STACY: 28-CM-THICK SLABS OF 10%-ENRICHED URANYL NITRATE SOLUTIONS REFLECTED WITH CONCRETE

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1.0 DETAILED DESCRIPTION

1.1 Overview of Experiments

Six critical configurations included in this evaluation are part of a series of experiments with the Static Experiment Critical Facility (STACY) performed from 1997 to the summer of 1998 at the Nuclear Fuel Cycle Safety Engineering Research Facility (NUCEF) in the Tokai Research Establishment of the Japan Atomic Energy Research Institute (JAERI). Employing the 28-cm-thick, 69-cm-wide slab core tank, a 10%-enriched uranyl nitrate solution was used in these experiments. The uranium concentration and the free nitric-acid concentration were adjusted to approximately 310-315 g/l and 0.8-1.0 mol/l, respectively. Six thicknesses of reflectors, concrete blocks packed in slab-shaped containers, were prepared and arranged symmetrically on the large side walls of the core tank. All six experiments are acceptable benchmark experiments.

Other STACY experiments with 10%-enriched uranyl nitrate solution are evaluated in LEU-SOL-THERM-004, LEU-SOL-THERM-016, and LEU-SOL-THERM-020 (water reflector); LEU-SOL-THERM-007, LEU-SOL-THERM-017, and LEU-SOL-THERM-021 (unreflected); LEU-SOL-THERM-008 (concrete reflector), LEU-SOL-THERM-009 (borated-concrete reflector); and LEU-SOL-THERM-010 and LEU-SOL-THERM-019 (polyethylene reflector).

1.2 Description of Experimental Configuration

The schematic view of the 280T core tank is shown in Figure 1. The dimensions shown in mm units are the design values. The 280T core tank was made of stainless steel, S.S.304L (or SUS304L), and the inner-thickness, inner-width, and inner-height design values were, respectively, 280 mm, 690 mm, and 1500 mm. The side walls, lower plate, and upper plate thicknesses were respectively 25 mm, 20 mm, and 25 mm. The inspected dimensions of the 280T core tank compared with design values are listed in Table 1. The standard deviation (1σ) is due to many measurements during the inspection process. The accuracy means the precision of the measurement instrument.

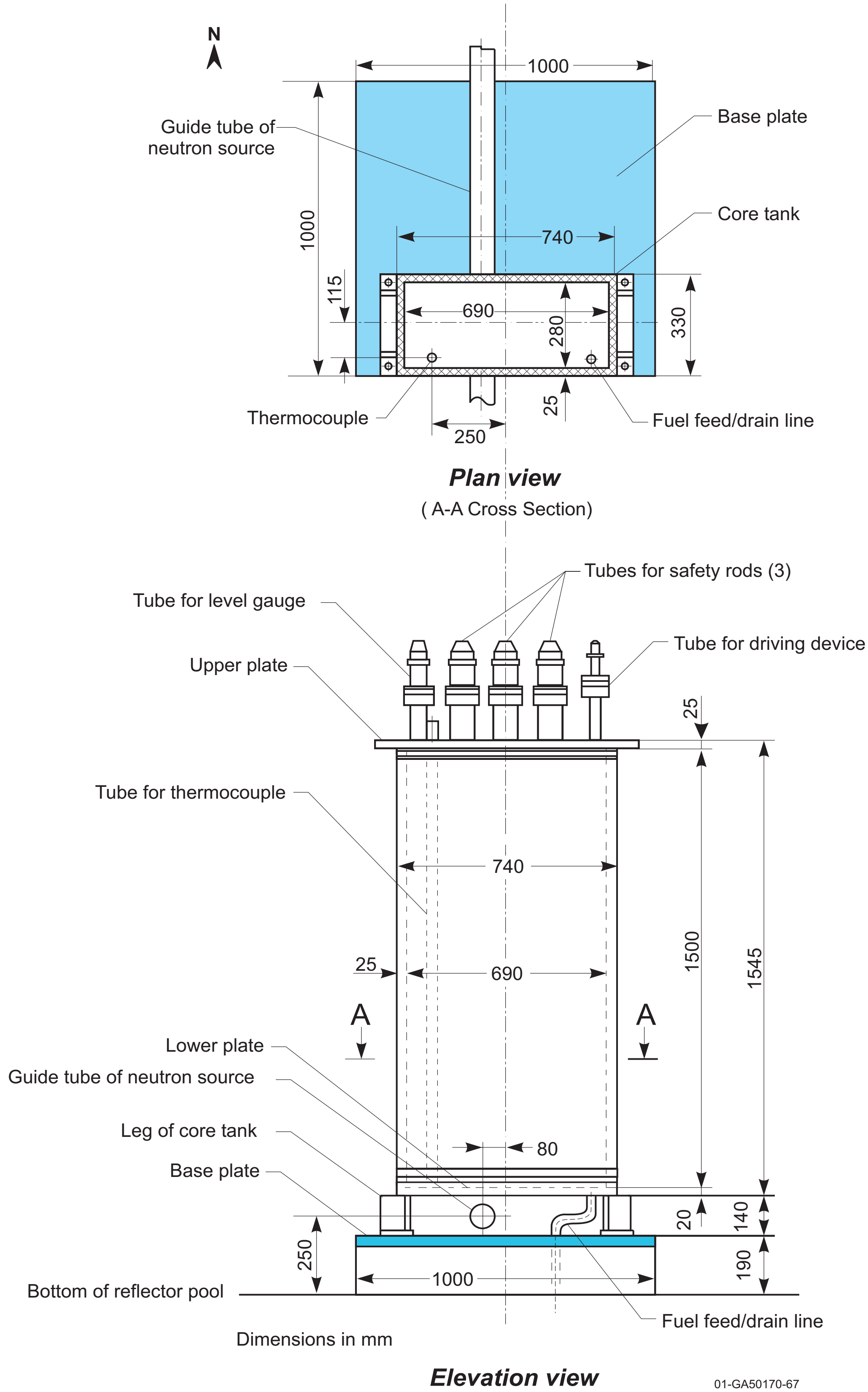


Figure 1. Schematic View of STACY Core Tank.
(design dimensions)

Table 1.a. Dimensions of the 280T-Slab Core Tank (Unit: mm).

Tank	Dimension	Inspected Result [a]	Design Value
(inner size)	thickness	280.8±0.5	280.0
	width	690.3±0.5	690.0
	height	1497.5±0.6	1500.0
(thickness)	side wall	25.3±0.1	25.0
	lower plate	20.4±0.1	20.0
	upper plate	28.8±0.1	25.0

(a) Uncertainties are from the standard deviation of inspected data and the accuracy, added quadratically.

Table 1.b. Detailed Measurements[a] of the 280T-Slab Core Tank (Unit: mm).

Measured Item	Number of Measured Points	Average	Standard Deviation	Accuracy	Uncertainty
Thickness of upper plate	4	28.75	0.03	0.10	0.10
Thickness of lower plate	14	20.41	0.02	0.10	0.10
Thickness of side wall	90	25.32	0.03	0.10	0.10
Outer height of tank	4	1546.61	0.24	0.50	0.55
Outer thickness of tank	45	331.39	0.13	0.50	0.52
Outer width of tank	30	740.95	0.11	0.50	0.51

(a) The outer size of the tank is measured by the usual methods, and the others are measured by the supersonic wave-measure method.

In this paper, all measurements are given with an uncertainty corresponding to one standard deviation.

The core tank was vertically penetrated by a tube (the outer diameter was 17.3 mm, and its wall thickness was 3.2 mm) for thermocouples; this tube extended to the bottom of the core tank. A level gauge and three cylindrical safety rods containing B_4C pellets were held at the upper part of the core tank. In their withdrawn position, the bottom of the safety rods was at 1850 mm above the bottom of the core tank. In their fully inserted position, the bottom of the safety rods was at 50 mm above the bottom of the core tank. The cladding tube of the safety rod, which was made of stainless steel, had an outer diameter of 61.9 mm, an inner diameter of 54.9 mm, a bottom cover thickness of 3.5 mm, and total length of 2277 mm. The diameter of the B_4C pellets was 54.6 mm, and their active length in the cladding tube was 1550 mm.

The fuel solution was fed into the tank from the bottom through the fuel feed/drain line, which had an outer diameter of 27.2 mm and a thickness of 2.9 mm. In the operating condition, the fuel feed/drain line was filled with fuel solution.

The core tank was supported by four stainless steel legs. These legs were 140 mm high, and stood on the core tank support. The top of the core tank support was a stainless steel base plate, which was 1000 mm wide, 1000 mm long, and 30 mm thick. The base plate was centered under the tank in the east-west direction, but was not centered in the north-south direction, as shown in Figure 1. The base plate was supported by 160-mm-high stainless steel beams located on the bottom of the empty water-reflector pool tank. A guide tube, which had an outer diameter of 89.1 mm and a thickness of 5.5 mm, for inserting an Am-Be neutron source lay horizontally between the lower plate of the core tank and the base plate in the north-south direction. The centerline of this tube was 100 mm below the bottom of the active region in the core tank, and 80 mm west of the centerline of the core tank.

The schematic view of the configuration in which two reflectors were arranged next to each of the two larger side walls of the core tank is shown in Figure 2. The reflector material was packed in the slab-shaped containers, which consisted of the frame plates and the cover plates. The frame plates, which were made of stainless steel, surrounded the reflector material on the four small sides, and had a nominal thickness of 30 mm. The cover plates, which were made of aluminum, held the concrete and the frame plates on the two larger sides, and had a nominal thickness of 8 mm.

For the experiments, four sizes of reflectors were prepared; they were named C25, C50, C100 and C150, for which the reflector design thicknesses were 25, 50, 100 and 150mm. A dimensional inspection was carried out after fabrication. The inner gaps between the core tank and the reflectors were measured for each experiment. The experimental cases and the smaller horizontal dimensions are listed in Table 2. The larger horizontal dimensions and the vertical dimensions of each reflector are listed in Tables 3 and 4, respectively. The active size of concrete is equal to the inner size of the container, because the reflectors were built by directly packing the concrete into the containers.

To insert a small neutron detector or a gold wire, the reflectors were horizontally and/or vertically penetrated by small holes. The diameters of the holes are 16 mm for neutron detectors and 5 mm for gold wire. (Details are given in Appendix D.)

Four legs of the reflector support, which were made of stainless steel, stood on the bottom of the pool tank (south side) or the base plate (north side). The heights of these legs were 32 cm on the south side and 13 cm on the north side.

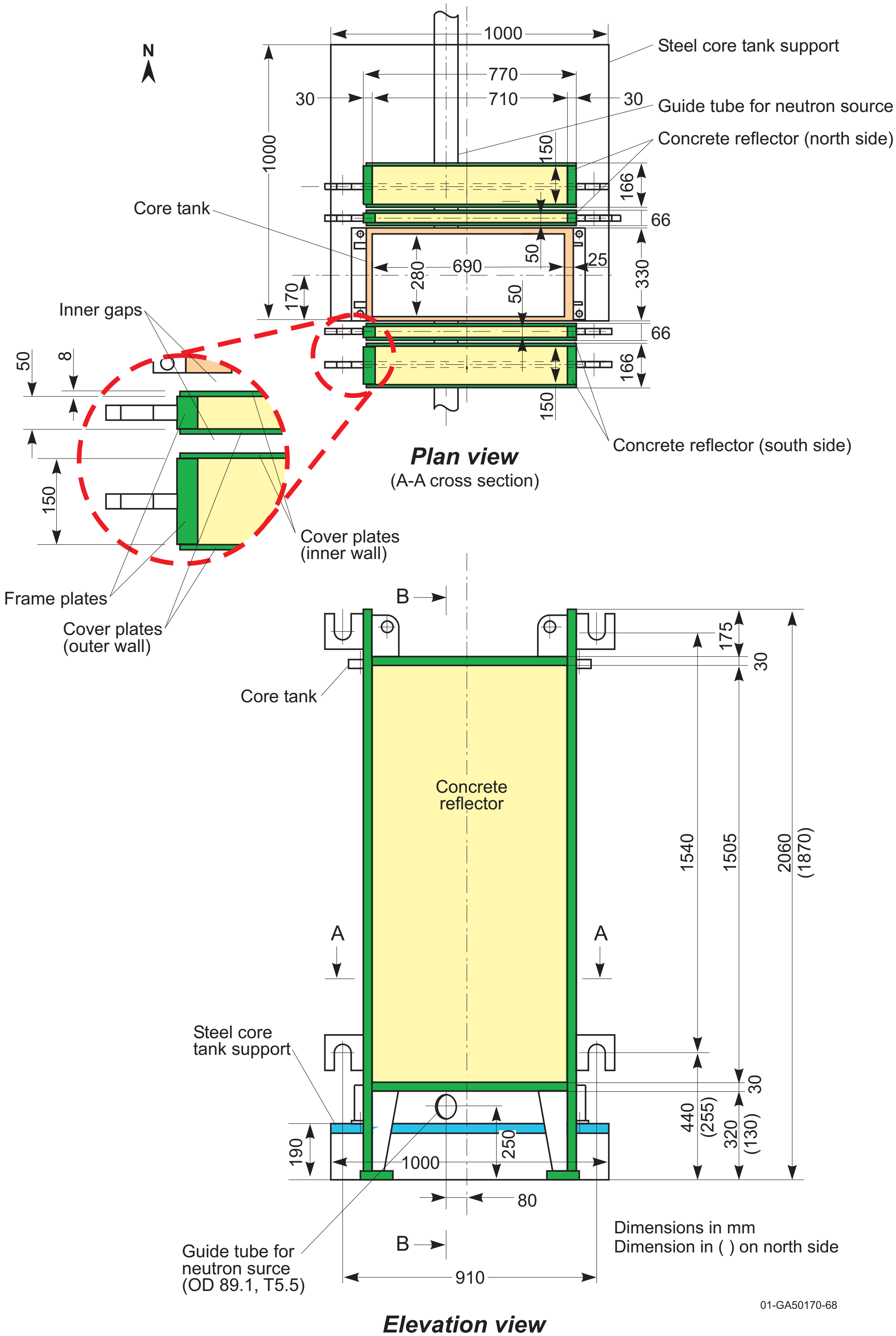


Figure 2.a. Schematic View of the Core Tank and the Reflector (C200).
(design dimensions)

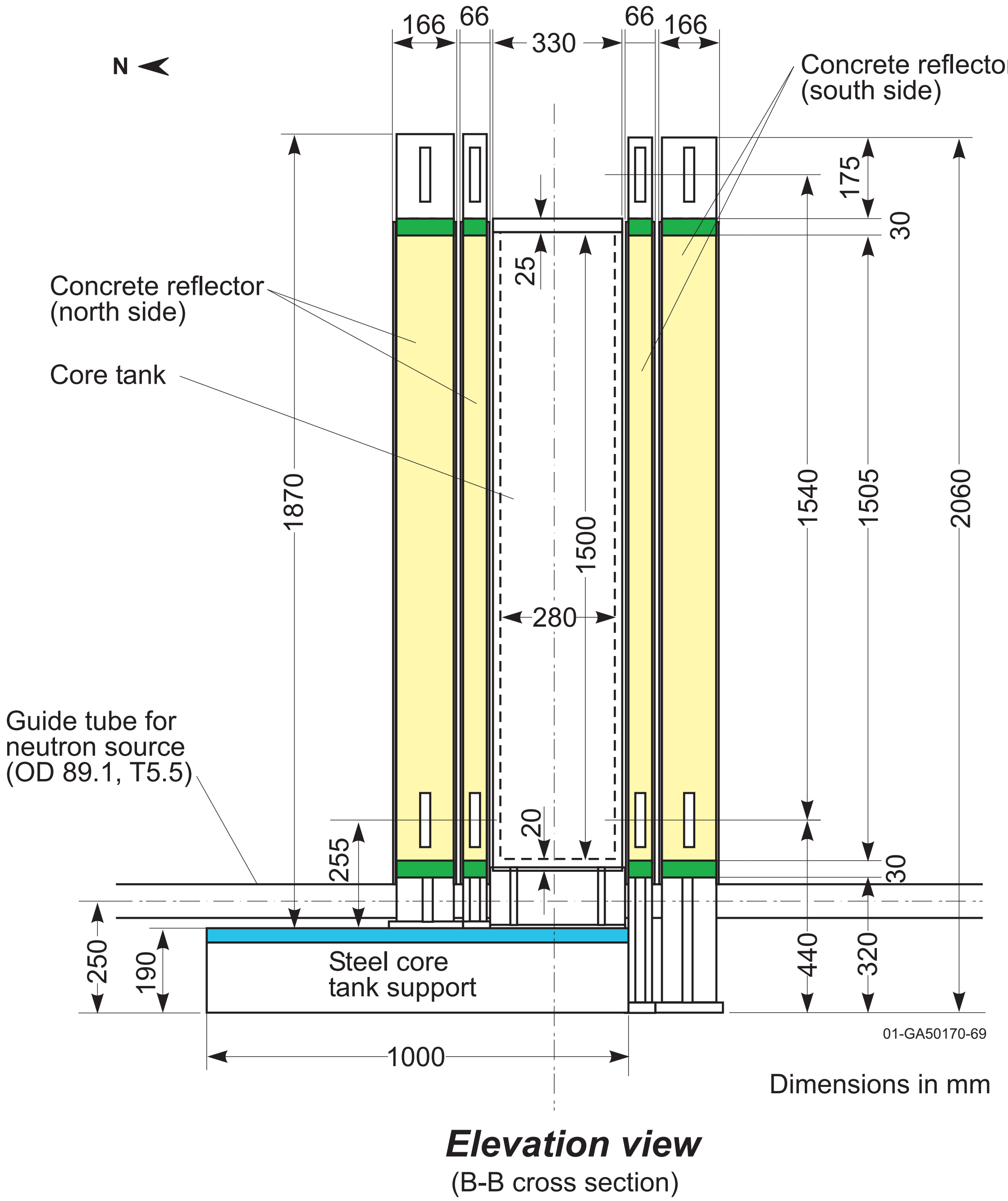


Figure 2.b. Schematic View of the Core Tank and the Reflector (B-B cross section).

Table 2. Smaller Horizontal Dimensions[a] of Reflectors (Unit : cm).

Run No.	Reflector	Inner Gap	Inner Wall	Concrete Region	Outer Wall
133	C150	0.23±0.03	0.81±0.01	15.00±0.04	0.81±0.01
142	C25	0.27±0.06	0.81±0.01	2.53±0.05	0.81±0.01
143	C50	0.21±0.03	0.81±0.01	5.01±0.04	0.81±0.01
144	C100	0.22±0.04	0.81±0.01	10.07±0.04	0.81±0.01
145 (C200)	C50	0.22±0.04	0.81±0.01	5.01±0.04	0.81±0.01
	C150	0.08±0.06	0.81±0.01	15.00±0.07	0.81±0.01
146 (C300)	C50	0.23±0.05	0.81±0.01	5.01±0.04	0.81±0.01
	C150	0.06±0.06	0.81±0.01	15.00±0.07	0.81±0.01
	C100	0.16±0.08	0.81±0.01	10.07±0.04	0.81±0.01

(a) The dimensions are averages of the north and south side values. Two or three kinds of reflectors were combined for Run No.145 and 146. These reflectors are listed in the table in order, from the inner position next to the core tank.

Table 3. Larger Horizontal Dimensions[a] of Reflectors (Unit : cm).

Reflector	Side	Active Width of Concrete/ Inner Width of Container	Thickness of Side Walls
C25	north	71.4±0.1	3.02±0.01
	south	71.4±0.1	3.02±0.02
C50	north	71.5±0.1	3.01±0.02
	south	71.5±0.1	3.01±0.02
C100	north	71.5±0.1	2.99±0.01
	south	71.4±0.1	2.99±0.01
C150	north	71.5±0.1	3.02±0.01
	south	71.4±0.1	3.02±0.02

(a) The concrete was directly built in the containers, so the active width of material is equal to the inner width of the container. The thickness of side walls is the average of the east and west walls.

Table 4. Vertical Dimensions[a] of Reflectors (Unit : cm).

Reflector	Side	Thickness of Lower Plate	Active Height of Concrete/ Inner Height of Container	Thickness of Upper Wall
C25	north	3.02±0.01	150.5±0.1	3.03±0.01
	south	3.02±0.01	150.6±0.1	3.01±0.01
C50	north	2.98±0.01	150.4±0.1	2.98±0.01
	south	2.99±0.01	150.6±0.1	3.03±0.01
C100	north	3.00±0.01	150.6±0.1	2.98±0.01
	south	2.98±0.01	150.6±0.1	2.99±0.01
C150	north	3.05±0.01	150.6±0.1	3.04±0.01
	south	3.04±0.01	150.7±0.1	3.04±0.01

(a) The concrete was directly built in the containers, so the active height of the material is equal to the inner height of the container.

The scale drawing and side views of the large empty tank in which the core tank and the reflectors were set are shown in Figures 3.a and 3.b. The outer dimensions of the pool tank, which was made of stainless steel, were 2020 mm width (east-west direction), 4020 mm length (north-south direction), and 2400 mm height. The thicknesses of the side walls and of the bottom plate were 10 mm and 15 mm, respectively. The bottom of the core tank was 330 mm above the bottom of the pool tank. The shortest distance between the side wall of the core tank and the inner surface of the pool tank is approximately 630 mm. The reflector on the north side of the core tank was set on the base plate of the core tank, and the reflector on the south side of the core tank was set on the bottom of water-reflector pool, as shown in Figure 3.b. The heights of the reflector legs, which were made of stainless steel, were 130 mm for the north-side reflector and 320 mm for the south-side reflector, as shown in Figure 2. By these reflector legs, the lower ends of the reflector materials were adjusted to within 0.1 cm of the same level as the bottom of the active fuel region in the core tank.

The pool tank was surrounded by a hood. The hood had a cubic shape and its internal dimensions were 9 x 10 meters horizontally and 9.8 meters high. This hood was installed in the reactor room, which was 12.6 meters wide, 13.1 meters long, and 12.1 meters high (Figure 4). All walls of the reactor room were made of concrete. The thickness of the concrete wall was more than 1 meter.

The STACY facility consisted of the core tank containing fuel solution, a solution transfer system, a fuel treatment system, and a fuel storage system. Reactivity was controlled by adjusting the fuel solution level in the core tank. Initially, a fast-feed pump was used to feed the fuel solution to just below half of the predicted critical height. After that, a slow-feed pump was used to feed the fuel solution to the near-critical state. The maximum excess reactivity and maximum reactivity addition rate were adjusted by limiting the position of the contact-type level gauge and the feed speed of the slow-feed pump. The level gauge consisted of a needle to detect the surface of solution, an electric motor for changing the vertical position of the needle, and an encoder indicating the vertical position. The accuracy of this level gauge was 0.2 mm.

The accuracy of the level gauge (0.2 mm) was determined during the inspection at manufacture, using a highly accurate gauge as reference. The reproductive performance of this gauge, which is confirmed every annual inspection by using a higher-accuracy gauge, is almost within 0.02 mm (1/10 of the accuracy). After every annual inspection or changing the core tank, the adjustment of the zero level is performed by directly detecting the bottom of the core tank and resetting the indication of level gauge.

The bottom of the tank was exactly flat and horizontal. After manufacturing the tank, the inclination of the bottom plate was measured and found to be within 0.6 mm (maximum height minus minimum height at edge). Also, after setting the core tank in the pool tank, the inclination of the axis was measured and found to be within 1/1500 mm per mm.

To obtain the critical height, first a critical solution height was confirmed by observing the steady-state neutron flux level. Then the final critical height was determined by a series of reactivity measurements for which the fuel solution was repeatedly drained and fed near the critical state. In the measurements, subcritical and supercritical conditions were repeated, not only subcritical conditions. For example, measured reactivities might have been –3 cents, +3 cents, -6 cents, +6 cents, -9 cents, and +9 cents. The reactivities were measured, employing a digital reactivity meter. A digital reactivity meter calculates reactivities by solving the reactor kinetics equation in real time, using an analog signal from a neutron detector. Near the critical state, reactivity is linear with solution height.

The arrangement of the neutron detectors is shown in Figure 5. The positions of the neutron detectors were variable depending on the experimental requirements. Figure 5 shows the arrangement for Run No.145 as an example, in which the experiment of the symmetric reflected condition with C50 and C150 reflectors (i.e. C200 reflector) was performed. Two ^{10}B-lined proportional counters (ST-A and B) and four gamma-ray compensated ionization chambers (LIN-A, B, LOG-A and B) were located around the core tank to measure the neutron flux level for the start-up power range and the operational power range, respectively. Maximum power was limited to 200W. Nine additional experimental neutron detectors were also located around the core tank: two ^{3}He proportional counters (Ch-1 and 3) on the west side, one gamma-ray compensated ionization chamber (Ch-7), used as input to a digital reactivity meter on the west side, one ^{3}He proportional counter (Ch-2) on the east side, one gamma-ray compensated ionization chamber (Ch-5) on the east side, one ^{3}He proportional counter (Ch-8) on the north side, one ^{10}B-lined proportional counter (Ch-4), one ^{3}He proportional counter (Ch-9) on the south side, and one ^{3}He proportional counter (Ch-10) in the southern reflector. Further, a pulsed neutron source (Pulsatron) was located on the north side for Run No. 144. For improving the neutron efficiency, the detectors were covered with polyethylene. The thicknesses of polyethylene are given in the tables in Figure 5.a.

Six critical conditions are summarized in Table 5.

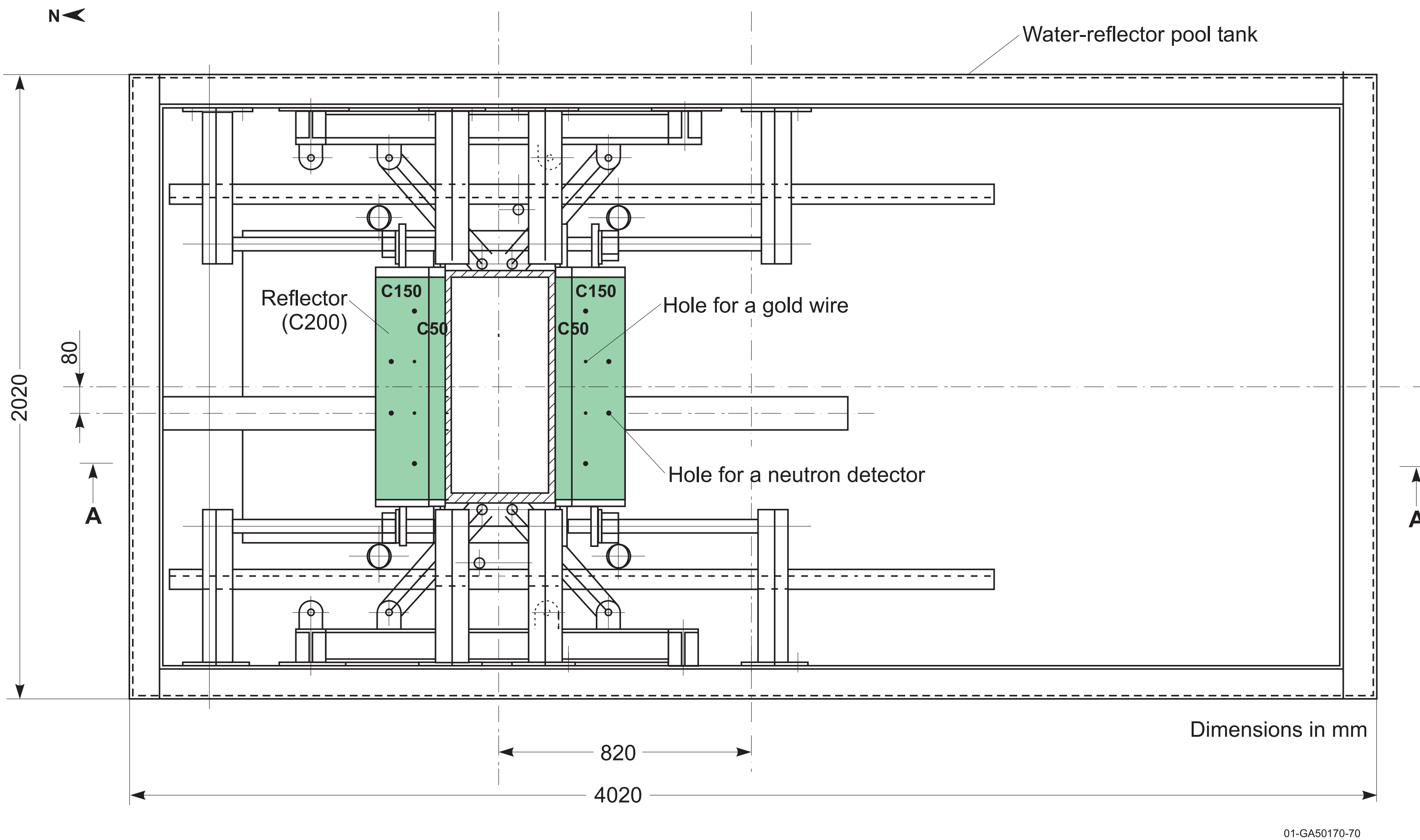


Figure 3.a. Horizontal View of an Experiment in the Empty Water-Reflector Pool Tank.

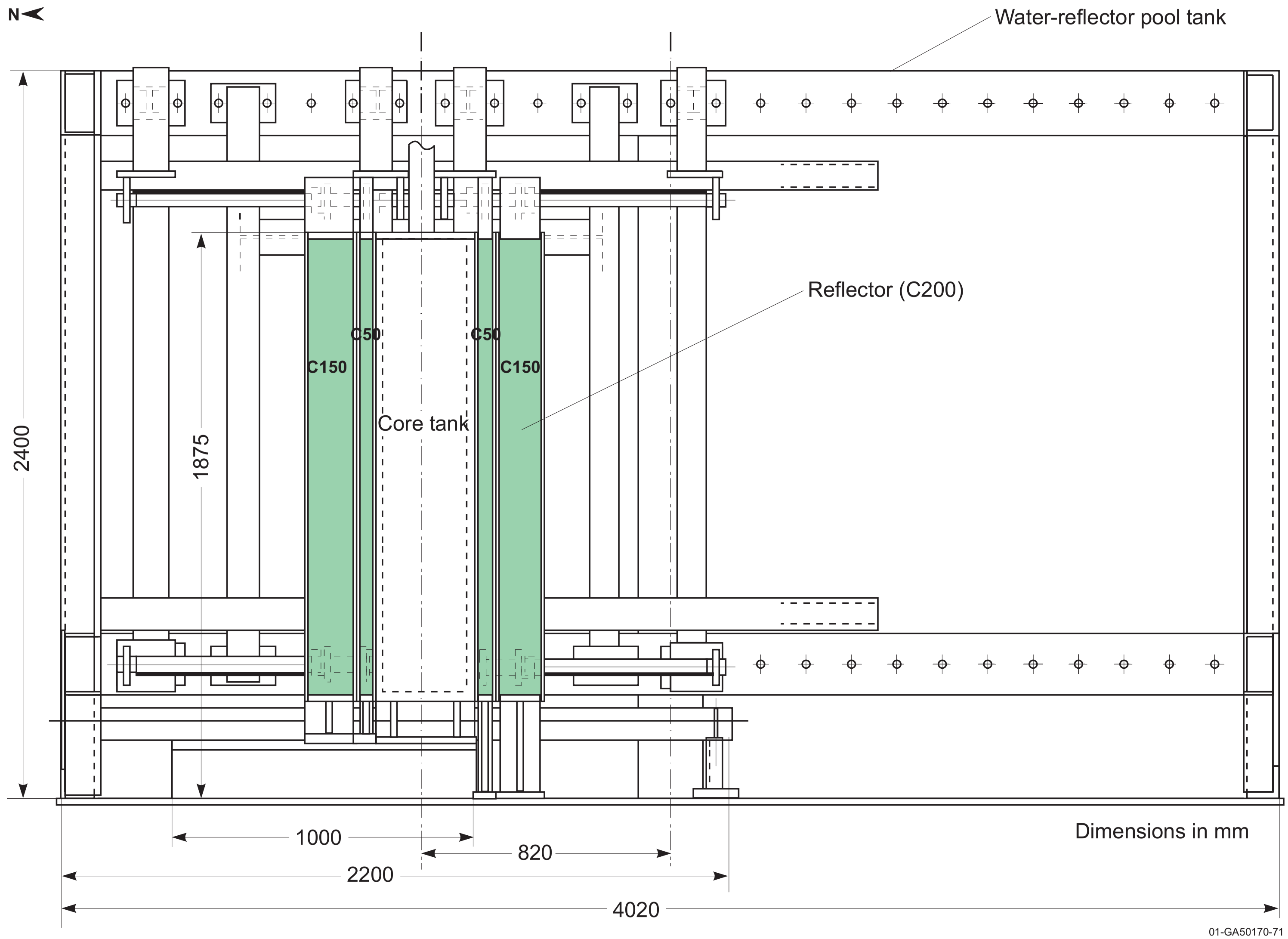


Figure 3.b. Elevation View of an Experiment in the Empty Water-Reflector Pool Tank (A-A cross section).

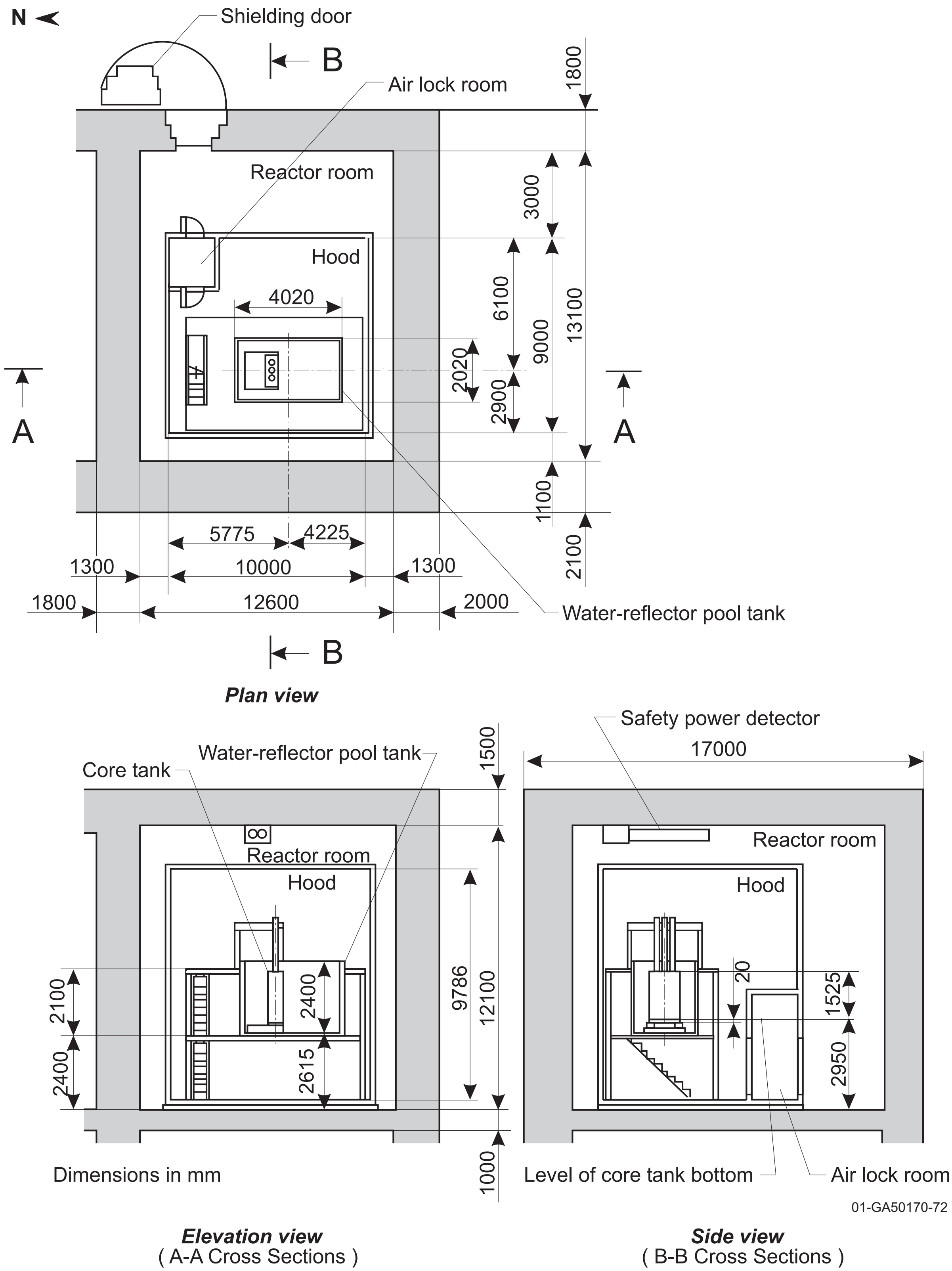
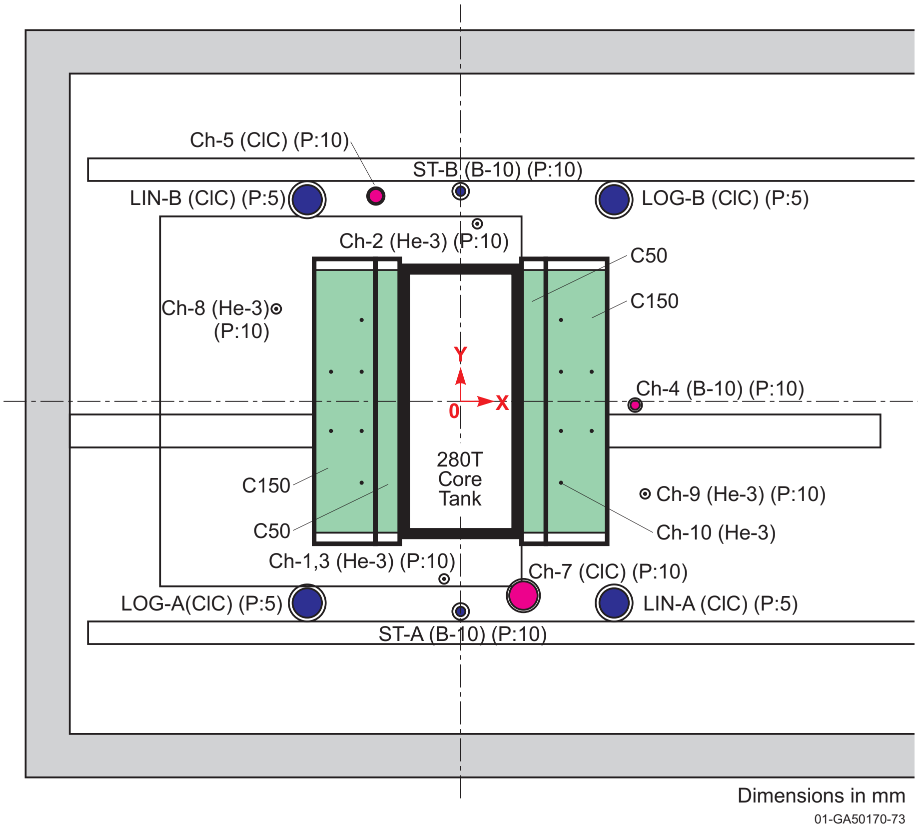


Figure 4. Schematic View Inside the Reactor Room.



Experimental Channels

ID	Type	X , Y	Hc	OD1	L1	OD2	A	L , U (A)	P	L , U (P)
Ch-1	He-3(H)	-45 , -480	168	6.0	82.5	22.0	1.0	-160 , 2240	10.0	73 , 263
Ch-2	He-3(H)	45 , 480	335	6.0	82.5	22.0	1.0	-160 , 2240	10.0	240 , 430
Ch-3	He-3(H)	-45 , -480	503	6.0	82.5	22.0	1.0	-160 , 2240	10.0	408 , 598
Ch-4	B-10	473 , -10	335	25.4	295.1	37.0	3.0	149 , 623	10.0	161 , 541
Ch-5	CIC	-230 , 555	335	38.1	235.0	47.0	3.0	177 , 601	10.0	189 , 539
Ch-7	CIC	170 , -525	335	77.0	241.0	90.0	4.0	188 , 699	10.0	218 , 578
Ch-8	He-3(L)	-500 , 250	335	6.3	10.0	22.0	1.0	-350 , 2050	10.0	310 , 360
Ch-9	He-3(L)	500 , -250	335	6.3	10.0	22.0	1.0	-350 , 2050	10.0	310 , 360
Ch-10	He-3(H)	272 , -220	400	6.0	82.5	-	-	- , -	-	- , -

Nuclear Instruments

ID	Type	X , Y	Hc	OD1	L1	OD2	A	L , U (A)	P	L , U (P)
ST-A	B-10	0 , -568	200	25.4	266.7	45.0	3.0	-350 , 2150	10.0	-25 , 425
ST-B	B-10	0 , 568	200	25.4	266.7	45.0	3.0	-350 , 2150	10.0	-25 , 425
LIN-A	CIC	416 , -545	343	79.5	355.6	100.0	3.0	-350 , 2150	5.0	63 , 623
LIN-B	CIC	-416 , 545	343	79.5	355.6	100.0	3.0	-350 , 2150	5.0	63 , 623
LOG-A	CIC	-416 , -545	343	79.5	355.6	100.0	3.0	-350 , 2150	5.0	63 , 623
LOG-B	CIC	416 , 545	343	79.5	355.6	100.0	3.0	-350 , 2150	5.0	63 , 623

X,Y: Horizontal position
Hc : Height of center of neutron counter relative to bottom of active core
OD1: Counter diameter
L1: Counter length
OD2: Outer diameter of aluminum guide tube and inner diameter of polyethylene sheet
A, P: Thicknesses of aluminum guide tube and polyethylene sheet, respectively
L,U (A): Height of lower and upper end of aluminum guide tube, respectively
L,U (P): Height of lower and upper end of polyethylene sheet, respectively

Origin of vertical position is the bottom of solution.

He Gas Pressure: He-3(H); 102Pa, He-3(L); 39Pa Polyethylene Density: 0.97 g/cm^3

Figure 5.a. Neutron-Detector Locations, from Above (Run No. 145, C200 Reflector).

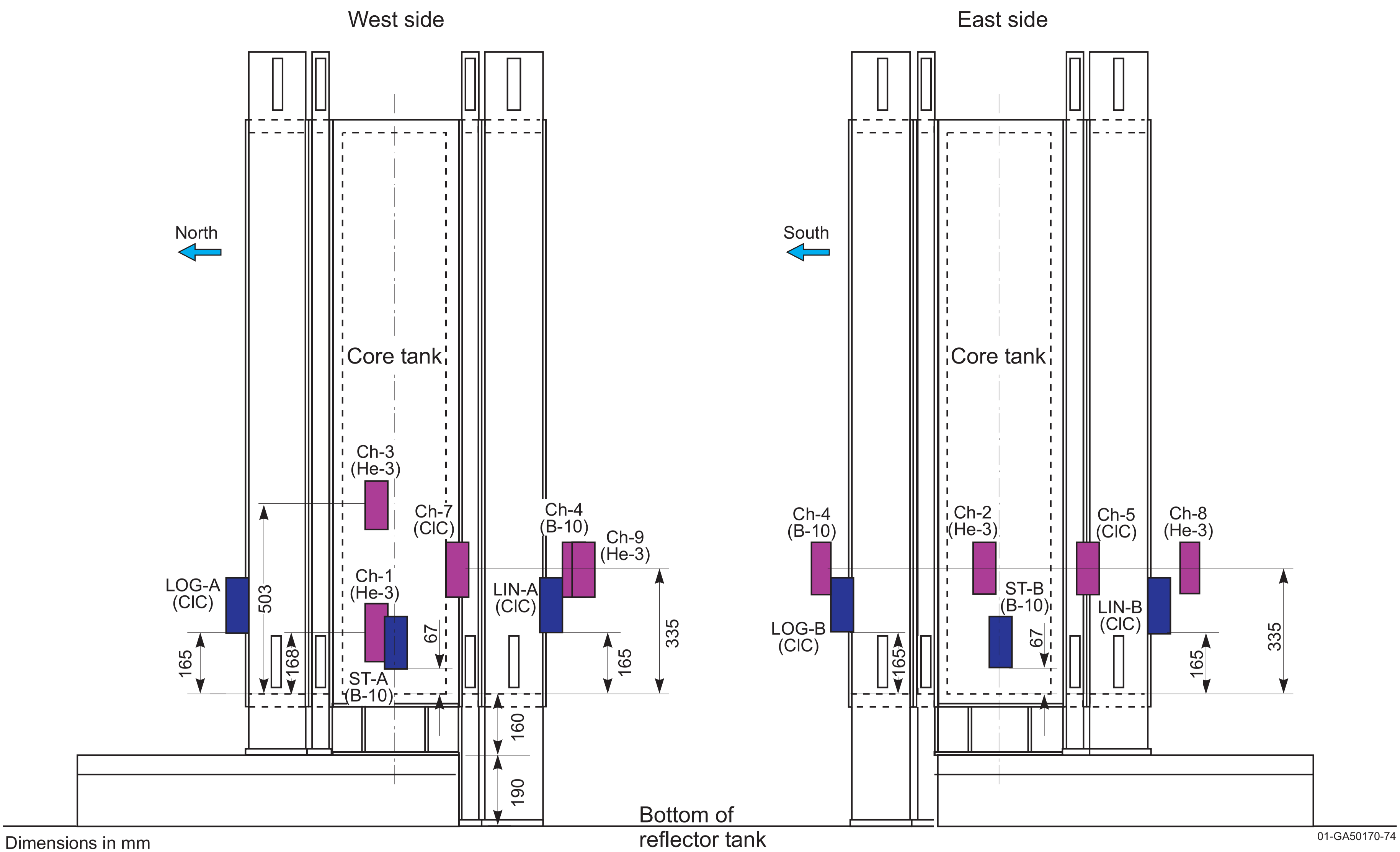


Figure 5.b. Counter Allocation from West.

Figure 5.c. Counter Allocation from East.

1.3 Description of Material Data

The chemical analyses (uranium concentration, free nitric acid concentration, and solution density) of the uranyl nitrate solution were carried out approximately every week during a series of experiments. The uranium concentration and the free nitric acid concentration were adjusted to approximately 310-315 gU/l and 0.8-1.0 mol/l, respectively.

The fuel solution characteristics at the time of each experiment were determined by interpolation of the chemical analyses and are given in Table 5. The uncertainties of the measured values in Table 5 include uncertainties for the interpolation.

Table 5. Critical conditions of STACY.

Run No.	Date (yy.mm.dd)	Reflector	Condition of fuel solution at 25 °C			Critical Height (cm)	Temp. (°C)
			U Conc. (gU/l)	H^+ (mol/l)	Density (g/cm^3)		
133	97.07.22	C150	308.1±0.7	0.800±0.014	1.4380±0.0006	67.91±0.02	24.8
142	97.10.15	C25	312.2±0.6	0.955±0.015	1.4476±0.0005	80.57±0.02	24.9
143	97.10.20	C50	312.7±0.6	0.955±0.015	1.4484±0.0005	73.18±0.02	24.7
144	97.10.24	C100	313.2±0.6	0.955±0.015	1.4490±0.0004	67.95±0.02	25.0
145	97.10.30	C200	313.8±0.6	0.955±0.015	1.4500±0.0004	65.56±0.02	25.2
146	97.11.06	C300	314.6±0.6	0.955±0.015	1.4511±0.0004	65.00±0.02	25.2

The isotopic composition of uranium, which was measured by mass spectrometry before the series of experiments, is given in Table 6. The enrichment of the uranium was 9.97±0.013 wt.%.

Table 6. Isotopic Composition of Uranium.

Isotope	wt.%
^{234}U	0.08
^{235}U	9.97±0.013
^{236}U	0.01
^{238}U	89.94

Uranyl nitrate solution consists of uranyl nitrate [$UO_2(NO_3)_2$], free nitric acid [HNO_3], and water [H_2O]. A sample of uranyl nitrate solution was taken from the dump tank, which was located in the basement under the reactor room. The results of the chemical analysis were obtained at a fixed solution temperature of 25 °C. The uranium concentration was measured by Davies and Gray's method. The uncertainty of the uranium concentration was determined to be 0.7 gU/l. The measurement of free nitric acid concentration was as follows: Initially, the uranium was precipitated by adding $(NH_4)_2SO_4$ and H_2O_2 to a sample solution. After that, the total acidity was determined by titration with sodium hydroxide. The free nitric acid concentration was estimated by subtracting the radical of uranyl nitrate from the total acidity. The uncertainty of free nitric acid concentration was determined to be 0.015 mol/l. The solution density was measured by employing a digital density meter. The accuracy of this meter was ±0.0001 g/cm^3. The uncertainty including the error of the sampling process was estimated to be ±0.0006 g/cm^3.

The temperature of the fuel solution was measured during an operation by the thermocouple inserted in the guide tube within the core tank.

Three elements, Fe, Cr, and Ni, were considered as the main impurities contained in the fuel solution; their concentrations were measured by chemical analysis. The measured concentrations of Fe, Cr and Ni were, respectively, lower than 252 mg/l, 67 mg/l, and 45 mg/l; no analysis of other impurities was made.

The main body of the core tank (the side wall, the lower plate, and the upper plate) and the frame plate of reflector container were made of stainless steel S.S.304L (or SUS304L) and S.S.304(or SUS304), respectively. The measured chemical compositions of those are given in Table 7. The density of stainless steel is 7.93 g/cm^3 according to the Japanese Industrial Standard (JIS). Other structural material (legs of core tank, tube for thermocouple, guide tube of safety rod, base plate, walls of water-reflector pool tank, fuel feed/drain line, and sheath of B_4C pellets) were also made of stainless steel S.S.304. The containers of the neutron detectors were made of aluminum. The structural materials for fixing the detectors were also made of aluminum.

Table 7. Measured chemical composition of stainless steel (Unit : wt.%).

Element	Main Body of Core Tank	Frame Plate of Reflector Container
C	0.018	0.052
Si	0.42	0.39
Mn	1.14	1.16
P	0.033	0.032
S	0.007	0.011
Ni	10.52	8.22
Cr	18.21	18.29
Fe	69.652	71.845

The cover plates of the reflector containers were made of aluminum. The measured chemical composition of the aluminum cover plates is given in Table 8. The density of aluminum is 2.69 g/cm^3, according to “the Science Table (Japan National Astronomical Observatory)”.

Table 8. Chemical Composition of Aluminum Alloy (Unit : wt.%).

Al	Si	Fe	Cu
99.20	0.14	0.59	0.07

Concrete was used as the reflector material. To determine the chemical composition, the analyses were performed for cylindrical specimens representative of all the reflectors. The averaged bulk density was estimated by measuring the dimensions and the weights for each specimen, and the uncertainty of measurement was 0.02 g/cm^3. No significant change of water content in the concrete composition over time was observed. The free-water ratio and the bound-water ratio were estimated by the drying process and the baking process. The measured chemical composition of concrete is given in Table 9. The amounts of other compounds were determined by the chemical analyses. Details of determining the concrete composition are described in Appendix B.

Table 9. Chemical Composition of Concrete.

Chemical Compound	(g/cm^3)
free H_2O	0.1145±0.0028
bound H_2O	0.1028±0.0026
SiO_2	1.4716±0.0281
Al_2O_3	0.1315±0.0093
Fe_2O_3	0.0369±0.0028
CaO	0.3663±0.0187
MgO	0.0131±0.0009
SO_3	0.0145±0.0012
Na_2O	0.0542±0.0081
K_2O	0.0150±0.0005
Cl^-	5.3E-5±2.3E-5
Total	2.321±0.019

As indicated in Table 9, total H_2O is 0.2173 ± 0.0038g/cm^3. The uncertainty is determined by adding uncertainties of free and bound H_2O quadratically, and is about 2%.

1.4 Supplemental Experimental Measurements

As mentioned in Section 1.2, the critical height was determined by reactivity measurement, employing a digital reactivity meter. The differential reactivity worth with respect to solution height was also estimated from this measurement. In a series of experiments employing various reflectors, the reactivity effects of reflector materials were evaluated by integrating the differential reactivity worth between the critical heights of the objective reflected condition and the reference condition. The main results of these measurements are described in Reference 1.

The neutron flux distribution in the reflector was measured by a gold-wire activation method. The Cd-covered and the uncovered gold wires were positioned in the measuring holes, which penetrated the reflector horizontally and vertically with 5-mm diameter. After high power operation, the gold wires were removed from the measuring holes. The 0.412 MeV photoelectric peak of ^{198}Au was measured with a 3-inch-thick well-type NaI(Tl) scintillation counter.

For a typical core configuration, the kinetic parameter β/l was also measured by the pulsed neutron method and/or frequency noise analysis. At the present time, the β/l measurement for the slab core tank is written in the unpublished internal report, while the measurement for the 60-cm-diameter core tank is written in the published report.[a]

[a] K.Tonoike et al., Proc. ICNC 99, 1215 Versailles, France(1999).

2.0 EVALUATION OF EXPERIMENTAL DATA

2.1 General Notes

Six critical configurations were collected from the logbook and other unpublished internal documents. The effects on k_{eff} of uncertainties in measured data were estimated by sensitivity studies. The sensitivity studies were performed with a two-dimensional transport code, TWOTRAN, and a 16-energy-group cross section set collapsed from the 107-energy-group SRAC public library based on the evaluated nuclear data library, JENDL-3.2. The k_{eff}'s were calculated with a convergence criteria of 1×10^{-5}.

For the sensitivity studies, a density formula for uranyl nitrate solution developed at JAERI was used. This formula gives the density of uranyl nitrate solution as a function of uranium concentration, free nitric acid concentration, and solution temperature. The details of this formula are described in Appendix C. This formula was not used to determine the benchmark solution densities. The measured densities at 25°C were used for the benchmark model.

Horizontal XY calculations (X: north-south; Y: east-west) with 6.9-cm extrapolation length in the Z (vertical) direction were performed for the horizontal-dimension sensitivity studies. The XZ calculations with 8.9-cm extrapolation length in the Y direction were done for the vertical-dimension sensitivity studies.

2.2 Fuel Solution Uncertainties

As mentioned in Section 1.3, the uncertainties of uranium enrichment, uranium concentration, free nitric acid concentration, and solution density were determined to be 0.013 wt.%, 0.7 gU/l, 0.015 mol/l, and 0.0006 g/cm^3, respectively. The solution height was measured with a contact-type level gauge, of which the accuracy was 0.2 mm. The solution temperature was measured with a thermocouple. The temperature change during the operation was estimated to be within 0.3 ^{o}C, including accuracy of the device. The concentration of the main impurities Fe, Cr, and Ni were less than 252 mg/l, 67 mg/l, and 45 mg/l, respectively. The effects on k_{eff} of uncertainties pertaining to the fuel solution are given in Table 10.

Table 10. Effects on k_{eff} of Uncertainties Pertaining to the Fuel Solution. (Δk_{eff} ,%).

Parameter	Variation	Run No.					
		133	142	143	144	145	146
U enrichment	±0.013 wt.%	±0.047	±0.046	±0.046	±0.046	±0.046	±0.047
U concentration	±0.7 gU/l	±0.059	±0.058	±0.058	±0.058	±0.057	±0.057
H^+ concentration	±0.015 mol/l	-/+0.022	-/+0.022	-/+0.023	-/+0.022	-/+0.022	-/+0.022
Solution density	±0.0006 g/cm^3	±0.010	±0.010	±0.010	±0.010	±0.010	±0.010
Solution height	±0.2 mm	±0.003	±0.002	±0.002	±0.003	±0.003	±0.003
Temperature	±0.3 °C	-/+0.008	-/+0.010	-/+0.010	-/+0.010	-/+0.010	-/+0.011
Impurity (Fe)	+252 mg/l	-0.008	-0.008	-0.008	-0.008	-0.008	-0.007
Impurity (Cr)	+67 mg/l	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003
Impurity (Ni)	+45 mg/l	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Total		±0.080	±0.079	±0.079	±0.079	±0.078	±0.079

There are two uncertainties on the temperature:

(1) The change of temperature during the experiment (0.3°C).

(2) The fact that atom densities are known at 25°C and the experiments are conducted at other temperatures, a maximum difference of 0.3°C (25-24.7).

The temperature uncertainty has two effects.

(1) The change in solution density, which is calculated with the density formula;

(2) The change in uranium concentration C(U).

The following relationships hold for volume, density, and concentration:

Volume×Density=Constant,
Volume×Concentration=Constant.

Therefore, the following relationships are derived:

$$\Delta V/V = -\Delta\rho/\rho = -\Delta C(U)/C(U)\ .$$

ΔC may be calculated, since $\Delta\rho$ is calculated with the density formula. All these effects are included in the Δk_{eff}'s for temperature in Table 10.

In the sensitivity studies of the impurities, each impurity was added without changing the other constituents of the fuel solution.

2.3 Core Tank Uncertainties

The inner thickness of the tank was estimated using the tank outer thickness and double the side-wall thickness. In the same way, the inner width of the tank was estimated using the tank outer width and double the side-wall thickness. The inner height of the tank was estimated using the tank outer height and the upper and lower plate thicknesses.

As to the effects on k_{eff} of uncertainties pertaining to the core tank, the effects caused by the dimensional uncertainties were evaluated: core thickness, core width, thicknesses of side wall and lower plate. As shown in Table 1, the uncertainties of those were 0.05 cm, 0.05 cm, 0.01 cm, and 0.01 cm, respectively. The effect caused by the stainless steel density was also evaluated. The uncertainty of the density is assumed to be in the least significant digit, 0.01 g/cm^3. The effects on k_{eff} of uncertainties pertaining to the core tank were calculated using these uncertainties as variations, and the results are given in Table 11. The calculated effect on k_{eff} was divided by the square root of the number of measurements (Table 1.b) to obtain the standard deviation of the mean.

Table 11. Effects on k_{eff} of Uncertainties Pertaining to the Core Tank (Δk_{eff}, %).

Parameter	Variation	Run No.					
		133	142	143	144	145	146
Solution thickness	±0.05cm	±0.042	±0.046	±0.044	±0.042	±0.041	±0.041
Solution width	±0.05cm	±0.006	±0.006	±0.006	±0.006	±0.006	±0.006
Side-wall thickness (X)[a]	±0.01cm	±0.003	±0.007	±0.005	±0.004	±0.003	±0.003
Side-wall thickness (Y)[b]	±0.01cm	±0.001	±0.001	±0.001	±0.001	±0.001	±0.001
Lower-plate thickness	±0.01cm	<0.001	<0.001	<0.001	<0.001	<0.001	±0.001
Stainless steel density	±0.01 g/cm^3	±0.002	±0.003	±0.002	±0.002	±0.002	±0.002
Total		±0.043	±0.047	±0.045	±0.043	±0.042	±0.042

(a) X: north-south direction
(b) Y: east-west direction

2.4 Reflector Uncertainties

As shown in Table 2, the uncertainties of inner wall thickness, concrete thickness, outer wall thickness, and inner gap width were 0.01 cm, less than 0.1 cm, 0.01 cm, and less than 0.1 cm, respectively. As shown in Table 3, the uncertainties of active concrete width was 0.1 cm. And as shown in Table 4, the uncertainties of active concrete height and the lower plate thickness were 0.1 cm and 0.01 cm, respectively. By setting the reflector on the reflector support, the lower ends of the concrete and the active fuel region were adjusted to the same vertical levels. The accuracy of this adjustment were estimated to be 0.1 cm (vertical position of reflector). The uncertainty of the concrete density was estimated to be 0.02 g/cm^3 . The effects on k_{eff} of uncertainties pertaining to the reflectors are given in Table 12.

Table 12. Effects on k_{eff} of Uncertainties Pertaining to Reflectors (Δk_{eff},%).

Parameter	Variation	Run No.					
		133	142	143	144	145	146
Inner gap width	±0.10 cm	-/+0.025	-/+0.013	-/+0.018	-/+0.024	-/+0.027	-/+0.026
Inner wall thickness	±0.01 cm	±0.001	±0.003	±0.002	±0.001	±0.001	±0.001
Concrete thickness	±0.10 cm	±0.001	±0.034	±0.019	±0.005	±0.001	±0.001
Outer wall thickness	±0.01 cm	<0.001	±0.002	±0.001	<0.001	<0.001	<0.001
Concrete width	±0.1 cm	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Concrete height	±0.1 cm	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lower plate thickness	±0.01 cm	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vertical position	±0.1 cm	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Concrete density	±0.02 g/cm^3	±0.005	±0.007	±0.009	±0.007	±0.003	±0.003
Total		±0.026	±0.037	±0.028	±0.026	±0.027	±0.026

2.5 <u>Concrete Composition Uncertainties</u>

As shown in Table 9, the concrete consisted of ten kinds of chemical compounds. The relative uncertainties of each compound were estimated to be less than the following values:

H_2O	2.0%;
SiO_2	2.0%;
Al_2O_3	8.0%;
Fe_2O_3	8.0%;
CaO	6.0%;
MgO	8.0%;
SO_3	10%;
Na_2O	20%;
K_2O	5.0%;
and Cl^-	50%.

The effects on k_{eff} of uncertainties pertaining to the concrete composition are given in Table 13.

Table 13. Effects on k_{eff} of Uncertainties Pertaining to Concrete Composition (Δk_{eff} ,%).

Chemical Compound	Variation (%)	Run No.					
		133	142	143	144	145	146
H_2O	±2.0%	-/+0.003	-/+0.003	-/+0.003	-/+0.003	-/+0.003	-/+0.003
SiO_2	±2.0%	±0.010	±0.010	±0.010	±0.010	±0.010	±0.010
Al_2O_3	±8.0%	±0.005	±0.004	±0.005	±0.005	±0.004	±0.004
Fe_2O_3	±8.0%	±0.001	±0.001	±0.001	±0.001	±0.001	±0.001
CaO	±6.0%	±0.008	±0.006	±0.008	±0.008	±0.007	±0.007
MgO	±8.0%	±0.001	±0.001	±0.001	±0.001	<0.001	<0.001
SO_3	±10%	±0.001	±0.001	±0.001	±0.001	±0.001	±0.001
Na_2O	±20%	±0.007	±0.006	±0.008	±0.008	±0.006	±0.006
K_2O	±5.0%	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cl^-	±50%	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total		±0.016	±0.014	±0.016	±0.016	±0.015	±0.015

2.6 <u>Reactivity Effect of Reflector</u>

The reflector effects of concrete were estimated by TWOTRAN calculations with a convergence criteria of $1x10^{-5}$. The definition of the reflector effect is as follows:

$$\rho(\%\Delta k/k) = \left(\frac{1}{k_{eff}^{(unref)}} - \frac{1}{k_{eff}^{(ref)}} \right) \times 100,$$

where

$k_{eff}^{(ref)}$ is k_{eff} of the system with a reflector,

$k_{eff}^{(unref)}$ is k_{eff} of the system without a reflector.

The calculated k_{eff}'s and the estimated effects are given in Table 14.

Table 14. Evaluated Results of Reflector Effects.

Run No.	Reflector	Concrete Thickness (cm)	Calculated k_{eff}		Reflector Effect (% Δk/k)
			$k_{eff}^{(ref)}$	$k_{eff}^{(unref)}$	
133	C150	15.00	1.00371	0.97562	2.87
142	C25	2.53	1.00587	0.98861	1.74
143	C50	5.01	1.00545	0.98261	2.31
144	C100	10.07	1.00452	0.97727	2.78
145	C200	20.01	1.00358	0.97476	2.95
146	C300	30.08	1.00335	0.97464	2.94

2.7 Conclusions

The calculated effects of material and geometrical uncertainties are summarized in Table 15 .

Table 15. Summary of Effects on k_{eff} for Materials and Geometrical Uncertainties (Δk_{eff}, %).

Parameter	Run No.					
	133	142	143	144	145	146
Fuel Solution	±0.080	±0.079	±0.079	±0.079	±0.078	±0.079
Core Tank Dimension and Density	±0.043	±0.047	±0.045	±0.043	±0.042	±0.042
Reflector Dimension and Density	±0.026	±0.037	±0.028	±0.026	±0.027	±0.026
Concrete Composition of Reflector	±0.016	±0.014	±0.016	±0.016	±0.015	±0.015
Total	±0.096	±0.100	±0.096	±0.095	±0.094	±0.094

Because the experimental conditions are obviously known and the uncertainties of those have been sufficiently quantified, the six critical configurations included in this evaluation are acceptable benchmark experiments.

3.0 BENCHMARK SPECIFICATIONS

3.1 Description of Model

The model consists of the fuel solution, the core tank, the concrete reflectors, and the reflector containers. The following structure and devices are not included in the benchmark model, for simplification:

(1) Tube for the thermocouple within the core tank.
(2) Contact-type level gauge. This is above the surface of the fuel solution.
(3) Four legs supporting the core tank.
(4) Fuel feed/drain line containing fuel solution. The outer diameter of the tube is 27.2 mm, and its thickness is 3.4 mm.
(5) Guide tube for the neutron source. This tube lies horizontally below the core tank.
(6) Base plate supporting four legs. The upper surface of this plate is 14 cm below the bottom of the core tank. The thickness of this plate is 30 mm.
(7) Beams supporting the base plate. These beams lie on the bottom of the pool tank. The height of these beams is 16 cm.
(8) Four legs of the reflector support which stand on the bottom of the pool tank (south side) or the base plate (north side). The height of these legs on the south and north sides are 32 cm and 13 cm, respectively.
(9) Holes penetrating the reflector horizontally and vertically. These holes were prepared to set up neutron detectors or gold wire. The diameter of these holes is 16 mm for neutron detectors, or 5 mm for gold wire.
(10) Six neutron detectors for reactor operation; two ^{10}B-lined proportional counters, and four gamma-ray compensated ionization chambers. These were covered with polyethylene to improve the neutron efficiency, and were located beside the reflectors.
(11) Nine neutron detectors and pulsed neutron source (for Run No. 144.) for the experimental measurements; five ^{3}He proportional counters, one ^{10}B-lined proportional counter and three gamma-ray compensated ionization chambers. The arrangement of neutron detectors for Run No.145 was shown in Figure 5.
(12) Structures and devices on the top of the core tank; guide tubes of the safety rods, device of the level gauge, safety rods, and so on.
(13) Side walls and bottom plate of the pool tank. The thickness of the side walls and the bottom plate are 10 mm and 15 mm, respectively. The side wall is at least 39 cm away from the outer surface of the reflector. The bottom plate is 33 cm below the core tank.
(14) Hood and concrete walls of the reactor room.
(15) Other structure outside the core tank.
(16) Holes for gold wires and detectors in the reflector.

To estimate the model simplification effect for each core configuration, a detailed model that includes the structures (1)-(16) was constructed. The model simplification effect is defined as the difference of k_{eff}'s between the benchmark model and the detailed model. The calculations of k_{eff} were carried out by MCNP4B with JENDL-3.2 (10^7 neutron histories). The estimated results of the model simplification effects are given in Table 16.

Table 16. Estimated Results of Model Simplification Effect.

Run No.	Reflector	Calculated k_{eff} ($\pm 1\sigma$)		Model Simplification Effect, Δk_{eff} (%)
		Benchmark Model	Detailed Model	
133	C150	1.0069± 0.0002	1.0077±0.0002	-0.08±0.03
142	C25	1.0075± 0.0002	1.0079±0.0002	-0.04±0.03
143	C50	1.0080± 0.0002	1.0083±0.0002	-0.03±0.03
144	C100	1.0075± 0.0002	1.0078±0.0002	-0.03±0.03
145	C200	1.0071± 0.0002	1.0080±0.0002	-0.09±0.03
146	C300	1.0075± 0.0002	1.0080±0.0002	-0.05±0.03

Because a reflector acts as a neutron isolator of the core tank and the outer objects, it is expected that the model simplification effect decreases as the thickness of concrete increases. As shown in Table 16, however, it was not observed that the model simplification effect depends on the thickness of concrete. Although such a trend in the model simplification effect is not clear in Table 16, values are negative as expected, since most simplifications decrease reflection. It was determined that the model simplification effects should be considered as biases, and the combined standard deviations (1σ) of the Monte Carlo calculations should be included as the uncertainties.

In the benchmark model, impurities such as Fe, Cr, and Ni are omitted. The reactivity effects of these impurities were obtained in Section 2.2. Because the reactivity effects were estimated with the maximum concentrations during the experiments and the estimated effects were very small, they are not included as biases in the benchmark-model k_{eff}'s. But they are included as uncertainties in the benchmark-model k_{eff}'s.

3.2 <u>Dimensions</u>

The benchmark model with one reflector piece on each of the two larger sides of the core tank is shown in Figure 6.a. The model for Run 145, with a combination of two reflectors on each of the two larger sides, is given in Figure 6.b. And the model for Run 146, with a combination of three reflectors on each of the two larger sides, is given in Figure 6.c. The dimensions of the benchmark model are given in the figure, except the solution height and some horizontal dimensions of the reflector, which are given in Table 17.

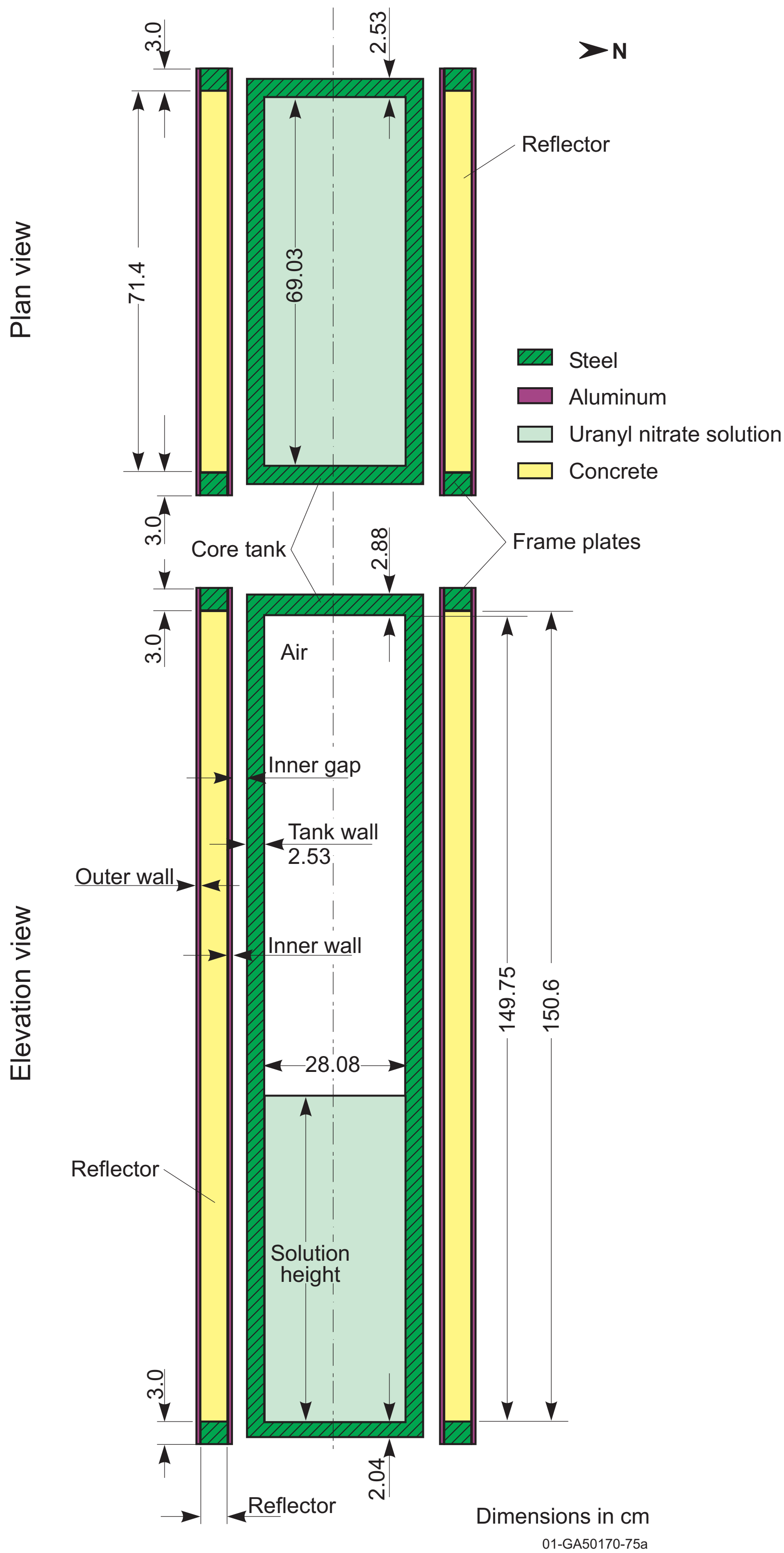


Figure 6.a. Benchmark Model of Run No. 133, 142, 143, and 144.
(one reflector on each side)

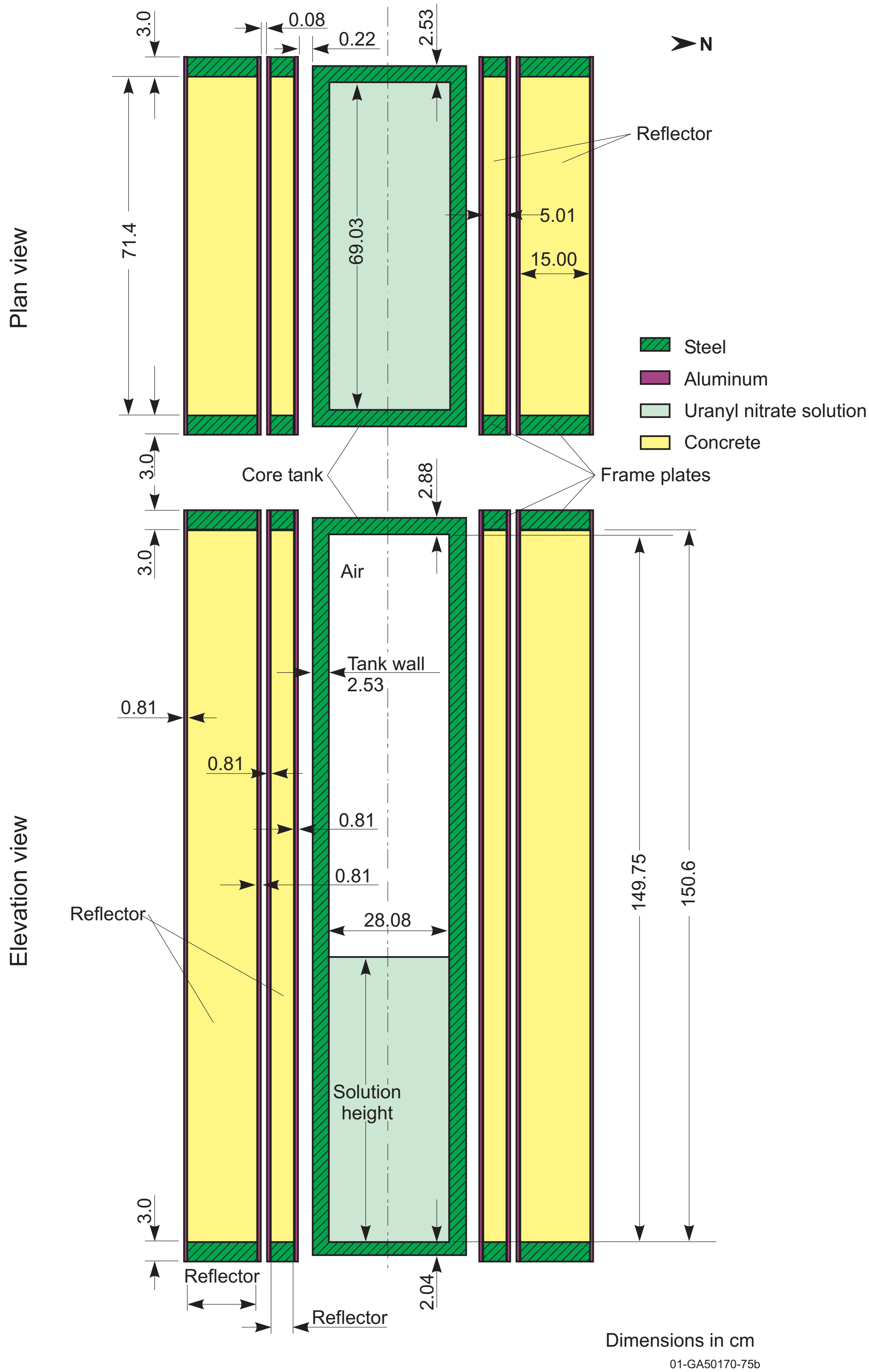


Figure 6.b. Benchmark Model of Run No. 145.
(combination of two sizes of reflectors on each side)

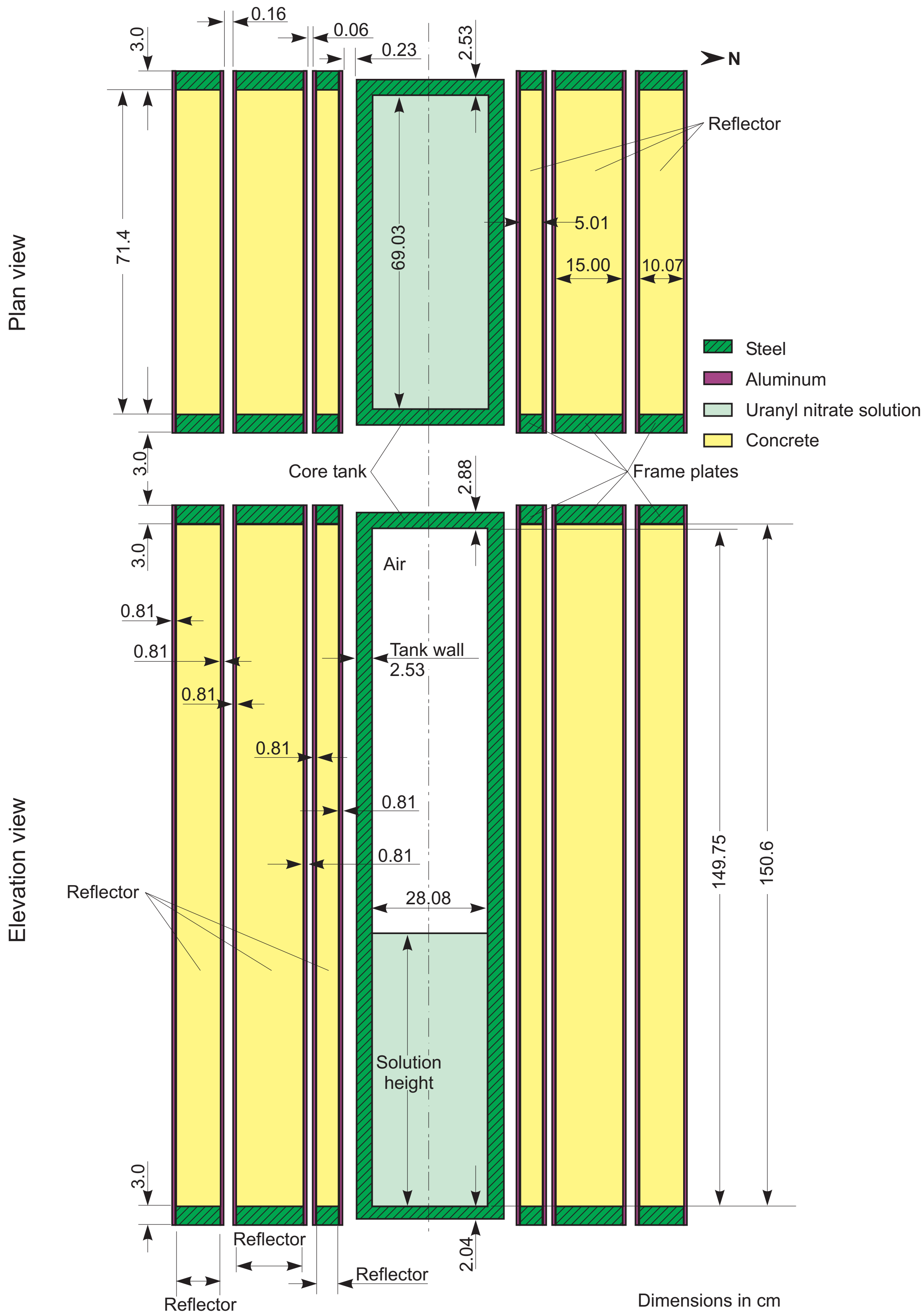


Figure 6.c. Benchmark Model of Run No. 146.
(combination of three sizes of reflectors on each side)

Table 17. Solution Height and Horizontal Dimensions of Reflector (Unit: cm).

Run No.	Solution Height	Reflector	Horizontal Dimensions of Reflector			
			Inner Gap	Inner Wall	Concrete	Outer Wall
133	67.91	C150	0.23	0.81	15.00	0.81
142	80.57	C25	0.27	0.81	2.53	0.81
143	73.18	C50	0.21	0.81	5.01	0.81
144	67.95	C100	0.22	0.81	10.07	0.81
145 [(a)] (C200)	65.56	C50	0.22	0.81	5.01	0.81
		C150	0.08	0.81	15.00	0.81
146 [(a)] (C300)	65.00	C50	0.23	0.81	5.01	0.81
		C150	0.06	0.81	15.00	0.81
		C100	0.16	0.81	10.07	0.81

(a) The reflectors and gaps are listed in order, from the core tank outward.

The core is uranyl nitrate solution in a rectangular stainless steel tank. The tank's inner dimensions are 28.08 cm x 69.03 cm x 149.75 cm high. The four side walls are 2.53 cm thick. The tank bottom is 2.04 cm thick, and the top is 2.88 cm thick. The tank is centered horizontally between the reflectors.

The reflector width is 71.4 cm. And the reflector height is 150.6 cm. The bottom surface of the concrete is level with the bottom of the solution. The thickness of the frame plate is 3.0 cm.

The critical solution heights and the horizontal dimensions of reflectors for each case are summarized in Table 17.

3.3 Material Data

The uranium concentration, the free nitric acid concentration, and the solution density at 25°C are known for each core configuration. The atom densities of the fuel solution are given in Table 18. Their derivation is described in Appendix F.

Table 18. Atom Densities of Fuel Solution at 25°C (Unit: atoms/barn-cm).

Run No.	^{234}U	^{235}U	^{236}U	^{238}U	H	N	O
133	6.3422E-07	7.8702E-05	7.8604E-08	7.0101E-04	5.9135E-02	2.0426E-03	3.7015E-02
142	6.4266E-07	7.9749E-05	7.9650E-08	7.1034E-04	5.8763E-02	2.1567E-03	3.7146E-02
143	6.4369E-07	7.9877E-05	7.9777E-08	7.1147E-04	5.8762E-02	2.1593E-03	3.7155E-02
144	6.4472E-07	8.0005E-05	7.9905E-08	7.1261E-04	5.8746E-02	2.1618E-03	3.7158E-02
145	6.4595E-07	8.0158E-05	8.0058E-08	7.1398E-04	5.8747E-02	2.1648E-03	3.7170E-02
146	6.4760E-07	8.0362E-05	8.0262E-08	7.1580E-04	5.8732E-02	2.1689E-03	3.7179E-02

The density of the stainless steel S.S.304L is 7.93 g/cm^3 . The atom densities of the stainless steel used for the core tank and the frame plates of the reflector containers are given in Table 19.

Table 19. Atom Densities of Stainless Steel (Unit: atoms/barn-cm).

	C	Si	Mn	P	S	Ni	Cr	Fe
(a)	7.1567E-5	7.1415E-4	9.9095E-4	5.0879E-5	1.0424E-5	8.5600E-3	1.6725E-2	5.9560E-2
(b)	2.0675E-4	6.6314E-4	1.0083E-3	4.9337E-5	1.6380E-5	6.6885E-3	1.6798E-2	6.1435E-2

(a) Main body of core tank
(b) Frame plates of reflector container.

The density of aluminum is 2.69 g/cm^3. The aluminum is used for the cover plates (inner and outer walls) of the reflector containers. The aluminum atom densities are listed in Table 20.

Table 20. Atom Densities of Aluminum Alloy (Unit: atoms/barn-cm).

Al	Si	Fe	Cu
5.9559E-02	8.0751E-05	1.7114E-04	1.7845E-05

The density of concrete is 2.321 g/cm^3. The chemical composition of the concrete is known in g/cm^3. The atomic number densities of the concrete are given in Table 21.

Table 21. Atom Density of Concrete.

Element	(atoms/barn-cm)
H	1.4528E-02
O in water	7.2639E-03
O in mix	3.7326E-02
Na	1.0533E-03
Mg	1.9573E-04
Al	1.5533E-03
Si	1.4749E-02
S	1.0906E-04
Cl	9.0027E-07
K	1.9179E-04
Ca	3.9337E-03
Fe	2.7830E-04

It is assumed that the void region above the surface of the fuel solution is occupied by air of density 0.001184 g/cm^3. The air is composed of 76.64 wt.% nitrogen and 23.36 wt.% oxygen[a]. The atom density (atoms/barn-cm) of the air is as follows:

3.9014E-05 for nitrogen,
and 1.0410E-05 for oxygen

3.4 Temperature Data

The solution temperature for each core configuration varies from 24.7°C to 25.2°C. However, the solution temperature adopted in the benchmark models is fixed at 25°C because the chemical analyses were performed at this temperature. The effects of the temperature differences were estimated by TWOTRAN calculations with a convergence criteria of 1×10^{-5}. To obtain the atom densities at each temperature, the density formula was used (Appendix C). The calculation was performed considering the change in water density and uranium concentration based on the density formulation, as discussed in Section 2.2. The k_{eff}'s at the experimental temperature and at the adopted temperature were calculated. The cross section modification due to the differences of temperature were included in the TWOTRAN calculations. The estimated results of the temperature effects are given in Table 22.

[a] B. TAMAMUSHI et al., Rikagaku Jiten (Science Encyclopedia), Iwanami Shoten (1975) (in Japanese). Other elements were neglected. The wt.% of N and O were adjusted such that the ratio of these were conserved.

Table 22. Evaluated Results of Temperature Effects.

Run No.	Reflector	Experimental Temperature (°C)	k_{eff} at 25.0 (°C)	k_{eff} at Experimental Temperature	Temperature Effect Δk_{eff} (%)
133	C150	24.8	1.00456	1.00461	-0.005
142	C25	24.9	1.00686	1.00689	-0.003
143	C50	24.7	1.00649	1.00659	-0.010
144	C100	25.0	1.00545	1.00545	0.0
145	C200	25.2	1.00541	1.00534	+0.007
146	C300	25.2	1.00418	1.00411	+0.007

Each temperature effect is regarded as a bias in the benchmark-model k_{eff}.

3.5 Experimental and Benchmark-Model k_{eff}

The experimental k_{eff}'s are unity. The following sources should be considered as possible biases in the benchmark models:

(1) model simplification effect – omitting the structures and devices around the core configuration, for simplification,
(2) impurity effect – excluding the impurities (Fe, Cr, and Ni) from the fuel solution, and
(3) temperature effect – difference between the experimental temperature and the adopted temperature (25 °C).

Both the model simplification effect and the temperature effect are considered to be biases in the benchmark models. They were estimated in Sections 3.1 and 3.4.

As discussed in Section 3.1, the combined standard deviations (1σ) of the Monte Carlo calculations of simplifications were also included in the uncertainties. Also, as discussed in Section 3.1, the impurity effects are not included in the biases, but are included in the uncertainties (those pertaining to the fuel solution). In Section 2.0, the uncertainties are estimated as having the following origins:

(1) fuel solution,
(2) core tank, and
(3) reflectors.

The uncertainties of the k_{eff}'s included in the benchmark model are obtained by the square root of the sum of individual uncertainties' squares, and correspond to one standard deviation. Consequently, the benchmark-model k_{eff}'s are:

Run 133 (C150) : 0.9992±0.0010,
Run 142 (C25) : 0.9996±0.0010,
Run 143 (C50) : 0.9996±0.0010,
Run 144 (C100) : 0.9997±0.0010,
Run 145 (C200) : 0.9992±0.0010, and
Run 146 (C300) : 0.9996±0.0010.

4.0 RESULTS OF SAMPLE CALCULATIONS

The results of the sample calculations using MCNP 4B with the JENDL-3.2 library are given in Table 23.a. These high values are known to be caused by the library's capture cross section of ^{235}U in the resonance energy range which is smaller than that of the other libraries.

In addition, the CRISTAL code system of IPSN (APOLLO-2 cell code with the CEA93 172-group library based on JEF2.2 evaluation, and MORET-4 Monte Carlo code with σ=0.03 %) were used for sample calculations. The results are given in Table 23.b. The results of KENO V.a with ENDF/B-IV and V libraries and MCNP4C calculations with ENDF/B-V and VI libraries are given in Table 23.c.

Table 23.a. Sample Calculation Results (Japan).

Case No.	Code (Cross Section Set) → Run No. (Reflector) ↓	MCNP (Continuous Energy JENDL-3.2)
1	133 (C150)	1.0069 ± 0.0002
2	142 (C25)	1.0075 ± 0.0002
3	143 (C50)	1.0080 ± 0.0002
4	144 (C100)	1.0075 ± 0.0002
5	145 (C200)	1.0071 ± 0.0002
6	146 (C300)	1.0075 ± 0.0002

Table 23.b. Sample Calculation Results (France). (a)

Case No.	Code (Cross Section Set) → Run No. (Reflector) ↓	APOLLO-2 / MORET-4 (CEA93 Library-172-Group)
1	133 (C150)	1.0047 ± 0.0003
2	142 (C25)	1.0050 ± 0.0003
3	143 (C50)	1.0052 ± 0.0003
4	144 (C100)	1.0046 ± 0.0003
5	145 (C200)	1.0047 ± 0.0003
6	146 (C300)	1.0052 ± 0.0003

(a) Results provided by IPSN/DPEA/SEC.

Table 23.c. Sample Calculation Results (United States). [(a)]

Case No.	Code (Cross Section Set)→ Run No. ↓	KENO			MCNP [(b)]	
		27-Group (ENDF/B-IV)	44-Group (ENDF/B-V)	238-Group (ENDF/B-V)	ENDF/B-V (.50c)	ENDF/B-VI (.60c)
1	133 (C150)	1.0017 ± 0.0002	1.0042 ± 0.0003	1.0033 ± 0.0002	1.0039 ± 0.0002	0.9997 ± 0.0002
2	142 (C25)	1.0019 ± 0.0003	1.0043 ± 0.0002	1.0039 ± 0.0003	1.0043 ± 0.0002	1.0002 ± 0.0002
3	143 (C50)	1.0020 ± 0.0003	1.0045 ± 0.0003	1.0040 ± 0.0003	1.0040 ± 0.0002	1.0002 ± 0.0002
4	144 (C100)	1.0021 ± 0.0003	1.0040 ± 0.0002	1.0041 ± 0.0002	1.0043 ± 0.0002	1.0008 ± 0.0002
5	145 (C200)	1.0016 ± 0.0003	1.0035 ± 0.0003	1.0037 ± 0.0003	1.0043 ± 0.0002	0.9999 ± 0.0002
6	146 (C300)	1.0014 ± 0.0003	1.0039 ± 0.0002	1.0037 ± 0.0003	1.0035 ± 0.0002	1.0000 ± 0.0002

(a) Results provided by Virginia Dean.
(b) Input listings provided by the authors; for ENDF/B-VI calculations, ^{235}U and ^{238}U cross sections were Release 4 (.49c).

5.0 REFERENCES

1. T. Kikuchi, Y. Miyoshi, Y. Yamane, K. Tonoike, H. Sono, H. Hirose and S. Onodera, “Reflector Effects of Structural Material for Cylindrical and Slab Cores Containing 10% Enriched Uranyl Nitrate Solution,” *JAERI-Conf 99-004* (1999).

2. S. Onodera, H. Sono, H. Hirose, Y. Takatsuki, M. Nagasawa, K. Murakami, T. Takahashi, K. Sakuraba, M. Miyauchi, T. Kikuchi, Y. Miyoshi and A. Ohno, “Annual Report of STACY Operation in F.Y. 1997 - 280 mm Thickness Slab Core -- 10% Enriched Uranyl Nitrate Solution - ,” (in Japanese) *JAERI-Tech 98-023*(1998).

APPENDIX A: TYPICAL INPUT LISTINGS

A.1 MCNP Input Listing

Japanese MCNP 4B with the continuous-energy cross sections based on the JENDL-3.2 library was run with 2,000 active generations of 5,000 neutrons each (10 million neutron histories), after skipping 50 generations (100,000 neutron histories).

United States MCNP4C calculations used the same inputs files except that cross sections were changed to .50c (sulphur to 16032.50c) for ENDF/B-V and were changed to .60c for ENDF/B-VI.4 (except ^{235}U and ^{238}U which were .49c), and 80 generations were run before the 2,000 active generations.

MCNP4B Benchmark-Model Input Listing for Run No.145, Table 23.a and Table 16.

```
STACY 280t Core tank critical analysis.
c   R145(C200)    ;Hc=65.56cm
c
c   cell card
c
1   1   9.88764316E-02   1  -2   3  -4   5  -7   imp:n=1 u=1
2   4   4.94240000E-05   1  -2   3  -4   7  -6   imp:n=1 u=1
3   2   8.66829700E-02  #1  #2                   imp:n=1 u=1
4   0                  11 -12  13 -14  15 -16   imp:n=1 u=2 fill=1
c
11   3   8.11829800E-02  27 -28  32 -33  25 -26             imp:n=1 u=2
12   6   8.68654070E-02  21 -22  32 -33  23 -24 #(27 -28 25 -26) imp:n=1 u=2
13   5   5.98285201E-02  21 -22  31 -34  23 -24 #( 32 -33)   imp:n=1 u=2
c
14   3   8.11829800E-02  27 -28  37 -36  25 -26             imp:n=1 u=2
15   6   8.68654070E-02  21 -22  37 -36  23 -24 #(27 -28 25 -26) imp:n=1 u=2
16   5   5.98285201E-02  21 -22  38 -35  23 -24 #( 37 -36)   imp:n=1 u=2
c
17   3   8.11829800E-02  27 -28  40 -41  25 -26             imp:n=1 u=2
18   6   8.68654070E-02  21 -22  40 -41  23 -24 #(27 -28 25 -26) imp:n=1 u=2
19   5   5.98285201E-02  21 -22  39 -42  23 -24 #( 40 -41)   imp:n=1 u=2
c
20   3   8.11829800E-02  27 -28  45 -44  25 -26             imp:n=1 u=2
21   6   8.68654070E-02  21 -22  45 -44  23 -24 #(27 -28 25 -26) imp:n=1 u=2
22   5   5.98285201E-02  21 -22  46 -43  23 -24 #( 45 -44)   imp:n=1 u=2
23   4   4.94240000E-05  #4 #(21 -22 31 -34 23 -24) #(21 -22 38 -35 23 -24)
                     #(21 -22 39 -42 23 -24) #(21 -22 46 -43 23 -24)
                                    imp:n=1 u=2
100  0                 81 -82  83 -84  85 -86   imp:n=1     fill=2
101  0                 #100                 imp:n=0

c
c   surface cards (origin x=0.0 y=0.0 z=0.0)
c   fuel
1    px    -34.515
2    px     34.515
3    py    -14.04
4    py     14.04
5    pz      0.0
6    pz    149.75
c   Critical level
7    pz     65.56
c   sus304
c
11   px    -37.045
12   px     37.045
13   py    -16.57
14   py     16.57
15   pz     -2.04
16   pz    152.63
c   c150 reflector
c
21   px     -38.7
22   px      38.7
23   pz     -3.0
24   pz    153.6
25   pz      0.0
26   pz    150.6
27   px     -35.7
28   px      35.7
31   py     16.79
32   py     17.60
33   py     22.61
34   py     23.42
35   py    -16.79
36   py    -17.60
```

MCNP4B Benchmark-Model Input Listing for Run No.145, Table 23.a and Table 16 (cont'd).

```
37   py    -22.61
38   py    -23.42
39   py     23.50
40   py     24.31
41   py     39.31
42   py     40.12
43   py    -23.50
44   py    -24.31
45   py    -39.31
46   py    -40.12
c    pool
c
81   px    -111.0
82   px     291.0
83   py    -100.0
84   py     100.0
85   pz     -34.5
86   pz     172.63

c
c    data cards
c
mode  n                    $ transport neutrons only
c
c    material cards
c
c    R145(C200);U=313.8/A=0.955/D=1.4500
c    atomic density =  9.88764316E-02
m1    1001.37c     5.8747E-02
      7014.37c     2.1648E-03
      8016.37c     3.7170E-02
     92234.37c     6.4595E-07
     92235.37c     8.0158E-05
     92236.37c     8.0058E-08
     92238.37c     7.1398E-04
mt1   lwtr.01t    $  300k
c
c    sus304L(tank) 7.93g/cm3
c    atomic density  8.668297E-2
m2    6012.37c 7.1567E-05  $ C
     14000.37c 7.1415E-04  $ Si
     25055.37c 9.9095E-04  $ Mn
     15031.37c 5.0879E-05  $ P
     16000.37c 1.0424E-05  $ S
     28000.37c 8.5600E-03  $ Ni
     24000.37c 1.6725E-02  $ Cr
     26000.37c 5.9560E-02  $ Fe
c
c    concrete  (STACY-280T) T-ave.
c    atomic density  8.11829800E-02
m3    1001.37c   1.4528e-02
      8016.37c   4.4590E-02
     11023.37c   1.0533E-03
     12000.37c   1.9573E-04
     13027.37c   1.5533E-03
     14000.37c   1.4749E-02
     16000.37c   1.0906E-04
     17000.37c   9.0027E-07
     19000.37c   1.9179E-04
     20000.37c   3.9337E-03
     26000.37c   2.7830E-04
mt3   lwtr.01t    $  300k
c
c     air (0.001184 g/cm3)
c    atomic density  4.9424E-05
m4    7014.37c 3.9014E-05
      8016.37c 1.0410E-05
```

MCNP4B Benchmark-Model Input Listing for Run No.145, Table 23.a and Table 16 (cont'd).

```
c
c    aluminum 2.69 g/cm3
c    atomic density  5.98285201E-02
m5   13027.37c 5.9559E-02  $ Al
     14000.37c 8.0751E-05  $ Si
     26000.37c 1.7114E-04  $ Fe
     29000.37c 1.7845E-05  $ Cu
c
c    sus304L(futa)  7.93g/cm3
c    atomic density  8.68654070e-02
m6    6012.37c 2.0675E-04  $ C
     14000.37c 6.6314E-04  $ Si
     25055.37c 1.0083E-03  $ Mn
     15031.37c 4.9337E-05  $ P
     16000.37c 1.6380E-05  $ S
     28000.37c 6.6885E-03  $ Ni
     24000.37c 1.6798E-02  $ Cr
     26000.37c 6.1435E-02  $ Fe
c
c    criticality cards
c
kcode  5000  1.0  50  2050
sdef  cel=d1 x=d2 y=d3 z=d4  erg=d5
c
si1  l  100:4:1
sp1        1
c  *** x-coordinate
si2    h   -34.5  34.5
sp2     0  1
c  *** y-coordinate
si3    h   -14.0  14.0
sp3     0  1
c  *** z-coordinate
si4    h   0.0    65.56
sp4     0  1
c
sp5    -3
c
prdmp  j -100 1 3
c
print -175
c    ctme   10
```

MCNP4C ENDF/B-VI.4 Benchmark-Model Input Listing for Run No.146, Table 23.c.

```
STACY 280t Core tank critical analysis.
c   R146(C300)    ;Hc=65.0 cm
c
c   cellcard
c
1   1   9.88761485E-02   1  -2   3  -4   5  -7   imp:n=1 u=1
2   4   4.94240000E-05   1  -2   3  -4   7  -6   imp:n=1 u=1
3   2   8.66829700E-02  #1  #2                 imp:n=1 u=1
4   0                  11 -12  13 -14  15 -16   imp:n=1 u=2 fill=1
c
11   3   8.11829800E-02  27 -28  32 -33  25 -26            imp:n=1 u=2
12   6   8.68654070E-02  21 -22  32 -33  23 -24 #(27 -28 25 -26) imp:n=1 u=2
13   5   5.98285201E-02  21 -22  31 -34  23 -24 #( 32 -33)   imp:n=1 u=2
c
14   3   8.11829800E-02  27 -28  37 -36  25 -26            imp:n=1 u=2
15   6   8.68654070E-02  21 -22  37 -36  23 -24 #(27 -28 25 -26) imp:n=1 u=2
16   5   5.98285201E-02  21 -22  38 -35  23 -24 #( 37 -36)   imp:n=1 u=2
c
17   3   8.11829800E-02  27 -28  40 -41  25 -26            imp:n=1 u=2
18   6   8.68654070E-02  21 -22  40 -41  23 -24 #(27 -28 25 -26) imp:n=1 u=2
19   5   5.98285201E-02  21 -22  39 -42  23 -24 #( 40 -41)   imp:n=1 u=2
c
20   3   8.11829800E-02  27 -28  45 -44  25 -26            imp:n=1 u=2
21   6   8.68654070E-02  21 -22  45 -44  23 -24 #(27 -28 25 -26) imp:n=1 u=2
22   5   5.98285201E-02  21 -22  46 -43  23 -24 #( 45 -44)   imp:n=1 u=2
c
23   3   8.11829800E-02  27 -28  48 -49  25 -26            imp:n=1 u=2
24   6   8.68654070E-02  21 -22  48 -49  23 -24 #(27 -28 25 -26) imp:n=1 u=2
25   5   5.98285201E-02  21 -22  47 -50  23 -24 #( 48 -49)   imp:n=1 u=2
c
26   3   8.11829800E-02  27 -28  53 -52  25 -26            imp:n=1 u=2
27   6   8.68654070E-02  21 -22  53 -52  23 -24 #(27 -28 25 -26) imp:n=1 u=2
28   5   5.98285201E-02  21 -22  54 -51  23 -24 #( 53 -52)   imp:n=1 u=2
29   4   4.94240000E-05  #4 #(21 -22 31 -34 23 -24) #(21 -22 38 -35 23 -24)
                         #(21 -22 39 -42 23 -24) #(21 -22 46 -43 23 -24)
                         #(21 -22 47 -50 23 -24) #(21 -22 54 -51 23 -24)
                                  imp:n=1 u=2
100  0                  81 -82  83 -84  85 -86   imp:n=1     fill=2
101  0                  #100                  imp:n=0

c
c   surface cards (origin x=0.0 y=0.0 z=0.0)
c   fuel
1   px    -34.515
2   px     34.515
3   py    -14.04
4   py     14.04
5   pz      0.0
6   pz    149.75
c   Critical level
7   pz     65.0
c   sus304
c
11   px    -37.045
12   px     37.045
13   py    -16.57
14   py     16.57
15   pz     -2.04
16   pz    152.63
c   c50+c150+c100 refrector
c
21   px     -38.7
22   px      38.7
23   pz     -3.0
24   pz    153.6
25   pz      0.0
```

MCNP4C ENDF/B-VI.4 Benchmark-Model Input Listing for Run No.146, Table 23.c (cont'd).

```
26   pz    150.6
27   px     -35.7
28   px      35.7
31   py     16.80
32   py     17.61
33   py     22.62
34   py     23.43
35   py    -16.80
36   py    -17.61
37   py    -22.62
38   py    -23.43
39   py     23.49
40   py     24.30
41   py     39.30
42   py     40.11
43   py    -23.49
44   py    -24.30
45   py    -39.30
46   py    -40.11
47   py     40.27
48   py     41.08
49   py     51.15
50   py     51.96
51   py    -40.27
52   py    -41.08
53   py    -51.15
54   py    -51.96
c    pool
c
81   px    -111.0
82   px     291.0
83   py    -100.0
84   py     100.0
85   pz     -34.5
86   pz     172.5

c
c    data cards
c
mode  n                    $ transfort neutrons only
c
c    material cards
c
c    R146(C300);U=314.6/A=0.955/D=1.4511
c    atomic density =  9.88761485E-02
m1    1001.60c     5.8732E-02
      7014.60c     2.1689E-03
      8016.60c     3.7179E-02
     92234.60c     6.4760E-07
     92235.49c     8.0362E-05
     92236.60c     8.0262E-08
     92238.49c     7.1580E-04
mt1   lwtr.01t   $  300k
c
c    sus304L(tank) 7.93g/cm3
c    atomic density  8.668297E-2
m2    6000.60c 7.1567E-05  $ C
     14000.60c 7.1415E-04  $ Si
     25055.60c 9.9095E-04  $ Mn
     15031.60c 5.0879E-05  $ P
     16032.60c 1.0424E-05  $ S
     28058.60c  5.8439E-03 $ Ni
     28060.60c  2.2342E-03
     28061.60c  9.6728E-05
     28062.60c  3.0730E-04
     28064.60c  7.7896E-05
     26054.60c 3.5140E-03  $ Fe
```

MCNP4C ENDF/B-VI.4 Benchmark-Model Input Listing for Run No.146, Table 23.c (cont'd).

```
     26056.60c 5.4628E-02
     26057.60c 1.2508E-03
     26058.60c 1.6677E-04
     24050.60c  7.2669E-04 $ Cr
     24052.60c  1.4014E-02
     24053.60c  1.5889E-03
     24054.60c  3.9554E-04
c    concrete  (STACY-280T) T-ave.
c    atomic density  8.11829800E-02
m3    1001.60c   1.4528e-02
      8016.60c   4.4590E-02
     11023.60c   1.0533E-03
     12000.60c   1.9573E-04
     13027.60c   1.5533E-03
     14000.60c   1.4749E-02
     16032.60c   1.0906E-04
     17000.60c   9.0027E-07
     19000.60c   1.9179E-04
     20000.60c   3.9337E-03
     26054.60c 1.6420E-05
     26056.60c 2.5526E-04
     26057.60c 5.8444E-06
     26058.60c 7.7925E-07
mt3   lwtr.01t    $  300k
c
c     air (0.001184 g/cm3)
c    atomic density  4.9424E-05
m4    7014.60c 3.9014E-05
      8016.60c 1.0410E-05
c
c    alminum 2.69 g/cm3
c    atomic density  5.98285201E-02
m5   13027.60c 5.9559E-02  $ Al
     14000.60c 8.0751E-05  $ Si
     26054.60c  1.0097E-05 $ Fe
     26056.60c  1.5697E-04
     26057.60c  3.5939E-06
     26058.60c  4.7919E-07
     29063.60c  1.2343E-05 $ Cu
     29065.60c  5.5015E-06
c
c    sus304L(futa)  7.93g/cm3
c    atomic density  8.68654070e-02
m6    6000.60c 2.0675E-04  $ C
     14000.60c 6.6314E-04  $ Si
     25055.60c 1.0083E-03  $ Mn
     15031.60c 4.9337E-05  $ P
     16032.60c 1.6380E-05  $ S
     28058.60c 4.5662E-03  $ Ni
     28060.60c 1.7457E-03
     28061.60c 7.5580E-05
     28062.60c 2.4012E-04
     28064.60c 6.0865E-05
     24050.60c 7.2989E-04  $ Cr
     24052.60c 1.4075E-02
     24053.60c 1.5958E-03
     24054.60c 3.9728E-04
     26054.60c 3.6246E-03  $ Fe
     26056.60c 5.6348E-02
     26057.60c 1.2901E-03
     26058.60c 1.7202E-04
c
c    criticality cards
c
kcode  5000  1.0  80  2080
sdef  cel=d1 x=d2 y=d3 z=d4  erg=d5
```

MCNP4C ENDF/B-VI.4 Benchmark-Model Input Listing for Run No.146, Table 23.c (cont'd).

```
c
si1  l  100:4:1
sp1        1
c  *** x-coodinate
si2    h   -34.5  34.5
sp2     0  1
c  *** y-coodinate
si3    h   -14.0  14.0
sp3     0  1
c  *** z-coodinate
si4    h   0.0    65.0
sp4     0  1
c
sp5    -3
c
prdmp  j -100 1 3
c
print -175
c    ctme   10
```

A.2 CRISTAL: APOLLO-2 / MORET-4 Input Listing

The calculations of k_{eff}'s were run in two steps, using the CRISTAL code system.

1) APOLLO-2 is a one-dimensional multigroup cell code. It is used to determine material buckling B_m^2, infinite multiplication factor (k_{inf}), and homogeneous macroscopic medium cross sections.
2) MORET-4 is a three-dimensional multigroup Monte Carlo code. It uses macroscopic cross sections coming from APOLLO-2. It uses P5 anisotropic treatment and 172-group library. Each calculation employed 1,000 neutrons per batch and was run to achieve precision of 0.0010.

The APOLLO-2 used the CEA93 172-group library based on JEF2.2 evaluation. A pre-processor called CIGALES-PREAPOL is used to prepare the APOLLO-2 input data.

CRISTAL Input Listing for Run No.133, Table 23.b.

```
DEBUT_APOLLO2
****************************************************
*      C.E.A / I.P.S.N. SYSTEM CODES            *
* CRISTAL : APOLLO2 (CEA93 172gr library)- MORET4 *
*................................................*
*      I.C.S.B.E.P : LEU-SOL-THERM-018          *
*................................................*
*         CONCRETE REFLECTOR C150              *
*     STACY EXPERIMENT U(9.97%)O2(NO3)2         *
*        RUN N□133    C(U)=308.1 g/l           *
****************************************************
*=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
*     CIGALES version 2.0   en date du 18/05/2001
*             Creation du Fichier le 21/05/01 17:33:04
*=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
*                -=- INITIALISATION - CALCUL 1 -=-
CALCUL_CRISTAL = 1                                    ;
REPPROC          = OUVRIR: 22 'VARIABLE' 1024 10000
                   'ADRESSE' 'aprocristal'            ;
CHARGE_APROCRISTAL = LIRE: REPPROC 'APROC' 'CHARGE_APROCRISTAL'     ;
FERMER: REPPROC                                       ;
EXECUTER CHARGE_APROCRISTAL                                  ;
TSTR TOPT = INITIALISER_CRISTAL 1                           ;
*          -=- OPTIONS -=-
*
TOPT.'STCRI'.'NGROUP_FINAL' = 172                          ;
TOPT.'STCRI'.'ANISOTROPIE'  = 'P5'                         ;
*
*==============================================================
* APOLLO PIJ CALCUL  1
*
ANISO = CONCAT: '&' TOPT.'STCRI'.'ANISOTROPIE'                  ;
*==============================================================
*
* air
TITRE: ' air                                       ' ;
WRITE: TOPT.'RESU' '*air                                ' ' ' ;
*
*          -=- Description des milieux -=-
*air
nom_calc =  'MILHOM1'                                 ;
TOPT.'STCRI'.'CALCUL_INITIAL' = nom_calc                     ;
TOPT.'STCRI'.'CALCULS_INITIAUX'.nom_calc = TABLE:                 ;
TSTR.nom_calc = TABLE:                                ;
*
nom_mil = 'air'                              ;
TOPT.'STMIL'.nom_mil = TABLE:                              ;
TOPT.'STMIL'.nom_mil.'N14     ' =    4.18048E-05             ;
TOPT.'STMIL'.nom_mil.'O16     ' =    1.12633E-05             ;
TOPT.'STMIL'.nom_mil.'TEMPERATURE'  =  25.                      ;
*
TRES TSTR TOPT = GENERE_MILIEUX_S 2 TSTR TOPT                    ;
*
*                    -=- Creation de la geometrie -=-
*
TSTR.nom_calc.'GEO' = GEOM: &CYLI &MAIL 1 &EQD 1.
                  &MILI TSTR.'MILREF'.nom_mil 1          ;
*
*          -=- Creation de la bibliotheque interne -=-
*
TSTR.'APOLIB' = BIBINT: &EDIT 1 TSTR.'IDB' TSTR.nom_calc.'GEO'
                     ( TEXTE TOPT.'REPBIB' )            ;
*
TSTR.nom_calc.'MAC' = MACROLIB: &EDIT TOPT.'STIMP'.'MACROLIB'
                TSTR.'MILREF'.nom_mil
                &TOTA &SELF &ABSO &ENER &FISS &ENER
```

CRISTAL Input Listing for Run No.133, Table 23.b (cont'd).

```
                &SNNN &TRAC &P0   &DIFF ANISO &TRAN ANISO     ;
*
*         -=- Creation de la Macrolib pour le milieu MILHOM1  -=-
*
APOTRIM: &EDIT 1 TSTR.nom_calc.'MAC' ANISO
       &FICH 47 &NOMMIL TSTR.'MILREF'.nom_mil nom_mil            ;
*==============================================================
* APOLLO PIJ CALCUL  2
*==============================================================
*
* core tank stainless steel
TITRE: ' core tank stainless steel                        ' ;
WRITE: TOPT.'RESU' '*core tank stainless steel                  ' ' ' ;
*
*         -=- Description des milieux -=-
**********************************************************
TSTR TOPT = INITIALISER_CRISTAL 1 TSTR TOPT                       ;
*core tank stainless steel
nom_calc =  'MILHOM2'                                    ;
TOPT.'STCRI'.'CALCUL_INITIAL' = nom_calc                        ;
TOPT.'STCRI'.'CALCULS_INITIAUX'.nom_calc = TABLE:                  ;
TSTR.nom_calc = TABLE:                                   ;
*
nom_mil = 'core tank stainless st'                         ;
TOPT.'STMIL'.nom_mil = TABLE:                               ;
TOPT.'STMIL'.nom_mil.'FENAT    ' =    5.95600E-02                ;
TOPT.'STMIL'.nom_mil.'CRNAT    ' =    1.67248E-02                ;
TOPT.'STMIL'.nom_mil.'NINAT    ' =    8.55998E-03                ;
TOPT.'STMIL'.nom_mil.'MN55     ' =    9.90953E-04                ;
TOPT.'STMIL'.nom_mil.'SINAT    ' =    7.14148E-04                ;
TOPT.'STMIL'.nom_mil.'CNAT     ' =    7.15673E-05                ;
TOPT.'STMIL'.nom_mil.'P31      ' =    5.08793E-05                ;
TOPT.'STMIL'.nom_mil.'S32      ' =    1.04556E-05                ;
TOPT.'STMIL'.nom_mil.'TEMPERATURE'  =  25.                       ;
*
TRES TSTR TOPT = GENERE_MILIEUX_S 2 TSTR TOPT                    ;
*
*                   -=- Creation de la geometrie -=-
*
TSTR.nom_calc.'GEO' = GEOM: &CYLI &MAIL 1 &EQD 1.
                    &MILI TSTR.'MILREF'.nom_mil 1            ;
*
*         -=- Creation de la bibliotheque interne -=-
*
TSTR.'APOLIB' = BIBINT: &EDIT 1 TSTR.'APOLIB'
                       TSTR.'IDB' TSTR.nom_calc.'GEO'
                       ( TEXTE TOPT.'REPBIB' )            ;
*
TSTR.nom_calc.'MAC' = MACROLIB: &EDIT TOPT.'STIMP'.'MACROLIB'
                TSTR.'MILREF'.nom_mil
                &TOTA &SELF &ABSO &ENER &FISS &ENER
                &SNNN &TRAC &P0   &DIFF ANISO &TRAN ANISO     ;
*
*         -=- Creation de la Macrolib pour le milieu MILHOM2  -=-
*
APOTRIM: &EDIT 1 TSTR.nom_calc.'MAC' ANISO &NOMA
       &FICH 47 &NOMMIL TSTR.'MILREF'.nom_mil nom_mil            ;
*==============================================================
* APOLLO PIJ CALCUL  3
*==============================================================
*
*stacy * run 133                              CAS 3
TITRE: 'stacy * run 133                              CAS 3 ' ;
WRITE: TOPT.'RESU' 'NITR ANALY C(U)=308.100 C(PU)=0.000 '
' CAS 3'                                              ;
*
*         -=- Description des milieux -=-
```

CRISTAL Input Listing for Run No.133, Table 23.b (cont'd).

```
***********************************************************
TSTR TOPT = INITIALISER_CRISTAL 1 TSTR TOPT                    ;
*NITR ANALY C(U)=308.100 C(PU)=0.000 H+=0.80 =0.00
nom_calc =  'MILHOM3'                                  ;
TOPT.'STCRI'.'CALCUL_INITIAL' = nom_calc                       ;
TOPT.'STCRI'.'CALCULS_INITIAUX'.nom_calc = TABLE:                  ;
TSTR.nom_calc = TABLE:                                   ;
*
nom_mil = 'NITR ANALY C(U)=308,10'                             ;
TOPT.'STMIL'.nom_mil = TABLE:                                ;
TOPT.'STMIL'.nom_mil.'U234    ' =    6.34217E-07                ;
TOPT.'STMIL'.nom_mil.'U235    ' =    7.87020E-05                ;
TOPT.'STMIL'.nom_mil.'U236    ' =    7.86038E-08                ;
TOPT.'STMIL'.nom_mil.'U238    ' =    7.01008E-04                ;
TOPT.'STMIL'.nom_mil.'H2O     ' =    2.95676E-02                ;
TOPT.'STMIL'.nom_mil.'O16     ' =    7.44780E-03                ;
TOPT.'STMIL'.nom_mil.'N14     ' =    2.04261E-03                ;
TOPT.'STMIL'.nom_mil.'TEMPERATURE'  =  25.                      ;
*
TRES TSTR TOPT = GENERE_MILIEUX_S 2 TSTR TOPT                    ;
*
*                     -=- Creation de la geometrie -=-
*
TSTR.nom_calc.'GEO' = GEOM: &CYLI &MAIL 1 &EQD 1.
                      &MILI TSTR.'MILREF'.nom_mil  1          ;
*
*           -=- Creation de la bibliotheque interne -=-
*
TSTR.'APOLIB' = BIBINT: &EDIT 1 TSTR.'APOLIB'
                         TSTR.'IDB' TSTR.nom_calc.'GEO'
                         ( TEXTE TOPT.'REPBIB' )            ;
*
*           -=-  autoprotection -=-
*
TSTR.'GEOAU' = TSTR.nom_calc.'GEO'                             ;
*
TRES TSTR TOPT = AUTOPROTECTION_CRI_S 1 TSTR TOPT                 ;
*
*           -=- Flux a B2 nul -=-
*
TOPT.'TYPE_B2' = 'NUL'                                    ;
TRES TSTR TOPT = CALFLUX_PIJ_CRI_S 1 TSTR TOPT                   ;
*
*           -=- Flux a B2 critique -=-
*
SI ( TRES.'KINF' GT 1. )                                ;
TOPT.'TYPE_B2' = 'CRITIQUE'                                 ;
TRES TSTR TOPT = CALFLUX_PIJ_CRI_S 1 TSTR TOPT                   ;
FINSI                                           ;
*
TOPT.'STCRI'.'CALCULS_INITIAUX'.nom_calc.'B2' = TRES.'B2'          ;
TOPT.'STCRI'.'CALCULS_INITIAUX'.nom_calc.'KINF' = TRES.'KINF'       ;
*
*           -=- Condensation homogeneisation  -=-
*
TRES TSTR TOPT = HOMOGE_COND_S  1 TSTR TOPT                     ;
*
*           -=- Creation de la Macrolib pour le milieu MILHOM3  -=-
*
APOTRIM: &EDIT 1 TSTR.nom_calc.'MAC' ANISO &NOMA
       &FICH 47 &NOMMIL TSTR.nom_calc.'MILEQ' nom_mil            ;
*==============================================================
* APOLLO PIJ CALCUL  4
*==============================================================
*
* reflector frame  stainless steel
```

CRISTAL Input Listing for Run No.133, Table 23.b (cont'd).

```
TITRE: ' reflector frame  stainless steel                    ' ;
WRITE: TOPT.'RESU' '*reflector frame stainless steel          ' ' ' ;
*
*        -=- Description des milieux -=-
************************************************************
TSTR TOPT = INITIALISER_CRISTAL 1 TSTR TOPT                    ;
*reflector frame stainless steel
nom_calc =  'MILHOM4'                              ;
TOPT.'STCRI'.'CALCUL_INITIAL' = nom_calc                     ;
TOPT.'STCRI'.'CALCULS_INITIAUX'.nom_calc = TABLE:                ;
TSTR.nom_calc = TABLE:                                  ;
*
nom_mil = 'reflector frame stainl'                       ;
TOPT.'STMIL'.nom_mil = TABLE:                            ;
TOPT.'STMIL'.nom_mil.'FENAT    ' =    6.14353E-02              ;
TOPT.'STMIL'.nom_mil.'CRNAT    ' =    1.67983E-02              ;
TOPT.'STMIL'.nom_mil.'NINAT    ' =    6.68850E-03              ;
TOPT.'STMIL'.nom_mil.'MN55     ' =    1.00834E-03              ;
TOPT.'STMIL'.nom_mil.'SINAT    ' =    6.63138E-04              ;
TOPT.'STMIL'.nom_mil.'CNAT     ' =    2.06750E-04              ;
TOPT.'STMIL'.nom_mil.'P31      ' =    4.93375E-05              ;
TOPT.'STMIL'.nom_mil.'S32      ' =    1.64302E-05              ;
TOPT.'STMIL'.nom_mil.'TEMPERATURE'  =  25.                     ;
*
TRES TSTR TOPT = GENERE_MILIEUX_S 2 TSTR TOPT                  ;
*
*                   -=- Creation de la geometrie -=-
*
TSTR.nom_calc.'GEO' = GEOM: &CYLI &MAIL 1 &EQD 1.
                     &MILI TSTR.'MILREF'.nom_mil 1          ;
*
*        -=- Creation de la bibliotheque interne -=-
*
TSTR.'APOLIB' = BIBINT: &EDIT 1 TSTR.'APOLIB'
                        TSTR.'IDB' TSTR.nom_calc.'GEO'
                        ( TEXTE TOPT.'REPBIB' )            ;
*
TSTR.nom_calc.'MAC' = MACROLIB: &EDIT TOPT.'STIMP'.'MACROLIB'
                TSTR.'MILREF'.nom_mil
                &TOTA &SELF &ABSO &ENER &FISS &ENER
                &SNNN &TRAC &P0   &DIFF ANISO &TRAN ANISO     ;
*
*        -=- Creation de la Macrolib pour le milieu MILHOM4  -=-
*
APOTRIM: &EDIT 1 TSTR.nom_calc.'MAC' ANISO &NOMA
       &FICH 47 &NOMMIL TSTR.'MILREF'.nom_mil nom_mil           ;
*============================================================
* APOLLO PIJ CALCUL  5
*============================================================
*
* relector Aluminium alloy
TITRE: ' relector Aluminium alloy                            ' ;
WRITE: TOPT.'RESU' '*relector Aluminium alloy                ' ' ' ;
*
*        -=- Description des milieux -=-
************************************************************
TSTR TOPT = INITIALISER_CRISTAL 1 TSTR TOPT                    ;
*relector Aluminium alloy
nom_calc =  'MILHOM5'                              ;
TOPT.'STCRI'.'CALCUL_INITIAL' = nom_calc                     ;
TOPT.'STCRI'.'CALCULS_INITIAUX'.nom_calc = TABLE:                ;
TSTR.nom_calc = TABLE:                                  ;
*
nom_mil = 'relector Aluminium all'                        ;
TOPT.'STMIL'.nom_mil = TABLE:                            ;
TOPT.'STMIL'.nom_mil.'AL27     ' =    5.95588E-02              ;
TOPT.'STMIL'.nom_mil.'SINAT    ' =    8.07507E-05              ;
```

CRISTAL Input Listing for Run No.133, Table 23.b (cont'd).

```
TOPT.'STMIL'.nom_mil.'FENAT    ' =    1.71140E-04                  ;
TOPT.'STMIL'.nom_mil.'CUNAT    ' =    1.78447E-05                  ;
TOPT.'STMIL'.nom_mil.'TEMPERATURE'  =  25.                         ;
*
TRES TSTR TOPT = GENERE_MILIEUX_S 2 TSTR TOPT                      ;
*
*                    -=- Creation de la geometrie -=-
*
TSTR.nom_calc.'GEO' = GEOM: &CYLI &MAIL 1 &EQD 1.
                    &MILI TSTR.'MILREF'.nom_mil 1           ;
*
*          -=- Creation de la bibliotheque interne -=-
*
TSTR.'APOLIB' = BIBINT: &EDIT 1 TSTR.'APOLIB'
                       TSTR.'IDB' TSTR.nom_calc.'GEO'
                       ( TEXTE TOPT.'REPBIB' )             ;
*
TSTR.nom_calc.'MAC' = MACROLIB: &EDIT TOPT.'STIMP'.'MACROLIB'
                TSTR.'MILREF'.nom_mil
                &TOTA &SELF &ABSO &ENER &FISS &ENER
                &SNNN &TRAC &P0   &DIFF ANISO &TRAN ANISO     ;
*
*          -=- Creation de la Macrolib pour le milieu MILHOM5  -=-
*
APOTRIM: &EDIT 1 TSTR.nom_calc.'MAC' ANISO &NOMA
       &FICH 47 &NOMMIL TSTR.'MILREF'.nom_mil nom_mil            ;
*===============================================================
* APOLLO PIJ CALCUL  6
*===============================================================
*
* stacy : concrete reflector
TITRE: ' stacy : concrete reflector                        ' ;
WRITE: TOPT.'RESU' '*stacy : concrete reflector                  ' ' ' ;
*
*          -=- Description des milieux -=-
***************************************************************
TSTR TOPT = INITIALISER_CRISTAL 1 TSTR TOPT                      ;
*stacy : concrete reflector
nom_calc =  'MILHOM6'                                    ;
TOPT.'STCRI'.'CALCUL_INITIAL' = nom_calc                         ;
TOPT.'STCRI'.'CALCULS_INITIAUX'.nom_calc = TABLE:                  ;
TSTR.nom_calc = TABLE:                                   ;
*
nom_mil = 'stacy : concrete refle'                       ;
TOPT.'STMIL'.nom_mil = TABLE:                                ;
TOPT.'STMIL'.nom_mil.'NA23     ' =    1.05330E-03                 ;
TOPT.'STMIL'.nom_mil.'MGNAT    ' =    1.95730E-04                 ;
TOPT.'STMIL'.nom_mil.'AL27     ' =    1.55330E-03                 ;
TOPT.'STMIL'.nom_mil.'SINAT    ' =    1.47490E-02                 ;
TOPT.'STMIL'.nom_mil.'S32      ' =    1.09060E-04                 ;
TOPT.'STMIL'.nom_mil.'CLNAT    ' =    9.00270E-07                 ;
TOPT.'STMIL'.nom_mil.'KNAT     ' =    1.91790E-04                 ;
TOPT.'STMIL'.nom_mil.'CANAT    ' =    3.93370E-03                 ;
TOPT.'STMIL'.nom_mil.'FENAT    ' =    2.78300E-04                 ;
TOPT.'STMIL'.nom_mil.'H2O      ' =    7.26390E-03                 ;
TOPT.'STMIL'.nom_mil.'O16      ' =    3.73260E-02                 ;
TOPT.'STMIL'.nom_mil.'TEMPERATURE'  =  25.                        ;
*
TRES TSTR TOPT = GENERE_MILIEUX_S 2 TSTR TOPT                      ;
*
*                    -=- Creation de la geometrie -=-
*
TSTR.nom_calc.'GEO' = GEOM: &CYLI &MAIL 1 &EQD 1.
                    &MILI TSTR.'MILREF'.nom_mil 1           ;
*
*          -=- Creation de la bibliotheque interne -=-
```

CRISTAL Input Listing for Run No.133, Table 23.b (cont'd).

```
*
TSTR.'APOLIB' = BIBINT: &EDIT 1 TSTR.'APOLIB'
                        TSTR.'IDB' TSTR.nom_calc.'GEO'
                        ( TEXTE TOPT.'REPBIB' )          ;
*
TSTR.nom_calc.'MAC' = MACROLIB: &EDIT TOPT.'STIMP'.'MACROLIB'
                TSTR.'MILREF'.nom_mil
                &TOTA &SELF &ABSO &ENER &FISS &ENER
                &SNNN &TRAC &P0   &DIFF ANISO &TRAN ANISO     ;
*
*          -=- Creation de la Macrolib pour le milieu MILHOM6  -=-
*
APOTRIM: &EDIT 1 TSTR.nom_calc.'MAC' ANISO &NOMA
       &FICH 47 &NOMMIL TSTR.'MILREF'.nom_mil nom_mil            ;
*
EDTIME: ;
ARRET: ;
FIN_APOLLO2
****************************************************
*      C.E.A / I.P.S.N. SYSTEM CODES            *
* CRISTAL : APOLLO2 (CEA93 172gr library)- MORET4 *
*................................................*
*      I.C.S.B.E.P : LEU-SOL-THERM-018          *
*................................................*
*          CONCRETE REFLECTOR C150              *
*     STACY EXPERIMENT U(9.97%)O2(NO3)2         *
*        RUN N□133    C(U)=308.1 g/l            *
****************************************************
*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*
*     CIGALES version 2.0   en date du 18/05/2001
*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*
(
 air
*air
*****  Milieu  1 CONC. ATOMIQUES- %volumique  100
*N14          4.18048E-05
*O16          1.12633E-05
)
OPTION  V4 GROUP 172 P5 TEMPER  25  FINOPTION
MORET
 GEOM HOMO
CHIMIE
*air
 MICRO 1 2     N14         O16
CONC          4.18048E-05 1.12633E-05
FINC
SECTION TOUT
FIN
(
 core tank stainless steel
*core tank stainless steel
*****  Milieu  1 %-prop MASSIQUES- Dens= 7.93- %volumique  100
*FENAT        69.652
*CRNAT         18.21
*NINAT        10.52
*MN55         1.14
*SINAT        0.42
*CNAT         0.018
*P31          0.033
*S32          0.007
)
OPTION  V4 GROUP 172 P5 TEMPER  25  FINOPTION
MORET
 GEOM HOMO
CHIMIE
*core tank stainless steel
 MICRO 1 8     FENAT       CRNAT       NINAT       MN55        SINAT
```

CRISTAL Input Listing for Run No.133, Table 23.b (cont'd).

```
          CNAT       P31        S32
CONC         5.95600E-02 1.67248E-02 8.55998E-03 9.90953E-04 7.14148E-04
          7.15673E-05 5.08793E-05 1.04556E-05
FINC
SECTION TOUT
FIN
*              RAPPEL DONNEES  MORET Pij
*========================================================================
* BIBLIO CEA93.V4  172 groupes   ANISOTROPIE P5
*______________________________________________________________________
*<*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*><*>
*              RAPPEL GEOMETRIE du MILIEU FISSILE
*______________________________________________________________________
* GEOMETRIE HOMOGENE
*______________________________________________________________________
* MILIEU FISSILE 1:
* NOUVELLE LOI DE DILUTION 2001 : Nitrate analyse
*    Densit□1.438
*______________________________________________________________________
*    VECTEUR ISOTOPIQUE    MASSE
*______________________________________________________________________
*    Uranium:
*    U233:
*    U234: 0.08
*    U235: 9.97
*    U236: 0.01
*    U238: 89.94
*______________________________________________________________________
*  Delta Date (Analyse chimique - Analyse isotopique) :
*  Delta Date (Experience - Analyse chimique) :
*  C(U)=3.081e02  C(Pu)=
*  Impuretes (g/l) :
*  Fe=0.000e00  Cr=0.000e00  Ni=0.000e00
*  Mn=0.000e00  Ca=0.000e00  Cu=0.000e00
*  Al=0.000e00  Mg=0.000e00  Zn=0.000e00
*  Na=0.000e00  Co=0.000e00
*______________________________________________________________________
* MASSES ATOMIQUES MOYENNES
* Uranium: 237.74411 - Plutonium:  - Uranium+Plutonium:
*    ACIDITE : 8.000e-01 N
*========================================================================
*========================================================================
(
stacy * run 133                              CAS 3
NITR ANALY    C(U)=308.100    C(PU)=0.000   □CAS  3
*NITR ANALY    C(U)=308.100    C(PU)=0.000      H+=0.80    =0.00
SORTIE SECTIONS TOUTE LA CELLULE
)
OPTION V4 GROUP 172 P5 TEMPER  25  FINOPTION
MORET
GEOMETRIE HOMOGENE
CHIMIE
*NITR ANALY    C(U)=308.100    C(PU)=0.000      H+=0.80    =0.00
 MICRO 1 7     U234        U235        U236        U238        H2O
          O16        N14
VERIF 1.43800  6.34217E-07 7.87020E-05 7.86038E-08 7.01008E-04 2.95676E-02
          7.44780E-03 2.04261E-03
FINC
SECTION TOUT
FIN
(
 reflector frame  stainless steel
*reflector frame  stainless steel
*****  Milieu  1 %-prop MASSIQUES- Dens= 7.93- %volumique  100
*FENAT        71.845
*CRNAT         18.29
*NINAT        8.22
```

CRISTAL Input Listing for Run No.133, Table 23.b (cont'd).

```
*MN55        1.16
*SINAT       0.39
*CNAT        0.052
*P31         0.032
*S32         0.011
)
OPTION  V4 GROUP 172 P5 TEMPER  25  FINOPTION
MORET
 GEOM HOMO
CHIMIE
*reflector frame  stainless steel
 MICRO 1 8     FENAT       CRNAT       NINAT       MN55        SINAT
           CNAT        P31         S32
CONC          6.14353E-02 1.67983E-02 6.68850E-03 1.00834E-03 6.63138E-04
           2.06750E-04 4.93375E-05 1.64302E-05
FINC
SECTION TOUT
FIN
(
 relector Aluminum alloy
*relector Aluminum alloy
*****  Milieu  1 %-prop MASSIQUES- Dens= 2.69- %volumique  100
*AL27        99.2
*SINAT       0.14
*FENAT       0.59
*CUNAT       0.07
)
OPTION  V4 GROUP 172 P5 TEMPER  25  FINOPTION
MORET
 GEOM HOMO
CHIMIE
*reflector Aluminum alloy
 MICRO 1 4     AL27        SINAT       FENAT       CUNAT
CONC          5.95588E-02 8.07507E-05 1.71140E-04 1.78447E-05
FINC
SECTION TOUT
FIN
(
 stacy : concrete reflector
*stacy : concrete reflector
*****  Milieu  1 CONC. ATOMIQUES- %volumique  100
*NA23        1.0533E-03
*MGNAT       1.9573E-04
*AL27        1.5533E-03
*SINAT       1.4749E-02
*S32         1.0906E-04
*CLNAT       9.0027E-07
*KNAT        1.9179E-04
*CANAT       3.9337E-03
*FENAT       2.7830E-04
*H2O         7.2639E-03
*O16         3.7326E-02
)
OPTION  V4 GROUP 172 P5 TEMPER  25  FINOPTION
MORET
 GEOM HOMO
CHIMIE
*stacy : concrete reflector
 MICRO 1 11    NA23        MGNAT       AL27        SINAT       S32
           CLNAT       KNAT        CANAT       FENAT       H2O
           O16
CONC          1.05330E-03 1.95730E-04 1.55330E-03 1.47490E-02 1.09060E-04
           9.00270E-07 1.91790E-04 3.93370E-03 2.78300E-04 7.26390E-03
           3.73260E-02
FINC
SECTION TOUT
FIND
```

CRISTAL Input Listing for Run No.133, Table 23.b (cont'd).

```
DEBUT_MORET4
    ICSBEP       LEU-SOL-THERM-018     RUN 133
*                                         *
* U(9.97%)O2(NO3)2     C(U)=308.1 g/l  H+=0.800   *
*                                         *
* CRITICAL HEIGHT 67.91   CONCRETE REFLECTED C150 *
*.................................................*
*                                         *
*    benchmark Keff = 1.0000 +/- 0.0014           *
*                                         *
***************************************************
* precision
  SIGI 0.00033 SIGE 0.00033 MINI 100 PAS 50   NOBIL
* SIGI 0.015 SIGE 0.015  MINI 10 NOBIL
* medium
* 1   *-  air
* 2   *-  tank wall stainless steel
* 3   *-  U(10)O2(NO3)2 solution
* 4   *-  reflector frame stainless steel
* 5   *-  reflector sheet aluminum alloy
* 6   *-  concrete
CHIMIE
 SEALINK 6  APO2      6    1 2 3 4 5 6
FINCHIMIE
*
GEOMETRY
** core tank
*................. air external volume  .......................
  TYPE 1 BOITE 100 100 100
  VOLUME 1 0 1 1   0.0 0.0 100
*.......... tank : st.st. SUS 304 L ......
  TYPE 2 BOITE 16.57 37.045 77.335
  VOLUME 2 1 2 2   0.0 0.0 78.295
*.................  air ........................................
  TYPE 3 BOITE 14.04 34.515 74.875
  VOLUME 3 2 3 1   0.0 0.0 77.875
* ..........fissile solution Hc = 67.91 cm  altitude = Hc + 3
  TYPE 4 PLAZ INF 70.91
  VOLUME 4 3 4 3   0.0 0.0 52.0  ETSUP 1 3
** reflectors C150 : AL / ST.ST. / CONCRETE
  TYPE 5 BOITE 8.31 38.7 78.3
  TYPE 6 BOITE 7.5  38.7 78.3
  TYPE 7 BOITE 7.5  35.7 75.3

  VOLUME 5 1 5 5 25.11 0.0 78.3
  VOLUME 6 5 6 4 25.11 0.0 78.3
  VOLUME 7 6 7 6 25.11 0.0 78.3

  VOLUME 15  1 5 5 -25.11 0.0 78.3
  VOLUME 16 15 6 4 -25.11 0.0 78.3
  VOLUME 17 16 7 6 -25.11 0.0 78.3
FINGEOMETRY

*...........     sources    ....................................
  SOURCE NRES POINT  1000  4 0.0 0.0 35.0
  FINSOURCE
* GRAPH Z 100 FGRAPH
SORTIE
MAIL 1 5 21 48 95 135 172
GLOBAL
FSORTIE
FINDATA
FIN_MORET4
```

A.3 KENO Input Listing

KENO V.a with the 238-group ENDF/B-V cross section library from SCALE4.4 was run with 1020 active generations of 9999 neutrons each (10 million neutron histories), after skipping 80 generations (799,920 neutron histories).

KENO V.a 238-group ENDF/B-V Benchmark-Model Input Listing for Run No.146, Table 23.c.

```
=C  SAS25     PARM=SIZE=4500000
 LST18-6, STACY RUN 146, 28-CM SLAB OF U(10)O2(NO3)2 SOLN, 30-CM-THK CONCRETE REFL
 238GROUPNDF5 MULTIREGION
 ' U(9.97)02(NO3)2 SOLUTION
 U-234  1 0  6.4760E-07    END
 U-235  1 0  8.0362E-05 END
 U-236  1 0  8.0262E-08  END
 U-238  1 0  7.1580E-04    END
 H  1 0  5.8732E-02 END
 N  1 0  2.1689E-03 END
 O  1 0  3.7179E-02 END
 ' SS Tank
 C   2 0  7.1567E-05 END
 Si  2 0  7.1415E-04 END
 Mn  2 0  9.9095E-04 END
 P   2 0  5.0879E-05 END
 S   2 0  1.0424E-05 END
 Ni  2 0  8.5600E-03 END
 Cr  2 0  1.6725E-02 END
 Fe  2 0  5.9560E-02 END
 ' SS Frame Plates
 C   3 0  2.0675E-04 END
 Si  3 0  6.6314E-04 END
 Mn  3 0  1.0083E-03 END
 P   3 0  4.9337E-05 END
 S   3 0  1.6380E-05 END
 Ni  3 0  6.6885E-03 END
 Cr  3 0  1.6798E-02 END
 Fe  3 0  6.1434E-02 END
 ' Aluminum cover plates of reflector
 Al 4 0 5.9559E-02 END
 Si 4 0 8.0751E-05 END
 Fe 4 0 1.7114E-04 END
 Cu 4 0 1.7845E-05 END
 ' Concrete
 H  5 0 1.4528E-02 END
 O  5 0 4.45899E-02 END
 Na 5 0 1.0533E-03 END
 Mg 5 0 1.9573E-04 END
 Al 5 0 1.5533E-03 END
 Si 5 0 1.4749E-02 END
 S  5 0 1.0906E-04 END
 Cl 5 0 9.0027E-07 END
 K  5 0 1.9179E-04 END
 Ca 5 0 3.9337E-03 END
 Fe 5 0 2.7830E-04 END
 ' Air
 N  6 0  3.9014E-05 END
 O  6 0  1.0410E-05 END
 END COMP
 BUCKLEDSLAB VAC REFL 0.0 69.03 65 END
   1 14.04 2 16.57 0 16.80 4 17.61 5 47.61 END ZONE
 LST18-6, STACY RUN 146, 28-CM SLAB OF U(10)O2(NO3)2 SOLN, 30-CM-THK CONCRETE REFL
 READ PARA TME=200 GEN=1100 NPG=9999 NSK=80 NUB=YES XS1=YES RUN=YES
 END PARA
 READ GEOM
 UNIT 1
  COM=* SOLUTION IN TANK, INNER GAP *
  CUBOID  1 1  28.08 0.0 69.03 0.0 65.00 0.0
  CUBOID  6 1  28.08 0.0 69.03 0.0 149.75 0.0
  REPLICATE  2 1  4R2.53 2.88 2.04 1
  REPLICATE  0 1  2R0.23 2R1.655 0.97 0.96  1
 UNIT 2
  COM=* FIRST CONCRETE REFLECTOR *
  CUBOID  5 1  5.01 0.0 71.4 0.0 150.6 0.0
  CUBOID  3 1  5.01 0.0 74.4 -3.0 153.6 -3.0
```

KENO V.a 238-group ENDF/B-V Benchmark-Model Input Listing for Run No.146, Table 23.c (cont'd).

```
 REPLICATE  4 1  2R0.81 4R0 1
UNIT 3
 COM=* SECOND CONCRETE REFLECTOR *
 CUBOID  5 1  15.0 0.0 71.4 0.0 150.6 0.0
 CUBOID  3 1  15.0 0.0 74.4 -3.0 153.6 -3.0
 REPLICATE  4 1  2R0.81 4R0 1
UNIT 4
 COM=* THIRD CONCRETE REFLECTOR *
 CUBOID  5 1 10.07 0.0 71.4 0.0 150.6 0.0
 CUBOID  3 1 10.07 0.0 74.4 -3.0 153.6 -3.0
 REPLICATE  4 1  2R0.81 4R0 1
UNIT 5
 COM=* FIRST GAP BETWEEN CONCRETE REFLECTORS *
 CUBOID  0 1  0.06 0.0 74.4 -3.0 153.6 -3.0
UNIT 6
 COM=* SECOND GAP BETWEEN CONCRETE REFLECTORS *
 CUBOID  0 1  0.16 0.0 74.4 -3.0 153.6 -3.0
GLOBAL
UNIT 7
 COM=* REFLECTOR, TANK, REFLECTOR *
 ARRAY 1 3R0
END GEOM
READ START  NST=1  END START
READ ARRAY  ARA=1 NUX=11  FILL 4 6 3 5 2 1 2 5 3 6 4 END FILL
END ARRAY
READ PLOT
 TTL="HORIZONTAL CROSS SECTION"
 LPI=10 XUL=-2.0 YUL=80. ZUL=10 XLR=106.0 YLR=-2.0
 ZLR=10  UAX=1  VDN=-1 NAX=1200  NCH=' S23*ca' END
 TTL="VERTICAL CROSS SECTION"
 XUL=-2.0 YUL=30. ZUL=160 XLR=106.0 YLR=30.0
 ZLR=-2  UAX=1  WDN=-1 NAX=1200  NCH=' S23*ca' END
END PLOT
END DATA
END
```

APPENDIX B: CONCRETE COMPOSITION

The aim of this appendix is to describe the concrete-composition analysis carried out.

Concrete reflectors were built by pouring the concrete directly into the slab-shaped containers. The reflectors were manufactured in 3 steps:

- mixing together sand and pebbles (mainly SiO_2), cement, and water,
- casting of the mixture in the slab-shaped container,
- covering of concrete until set for preventing evaporation of water.

Samples for analysis were manufactured at the same time. Samples were made by pouring concrete into a vinyl-chloride tube, which had an inner diameter of 10 cm, and a height of 140 cm (almost the same as the active height of the reflector). The manufacture of the reflectors was finished at the end of 1996, a year before the start of the experiments.

The analyses of the chemical compositions were carried out in the autumn of 1997 and at the beginning of 2001. Each sample was divided vertically into three parts: top, middle, and bottom parts. The sampling positions are shown in Table B.1. The analyses were caried out mainly for seven middle parts and one bottom part. No significant change of water content in the concrete composition over time was observed.

Table B.1. Sampling Position of Reflector Material.

Reflector	Side	
	north	south
C25	---	middle
C50	---	middle
C100	middle	middle
C150	middle	middle (2 parts), bottom

Three specimens - X, Y, and Z specimens - were prepared from each part. Therefore, there were 24 specimens. The sampling methods for each specimen are shown in Figures B.1 and B.2.

The following analyses were performed:

X specimen - Three bulk densities were estimated by measuring the dimensions and weight: in the collected condition, wet condition, and dried condition. The wet and dried conditions mean the condition after soaking in water for 24 hours, or after drying at 110°C for 7-10 days, respectively.

Y specimen - Two bulk densities were estimated by measuring the dimensions and weight in the collected and dried conditions. The dried condition means the same as the above definition. The dried Y specimen was crushed to powder, and the chemical analysis was carried out.

Z specimen - Two kinds of bulk densities were estimated by measuring the dimensions and weight: in the collected and dried conditions. Here, the dried condition means the condition after drying at 110°C for 24 days. The content of bound water was measured, using the dried Z specimen. (The method will be described later.)

All 24 specimens had data for the bulk density in the collected and dried conditions. The average of those in the collected condition is (2.321±0.019) g/cm^3. The ratio of free water to the dried condition is defined as follows:

$$R_{freeH2O}(\%) = \frac{density_{collected} - density_{dried}}{density_{dried}} \times 100 .$$

The ratios of free water were estimated for all 24 specimens. The drying processes of X and Y specimens were stopped when mass decreases were no longer observed (7-10 days). From the viewpoint of drying term, the free-water ratio measured for the Z specimen should be larger than those of X and Y specimens, if the composition of concrete were uniform. However, the ratios of free water measured for Z specimens were not always larger than those for X and Y specimens. The final value of the ratio of free water estimated from the average of 24 data is (5.19 ± 0.12)%.

The bulk density in the dried condition was estimated from that in the collected condition and the ratio of free water:

$$density_{dried} = \frac{100 \cdot density_{collected}}{R_{free\,H2O}(\%) + 100} ,$$

and the estimated value is (2.206 ± 0.018) g/cm^3.

The content of bound water was measured on eight Z specimens. The schematic view of the equipment is shown in Figure B.2. The specimen was set on the heated table in a nitrogen atmosphere. The temperature around the heated table was above 1000 °C, and the specimen was baked for about 2 hours. The bound water was adsorbed onto calcium chloride ($CaCl_2$) at the outlet. (Calcium chloride in the inlet adsorbed any water in the nitrogen gas.) The content of bound water was estimated from the mass increase of calcium chloride at the outlet. The averaged ratio of bound water to the dried condition (mass of specimen before heating) is (4.66 ± 0.11)%.

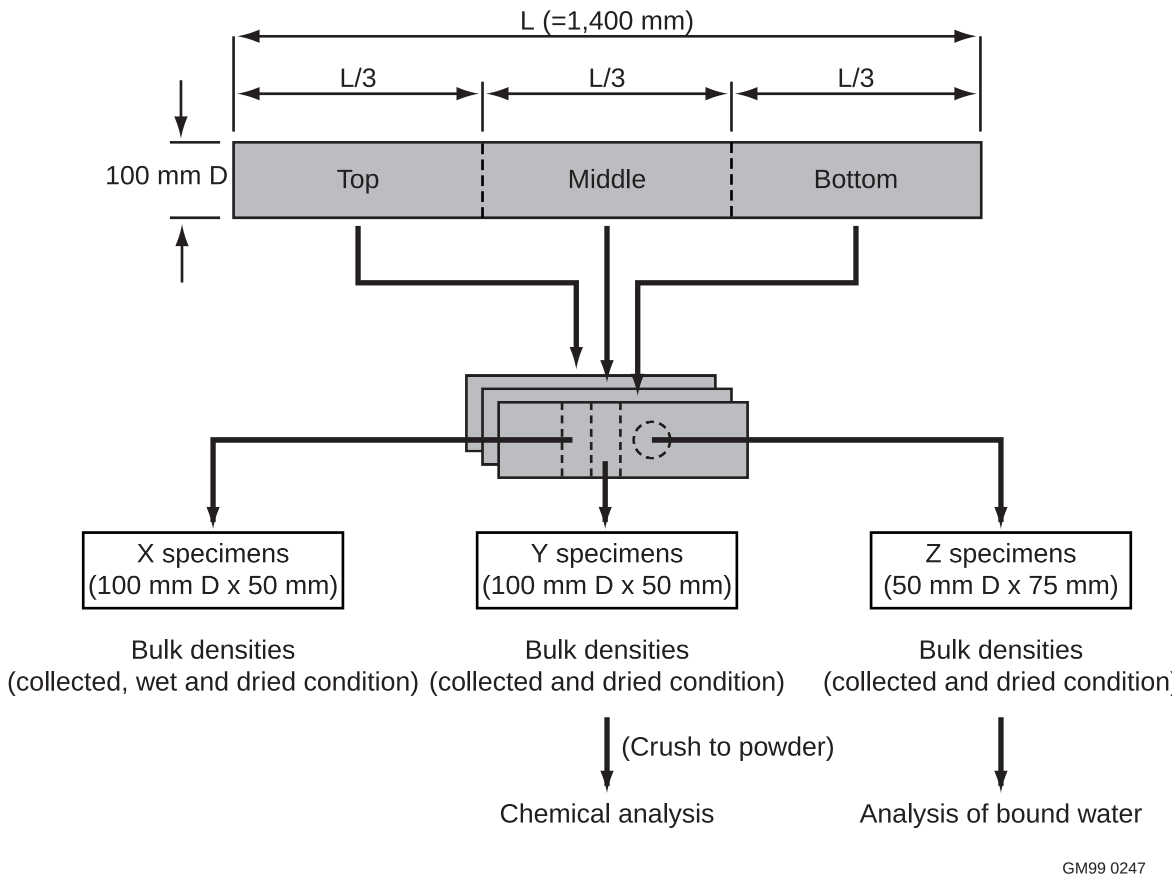


Figure B.1. Sampling Method of Specimens.

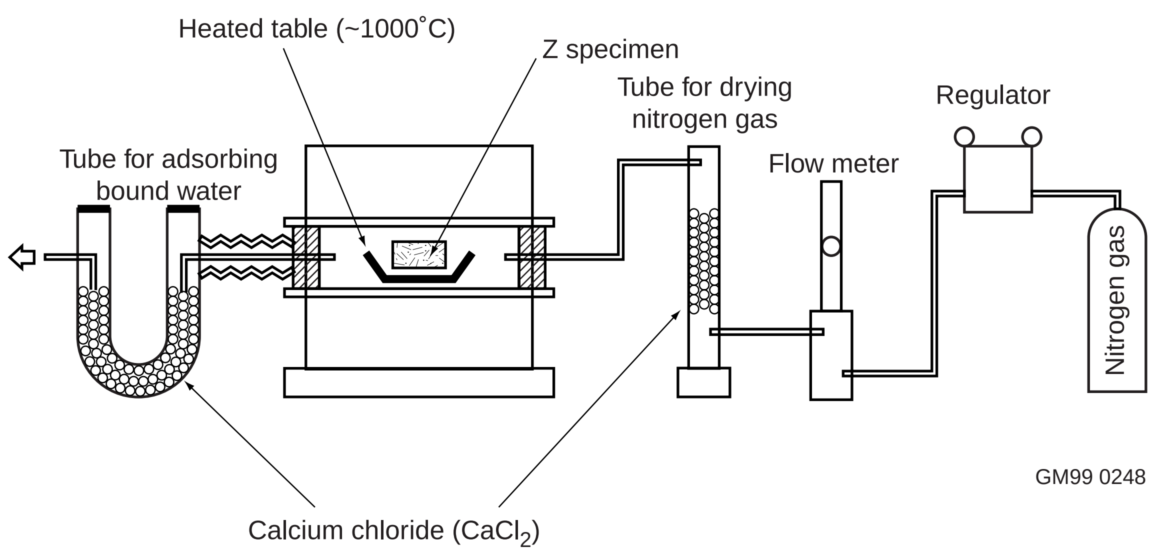


Figure B.2. Schematic View of the Equipment Used for Analysis of Bound Water.

The chemical analyses were carried out on the concrete powder made from eight dried Y specimens, based on JIS R5202 (Japanese Industrial Standard: Method for chemical analysis of Portland cement). The measured results of the chemical analysis are given in Table B.2, in which the average and the standard deviation for each chemical compound are listed. The bound water is included in the dried Y specimen. However, the sum of wt.% of bound water and the total wt.% of measured chemical compounds is not 100 wt.%. It is thought that this discrepancy was caused by the existence of chemical compounds in various forms ($Fe_2O_3 \rightarrow Fe_3O_4$, $CaO \rightarrow CaCO_3$, etc.). The chemical composition without the free and bound water was determined by assuming that the existing ratios were kept. For convenience, the normalized ratios, which total 100 wt.%, are also given in Table B.2.

Table B.2. Result of Chemical Analysis on Concrete Powder (Unit: wt.%).

Chemical Compound	Measured	Normalized[b]
SiO_2	63.8± 1.1	70.0± 1.2
Al_2O_3	5.70± 0.40	6.25± 0.44
Fe_2O_3	1.60 ± 0.12	1.75 ± 0.13
CaO	15.88 ± 0.80	17.43± 0.88
MgO	0.57 ± 0.04	0.62 ± 0.04
SO_3	0.63 ± 0.05	0.69 ± 0.05
Na_2O	2.35 ± 0.35	2.58 ± 0.38
K_2O	0.65 ± 0.02	0.71 ± 0.02
Cl^-	0.0023± 0.0010	0.0025± 0.0011
Total	91.1823[a]	(100.0325)

(a) Extra digit used for normalization is shown.
(b) These values are shown only for information: the measured values and total of those are used for the derivation of each compound's density, in fact.

Each chemical component is given in g/cm^3 (Table 9). Using the bulk density in the dried condition and the ratio of free water and bound water to the dried condition, the densities of free and bound water are estimated as follows:

$$\begin{aligned} density_{free\ H2O} &= density_{dried} \text{ x } R_{free\ H2O} \\ &= (2.206 \pm 0.018) \text{ x } (0.0519 \pm 0.0012) \\ &= (0.1145 \pm 0.0028) \text{ g/cm}^3 \\ density_{bound\ H2O} &= density_{dried} \text{ x } R_{bound\ H2O} \\ &= (2.206 \pm 0.018) \text{ x } (0.0466 \pm 0.0011) \\ &= (0.1028 \pm 0.0026) \text{ g/cm}^3 \end{aligned}$$

The densities of other compounds are estimated using the bulk density in the dried condition, the ratios of all compounds without bound water, and the normalized ratio of each compound to the dried condition. For example, the density of SiO_2 is estimated as follows:

$$
\begin{aligned}
\textit{density}_{SiO2} &= \textit{density}_{dried} \text{ x } (1 - R_{bound\ H2O}) \text{ x } \textit{normalized}_{SiO2} \\
&= (2.206 \pm 0.018) \text{ x } (0.9534 \pm 0.0011) \text{x } (63.8 \pm 1.1) / 91.1823 \\
&= (1.4716 \pm 0.0281) \text{ g/cm}^3
\end{aligned}
$$

The uncertainties are derived as follows:

$$d = D \times \{(a/A)^2 + (b/B)^2 + (c/C)^2\}^{1/2}$$

where A and a are value and uncertainty of $\textit{density}_{dried}$,
B and b are value and uncertainty of $(1 - R_{bound\ H2O})$,
C and c are value and uncertainty of $\textit{normalized}_{SiO2}$, and
D and d are value and uncertainty of $\textit{density}_{SiO2}$.

Values of other compounds are given in Table 9.

APPENDIX C: DENSITY FORMULA[a]

The density formula usable for U(VI)-nitrate aqueous solution, Pu(IV)-nitrate aqueous solution and U(VI)-Pu(IV)-nitrate aqueous solution was used for sensitivity calculations in Section 2 and for calculating the bias in the benchmark-model k_{eff} due to temperature. The equation is as follows:

$$\begin{aligned}\rho = {} & 0.99833 + 1.6903\times10^{-3}\cdot C_{Pu25} + 1.4276\times10^{-3}\cdot C_{U25} \\ & + 3.9956\times10^{-2}\cdot C_{HN25} - 8.696\times10^{-8}\cdot(C_{Pu25})^2 \\ & - 1.087\times10^{-7}\cdot(C_{U25})^2 - 8.513\times10^{-4}\cdot(C_{HN25})^2 \\ & - 5.442\times10^{-6}\cdot T^2 - 4.4889\times10^{-5}\cdot C_{Pu25}\cdot C_{HN25} \\ & - 1.310\times10^{-6}\cdot C_{Pu25}\cdot T - 1.564\times10^{-5}\cdot C_{U25}\cdot C_{HN25} \\ & - 9.487\times10^{-7}\cdot C_{U25}\cdot T - 8.684\times10^{-5}\cdot C_{HN25}\cdot T,\end{aligned}$$

where

ρ : density of solution at T (g/cm^3),
C_{Pu25} : concentration of plutonium at 25°C (g/liter),
C_{U25} : concentration of uranium at 25°C (g/liter),
C_{HN25} : concentration of free nitric acid at 25°C (mol/liter),
T : temperature (°C).

The equation is valid under the following conditions:

C_{U25}<530 g/liter,
C_{Pu25}<480 g/liter,
$C_{Pu25}+C_{U25}$<350 g/liter (valid for mixed fuel solution),
C_{HN25}<7 mol/liter,
10<T<60 °C.

The accuracy of this equation is 0.0032 g/cm^3.

[a] S. Sakurai and S. Tachimori, “Modified density equation for aqueous solutions with plutonium (IV), uranium (IV) and nitric acid,” JAERI-M 88-127 (1988) (in Japanese).

APPENDIX D: HOLES IN REFLECTORS FOR MEASURING DEVICES

Table D.1. Number of Holes and Total Volume.

item / reflecror	reflector dimensions (cm)			number of holes for gold wire (0.5 cm dia.)			number of holes for measurement (1.6 cm dia.)			volume of reflector V(cm^3)	volume of holes v(cm^3)	volume fraction of holes v/V(%)
	X(a)	Y(a)	Z	X	Y	Z	X	Y	Z			
C25	2.53	71.4	150.6	6			2			27205	13.15	0.048
C50	5.01	71.5	150.5	6			2			53911	26.05	0.048
C100	10.07	71.4	150.6	6	2	2	2		2	108281	745.14	0.688
C150	15.00	71.4	150.7	6		2	2	2	4	161400	1636.29	1.014

(a) X is north-south direction, Y is east-west direction

APPENDIX E: MCNP4B DETAILED-MODEL INPUT LISTING

The MCNP4B detailed-model input listing for Run No.145, Table 16, is provided below. The continuous-energy cross sections based on the JENDL-3.2 library were used. MCNP4B was run with 2,000 active generations of 5,000 neutrons each (10 million neutron histories), after skipping 50 generations (100,000 neutron histories).

```
file name=run145; STACY ( model 5 )
c   FUEL UO2(NO3)2
c   Hc = 65.56 cm
c   200T Concrete
c   Tank is all considered.
c
c   cell card
c
221  2  8.66829700E-02   #(-226 227 -231) -226 1 -230 imp:n=1 u=2
222  2  8.66829700E-02   227 -2 -228 229     imp:n=1 u=2
223  4  4.94240000E-05   227 -2 -229         imp:n=1 u=2
224  4  4.94240000E-05  -229  2 -3          imp:n=1 u=2
225  2  8.66829700E-02   229 -228 2 -3       imp:n=1 u=2
226  1  9.88764316E-02   -500 501 -233       imp:n=1 u=2
1    1  9.88764316E-02   1  -2  11 -12 13 -14  228 #221  imp:n=1 u=2
2    4  4.94240000E-05   228 2  -3  11 -12 13 -14        imp:n=1 u=2
3    2  8.66829700E-02  -4 #(11 -12 13 -14 1 -3) #226
       #(3 -229) #(3 -221) #(3 -222) #(3 -223)           imp:n=1 u=2
70   2  8.66829700E-02  #(4 -221 -225) -171 4
                  #(330 -331)          imp:n=1 u=2
261  19 1.37809E-01       330 -331           imp:n=1 u=2
71   2  8.66829700E-02  #(4 -222 -225) -172 4
                  #(330 -332)          imp:n=1 u=2
262  19 1.37809E-01       330 -332           imp:n=1 u=2
72   2  8.66829700E-02  #(4 -223 -225) -173 4
                  #(330 -333)          imp:n=1 u=2
263  19 1.37809E-01       330 -333           imp:n=1 u=2
74   2  8.66829700E-02  4  -176 -175        imp:n=1 u=2
75   2  8.66829700E-02  4  -177             imp:n=1 u=2
76   2  8.66829700E-02  4  -178             imp:n=1 u=2
77   2  8.66829700E-02  4  -179             imp:n=1 u=2
210  2  8.66829700E-02  4  -220             imp:n=1 u=2
170  4  4.94240000E-05  3 -221 -225         imp:n=1 u=2
171  4  4.94240000E-05  3 -222 -225         imp:n=1 u=2
172  4  4.94240000E-05  3 -223 -225         imp:n=1 u=2
174  4  4.94240000E-05  3 -4 -229           imp:n=1 u=2
78   4  4.94240000E-05  #(11 -12 13 -14 1 -3)  #3 #70 #71 #72
                  #210 #74 #75 #76 #77
                  #170 #171 #172      #174 #226
                  #261 #262 #263
                                  imp:n=1 u=2
79   0  5  15 -16 17 -18                    imp:n=1 u=3 fill=2
c   NS guide pipe
c   250  4  4.94240000E-05   -531              imp:n=1 u=3
c   251  2  8.66829700E-02   531 -532          imp:n=1 u=3
c   252  4  4.94240000E-05   532 -533          imp:n=1 u=3
c   253  2  8.66829700E-02   533 -534          imp:n=1 u=3
c   12   2  8.66829700E-02   41 -42            imp:n=1 u=3
c   163  4  4.94240000E-05   534 -41           imp:n=1 u=3
c
c   Foot of tank
 4   2  8.66829700E-02  (15 -16 51 -52  -5 43):
                    (15 -16 52 -53 -57 43) imp:n=1 u=3
 5   2  8.66829700E-02  (15 -16 -54 55  -5 43):
                    (15 -16 -55 56 -57 43) imp:n=1 u=3
c
c fuel feed pipe 1
c
```

```
227  1  9.88764316E-02  -233 234  -5    imp:n=1 u=3
228  2  8.66829700E-02   233 -232 234 -5 imp:n=1 u=3
c
c fuel feed pipe 2
c
230  1  9.88764316E-02  -236  237 -238  imp:n=1 u=3
231  2  8.66829700E-02   236 -235 237 -238  imp:n=1 u=3
c
c fuel feed pipe 3
c
233  1  9.88764316E-02 -241 -242  43    imp:n=1 u=3
234  2  8.66829700E-02  241 -240 -242 43 imp:n=1 u=3
c
c  8    4  4.94240000E-05  #12 #163 #4 #5 #6 #7 #250 #251 #252 #253
c       #(-232 234) #(237 -238 -235) #(-242 -240) imp:n=1 u=5
c
c  85   0  -5 43 -51                      imp:n=1 u=3 fill=5
c
c   base plate
13   2  8.66829700E-02 (-43 44 -45 46 -47 48) 410 imp:n=1 u=3
330  2  8.66829700E-02  -44  412 (-45 46 -47 48)  411
                        (414:-415:416:-417) imp:n=1 u=3
331  2  8.66829700E-02   82 -413 (-45 46 -47 48)  411
                        (414:-415:416:-417) imp:n=1 u=3
332  2  8.66829700E-02 -412  413 (-418 419 -420 421)  411
                        (422:-423:424:-425) imp:n=1 u=3
333  2  8.66829700E-02 -412  413  410 -411        imp:n=1 u=3
c   neutron source guide tube
254  4  4.94240000E-05  -531  -530 84          imp:n=1 u=3
255  2  8.66829700E-02  531 -532  -530 84       imp:n=1 u=3
256  4  4.94240000E-05  532 -533  -530 84       imp:n=1 u=3
257  2  8.66829700E-02  533 -534  -530 84       imp:n=1 u=3
86   2  8.66829700E-02  41 -42  -530 84         imp:n=1 u=3
164  4  4.94240000E-05  534 -41  -530 84        imp:n=1 u=3
c
c   ch-4
21  13  5.02274000E-02   -101 -102  103             imp:n=1 u=3
401  6  1.24933300E-01   -105 106 101 -104           imp:n=1 u=3
c   ch-5
24  14  1.07067000E-01   -107 -108  109         imp:n=1 u=3
410  6  1.24933300E-01    107 -110 -111  112     imp:n=1 u=3
c   ch-6
c  27  15  8.80834000E-02   -113 -114  115          imp:n=1 u=3
c  420  6  1.24933300E-01    113 -116 -117  118     imp:n=1 u=3
c   ch-7
30  16  3.46630000E-02   -122  123 -119         imp:n=1 u=3
31  16  3.46630000E-02   -122  123  119 -120     imp:n=1 u=3
430  6  1.24933300E-01   -121  120  125 -124     imp:n=1 u=3
c  66   4  4.94240000E-05   -121 -136 137 #30 #31 #32 imp:n=1 u=3
c   ch-1 2
90   4  4.94240000E-05   -136  163 -180         imp:n=1 u=3
91   7 -2.69900000E+00   -136  163  180 -161     imp:n=1 u=3
440  6  1.24933300E-01   -162  161  163 -164     imp:n=1 u=3
c  92   3  9.99870000E-02   -162  161  163 -164     imp:n=1 u=3
c  93   4  4.94240000E-05   -162 -136 137 #90 #91 #92 imp:n=1 u=3
c   ch-3
94   4  4.94240000E-05   -136  163 -190         imp:n=1 u=3
95   7 -2.69900000E+00   -136  163  190 -181     imp:n=1 u=3
450  6  1.24933300E-01    163 -164  181 -182     imp:n=1 u=3
c  96   3  9.99870000E-02   -182  181  183 -184     imp:n=1 u=3
c  97   4  4.94240000E-05   -182 -136 137 #94 #95 #96 imp:n=1 u=3
c   pulsartron
c  33  17  2.726620E-02     -325 -126 127          imp:n=1 u=3
c  460  6  1.249333E-01      325 -128 -129 130     imp:n=1 u=3
c   35   3  9.99870000E-02   -128 -126 127 #33 #34   imp:n=1 u=3
c   st-a
36  11  1.25762000E-02   -131 -134  135         imp:n=1 u=3
37   4  4.94240000E-05   -131 -136  137 #36      imp:n=1 u=3
38   7 -2.69900000E+00    131 -132 -136  137     imp:n=1 u=3
470  6  1.24933300E-01   -133  132 -138  139     imp:n=1 u=3
c   40   4  4.94240000E-05    132 -133 -136  137 #39 imp:n=1 u=3
```

```
c    st-b
41  11  1.25762000E-02   -140 -134  135          imp:n=1 u=3
42   4  4.94240000E-05   -140 -136  137 #41      imp:n=1 u=3
43   7 -2.69900000E+00    140 -141 -136  137     imp:n=1 u=3
480  6  1.24933300E-01    141 -142 -138  139     imp:n=1 u=3
c   45   4  4.94240000E-05    141 -142 -136  137 #44 imp:n=1 u=3
c    lin-a
46  12  1.86958000E-02   -143 -146  147          imp:n=1 u=3
47   4  4.94240000E-05   -143 -136  137 #46      imp:n=1 u=3
48   7 -2.69900000E+00    143 -144 -136  137     imp:n=1 u=3
49   6  1.24933300E-01    144 -145 -150  151     imp:n=1 u=3
c  50   4  4.94240000E-05    144 -145 -148  137 #49 imp:n=1 u=3
c    lin-b
51  12  1.86958000E-02   -152 -146  147          imp:n=1 u=3
52   4  4.94240000E-05   -152 -136  149 #51      imp:n=1 u=3
53   7 -2.69900000E+00    152 -153 -136  149     imp:n=1 u=3
54   6  1.24933300E-01    153 -154 -350  351     imp:n=1 u=3
c   55   4  4.94240000E-05    153 -154 -148  149 #54 imp:n=1 u=3
c    log-a
56  12  1.86958000E-02   -155 -146  147          imp:n=1 u=3
57   4  4.94240000E-05   -155 -136  149 #56      imp:n=1 u=3
58   7 -2.69900000E+00    155 -156 -136  149     imp:n=1 u=3
59   6  1.24933300E-01    156 -157 -150  151     imp:n=1 u=3
c   60   4  4.94240000E-05    156 -157 -148  149 #59 imp:n=1 u=3
c    log-b
61  12  1.86958000E-02   -158 -146  147          imp:n=1 u=3
62   4  4.94240000E-05   -158 -136  137 #61      imp:n=1 u=3
63   7 -2.69900000E+00    158 -159 -136  137     imp:n=1 u=3
64   6  1.24933300E-01    159 -160 -350  351     imp:n=1 u=3
c   65   4  4.94240000E-05    159 -160 -148  137 #64 imp:n=1 u=3
c
270  2  8.66829700E-02  3 -4  15 -16 502 -503 #(17 -18) imp:n=1 u=3
c
c    reflector support plate
c
c     Concrete reflector
c
301 21   8.11829800E-02 267 -268 272 -273  265 -266
                 481  482  483  484  485  486  487  488   imp:n=1 u=3
302 22   8.68654070E-02 261 -262 272 -273 263 -264 #(267 -268 265 -266)
                                               imp:n=1 u=3
303 20   5.98285201E-02 261 -262 271 -274 263 -264 #(272 -273)
                 481  482  483  484  485  486  487  488   imp:n=1 u=3
c
304 21   8.11829800E-02 267 -268 277 -276  265 -266
                 481  482  483  484  485  486  487  488   imp:n=1 u=3
305 22   8.68654070E-02 261 -262 277 -276 263 -264 #(267 -268 265 -266)
                                               imp:n=1 u=3
306 20   5.98285201E-02 261 -262 278 -275 263 -264 #(277 -276)
                 481  482  483  484  485  486  487  488   imp:n=1 u=3
c
307 21   8.11829800E-02 267 -268 282 -283  265 -266
                 461  462  463  464  465  466  467  468
                 481  482  483  484  485  486  487  488   imp:n=1 u=3
308 22   8.68654070E-02 261 -262 282 -283 263 -264 #(267 -268 265 -266)
                 461  462  463  464  465  466  467  468   imp:n=1 u=3
309 20   5.98285201E-02 261 -262 281 -284 263 -264 #(282 -283)
                 481  482  483  484  485  486  487  488   imp:n=1 u=3
c
310 21   8.11829800E-02 267 -268 287 -286  265 -266
                 471  472  473  474  475  476  477  478
                 481  482  483  484  485  486  487  488   imp:n=1 u=3
311 22   8.68654070E-02 261 -262 287 -286 263 -264 #(267 -268 265 -266)
                 471  472  473  474  475  476  477  478   imp:n=1 u=3
312 20   5.98285201E-02 261 -262 288 -285 263 -264 #(287 -286)
                 481  482  483  484  485  486  487  488   imp:n=1 u=3
c
c   gold wir and detector
c
313  4   4.94240000E-05 261 -262  263 -264
                 (-461:-462:-463:-464:-465:-466:-467:-468)
```

```
                                        imp:n=1 u=3
314  4   4.94240000E-05 261 -262  263 -264
                  (-471:-472:-473:-474:-475:-476:-477:-478)
                                        imp:n=1 u=3
315  4   4.94240000E-05 ((271 -274):(-275 278):(281 -284):(-285 288))
                  (-481:-482:-483:-484:-485:-486:-487:-488)
                                        imp:n=1 u=3
c
c    Support of reflector
c
320 22   8.68654070E-02 (-267 261 272 -283 -263  82 ) :
                  (267 -343 272 -283 -340  82 ) :
                  (-267 261 272 -283  264 -342)    imp:n=1 u=3
321 22   8.68654070E-02 (268 -262 272 -283 -263  82 ) :
                  (-268 344 272 -283 -340  82 ) :
                  (268 -262 272 -283  264 -342)    imp:n=1 u=3
322 22   8.68654070E-02 (-267 261 -276 287 -263  43 ) :
                  (267 -343 -276 287 -341  43 ) :
                  (-267 261 -276 287  264 -342)    imp:n=1 u=3
323 22   8.68654070E-02 (268 -262 -276 287 -263  43 ) :
                  (-268 344 -276 287 -341  43 ) :
                  (268 -262 -276 287  264 -342)    imp:n=1 u=3
c
199  4  4.94240000E-05   #79 #(-42 84 -530) #13
         #270
         #21         #401 #24         #410
         #(-120 -122 123) #430 #(-136 163 -161) #440 #(-136 163 -181) #450
         #(-132 -136 137) #470 #(-141 -136 137) #480 #(-144 -136 137) #49
         #(-153 -136 149) #54
         #(-156 -136 149) #59
         #(-159 -136 137) #64
         #4  #5
         #(-232 234 -5) #(237 -238 -235) #(-242 -240 43)
         #(261 -262 271 -274 263 -264) #(261 -262 -275 278 263 -264)
         #(261 -262 281 -284 263 -264) #(261 -262 -285 288 263 -264)
         #320 #321 #322 #323
         #330 #331 #332 #333
         imp:n=1 u=3
200  0               -81  82  -83  84  -85  86 imp:n=1 u=4 fill=3
201  2  8.66829700E-02      #200               imp:n=1 u=4
202  0               -91  92  -93  94  -95  96 imp:n=1 u=6 fill=4
281  19 1.37809E-01    91 -331 -335             imp:n=1 u=6
282  2  8.66829700E-02 91  331 -171 -335        imp:n=1 u=6
283  19 1.37809E-01    91 -332 -335             imp:n=1 u=6
284  2  8.66829700E-02 91  332 -172 -335        imp:n=1 u=6
285  19 1.37809E-01    91 -333 -335             imp:n=1 u=6
286  2  8.66829700E-02 91  333 -173 -335        imp:n=1 u=6
203  0 #281 #282 #283 #284 #285 #286          #202  imp:n=1 u=6
204  0  300 -301 302 -303 304 -305             imp:n=1 u=7 fill=6
205  2  8.66829700E-02  #204                   imp:n=1 u=7
206  0  306 -307 308 -309 310 -311             imp:n=1 u=8 fill=7
207  0  #206                             imp:n=1 u=8
208  0  312 -313 314 -315 316 -317             imp:n=1 u=9 fill=8
209  18  8.153E-2   #208                  imp:n=1 u=9
212  0  318 -319 320 -321 322 -323             imp:n=1 fill=9
211  0                      #212               imp:n=0

c
c    surface cards (origin x=0.0 y=0.0 z=0.0)
c    cylinder
500  pz   -0.0001
501  pz   -1.9999
502  py   -44.0
503  py    44.0
 1   pz      0.0
 2   pz     65.56
 3   pz    149.75
 4   pz    152.63
 5   pz     -2.04
11   px    -14.04
12   px     14.04
```

```
13   py    -34.515
14   py     34.515
15   px    -16.57
16   px     16.57
17   py    -37.045
18   py     37.045
c
41   c/x   -8.0  -10.0  3.905
42   c/x   -8.0  -10.0  4.455
531  c/x   -8.0  -10.0  1.3
532  c/x   -8.0  -10.0  1.5
533  c/x   -8.0  -10.0  2.65
534  c/x   -8.0  -10.0  3.0
530  px     220.0
c    41   gq    0.5 0.5 1. -1. 0. 0. 11.31371 -11.31371 20. 148.750975
c    42   gq    0.5 0.5 1. -1. 0. 0. 11.31371 -11.31371 20. 144.152975
43   pz    -16.0
44   pz    -19.0
45   py     50.0
46   py    -50.0
47   px     17.0
48   px    -83.0
c    49   py     78.48
c    50   px    -71.42
c   base plate lower pipe and hari
410  c/z     2.0  17.0  7.76
411  c/z     2.0  17.0  8.26
412  pz    -20.0
413  pz    -34.0
414  px      2.0
415  px    -68.0
416  py     35.0
417  py    -35.0
418  px      9.85
419  px    -75.85
420  py     42.85
421  py    -42.85
422  px      9.15
423  px    -75.15
424  py     42.15
425  py    -42.15
c
c   foot of tank
51   py    33.5
52   py    34.5
53   py    42.5
54   py   -33.5
55   py   -34.5
56   py   -42.5
57   pz   -15.0
c
c   pool wall
 81  pz    205.4
 82  pz    -35.0
 83  px    283.0
 84  px   -119.0
 85  py    100.0
 86  py   -100.0
 91  pz    205.401
 92  pz    -36.5
 93  px    284.0
 94  px   -120.0
 95  py    101.0
 96  py   -101.0
c
c   neutron counter
c  ch-4
101  c/z    47.3   -1.0   1.85
102  pz     63.781
103  pz     16.381
104  c/z    47.3   -1.0   2.85
```

```
105  pz     55.581
106  pz     17.581
c  ch-5
107  c/z   -23.0    55.5   2.35
108  pz     60.41
109  pz     18.01
110  c/z   -23.0    55.5   3.35
111  pz     54.21
112  pz     19.21
c  ch-6
113  c/z    73.0    27.5   2.35
114  pz     77.91
115  pz     24.51
116  c/z    73.0    27.5   3.35
117  pz     70.71
118  pz     25.71
c  ch-7
119  c/z    17.0 -52.5    4.499
120  c/z    17.0 -52.5    4.5
121  c/z    17.0 -52.5    5.5
122  pz     69.75
123  pz     18.65
124  pz     57.65
125  pz     21.65
c  ch-1 and 3
180  c/z   -4.5  -48.0  1.0
161  c/z   -4.5  -48.0  1.1
162  c/z   -4.5  -48.0  2.1
163  pz    -15.999
164  pz     53.0
c  ch-2
190  c/z    4.5   48.0  1.0
181  c/z    4.5   48.0  1.1
182  c/z    4.5   48.0  2.1
c
c pulsertron
c  325  c/z    65.2  38.0  5.5
c  126  pz     66.33
c  127  pz      5.33
c  128  c/z    65.2  38.0 10.5
c  129  pz     36.53
c  130  pz      6.53
c  st-a
131  c/z     0.0   -56.8   1.95
132  c/z     0.0   -56.8   2.25
133  c/z     0.0   -56.8   3.25
134  pz    36.393
135  pz     2.103
136  pz    205.5
137  pz    -34.999
138  pz    42.535
139  pz    -2.465
c  st-b
140  c/z     0.0   56.8   1.95
141  c/z     0.0   56.8   2.25
142  c/z     0.0   56.8   3.25
c  lin-a
143  c/z    41.6   -54.5  4.7
144  c/z    41.6   -54.5  5.0
145  c/z    41.6   -54.5  5.5
146  pz     57.445
147  pz     12.69
148  pz    205.5
149  pz     -15.999
150  pz     61.28
151  pz      5.28
c  lin-b
152  c/z   -41.6   54.5    4.7
153  c/z   -41.6   54.5    5.0
154  c/z   -41.6   54.5    5.5
350  pz     61.28
```

```
351  pz      5.28
c  log-a
155  c/z   -41.6  -54.5   4.7
156  c/z   -41.6  -54.5   5.0
157  c/z   -41.6  -54.5   5.5
c  log-b
158  c/z    41.6   54.5    4.7
159  c/z    41.6   54.5    5.0
160  c/z    41.6   54.5    5.5
c
330  pz     185.35
335  pz     340.35
c  crd-1
171  c/z    0.00    15.0  3.815
221  c/z    0.00    15.0  3.095
331  c/z    0.00    15.0  2.73
c  crd-2
172  c/z    0.00   -15.0  3.815
222  c/z    0.00   -15.0  3.095
332  c/z    0.00   -15.0  2.73
c  crd-3
173  c/z    0.0      0.0  3.815
223  c/z    0.0      0.0  3.095
333  c/z    0.0      0.0  2.73
c  spare
175  c/z    10.0    30.0  3.815
176  pz     184.5
c  n-4(level gauge)
177  c/z   -10.5   -30.0   2.4
c  n-2(gas-outlet)
178  c/z   -25.0     7.5   1.7
c  n-5(driving device)
179  c/z    -9.0    30.0   2.13
c  n-7(thermocouple guide)
220  c/z    11.5   -25.0    1.6
225  pz     185.0
226  pz     5.5
227  pz     2.5
228  c/z    11.5   -25.0    0.865
229  c/z    11.5   -25.0    0.545
230  c/z    11.5   -25.0    1.475
231  c/z    11.5   -25.0    0.975
c
c   fuel feed pipe
232  c/z    12.5    29.0     1.36
233  c/z    12.5    29.0     1.07
234  pz    -9.6
235  gq    0.5 0.5 1. -1. 0. 0.  16.5     -16.5      22. 255.275
236  gq    0.5 0.5 1. -1. 0. 0.  16.5     -16.5      22. 255.98
c    235   c/x    29.0  -11.0 1.36
c    236   c/x    29.0  -11.0 1.07
238  p     1.  1. 0.  41.5
237  p     1.  1. 0.  19.0
c    238  px     12.5
c    237  px    -12.5
c    239  px      6.2
240  c/z     2.0      17.0     1.36
241  c/z     2.0      17.0     1.07
242  pz    -12.3601
c
c  Reflector support plate
c
c   Kirikaki
c
378  p   1. -1. 0. -51.33595
379  p   1. -1. 0.  51.33595
380  p   1.  1. 0.  51.33595
381  p   1.  1. 0. -51.33595
382  p   1. -1. 0. -12.02082
383  p   1. -1. 0.  12.02082
384  p   1.  1. 0.  12.02082
```

```
385  p   1.  1. 0. -12.02082
c    c150+C50  concrete reflector
c
261  py     -38.7
262  py      38.7
263  pz     -3.0
264  pz    153.6
265  pz      0.0
266  pz    150.6
267  py    -35.7
268  py     35.7
271  px     16.79
272  px     17.60
273  px     22.61
274  px     23.42
275  px    -16.79
276  px    -17.60
277  px    -22.61
278  px    -23.42
281  px     23.50
282  px     24.31
283  px     39.31
284  px     40.12
285  px    -23.50
286  px    -24.31
287  px    -39.31
288  px    -40.12
c    c150+C50  detector and gold wire
c
461  c/z    35.31   8.0  0.25
462  c/z    35.31  -8.0  0.25
463  c/z    35.31  22.0  0.8
464  c/z    35.31 -22.0  0.8
465  c/z    27.31   8.0  0.8
466  c/z    27.31  -8.0  0.8
467  c/y    31.81  20.0  0.8
468  c/y    31.81  70.0  0.8
c
471  c/z   -35.31   8.0  0.25
472  c/z   -35.31  -8.0  0.25
473  c/z   -35.31  22.0  0.8
474  c/z   -35.31 -22.0  0.8
475  c/z   -27.31   8.0  0.8
476  c/z   -27.31  -8.0  0.8
477  c/y   -31.81  20.0  0.8
478  c/y   -31.81  70.0  0.8
c
481  c/x    15.0   30.0  0.25
482  c/x    15.0   60.0  0.25
483  c/x    15.0   90.0  0.25
484  c/x   -15.0   30.0  0.25
485  c/x   -15.0   60.0  0.25
486  c/x   -15.0   90.0  0.25
487  c/x     0.0   30.0  0.8
488  c/x     0.0   60.0  0.8
c
c Reflector support
c
340  pz    -33.0
341  pz    -14.0
342  pz     170.5
343  py    -24.5
344  py     24.5
c
c  Hood and Concrete
c
300  px    -487.5
301  px     512.5
302  py    -290.0
303  py     610.0
304  pz    -290.0
```

```
305  pz     738.0
306  px    -488.2
307  px     513.2
308  py    -290.7
309  py     610.7
310  pz    -290.7
311  pz     738.7
312  px     -617.0
313  px      642.0
314  py     -400.0
315  py      910.0
316  pz     -295.0
317  pz      915.0
318  px     -797.0
319  px      842.0
320  py     -610.0
321  py     1090.0
322  pz     -395.0
323  pz     1065.0

c
c    data cards
c
mode  n                    $ transport neutrons only
c
c    material cards
c
c    R145(C200);U=313.8/A=0.955/D=1.4500
c    atomic density =  9.88764316E-02
m1    1001.37c     5.8747E-02
      7014.37c     2.1648E-03
      8016.37c     3.7170E-02
     92234.37c     6.4595E-07
     92235.37c     8.0158E-05
     92236.37c     8.0058E-08
     92238.37c     7.1398E-04
mt1   lwtr.01t    $  300k
c
c    sus304L(tank) 7.93g/cm3
c    atomic density  8.668297E-2
m2    6012.37c 7.1567E-05  $ C
     14000.37c 7.1415E-04  $ Si
     25055.37c 9.9095E-04  $ Mn
     15031.37c 5.0879E-05  $ P
     16000.37c 1.0424E-05  $ S
     28000.37c 8.5600E-03  $ Ni
     24000.37c 1.6725E-02  $ Cr
     26000.37c 5.9560E-02  $ Fe
c
c     water 25 deg.c
c
m3    1001.37c   6.6658E-02    $ H
      8016.37c   3.3329E-02    $ O
mt3   lwtr.01t                $ 300K
c
c     air
c
m4    7014.37c  3.9014E-05
      8016.37c  1.0410E-05
c
c    polyethylene 0.97g/cm3
m6    1001.37c   8.32889E-02
      6012.37c   4.16444E-02
mt6   poly.01t    $  300k
c
c    aluminum 2.699g/cm3
m7   13027.37c  -100.0      $ Al
c
c    sus304 7.93g/cm3  (d)daiza,annaikan etc.
m9    6012.37c  -0.05       $ C
     14000.37c  -0.41       $ Si
```

```
     25055.37c  -0.93      $ Mn
     15031.37c  -0.030     $ P
     16000.37c  -0.004     $ S
     28000.37c  -8.29      $ Ni
     24000.37c -18.36      $ Cr
     26000.37c -71.930     $ Fe
c
c    st-a,b  (1.25762e-2)
m11   6012.37c  1.51491E-7   $ C
      8016.37c  3.02982E-7   $ O
     13027.37c  1.25729E-2   $ Al
     18040.37c  2.85066E-6   $ Ar
c
c    lin-a,b,log-a,b (1.86958e-2)
m12   7014.37c  3.82159E-5   $ N
     13027.37c  1.86576E-2   $ Al
c
c    ch-4(wl)   (5.02274e-2)
m13   6012.37c  8.92716E-8   $ C
      8016.37c  1.78543E-7   $ O
     13027.37c  5.02254E-2   $ Al
     18040.37c  1.70771E-6   $ Ar
c
c    ch-5      (1.07067e-1)
m14   7014.37c  3.11542E-5   $ N
     13027.37c  1.07036E-1   $ Al
c
c    ch-6      (8.80834e-2)
m15   7014.37c  2.47374E-5   $ N
     13027.37c  8.80587E-2   $ Al
c    ch-7      (3.46630e-2)
m16   7014.37c  2.27114E-5   $ N
     13027.37c  3.46403E-2   $ Al
c     pulsartron
m17   6012.37c  3.54473E-5   $ C
     13027.37c  1.29223E-2   $ Al
     14000.37c  1.14537E-4   $ Si
     25055.37c  1.33181E-4   $ Mn
     15031.37c  7.73834E-6   $ P
     16000.37c  8.85058E-7   $ S
     28000.37c  1.11341E-3   $ Ni
     24000.37c  2.78370E-3   $ Cr
     26000.37c  1.01550E-2   $ Fe
c    HANDBOOK Concrete
m18   1001.37c  1.3742e-2          $ H
      8016.37c  4.5919e-2          $ O
      6012.37c  1.1532e-4          $ C
     11023.37c  9.6395e-4          $ Na
     12000.37c  1.2388e-4          $ Mg
     13027.37c  1.7409e-3          $ Al
     14000.37c  1.6617e-2          $ Si
     19000.37c  4.6052e-4          $ K
     20000.37c  1.5025e-3          $ Ca
     26000.37c  3.4492e-4          $ Fe
mt18   lwtr.01t
c
c      B4C (2.51g/cm3)
c     1.37809e-1
m19   5010.37c   2.18289e-2
      5011.37c   8.84185e-2
      6012.37c   2.75619e-2
c
c     Aluminum for reflector
c    atomic density  5.98285201E-02
m20  13027.37c 5.9559E-02  $ Al
     14000.37c 8.0751E-05  $ Si
     26000.37c 1.7114E-04  $ Fe
     29000.37c 1.7845E-05  $ Cu
c
c    concrete  (STACY-280T) T-ave.
c    atomic density  8.11829800E-02
```

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m21   1001.37c   1.4528e-02
      8016.37c   4.4590E-02
     11023.37c   1.0533E-03
     12000.37c   1.9573E-04
     13027.37c   1.5533E-03
     14000.37c   1.4749E-02
     16000.37c   1.0906E-04
     17000.37c   9.0027E-07
     19000.37c   1.9179E-04
     20000.37c   3.9337E-03
     26000.37c   2.7830E-04
mt21  lwtr.01t
c
c    sus304L(futa)  7.93g/cm3
c    atomic density  8.68654070e-02
m22   6012.37c 2.0675E-04  $ C
     14000.37c 6.6314E-04  $ Si
     25055.37c 1.0083E-03  $ Mn
     15031.37c 4.9337E-05  $ P
     16000.37c 1.6380E-05  $ S
     28000.37c 6.6885E-03  $ Ni
     24000.37c 1.6798E-02  $ Cr
     26000.37c 6.1435E-02  $ Fe
c
c    sus304 Kadai
m23   6012.37c  1.5904E-04    $ C
     14000.37c  9.3519E-04    $ Si
     25055.37c  1.1213E-03    $ Mn
     15031.37c  4.4712E-05    $ P
     16000.37c  2.9782E-06    $ S
     28000.37c  6.8512E-03    $ Ni
     24000.37c  1.6890E-02    $ Cr
     26000.37c  6.0951E-02    $ Fe
c
c    criticality cards
c
kcode  5000 1.0  50  2050
sdef  cel=d1 x=d2 y=d3 z=d4  erg=d5
c
si1  l  212:208:206:204:202:200:79:1
sp1        1
c  *** x-coodinate
si2    h   -14.0  14.0
sp2     0  1
c  *** y-coodinate
si3    h   -34.5  34.5
sp3     0  1
c  *** z-coodinate
si4    h   0.0    65.56
sp4     0  1
c
sp5    -3
c
c     ctme   25
prdmp  j -100 1 3
c
print -175
```

APPENDIX F: DERIVATION OF ATOM DENSITIES OF FUEL SOLUTION

Run No.145 (C200 Reflector)

Atomic weight of H=	A1=	1.0079
Atomic weight of N=	A7=	14.0067
Atomic weight of O=	A8=	15.9994
Atomic weight of U234=	A24=	234.0409
Atomic weight of U235=	A25=	235.0439
Atomic weight of U236=	A26=	236.0456
Atomic weight of U238=	A28=	238.0508
Wt.% of U234=	W24=	0.08
Wt.% of U235=	W25=	9.97
Wt.% of U236=	W26=	0.01
Wt.% of U238=	W28=	89.94
Uranium concentration (g/l)=	UD=	313.8
Free nitric acid concentration (mol/l)=	AC=	0.955
Solution density (g/cc)=	D=	1.4500
Avogadro's number=	AV=	0.60221
Atom density of U234=N24=	UD/1000*W24/100/A24*AV=	6.4595E-07
Atom density of U235=N25=	UD/1000*W25/100/A25*AV=	8.0158E-05
Atom density of U236=N26=	UD/1000*W26/100/A26*AV=	8.0058E-08
Atom density of U238=N28=	UD/1000*W28/100/A28*AV=	7.1398E-04
Total uranium atom density=	UN=	7.9486E-04
HNO3		
NH(HNO3)=	AC/1000*AV=	5.7511E-04
NN(HNO3)=	AC/1000*AV=	5.7511E-04
NO(HNO3)=	AC/1000*AV*3=	1.7253E-03
Density of HNO3 (g/cc)=DN=	AC*(A1+A7+3*A8)/1000=	0.060177224
UO2(NO3)2		
Molecular weight of UO2(NO3)2=MWU=	(N24*A24+N25*A25+N26*A26 +N28*A28)/UN+2*A7+8*A8=	393.7527074
Density of UO2(NO3)2=DU=	MWU*UN/AV=	0.51971677
Density of H2O=DH=	D-DU-DN=	0.870106006
NH(H2O)=	DH/(2*A1+A8)*AV*2=	5.8172E-02
NO(H2O)=	DH/(2*A1+A8)*AV=	2.9086E-02
Atom density of H=	NH(HNO3)+NH(H2O)=	5.8747E-02
Atom density of O=	NO(H2O)+NO(HNO3)+8*UN=	3.7170E-02
Atom density of N=	NN(HNO3)+2*UN=	2.1648E-03