wall
14    py -112.039  $End of south panel on east side
15    pz  243.9    $Top of tanks
16    cz   35.2832 $Tank 3* inner cylinder inner wall
17    cz   35.9232 $Tank 3* inner cylinder outer wall
18    cz   39.6952 $Tank 3* outer cylinder inner wall
19    cz   40.3352 $Tank 3* outer cylinder outer wall
20    cz   41.2375 $Tank 2* inner cylinder inner wall
21    cz   41.8775 $Tank 2* inner cylinder outer wall
22    cz   45.6185 $Tank 2* outer cylinder inner wall
23    cz   46.2585 $Tank 2* outer cylinder outer wall
24    pz   31.26   $New position for tank bottoms
25    pz   31.90   $Top of tank bottom steel union piece/bottom of solution
26    c/z  -6.6244 -113.671 52.0929 $Tank 1 outer cylinder outer wall
27    c/z  -6.6244 -113.671 51.4529 $Tank 1 outer cylinder inner wall
28    c/z  -6.6244 -113.671 47.6149 $Tank 1 inner cylinder outer wall
29    c/z  -6.6244 -113.671 46.9749 $Tank 1 inner cylinder inner wall
30    c/z  -6.6244 -113.671 46.2077 $Tank 2 outer cylinder outer wall
31    c/z  -6.6244 -113.671 45.5677 $Tank 2 outer cylinder inner wall
32    c/z  -6.6244 -113.671 41.7197 $Tank 2 inner cylinder outer wall
33    c/z  -6.6244 -113.671 41.0797 $Tank 2 inner cylinder inner wall
34    c/z   6.8707  101.286 40.3428 $Tank 3 outer cylinder outer wall
35    c/z   6.8707  101.286 39.7028 $Tank 3 outer cylinder inner wall
36    c/z   6.8707  101.286 35.8568 $Tank 3 inner cylinder outer wall
37    c/z   6.8707  101.286 35.2168 $Tank 3 inner cylinder inner wall
38    c/z   6.8707  101.286 34.4703 $Tank 4 outer cylinder outer wall
39    c/z   6.8707  101.286 33.8303 $Tank 4 outer cylinder inner wall
40    c/z   6.8707  101.286 30.0483 $Tank 4 inner cylinder outer wall
41    c/z   6.8707  101.286 29.4083 $Tank 4 inner cylinder inner wall
42    pz  207.9    $Top of solution level for all tanks
43    pz    30.5   $bottom of plug steel plates/bottom of slabs
44    pz    31.14  $top of plug steel plates/bottom of plugs
45    c/z  -6.6244 -113.671 20.415 $30X0 1.2%B C inner wall inner paper
46    c/z  -6.6244 -113.671 20.765 $30X0 1.2%B C outer wall inner paper/inner plug wall
47    c/z  -6.6244 -113.671 38.1   $30X0 1.2%B C outer plug wall/outer paper inner wall/outer steel
plate
48    c/z  -6.6244 -113.671 38.86  $30X0 1.2%B C outer outer paper outer wall
49    pz  204.74                   $30X0 1.2%B C top of inner portion
50    cz  10.48  $22x8 1.1%B P steel plate inner wall/outer wall inner paper/plug inner wall
51    cz  10.16  $22x8 1.1%B P inner wall inner paper
52    cz  27.94  $22x8 1.1%B P outer plug wall/outer paper inner wall/outer steel plate
53    cz  28.51  $22x8 1.1%B P outer paper outer wall
54    c/z 6.8707  101.286  20.765  $22X16 1.1%B P inner steel plate/outer inner paper wall/inner
plug wall
55    c/z 6.8707  101.286  20.32   $22X16 1.1%B P inner paper inner wall
56    c/z 6.8707  101.286  27.94   $22X16 1.1%B P outer plug wall/outer paper inner wall/outer steel
plate
57    c/z 6.8707  101.286  28.51   $22X16 1.1%B P outer paper outer wall
60    pz  240.2  $top of slabs
61    px  54.5   $North edge of slabs
62    px -54.5   $South edge of slabs
63    py -54.8685 $east face of east slab
64    py -52.9685 $west face of east slab
65    py  54.551  $west face of west slab
66    py  52.651  $east face of west slab

C      Data Cards
C      Materials Cards
m1     1001.62c  1.4544e-2  $Boron-free concrete
       6000.66c  8.1181e-6
       8016.62c  4.5277e-2
       8017.66c  1.7212e-5
       11023.62c 5.7811e-5
       12000.62c 2.5732e-4
       13027.62c 3.0579e-3
       14028.62c 1.3683e-2
       14029.62c 6.9480e-4
```

```
        14030.62c 4.5802e-4
        16000.62c 6.7855e-5
        19000.62c 1.0740e-4
        20000.62c 2.0894e-3
        22000.62c 8.5175e-5
        23000.62c 3.5304e-6
        25055.62c 9.3431e-6
        26054.62c 3.6343e-5
        26056.62c 5.7050e-4
        26057.62c 1.3175e-5
        26058.62c 1.7534e-6
        28058.62c 2.0861e-7
        28060.62c 8.0355e-8
        28061.62c 3.4930e-9
        28062.62c 1.1137e-8
        28064.62c 2.8363e-9
        37085.66c 6.3564e-7
        37087.66c 2.4511e-7
        40000.66c 1.9714e-7
        56138.66c 9.3137e-6
        73181.66c 5.2937e-6
m2      1001.62c  2.0391e-5 $Tank steel
        6000.66c  5.0326e-5
        7014.62c  2.6142e-4
        7015.66c  9.6558e-7
        8016.62c  4.3305e-5
        8017.66c  1.6462e-8
        13027.62c 1.1948e-5
        16000.62c 3.0157e-6
        22000.62c 5.8915e-6
        23000.62c 8.4802e-5
        24050.62c 8.0819e-4
        24052.62c 1.5585e-2
        24053.62c 1.7672e-3
        24054.62c 4.3990e-4
        25055.62c 1.9365e-3
        26054.62c 3.3758e-3
        26056.62c 5.2993e-2
        26057.62c 1.2238e-3
        26058.62c 1.6287e-4
        27059.66c 1.6001e-4
        28058.62c 5.8896e-3
        28060.62c 2.2687e-3
        28061.62c 9.8618e-5
        28062.62c 3.1444e-4
        28064.62c 8.0078e-5
        42000.66c 9.9968e-5
        82206.66c 7.0307e-7
        82207.66c 6.8557e-7
        82208.66c 1.5287e-6
m3      1001.62c  5.8296e-2 $uranyl nitrate solution
        5010.66c  1.7432e-8
        5011.66c  7.0165e-8
        7014.62c  2.1685e-3
        7015.66c  8.0096e-6
        8016.62c  3.7320e-2
        8017.66c  1.4187e-5
        12000.62c 2.2138e-6
        13027.62c 2.7919e-6
        14028.62c 3.0392e-7
        14029.62c 1.5432e-8
        14030.62c 1.0173e-8
        25055.62c 1.0578e-7
        26054.62c 1.1601e-7
        26056.62c 1.8211e-6
        26057.62c 4.2057e-8
        26058.62c 5.5970e-9
        28058.62c 1.7226e-7
        28060.62c 6.6355e-8
        28061.62c 2.8844e-9
        28062.62c 9.1967e-9
```

```
       28064.62c 2.3421e-9
       29063.62c 1.8977e-7
       29065.62c 8.4581e-8
       42000.66c 1.6825e-7
       48106.66c 1.8668e-10
       48108.66c 1.3292e-10
       48110.66c 1.8653e-9
       48111.66c 1.9116e-9
       48112.66c 3.6037e-9
       48113.66c 1.8250e-9
       48114.66c 4.2907e-9
       48116.66c 1.1186e-9
       82206.66c 1.1015e-8
       82207.66c 1.0741e-8
       82208.66c 2.3950e-8
       83209.66c 7.0034e-9
       92234.66c 9.0307e-6
       92235.66c 8.5361e-4
       92236.66c 3.9390e-6
       92238.66c 4.8525e-5
mt3    lwtr.60t
m5     1001.62c  1.6944e-2 $ 1.2% B concrete
       3006.66c  5.0933e-7
       3007.66c  6.2012e-6
       5010.66c  2.9540e-4
       5011.66c  1.1890e-3
       6000.66c  4.8574e-5
       8016.62c  4.3204e-2
       8017.66c  1.6424e-5
       11023.62c 4.1850e-4
       12000.62c 4.7364e-4
       13027.62c 2.4910e-3
       14028.62c 1.1089e-2
       14029.62c 5.6307e-4
       14030.62c 3.7118e-4
       16000.62c 9.0706e-5
       19000.62c 9.7433e-5
       20000.62c 3.5242e-3
       22000.62c 6.3443e-5
       23000.62c 4.7184e-6
       25055.62c 8.7199e-6
       26054.62c 3.1167e-5
       26056.62c 4.8926e-4
       26057.62c 1.1299e-5
       26058.62c 1.5037e-6
       28058.62c 2.7881e-7
       28060.62c 1.0740e-7
       28061.62c 4.6684e-9
       28062.62c 2.9770e-8
       28064.62c 3.7908e-9
       37085.66c 6.4636e-7
       37087.66c 2.4925e-7
       40000.66c 2.6349e-7
       56138.66c 7.4104e-6
       73181.66c 4.4063e-6
m7     1001.62c  6.8858e-3 $ paper sonotubes
       6000.66c  4.1315e-3
       8016.62c  3.4416e-3
       8017.66c  1.3083e-6
m8     1001.62c  3.2048e-2 $ 1.1% B plaster
       3006.66c  3.8822e-7
       3007.66c  4.7267e-6
       5010.66c  2.2427e-4
       5011.66c  9.0271e-4
       6000.66c  3.9938e-4
       8016.62c  4.0166e-2
       8017.66c  1.5269e-5
       11023.62c 2.9613e-4
       12000.62c 2.3086e-4
       13027.62c 1.7055e-4
       14028.62c 8.2598e-4
```

```
       14029.62c 4.1941e-5
       14030.62c 2.7648e-5
       16000.62c 5.0862e-3
       19000.62c 1.6873e-5
       20000.62c 5.6862e-3
       26054.62c 1.7996e-6
       26056.62c 2.8250e-5
       26057.62c 6.5243e-7
       26058.62c 8.6826e-8
       56138.66c 1.7627e-7
C      Criticality control cards
kcode 50000 1.0 100 2100
ksrc 37.8092 0 23.78  -37.8092 0 23.78
     0 37.8092 47.56  0 -37.8092 47.56
     43.748 0 47.56  -43.748 0 47.56
     0 43.748 23.78  0 -43.748 23.78
```

MCNP5 ENDF/B-VI (Simple Model) Input Listing for Experiment 6 of Table 91.

```
1X3 array of nested tanks,Experiment 6 Simple
C   5                                                                    80
C      Cell Cards
C Concrete
1     1  -2.29  (-1 2 -3 4 -5 6):(4 -3 -5 12 1 -10):(-12 11 -3 13 -10 1):(1 -10
                -11 6 14 -3) imp:n=1 $platform/panels
2     1  -2.29  (2 -8 6 -5 -4 7):(2 -8 -3 7 -6 9) imp:n=1  $walls
C Tanks
3     2  -8.03  (1 -15 29 -28):(-25 24 28 -27):(-15 24 27 -26) imp:n=1  $Tank 1
4     2  -8.03  (1 -15 33 -32):(-25 24 32 -31):(-15 24 31 -30) imp:n=1  $Tank 2
5     2  -8.03  (1 -15 37 -36):(-25 24 36 -35):(-15 24 35 -34) imp:n=1  $Tank 3
6     2  -8.03  (1 -15 41 -40):(-25 24 40 -39):(-15 24 39 -38) imp:n=1  $Tank 4
7     2  -8.03  (1 -15 20 -21):(-25 24 21 -22):(-15 24 22 -23) imp:n=1  $Tank 2*
8     2  -8.03  (1 -15 16 -17):(-25 24 17 -18):(-15 24 18 -19) imp:n=1  $Tank 3*
C solution
11    3  -1.4982  -42 25 36 -35   imp:n=1  $in tank 3
12    3  -1.4982  -42 25 40 -39   imp:n=1  $in tank 4
13    3  -1.4982  -42 25 21 -22   imp:n=1  $in tank 2*
14    3  -1.4982  -42 25 17 -18   imp:n=1  $in tank 3*
C Void space
15    0  -7:-9:5:3:-2:8:(10 -8 -5 6 4 -3) imp:n=0 $Big Void outside enclosure
16    0  (4 -14 -11 6 1 -10):(15 -10 11 -12 4 -13):(1 28 -24 -26):(1 21 -24 -23)
         :(1 36 -24 -34):(-43 1 26 23 34 -12 11 -13 4)
         :(60 -15 26 23 34 -12 11 -13 4):(-63 43 -60 26 4 -12 11)
         :(64 -66 23 43 -60 -12 11):(65 -13 -12 11 -60 43 34)
         :(1 -15 -62 11 4 -13 26):(1 -15 61 -12 4 -13) imp:n=1 $SE corner,between tanks and panels
17    0  (1 -33 -43):(43 -15 -33 48):(43 -44 47 -48) imp:n=1  $betweeb tank 2 and plug
18    0  1 -15 -16 imp:n=1  $middle of tank 3*
19    0  (1 -43 -41):(43 -15 -41 57):(43 -44 -57 56) imp:n=1  $betweeb tank 4 and plug
20    0  (1 -24 32 -29):(-15 24 30 -29)  imp:n=1  $between tanks 1 and 2
21    0  (1 -24 17 -20):(-15 24 19 -20)  imp:n=1  $between tanks 2* and 3*
22    0  (1 -24 40 -37):(-15 24 38 -37)  imp:n=1  $between tanks 3 and 4
23    0  25 -15 28 -27  imp:n=1  $annular void tank 1
24    0  25 -15 32 -31  imp:n=1  $annular void tank 2
25    0  42 -15 36 -35  imp:n=1  $annular void tank 3
26    0  42 -15 40 -39  imp:n=1  $annular void tank 4
27    0  42 -15 21 -22  imp:n=1  $annular void tank 2*
28    0  42 -15 17 -18  imp:n=1  $annular void tank 3*
C plugs
29    2  -8.03  43 -44 -47       imp:n=1  $30X0 1.2%B C steel plate
30    7  -0.1854  44 -49 45 -46  imp:n=1  $30X0 1.2%B C inner paper
31    5  -2.22  (44 -49 46 -47):(-15 49 -47)  imp:n=1  $30X0 1.2%B concrete plug
32    7  -0.1854  44 -15 -48 47  imp:n=1  $outer paper 30X0 1.2%B C
33    0  -45 44 -49              imp:n=1  $in middle of 30X0 1.2%B C plug
39    2  -8.03  43 -44 -56 54       imp:n=1  $22X16 1.1%B P steel plate
40    7  -0.1854  -15 44 -54 55     imp:n=1  $22X16 1.1%B P inner paper
41    8  -1.875  -15 44 54 -56      imp:n=1  $22X16 1.1%B Plaster plug
42    7  -0.1854  -15 44 56 -57     imp:n=1  $22X16 1.1%B P outer paper
43    0  (-15 44 -55):(-44 43 -54)  imp:n=1  $in middle of 22X16 1.1%B P Concrete plug
C Slabs
44    8  -1.875 43 -60 -61 62 -64 63 imp:n=1 $east slab
45    8  -1.875 43 -60 -61 62 -65 66 imp:n=1 $west slab

C      Surface Cards
1     pz    0.0    $top of platform where panels and tanks are placed on
2     pz  -20.3    $bottom of platform, bottom of east and south walls
3     py  168.759  $West end of platform and west side of panels
4     py -173.939  $East end of platform and east wall
5     px   79.5785 $North side of platform and north side of panels
6     px  -79.7385 $South side of platform and south wall
7     py -295.939  $Outer east wall
8     pz  343.9    $Top of east and south walls
9     px -201.739  $Outer south wall
10    pz  244.0    $Top of panels
11    px  -59.4385 $South inner panel wall
12    px   59.2785 $North inner panel wall
13    py  148.459  $West inner panel wall
14    py -112.039  $End of south panel on east side
15    pz  243.9    $Top of tanks
```

```
16    cz   35.2832 $Tank 3* inner cylinder inner wall
17    cz   35.9232 $Tank 3* inner cylinder outer wall
18    cz   39.6952 $Tank 3* outer cylinder inner wall
19    cz   40.3352 $Tank 3* outer cylinder outer wall
20    cz   41.2375 $Tank 2* inner cylinder inner wall
21    cz   41.8775 $Tank 2* inner cylinder outer wall
22    cz   45.6185 $Tank 2* outer cylinder inner wall
23    cz   46.2585 $Tank 2* outer cylinder outer wall
24    pz   31.26   $New position for tank bottoms
25    pz   31.90   $Top of tank bottom steel union piece/bottom of solution
26    c/z  -6.6244 -113.671 52.0929 $Tank 1 outer cylinder outer wall
27    c/z  -6.6244 -113.671 51.4529 $Tank 1 outer cylinder inner wall
28    c/z  -6.6244 -113.671 47.6149 $Tank 1 inner cylinder outer wall
29    c/z  -6.6244 -113.671 46.9749 $Tank 1 inner cylinder inner wall
30    c/z  -6.6244 -113.671 46.2077 $Tank 2 outer cylinder outer wall
31    c/z  -6.6244 -113.671 45.5677 $Tank 2 outer cylinder inner wall
32    c/z  -6.6244 -113.671 41.7197 $Tank 2 inner cylinder outer wall
33    c/z  -6.6244 -113.671 41.0797 $Tank 2 inner cylinder inner wall
34    c/z   6.8707  101.286 40.3428 $Tank 3 outer cylinder outer wall
35    c/z   6.8707  101.286 39.7028 $Tank 3 outer cylinder inner wall
36    c/z   6.8707  101.286 35.8568 $Tank 3 inner cylinder outer wall
37    c/z   6.8707  101.286 35.2168 $Tank 3 inner cylinder inner wall
38    c/z   6.8707  101.286 34.4703 $Tank 4 outer cylinder outer wall
39    c/z   6.8707  101.286 33.8303 $Tank 4 outer cylinder inner wall
40    c/z   6.8707  101.286 30.0483 $Tank 4 inner cylinder outer wall
41    c/z   6.8707  101.286 29.4083 $Tank 4 inner cylinder inner wall
42    pz  135.12    $Top of solution level for all tanks
43    pz    30.5   $bottom of plug steel plates/bottom of slabs
44    pz    31.14  $top of plug steel plates/bottom of plugs
45    c/z  -6.6244 -113.671 20.415 $30X0 1.2%B C inner wall inner paper
46    c/z  -6.6244 -113.671 20.765 $30X0 1.2%B C outer wall inner paper/inner plug wall
47    c/z  -6.6244 -113.671 38.1   $30X0 1.2%B C outer plug wall/outer paper inner wall/outer steel
plate
48    c/z  -6.6244 -113.671 38.86  $30X0 1.2%B C outer outer paper outer wall
49    pz  204.74                   $30X0 1.2%B C top of inner portion
54    c/z 6.8707  101.286  20.765  $22X16 1.1%B P inner steel plate/outer inner paper wall/inner
plug wall
55    c/z 6.8707  101.286  20.32   $22X16 1.1%B P inner paper inner wall
56    c/z 6.8707  101.286  27.94   $22X16 1.1%B P outer plug wall/outer paper inner wall/outer steel
plate
57    c/z 6.8707  101.286  28.51   $22X16 1.1%B P outer paper outer wall
60    pz  240.2  $top of slabs
61    px  54.5   $North edge of slabs
62    px -54.5   $South edge of slabs
63    py -54.8685 $east face of east slab
64    py -52.9685 $west face of east slab
65    py  54.551  $west face of west slab
66    py  52.651  $east face of west slab

C      Data Cards
C      Materials Cards
m1     1001.62c  1.4544e-2  $Boron-free concrete
       6000.66c  8.1181e-6
       8016.62c  4.5277e-2
       8017.66c  1.7212e-5
       11023.62c 5.7811e-5
       12000.62c 2.5732e-4
       13027.62c 3.0579e-3
       14028.62c 1.3683e-2
       14029.62c 6.9480e-4
       14030.62c 4.5802e-4
       16000.62c 6.7855e-5
       19000.62c 1.0740e-4
       20000.62c 2.0894e-3
       22000.62c 8.5175e-5
       23000.62c 3.5304e-6
       25055.62c 9.3431e-6
       26054.62c 3.6343e-5
       26056.62c 5.7050e-4
       26057.62c 1.3175e-5
       26058.62c 1.7534e-6
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        28058.62c 2.0861e-7
        28060.62c 8.0355e-8
        28061.62c 3.4930e-9
        28062.62c 1.1137e-8
        28064.62c 2.8363e-9
        37085.66c 6.3564e-7
        37087.66c 2.4511e-7
        40000.66c 1.9714e-7
        56138.66c 9.3137e-6
        73181.66c 5.2937e-6
m2      1001.62c  2.0391e-5 $Tank steel
        6000.66c  5.0326e-5
        7014.62c  2.6142e-4
        7015.66c  9.6558e-7
        8016.62c  4.3305e-5
        8017.66c  1.6462e-8
        13027.62c 1.1948e-5
        16000.62c 3.0157e-6
        22000.62c 5.8915e-6
        23000.62c 8.4802e-5
        24050.62c 8.0819e-4
        24052.62c 1.5585e-2
        24053.62c 1.7672e-3
        24054.62c 4.3990e-4
        25055.62c 1.9365e-3
        26054.62c 3.3758e-3
        26056.62c 5.2993e-2
        26057.62c 1.2238e-3
        26058.62c 1.6287e-4
        27059.66c 1.6001e-4
        28058.62c 5.8896e-3
        28060.62c 2.2687e-3
        28061.62c 9.8618e-5
        28062.62c 3.1444e-4
        28064.62c 8.0078e-5
        42000.66c 9.9968e-5
        82206.66c 7.0307e-7
        82207.66c 6.8557e-7
        82208.66c 1.5287e-6
m3      1001.62c  5.8296e-2 $uranyl nitrate solution
        5010.66c  1.7432e-8
        5011.66c  7.0165e-8
        7014.62c  2.1685e-3
        7015.66c  8.0096e-6
        8016.62c  3.7320e-2
        8017.66c  1.4187e-5
        12000.62c 2.2138e-6
        13027.62c 2.7919e-6
        14028.62c 3.0392e-7
        14029.62c 1.5432e-8
        14030.62c 1.0173e-8
        25055.62c 1.0578e-7
        26054.62c 1.1601e-7
        26056.62c 1.8211e-6
        26057.62c 4.2057e-8
        26058.62c 5.5970e-9
        28058.62c 1.7226e-7
        28060.62c 6.6355e-8
        28061.62c 2.8844e-9
        28062.62c 9.1967e-9
        28064.62c 2.3421e-9
        29063.62c 1.8977e-7
        29065.62c 8.4581e-8
        42000.66c 1.6825e-7
        48106.66c 1.8668e-10
        48108.66c 1.3292e-10
        48110.66c 1.8653e-9
        48111.66c 1.9116e-9
        48112.66c 3.6037e-9
        48113.66c 1.8250e-9
        48114.66c 4.2907e-9
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       48116.66c 1.1186e-9
       82206.66c 1.1015e-8
       82207.66c 1.0741e-8
       82208.66c 2.3950e-8
       83209.66c 7.0034e-9
       92234.66c 9.0307e-6
       92235.66c 8.5361e-4
       92236.66c 3.9390e-6
       92238.66c 4.8525e-5
mt3    lwtr.60t
m5     1001.62c  1.6944e-2 $ 1.2% B concrete
       3006.66c  5.0933e-7
       3007.66c  6.2012e-6
       5010.66c  2.9540e-4
       5011.66c  1.1890e-3
       6000.66c  4.8574e-5
       8016.62c  4.3204e-2
       8017.66c  1.6424e-5
       11023.62c 4.1850e-4
       12000.62c 4.7364e-4
       13027.62c 2.4910e-3
       14028.62c 1.1089e-2
       14029.62c 5.6307e-4
       14030.62c 3.7118e-4
       16000.62c 9.0706e-5
       19000.62c 9.7433e-5
       20000.62c 3.5242e-3
       22000.62c 6.3443e-5
       23000.62c 4.7184e-6
       25055.62c 8.7199e-6
       26054.62c 3.1167e-5
       26056.62c 4.8926e-4
       26057.62c 1.1299e-5
       26058.62c 1.5037e-6
       28058.62c 2.7881e-7
       28060.62c 1.0740e-7
       28061.62c 4.6684e-9
       28062.62c 2.9770e-8
       28064.62c 3.7908e-9
       37085.66c 6.4636e-7
       37087.66c 2.4925e-7
       40000.66c 2.6349e-7
       56138.66c 7.4104e-6
       73181.66c 4.4063e-6
m7     1001.62c  6.8858e-3 $ paper sonotubes
       6000.66c  4.1315e-3
       8016.62c  3.4416e-3
       8017.66c  1.3083e-6
m8     1001.62c  3.2048e-2 $ 1.1% B plaster
       3006.66c  3.8822e-7
       3007.66c  4.7267e-6
       5010.66c  2.2427e-4
       5011.66c  9.0271e-4
       6000.66c  3.9938e-4
       8016.62c  4.0166e-2
       8017.66c  1.5269e-5
       11023.62c 2.9613e-4
       12000.62c 2.3086e-4
       13027.62c 1.7055e-4
       14028.62c 8.2598e-4
       14029.62c 4.1941e-5
       14030.62c 2.7648e-5
       16000.62c 5.0862e-3
       19000.62c 1.6873e-5
       20000.62c 5.6862e-3
       26054.62c 1.7996e-6
       26056.62c 2.8250e-5
       26057.62c 6.5243e-7
       26058.62c 8.6826e-8
       56138.66c 1.7627e-7
C      Criticality control cards
```

```
kcode 50000 1.0 100 2100
ksrc 37.8092 0 23.78  -37.8092 0 23.78
     0 37.8092 47.56  0 -37.8092 47.56
     43.748 0 47.56  -43.748 0 47.56
     0 43.748 23.78  0 -43.748 23.78
```

APPENDIX B: CALCULATED SPECTRAL DATA

Calculations were performed using the MCNP5 continuous energy ENDF/B-VI cross section library to determine the energy of the average lethargy causing fission (EALF). The percentages of fissions caused by thermal, intermediate, and fast neutrons for each of the 12 experimental configurations was also determined using MCNP5 with the continuous energy ENDF/B-VI cross section library. The results for the simplified models are shown in Table B.1. There were no significant differences in the spectra between the simplified and detailed models.

Table B.1. Spectral Data.

Configuration	k_{eff} (from Table 90)	EALF (eV)	Percentage of Neutrons Causing Fission		
	MCNP5		<0.625 eV	0.625 eV - 100 keV	>100 keV
1a	0.99404	0.28984	77.31	20.60	2.09
1b	0.99562	0.29182	77.24	20.67	2.10
1c	0.98567	0.30408	76.80	21.06	2.14
1d	0.98785	0.29286	77.19	20.72	2.09
2a	1.00237	0.29400	77.07	20.87	2.06
2b	1.00707	0.29478	77.04	20.91	2.05
3a5a	0.99072	0.29178	77.19	20.75	2.06
3b	0.99892	0.29316	77.13	20.81	2.06
4	0.99764	0.29562	77.01	20.93	2.07
5e	0.98024	0.29081	77.21	20.74	2.05
5f	0.97847	0.29356	77.14	20.77	2.09
6	0.97596	0.29503	77.11	20.79	2.10

APPENDIX C: DETERMINATION OF CONCRETE AND PLASTER COMPOSITIONS

This appendix presents the methodology for determining the concrete and plaster compositions used to calculate atom densities. The data in the experimental report were used as the basis. At times, the data obtained by chemical analysis were incomplete or conflicting. Often, as advised by the experimenter (Reference 2), theoretical constituents were used in place of those determined by chemical analysis.

C.1 Presentation of Data

Tables C.1 through C.6 provide data from the experimental report on the concrete and plaster components. The first three Tables—C.1, C.2, and C.3—give the mix constituents for boron-free concrete, borated concrete, and borated plaster. The concrete values are for the mixes before curing, while the plaster values are those for the set plaster. Three mixes were done for the boron-free concrete, and two each for the borated concrete and plaster. The next three Tables—C.4, C.5, and C.6—give constituents for mix components as obtained by chemical analysis. The mix components include sand, aggregate, cement, Pozzalith, Gerstley Borate, and Hydrostone Super X plaster.

Table C.1. Boron-Free Concrete Constituents, as Poured.[(a)]

Constituent	Plugs	Enclosure Panels	Platform
Portland Type II cement	1059 kg	1412 kg	1194 kg
Moist sand	3034 kg (7.1%)	3416 kg (2.3%)	2957 kg (5%)
Aggregate	3511 kg (1%)	4666 kg (0.9%)	3316 kg (1.7%)
Water	530 kg	607 kg	473 kg
Pozzalith	2 kg	not recorded	not recorded
Total water in set concrete	not specified	1.7% absorbed 7.8% hydrate	not specified

(a) Values in parentheses indicate percent of constituent weight that is absorbed water.

Table C.2. Mixed Borated Concrete Constituents, as Poured.[(a)]

Constituent	1.2-wt.% Boron	2.5-wt.% Boron
Portland Type I cement	0	271 kg
Portland Type II cement	1196 kg	1542 kg
Moist sand	1668 kg (6.9%)	270 kg (7%)
Aggregate	2291 kg (1%)	1539 kg (1%)
Gerstley Borate	1053 kg (4.17%)	2150 kg (4.17%)
Water	694 kg	1289 kg
Pozzalith	2 kg	3 kg

(a) Values in parentheses indicate percent of constituent weight that is absorbed water.

Table C.3. Borated Plaster Constituents, After Setting.[(a)]

Constituent	22 × 8 plug	22 × 16 plug
Hydrostone Super X Plaster	602 kg (6.7%)	311.4 kg (6.7%)
Gerstley Borate	121 kg (4.16%)	62.4 kg (4.16%)
Water	126.2 kg	61.5 kg

(a) Values in parentheses indicate percent of constituent weight that is absorbed water.

Table C.4. Impurities in Sand, Aggregate, and Portland Type II Cement.

Sampled Impurity	Moist Sand (wt.%)			Aggregate (wt.%)			Portland cement Type II (wt.%)
	0%B	1.2%B	2.5%B	0%B	1.2%B	2.5%B	
C	0.004	0.006	0.005	0.005	0.005	0.006	0.02
Na	0.0	0.1	0.0	0.1	0.0	0.1	0.2
Mg	0.2	0.2	0.2	0.7	0.2	0.5	1.2
Al	6.2	6.1	5.8	8.1	6.5	7.4	2.5
Si	23	Not Measured	25	24	Not measured	Not measured	7.0
SiO_2	Not measured	72.8 ± 0.5	Not measured	Not measured	71.0 ± 0.5	74.6 ± 0.5	Not measured
S	0.0	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	0.11
K	0.2	0.2	0.2	0.5	0.2	0.3	0.6
Ca	0.2	0.2	0.2	0.7	0.2	0.3	43.4
Ti	0.2	0.3	0.3	0.5	0.3	0.4	0.1
V	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	0.1
Mn	0.0	Not reported	Not reported	0.1	0.0	0.0	0.1
Fe	3.2	2.4	1.5	4.0	1.8	2.6	2.9
Ni	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	0.01
Zn	0.0	0.0	0.0	0.0	0.0	0.0	<0.01
Rb	0.01	0.0	0.0	0.01	0.0	0.0	0.02
Sr	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Zr	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	Below detection limit	0.01
Ba	0.1	0.1	0.1	0.1	0.1	0.1	0.06
Ta	Below detection limit	0.1	0.1	Below detection limit	0.1	0.1	0.1
Absorbed H2O	6.0	3.8	1.9	0.0	0.0	1.8	0.7

Table C.5. Weighted Average of Gerstley Borate Constituents, as Determined Analytically.[(a)]

Constituent	wt.%	Constituent	wt.%
Li	0.022	S	0.00027
B	7.55	K	0.060
C	0.232	Ca	14.9
Na	3.87	Fe	0.060
Mg	2.63	Sr	0.697
Al	0.347	Ba	0.015
Si	3.03	H_2O absorbed	4.17

(a) From analysis of three size ranges of particles, oxygen and hydrated H_2O not included.

Table C.6. Hydrostone Super X Plaster Components and Impurities.

Constituent	Plugs wt.%	Slabs wt.%
C	0.55 ± 5%	0.54 ± 5%
Na	0.07 ± 5%	0.07 ± 5%
Mg	0.17 ± 5%	0.17 ± 5%
Al	0.06 ± 50%	0.06 ± 50%
Si	0.52 ± 5%	0.54 ± 5%
SO_4	62.25 ± 0.1%	61.84 ± 0.1%
K	0.07 ± 50%	0.07 ± 50%
Ca	28.04 ± 0.1%	28.21 ± 0.1%
Fe	0.016 ± 5%	0.025 ± 5%
Sr	0.03 ± 50%	0.05 ± 50%
H_2O absorbed	6.7 ± 5%	6.8 ± 5%

C.2 Analysis of Constituents

Portland Cement

Tables C.7 and C.8 give the standard cement specifications and corresponding elemental breakdowns for Portland cement Type I and Type II. There is most likely some hydrated water present, but the reference used for the composition did not list any. Table C.8 does not include trace impurities or absorbed water. In part, the cement specifications were used in place of analytical values because of variations in the reported amount of silicon, which is a significant component. A comparison of reported analytical values for SiO_2 and elemental silicon in the sand and aggregate shows that elemental silicon values may be under reported.

Using the standard cement compositions was recommended by the experimenter and is more likely to represent the actual compositions.

Table C.7. Portland Cement Nominal Specifications.[(a) (b)]

Constituent Formula	Average wt.% in Type I	Average wt.% in Type II
C_3S, tricalcium silicate $3CaO \bullet SiO_2$	51.5	52.5
C_2S, dicalcium silicate $2CaO \bullet SiO_2$	20	19
C_3A, tricalcium aluminate $3CaO \bullet Al_2O_3$	10	5
C_4AF, tetracalcium alumino-ferrite $4CaO \bullet Al_2O_3 \bullet Fe_2O_3$	9	11
MgO	2.45	2.7
SO_3	3.2	3.05
Loss on Ignition, %	1.75	1.55
Na_2O eq.	0.655	0.585

(a) Concrete Manual, Concrete Quality and Field Practices, 4th ed., USA: International Conference of Building Officials, 1998, pp. 80–81.
(b) No information on amount of absorbed water was provided.

Table C.8. Portland Cement Theoretical Composition, Elemental Breakdown.

	Type I, wt.%	Type II, wt.%
Element		
O	35.99	36.07
Mg	1.50	1.64
Al	2.95	2.38
Si	9.65	10.19
S	1.30	1.23
Ca	45.99	45.50
Fe	2.13	2.54
Na	0.49	0.44

Table C.9 shows the Portland cement sampled impurities. This table also includes the reported absorbed water.

Table C.9. Portland Cement Sampled Impurities.

Element	wt.%
C	0.02
Na	0.2
K	0.6
Ti	0.1
V	0.1
Mn	0.1
Ni	0.01
Zn	0.005
Rb	0.02
Sr	0.2
Zr	0.01
Ba	0.06
Ta	0.1
Total:	1.525
Absorbed H_2O	0.7

Table C.10 shows the incorporation of the impurities and absorbed water into the Portland cement. It is assumed that since the Portland cement Type I and II compositions are quite similar, the impurity and absorbed water values may be used for both types. The impurities and absorbed water are added in using the values in Table C.9 and proportioning the Portland cement constituents so that the whole totals close to 100%. The silicon and sulfur appear to have been under reported by the chemical analysis.

Table C.10. Portland Cement with Impurities Included.

Element	Type I, wt.%	Type II, wt.%	Analysis Value
C	0.02	0.02	0.02
O	35.26	35.35	not reported
Na	0.48	0.43	0.2
Mg	1.47	1.61	1.2
Al	2.89	2.33	2.5
Si	9.46	9.99	7
S	1.27	1.21	0.11
K	0.6	0.6	0.6
Ca	45.06	44.58	43.4
Ti	0.1	0.1	0.1
V	0.1	0.1	0.1
Mn	0.1	0.1	0.1
Fe	2.09	2.49	2.9
Ni	0.01	0.01	0.01
Zn	0.005	0.005	<0.01
Rb	0.02	0.02	0.02
Sr	0.2	0.2	0.2
Zr	0.01	0.01	0.01
Ba	0.06	0.06	0.06
Ta	0.1	0.1	0.1
Absorbed H_2O	0.7	0.7	0.7

Sand and Aggregate

Sand and aggregate major components are aluminum, iron, and silicon. Table C.11 shows the reported values for these components, with silicon reported either as elemental silicon or in oxide form. The first three values were for sand, the final three for aggregate. The elemental silicon values are 40% to 45% lower than would be expected based on the SiO_2 values. The SiO_2 values are taken to be more correct, in part due to the similar discrepancy seen for silicon in Portland cement, in Table C.10.

Table C.11. Reported Values for Sand and Aggregate Major Components.

Component	Reported Values from Six Samples						Average
Al	6.2	6.1	5.8	8.1	6.5	7.4	6.68
Si	23	--	25	24	--	--	24
SiO_2	--	72.8	--	--	71.0	74.6	72.80
Fe	3.2	2.4	1.5	4.0	1.8	2.6	2.58

Table C.12 summarizes the sand and aggregate components. It is assumed that the components occur in oxide form. The average values are used because of the similarities in the components between the sand and aggregate. The major difference between the sand and aggregate is absorbed water present in each. Sand has 7%, while the aggregate had only 1%. The sum of all components as given in Table C.12 is 98.275% for sand, and 92.275% for aggregate.

Table C.13 shows the integration of aluminum, silicon, iron, impurities, and water. The absorbed water values were held constant; everything else was adjusted to total close to 100%.

Table C.12. Sand And Aggregate Components in Compound Form.

Element	Element wt.%	Compound	O wt.%	Compound wt.%
Major components:				
Al	6.68	Al_2O_3	5.94	12.63
Si	34.03	SiO_2	38.77	72.80
Fe	2.58	Fe_2O_3	1.11	3.69
Minor components and impurities:				
C	0.0052	C	0	0.0052
Na	0.05	Na_2O	0.0174	0.0674
Mg	0.33	MgO	0.219	0.553
K	0.267	K_2O	0.0546	0.321
Ca	0.3	CaO	0.120	0.420
Ti	0.33	TiO_2	0.223	0.556
Mn	0.025	MnO	0.0073	0.0323
Rb	0.0033	Rb_2O	0.0003	0.0036
Ba	0.1	BaO	0.0117	0.112
Ta	0.067	Ta_2O_5	0.0177	0.084
Totals:	1.4775		0.671	2.155
		H_2O Absorbed:	Sand	7
			Aggregate	1

Table C.13. Sand and Aggregate Compositions.

Element	Sand, wt.%	Aggregate, wt.%	Element	Sand, wt.%	Aggregate, wt.%
C	0.005	0.006	Ca	0.31	0.33
O	47.37	50.43	Ti	0.34	0.36
Na	0.05	0.05	Mn	0.03	0.03
Mg	0.34	0.36	Fe	2.63	2.8
Al	6.81	7.25	Rb	0.003	0.11
Si	34.67	36.91	Ba	0.1	0.07
K	0.27	0.29	Ta	0.07	0.1
			H_2O (abs.)	7	1

Gerstley Borate

A weighted average of the Gerstley Borate components, based on three batches of particles sorted by size, was given in Table C.5. These add up to 37.6 wt.%. Two significant components were omitted: hydrated water and oxygen.

Gerstley Borate consists of Ulexite, Colemanite, and sand. Table C.14 gives the chemical formulas and breakdown for Ulexite and Colemanite.

Table C.14. Ulexite and Colemanite Components by wt.%.

Ulexite $NaCaB_5O_9 \bullet 5H_2O$		Colemanite $Ca_2B_2O_{11} \bullet 5H_2O$	
B	15.39	B	15.78
O	41.00	O	42.81
Na	6.55	Ca	19.50
Ca	11.41	H_2O (hyd.)	21.91
H_2O (hyd.)	25.65		

It is reasonable to assume that Ulexite and Colemanite occur in equal amounts, such that the total boron is 7.55 wt.% (Reference 2). Using this assumption, the Ulexite and Colemanite weight percents are adjusted accordingly. Table C.15 shows the combined contributions for boron, oxygen, sodium, calcium, and hydrated water. These are then compared to reported values from the chemical analysis in Table C.5 to look for differences. The excess sodium and calcium present are taken to be free Ca and Na in the Gerstley Borate.

Table C.15. Combined Ulexite and Colemanite Contributions.

Component	Ulexite, wt.%	Colemanite, wt.%	Total, wt.%	Reported, wt.%	Excess, wt.%
B	3.73	3.82	7.55	7.55	0
O	9.93	10.37	20.30	not reported	-
Na	1.59	0	1.59	3.87	2.28
Ca	2.76	4.72	7.49	14.9	7.41
H_2O	6.21	5.31	11.52	not reported	-
Total	24.22	24.22	48.45	-	-

The Gerstley Borate impurities are given in Table C.16. Silicon, aluminum, and iron are not included; they are considered sand components. The sum of the Ulexite, Colemanite, impurities, excess sodium and calcium, and absorbed water as shown in Tables C.15 and C.16 is 65.97 wt.%. The remaining 34.03 wt.% of the Gerstley Borate is now assumed to be dry sand.

Table C.16. Gerstley Borate Impurities and Excess Sodium, Calcium.

Element	Element wt.%
Li	0.022
C	0.232
Na	2.28
Mg	2.63
K	0.06
Ca	7.41
Sr	0.697
Ba	0.015
Totals:	13.346
H_2O Absorbed:	4.17

The sand in the concrete was composed primarily of aluminum, silicon, and iron oxides. The ratio of SiO_2 to Al_2O_3 was 5.76, and that of SiO_2 to Fe_2O_3 was 19.73. Using these ratios and the total sand contribution to Gerstley Borate, 34.03 wt.%, the amounts assumed present are Al_2O_3 – 4.82 wt.%, SiO_2 – 27.80 wt.%, and

Fe_2O_3 – 1.41 wt.%. Of these compounds, the oxygen contributes 17.5 wt.%, aluminum 2.55 wt.%, silicon 13.00 wt.%, and iron 0.99 wt.%.

Table C.17 gives the total Gerstley Borate composition, including sand contributions.

Table C.17. Gerstley Borate Composition.

Element	wt.%	Element	wt.%
Li	0.022	Al	2.55
B	7.55	Si	13.00
C	0.232	K	0.06
O	37.80	Ca	14.9
Na	3.87	Fe	0.99
Mg	2.63	Sr	0.697
		Ba	0.015
		H_2O (abs.)	4.17
		H_2O (hyd.)	11.52

Hydrostone Super X Plaster

The primary component of Hydrostone Super X plaster is gypsum hemihydrate, $2CaSO_4{\bullet}H_2O$. Table C.18 gives the breakdown for the plaster sampled impurities and absorbed water from Table C.6.

Table C.18. Hydrostone Super X Impurities.

Element	Element wt.%
C	0.55
Na	0.07
Mg	0.17
Al	0.06
Si	0.52
K	0.07
Fe	0.016
Sr	0.03
Totals:	1.486
H_2O Absorbed:	6.7

The impurities and absorbed water total 8.19 wt.%. Assuming that the remainder is gypsum hemihydrate, Table C.19 gives the complete Hydrostone Super X plaster composition.

Table C.19. Hydrostone Super X Plaster Composition.

Element	wt.%	Element	wt.%
C	0.55	Si	0.52
O	40.48	S	20.29
Na	0.07	K	0.07
Mg	0.17	Ca	25.35
Al	0.06	Fe	0.016
		Sr	0.03
		H_2O (abs.)	6.7
		H_2O (hyd.)	5.70

C.3 Concrete and Plaster Compositions

Boron-free Concrete

As shown in Table C.1, boron-free concrete was used for plugs, enclosure panels, and the elevated platform. The assembly room walls were also composed of boron-free concrete; however, the specific components were not known. Table C.20 gives the major components of the boron-free concrete mixes. For all concrete compositions, the Pozzalith was ignored. At most, it constitutes 0.04% of the mix. The three mixes are quite similar. The plug composition is most important, as the enclosure panels and platform are not located as close to the tanks. Since the compositions are so similar, it is reasonable to use the plug composition to represent all three concrete sources.

Table C.20. Percentage of Constituents in Boron-Free Concrete Sources.

Constituent	Plugs	Enclosure Panels	Platform
Portland Type II Cement	13.0 %	14.0 %	15.0 %
Moist sand	37.3 %	33.8 %	37.2 %
Aggregate	43.2 %	46.2 %	41.8 %
Water	6.5 %	6.0 %	6.0 %

The biggest unknown is the water remaining in the cured concrete. Multiple plugs or panels were poured from each batch, making determination of the final amount of water difficult. The absorbed and hydrated water in the set concrete of the enclosure panels was measured, totaling 9.5 wt.%. Since the enclosure panels and plugs were poured at about the same time, it is reasonable to use 9.5-wt.% water for the plugs. The platform may have less water, but its position is about 0.3 m below the tanks and its precise water content will not significantly affect the experiment.

For the boron-free plug concrete, the dry weight of materials was 7349.1 kg, after removing the absorbed water from each component. The water mass for set concrete with 9.5-wt.% water was then 771.45 kg. The total weight must then be 8120.55 kg. Of this, 254.9 kg comes from the cement, sand, and aggregate, leaving 516.55 kg or 6.36 wt.% to be attributed to the mixing water. Table C.21 gives the resulting composition for the boron-free concrete.

Table C.21. Boron-Free Concrete Composition.

Component	Cement - II (13.041%)	Sand (37.362%)	Aggregate (43.236%)	Concrete wt.%
C	0.02	0.005	0.006	0.0070705
O	35.35	47.37	50.43	44.112
Na	0.43	0.5	0.05	0.096375
Mg	1.31	0.34	0.36	0.45352
Al	2.33	6.81	7.25	5.9828
Si	9.99	34.67	36.91	30.215
S	1.21	0.0	0.0	0.15780
K	0.6	0.27	0.29	0.30451
Ca	44.58	0.31	0.33	6.0722
Ti	0.1	0.34	0.36	0.29572
V	0.1	0.0	0.0	0.013041
Mn	0.1	0.03	0.03	0.037220
Fe	2.49	2.63	2.8	2.5179
Ni	0.01	0.0	0.0	0.0013041
Rb	0.02	0.003	0.004	0.0054585
Zr	0.01	0.0	0.0	0.0013041
Ba	0.06	0.1	0.11	0.092746
Ta	0.1	0.07	0.07	0.069460
H_2O abs.	0.7	7	1	3.1390
H_2O hyd.				Unknown
H_2O mixing				6.3610
			Total, H_2O	9.50

Borated Concrete

For the borated concrete compositions, the amount of water in the set concrete was inferred from the planned boron weight percent. The total boron mass was calculated for each concrete batch. The weight of components to achieve the desired boron content was then determined. It was assumed that all weight loss was due to water loss. Considering the absorbed water and the added water for each mix, the water loss would be 31.477% for the 1.2-wt.% boron concrete, and 40.052% for the 2.5-wt.% boron concrete.

Table C.22 gives the water loss and the resulting net mixing water for the borated concrete compositions. The net mixing water was determined by subtracting the water loss from the original amount of water mixed in. Values for absorbed water were obtained from Table C.1 and Table C.2. The other mixture components are also given in Table C.22. As with the boron-free concrete, Pozzalith is again ignored. Though the 2.5% B concrete had Type I cement added, it was treated as Type II due to their similarity.

Table C.22. Concrete Mix Calculated Water and Other Components.

Constituent	1.2-wt.% boron	2.5-wt.% boron
Curing weight loss	278.875 kg	571 kg
Total water, absorbed + mixing	885.95 kg	1425.64 kg
Water loss	31.477%	40.052%
Net mixing water	415.1 kg	718 kg
Portland cement Type II	1196 kg	1813 kg
Sand	1668 kg	270 kg
Aggregate	2291 kg	1539 kg
Gerstley Borate	1053 kg	2150 kg

Tables C.23 and C.24 give the compositions for 1.2-wt.% and 2.5-wt.% boron concrete. The water values are broken out separately at the bottoms of the tables.

Table C.23. 1.2-Wt.% Boron Concrete Composition.

Component	Cement - II (18.058%)	Sand (25.184%)	Aggregate (34.591%)	G. Borate (15.899%)	Concrete wt.%
Li	0.0	0.0	0.0	0.022	0.0034840
B	0.0	0.0	0.0	7.55	1.2004
C	0.02	0.005	0.006	0.232	0.043640
O	35.35	47.37	50.43	37.801	41.585
Na	0.43	0.05	0.05	3.87	0.71966
Mg	1.31	0.34	0.36	2.63	0.86107
Al	2.33	6.81	7.25	2.55	5.0274
Si	9.99	34.67	36.91	13.00	25.258
S	1.21	0.0	0.0	0.00027	0.21759
K	0.6	0.27	0.29	0.06	0.28495
Ca	44.58	0.31	0.33	14.90	10.565
Ti	0.1	0.34	0.36	0.0	0.22721
V	0.1	0.0	0.0	0.0	0.017979
Mn	0.1	0.03	0.03	0.0	0.035833
Fe	2.49	2.63	2.8	0.986	2.2275
Ni	0.01	0.0	0.0	0.0	0.0017979
Rb	0.02	0.003	0.004	0.0	0.0057256
Zr	0.01	0.0	0.0	0.0	0.0017979
Ba	0.06	0.1	0.11	0.015	0.076120
Ta	0.1	0.07	0.07	0.0	0.059639
H_2O abs.	0.7	7	1	4.17	2.898
H_2O hyd.				11.52	1.8315
H_2O mixing					6.687
				Total, H_2O	11.42

Table C.24. 2.5-Wt.% Boron Concrete Composition.

Component	Cement - II (27.935%)	Sand (4.16%)	Aggregate (23.713%)	G. Borate (33.128%)	Concrete wt.%
Li	0.0	0.0	0.0	0.022	0.0072881
B	0.0	0.0	0.0	7.55	2.50012
C	0.02	0.005	0.006	0.232	0.084075
O	35.35	47.37	50.43	37.801	36.327
Na	0.43	0.05	0.05	3.87	1.4161
Mg	1.31	0.34	0.36	2.63	1.3367
Al	2.33	6.81	7.25	2.553	3.499
Si	9.99	34.67	36.91	13.00	17.291
S	1.21	0.0	0.0	0.00027	0.33811
K	0.6	0.27	0.29	0.06	0.26749
Ca	44.58	0.31	0.33	14.90	17.481
Ti	0.1	0.34	0.36	0.0	0.12745
V	0.1	0.0	0.0	0.0	0.027935
Mn	0.1	0.03	0.03	0.0	0.036297
Fe	2.49	2.63	2.8	0.986	1.7956
Ni	0.01	0.0	0.0	0.0	0.0027935
Rb	0.02	0.003	0.004	0.0	0.0066604
Zr	0.01	0.0	0.0	0.0	0.0027935
Ba	0.06	0.1	0.11	0.015	0.051975
Ta	0.1	0.07	0.07	0.0	0.047447
H_2O abs.	0.7	7	1	4.17	2.1053
H_2O hyd.				11.52	3.8162
H_2O mixing					11.0632
				Total, H_2O	16.9847

Borated Plaster

A separate batch of borated plaster was mixed for each plaster plug and another batch for all the slabs. Table C.25 summarizes the compositions and densities, using the values from Table C.3. The compositions are nearly identical, so it is reasonable to use an averaged composition, which is given in Table C.26.

Table C.25. Comparison of Plaster Plug Components.

Component	22 × 8	22 × 16	Average
Hydrostone Super X	70.9%	71.5%	71.2%
Gerstley Borate	14.2%	14.3%	14.25%
Water	14.9%	14.1%	14.5%
Density, g/cm^3	1.89	1.86	1.875

Table C.26. 1.1-Wt.% Borated Plaster Composition.

Component	Hydrostone Super X (71.2%)	Gerstley Borate (14.3%)	Plaster wt.%
Li	0.0	0.022	0.0031442
B	0.0	7.55	1.0790
C	0.55	0.232	0.42483
O	40.481	37.801	34.230
Na	0.07	3.87	0.60294
Mg	0.17	2.63	0.49694
Al	0.06	2.553	0.40754
Si	0.52	13.00	2.228
S	20.29	0.00027	14.446
K	0.07	0.060	0.058425
Ca	25.35	14.90	20.183
Fe	0.016	0.986	0.15228
Ba	0.0	0.015	0.0021438
H_2O abs.	6.7	4.17	5.367
H_2O hyd.	5.70	11.52	5.704
H_2O mixing			14.49
		Total, H_2O	25.566

APPENDIX D: SUBCRITICAL CONFIGURATION

The configuration of the subcritical Experiment 5d consisted of the following:

- All six tanks were filled
- The 30 × 0 (1.2% B) concrete plug was placed in the tank on the east side
- A thick slab was placed between the east and central tanks
- The 22 × 8 (1.1% B) plaster plug was placed in the central tank
- A thick slab was placed between the central and west tanks
- The 22 × 16 (1.1% B) plaster plug was placed in the west tank
- A thin slab was rested against the west reflector panel between the west tank and the panel.

Table D.1 shows the distances between tanks, slabs, and reflector panels for the subcritical configuration.

Table D.1. Distances (east to west) between Slabs, Tanks, and Panels for the Subcritical Configuration.

From	To	Distance (mm)
Tank #1	East face of 275.6 kg slab	32
West face of 275.6 kg slab	Tank #2*	35
Tank #2*	East face of 266.1 kg slab	33
West face of 266.1 kg slab	Tank #3	25
Tank #3	East face of 117.0 kg slab	25
West face of 117.0 kg slab	Inside face of west reflector panel	0