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Measurements for the Jasper Program Intermediate Heat Exchanger Experiment

F. J. Muckenthaler
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ABSTRACT

The Intermediate Heat Exchanger (IHX) experiment was conducted at the Oak Ridge National Laboratory (ORNL) Tower Shielding Facility (TSF) during the last three months of 1991 and the first two months of 1992 as part of a continuing series of eight experiments planned for the Japanese-American Shielding Program for Experimental Research (JASPER) program that was started in 1986. This is the fifth experiment in that series, all of which are intended to provide support in the development of current reactor shield designs proposed for liquid metal reactor (LMR) systems both in Japan and the United States. The program is a cooperative effort between the United States Department of Energy (U.S. DOE) and the Japanese Power Reactor and Nuclear Development Corporation (PNC).

The experimental configurations consisted of a neutron spectrum modifier followed by various shield mockups. For the PNC portion of the program the modifier was a large volume of sodium typical of the area in which their IHX vessel would be located radially from the reactor core. Configurations studied in the U.S. part of the program were preceded by the same modifier of iron, aluminum, boral, and sodium used with the Advanced Liquid Metal Reactor (ALMR) mockups in the previous In-Vessel Fuel Storage (IVFS) experiment. This modifier was followed by mockups representative of three different off-axial locations that were being considered for placement of the IHX vessel. The PNC plan was concerned with the effort of surrounding a mockup of the sodium containing IHX vessel by a partial or full component boron carbide (B_4C) shield.

1. INTRODUCTION

This experiment is the fifth in a series of eight experiments to be performed at the TSF that were jointly planned by ORNL, participant for the U.S. DOE, and the PNC. This phase of the program, called the IHX experiment, was preceded by the Radial Shield Attenuation and Fission Gas Plenum experiments completed in 1986-87, the Axial Shield experiment completed in 1990, and the IVFS experiment completed in 1991.

The IHX experiment was designed to investigate and predict the sodium activation that will be generated in the secondary sodium contained within the IHX vessel. In reactor shield designs of the proposed type to be studied, calculation and prediction of the secondary coolant activation is most difficult because of the associated structure present and the resulting problems associated with defining the neutron paths in that area.

In this experiment two somewhat similar spectrum modifiers were used. For the U.S. portion of the program plan, the same sodium-pool-type modifier used in the IVFS study was utilized. This was followed by slabs of aluminum (Al), sodium (Na), B_4C, and in one study, stored fuel pins, that were placed in proper sequence to represent three different off-axial locations of the IHX vessel below the stored fuel, in the stored fuel area, and the Gas Plenum region of stored fuel. The modifier for the Japanese study was similar in nature, consisting only of sodium, which was followed by slabs of sodium representing the IHX vessel contained in a partial or full B_4C shield mockup.

The fuel pins are the same 4.81 wt% ^{235}U enriched rods that were contained in the so-called "homogeneous" vessel used in the previous IVFS experiment. Measurements were made behind it and the other slabs as they were placed in the horizontal neutron beam emanating from the Tower Shielding Reactor (TSR-II) as described in the program plan in Appendix A.

2. INSTRUMENTATION

The TSF Bonner ball detection system consists of a series of detectors (polyethylene balls), each of which measures an integral of the neutron flux weighted by the energy-dependent response function for that ball. The detection device of a Bonner ball consists of a 5.1-cm-diameter spherical proportional counter filled with BF_3 gas ($^{10}B/B$ concentration = 0.96) to a pressure of 0.5 atmospheres. In order to cover a range of neutron energies, the counter is used bare, covered with cadmium (Cd), or enclosed in various thicknesses of polyethylene shells surrounded by Cd, each detector being identified by the diameter of its shell. Bonner ball experimental results are predicted analytically by folding a calculated neutron spectrum with the Bonner ball response functions determined by R. E. Maerker et al.[1] and C. E. Burgart et al.[2]

An NE 213 liquid scintillator spectrometer covered the neutron spectral region from about 800 to 15 MeV. This device makes use of pulse-shape discrimination (PSD) to distinguish neutrons from gamma-ray pulses. Pulse-height data obtained with the spectrometer were unfolded with the FERD code[3] to yield absolute neutron energy spectra.

Spherical proton-recoil counters, filled with hydrogen to pressures of 1, 3, and 10 atmospheres, covered the neutron energy range from about 50 keV to 1 MeV. Pulse-height data from the counters were unfolded with the SPEC-4 code,[4] which makes use of the unfolded NE-213 neutron spectrum to correct for effects of higher-energy neutrons.

The measurements for each detector were referenced to the reactor power (watts) using the data from two fission chambers positioned along the reactor centerline as a basis. The response of these chambers as a function of reactor power level was established previously through several calorimetric measurements of the heat generated in the reactor during a temperature equilibrium condition (heat power run).

A study of the activation of the sodium in the spectrum modifier and in the shield mockups that followed was made using sodium carbonate- (Na_2CO_3) filled polystyrene capsules. The gamma-ray activity of the sodium within the capsules was measured by J. K. Dickens[5] utilizing a well-shielded Ge (Li) detector of 15% efficiency for a gamma-ray energy of 1.33 MeV when compared to a 7.5-cm x 7.5-cm NaI detector. The detector has a nominal resolution of about 2.5 keV for a gamma-ray energy of 1.33 MeV. The sodium activities experienced during the runs varied by more than four orders of magnitude from a low of about 16 Bq to nearly 10^5 Bq. For this range of activity, the overall absolute uncertainty assigned to the capsule activity was ±5%.

3. EXPERIMENTAL CONFIGURATION

The experimental program plan is essentially divided into three parts that list the mockups for the two spectrum modifiers, the three U.S.-sponsored axial locations of the IHX vessel, and the Japanese model where the IHX vessel is surrounded by partial or full complement shields. Neutron flux measurements were made behind each of the mockups as described in the program plan and sodium activation studies were made within both spectrum modifiers and between the mockup slabs in each of the Japanese model IHX configurations where feasible.

The U.S. design included configurations that began with the same sodium-pool-type spectrum modifier that was used in the previous IVFS experiment, followed by mockups that simulated the IHX vessel at three different off-axial locations. The regions selected represented locations below the spent fuel, at the spent fuel, and the fission gas plenum region of the spent fuel.

Configurations for the Japanese models began with a simple spectrum modifier of sodium followed by a simulated IHX vessel composed of a maximum of four sodium slabs, with and without a B_4C slab preceding them. These combinations were surrounded on two sides by additional sodium or a combination of sodium and B_4C that was considered to be part of the study. One of the mockups included a B_4C slab in front of the sodium slabs that had a cylindrical opening to represent a sodium inlet pipe into the IHX. A special mockup (see Item X) was included in the program plan to provide a benchmark mockup combining B_4C and aluminum that would provide a more stringent test of the three-dimensional transport codes developed in the U.S. and Japan.

The neutron source for all the measurements in the IHX experiment was the TSR-II placed in its Big Beam Shield that collimated the neutrons leaving the reactor into a horizontal beam through the use of a concrete shutter. The mockup slabs were centered on this horizontal beam and surrounded by concrete to reduce the background contribution. Measurements were made behind each of the slabs as it was added to the mockup, using a traversing mechanism that remotely positioned the detector while the reactor power was maintained. A typical mockup is pictured in Figure 1.

3.1 SPECTRUM MODIFIERS

Two different spectrum modifiers, noted in the program plan as SM-2 and SM-3, were necessary to provide the proper neutron distribution incident on the mockups for the U.S. DOE and PNC phases of the experiment. The first of these, SM-2, is the same modifier that was used in the previous IVFS experiment (see ORNL/TM-11989). The modifier, see Figure 2, consisted of two slabs of iron, 5.16 and 5.11 cm thick, followed by 9.17 cm of aluminum, 2.54 cm of boral, and 180 cm (nominal value) of sodium. The iron, aluminum, and boral slabs are 152.4 cm on an edge, while the sodium slab edges (including the aluminum vessel itself) are 2.54 cm wider. The actual thickness of the sodium slabs, shown in Figure 3, varied from the edge of the slabs to the middle, as there was some bulging along the slab centerlines. The centerline thickness for each slab in the modifier is also given in the lower left portion of the slabs shown in the schematics. Compositions of the iron, the type 6061 aluminum used throughout this experiment in the slabs and sodium tanks, and boral slabs are given in Tables 1, 2, and 3 respectively. The 30.5-cm-thick sodium slabs were obtained from Atomics International during the 1960s and have been used previously in various TSF experiments. The composition of the sodium is given in Table 4. This modifier preceded the mockups for the U.S. DOE-sponsored ALMR shield studies listed in the program plan as Items II, III, and IV. (Note: All tables are located in Appendix B).

The sides of the modifier SM-2 and all succeeding slabs used throughout the U.S. DOE-sponsored mockups were surrounded with lithiated paraffin whose thicknesses on all sides was not the same. The lithiated paraffin thickness against the vertical sides of the slabs was limited to 10.16 cm because of the number of bricks available at the TSF for the whole mockup. The configuration slabs were supported by a slab having one face of lithiated paraffin 20.3 cm thick in contact with the mockup slabs, the reverse side being 10.2 cm of concrete. Due to the tie-off pieces necessary at the top of each configuration slab, the thickness of lithiated paraffin in that area varied from 20 to 30 cm. In all cases, the lithiated paraffin on each edge of the slab was surrounded by a minimum of 61 cm of concrete. The concrete beyond the lithiated paraffin lining the vertical sides of the Fe, Al, and boral slabs consisted of concrete blocks, 15.24 x 15.24 x 30.48 cm, that were stacked to a radial depth of 61 cm, followed by other concrete as shown in the schematics. The composition of these small blocks is given in Table 5. The concrete adjacent to the lithiated paraffin bricks at the sides of the sodium tanks was of the 61- x 61- x 30.48-cm size and the composition of these is given in Table 6. The concrete covering the top of the spectrum modifier was in slab form and the analysis of this concrete is in Table 7. Additional concrete was added at the sides and over the top of the SM to reduce the background neutrons reaching the detector. The composition of the lithiated paraffin is given in Table 8.

The second modifier, SM-3, consisted of a combination of two 335.3-cm-diameter, cylindrical aluminum tanks filled with sodium, having thicknesses of 76.0 and 160.6 cm as measured on beam centerline (cylindrical centers). The aluminum faces of the cylinders were 1.27 cm thick, and this is included in the centerline measurement as quoted in the schematics in Figure 4. Concrete at least 45.7 cm thick surrounded the periphery of the tanks to reduce the effects of transverse leakage from the tanks. This was again followed by additional concrete to reduce background neutrons.

The sodium density was determined for previous usage by placing the tank between a 3-inch NaI detector and a ^{24}Na source and measuring accurately the counting rates in the uncollided gamma-ray peak at 2.75 MeV. From the ratio of this counting rate to the counting rate in this peak with no tank present and using the mass absorption coefficient for that energy gamma ray, the sodium density was determined to be an average of 0.945 g/cc for the two tanks. It was estimated that this value should be accurate to better than 1%. The maximum impurities in the sodium estimated by the vendor are presented in Table 9. A photograph of the tanks is given in Figure 5. Analysis of the concrete immediately surrounding the sodium is given in Table 10.

It should be noted that throughout the program plan in Appendix A, the material thickness mentioned for each slab is usually a nominal value. The actual thickness, in centimeters, for each slab is located in the left corner of that slab as it is displayed in the schematics in Appendix C. The values quoted represent the thickness of the slab, including the vessel walls, along the centerline of the slab. The center of the slabs coincided with the center of the reactor beam when placed in the mockup.

3.2 FUEL PIN ASSEMBLIES

A total of 1200 fuel pins were secured from the University of Florida for use in the preceding IVFS experiment and in this experiment. The pins were originally fabricated for use at the United States Atomic Energy Commission's National Reactor Testing Station near Idaho Falls, Idaho, for Special Power Excursion Reactor tests, hence the acronym SPERT fuel. Each of the rods consists of slightly enriched (4.81%), sintered

Uranium Oxide (UO_2) pellets encased in a 304 stainless steel (SS) tube and capped at both ends with SS. In each rod there exists an aluminum oxide (Al_2O_3) insulator between the UO_2 pellets and the SS caps at each end. Gas gaps for fuel expansion are provided at the upper end of the rod and around the pellets. A spring is located atop the fuel pellets to keep the pellets in place. The characteristics of a typical SPERT fuel rod may be seen, along with the schematic, in Figure 6. As is noted in the figure, the active fuel length is 91.44 cm, with an overall length of the fuel rod, ends included, of 106.05 cm. The pellets are 1.067 cm in diameter, and are clad in 1.184-cm-OD SS tubing with walls 0.051 cm thick. The UO_2 fuel pellet density is 10.08 g/cc and the ^{235}U in each rod amounts to 35.2 grams. Each of the pins is numbered to enhance record keeping. What was not noted in the schematic is that each of the pins has a weld bead at the top and bottom of the rod where the end caps join the tubing containing the fuel. This weld is slightly larger in diameter (1.20 cm) than the SS tubing (1.184 cm), and this larger diameter required some last minute changes in the fabrication of the vessels.

The fuel pins for this experiment were contained in what was referred to as the homogeneous vessel in the IVFS experiment. The expression "homogeneous" relates to the more general pin-aluminum distribution that occurred while maintaining the same fuel-to-aluminum volume fraction ratio that occurred in a more heterogeneous slab. In this arrangement (see Figure 7) the 536 pins were split into two groups by a 3.46-cm-thick aluminum divider that ran the full width of the vessel. On one side of the divider were two rows each of 77 and 76 pins stacked vertically, while on the other side were two rows of 77 pins and one row of 76 pins. The pins were spaced on a triangular pitch of 1.20 cm based on the diameter of the welds.

When the homogeneous vessel was placed in the mockup, it was necessary to place additional support beneath it to center the vessel on the reactor beam centerline since the length of the vessel was only 111.19 cm compared to the usual slab height of 152.4 cm. This was accomplished using 20.3 cm of lithiated paraffin. Likewise, since the width of the vessel, 97.38 cm, was also less than the usual slab width, 152.4 cm, it was necessary to fill the void beyond the vessel with lithiated paraffin bricks.

3.3 BORON CARBIDE SLABS

The B_4C slabs used in this experiment consisted of stainless steel cans filled with 120 grit B_4C powder. Six different containers were used, three of which were used in the previous IVFS experiment. These were noted as 4W and 5W, nominally 5 cm thick, and 2W, nominally 15 cm thick. The actual thicknesses are given in Figure 8, and the analysis of the B_4C is given in Table 11. All slabs were 152.4 cm on an edge. The densities were 1.39, 1.41, and 1.44 g/cc for slabs 2W, 4W, and 5W respectively. Three other B_4C slabs were fabricated specifically for this experiment. One was of the same thickness, nominally, as that noted for 2W, but it (see 6W in Figure 9) contained a cylindrical void at its center which was filled with an aluminum cylinder (type 6061) for this experiment. The other two slabs (7W and 8W) were nominally the same thickness as 4W and 5W, but were only half as wide (76.2 cm). Actual centerline thicknesses of the three slabs are also given in Figure 9, along with their densities and the dimensions of the aluminum insert. Analysis of the stainless steel vessels is given in Table 12.

3.4 ALUMINUM SLABS

Thin aluminum slabs were used throughout the spectrum modifier and in the ensuing mockups as a substitute for the sodium coolant in a typical U.S. ALMR reactor design. Special half-slabs of aluminum were fabricated for use in the Japanese series of mockups and these are shown in Figure 10. The slabs are all from the same type of aluminum, 6061, and their composition is listed in Table 2.

3.5 BACKGROUND SHIELDS

The procedure in the previous JASPER experiments was to obtain background measurements along with foreground measurements when the detectors were located at sufficient distances behind the mockups and the neutron contributions to that detector from areas other than the mockup being studied might not be negligible. These background measurements were obtained by placing a 40.6-cm-thick, 91.4-cm x 91.4-cm shadow shield of lithiated paraffin bricks between the detector and mockup in such a manner that contributions directly to the detector from just the mockup would be greatly reduced. This procedure was followed in making the measurements requested for the ALMR studies described in Items I through IV in the program plan. For the measurements requested in Items V through X of the program plan, PNC requested that the term mockup be extended to include the side B_4C and sodium tanks placed radially beyond the usual mockup slabs. This extension of the mockup width limited the number of background measurements that could be made using the same shadow shield described above to just the thicker mockups where the detector, when located at the 150 cm point, was adequately beyond the mockup to satisfy the procedure normally applied to obtain a background measurement. This request required changes in the measurements originally planned for the experiment and these changes have been made in the program plan in Appendix A.

Background measurements with the bare detector were extended to include some additional measurements with a sheet of Cd covering the face of the shadow shield nearest the detector. This measurement was considered important because the closeness of the shield to the detector might possibly contribute, through backscattering, to the detector count rate. This contribution can be estimated from the difference in the two background measurements.

3.6 HOMOGENEOUS IVFS VESSEL (NO FUEL)

The Homogeneous IVFS Vessel without the fuel pins was originally included as part of this mockup in Item IV. Since the fuel pins were absent and the dimensions of the vessel required the addition of extra lithiated paraffin bricks around its edges to extend its dimensions to 152.4 cm (standard slab size), the vessel was mocked up with 152.4-cm-on-edge slabs of equivalent aluminum and void thicknesses. The thicknesses used can be found in the schematic for Item IVA-E.

3.7 CADMIUM HUT

The Cd hut used in this experiment for making bare Bonner ball measurements at 30 cm behind the mockup may best be described as a small structure, approximately 152.4 cm on an edge, closely matching the dimensions of the mockup slabs, and 45.7 cm deep. The Al frame was covered with 30-40 mils of Cd, except for one face which was always open to the mockup. The open face allowed thermal neutron entry from the mockup slab while at the same time the Cd denied thermal neutron entry from any other direction. Thus it was possible to place the bare detector within the hut, make a measurement, and through a subtraction of the Cd-covered detector measurement at the same location, obtain a measure of the thermal flux leaving the mockup.

3.8 MOCKUP SHIELDING

The various slabs comprising the mockups were supported by several concrete slabs, stacked so that the center of the mockup slabs was coincidental with the reactor beam centerline. The support slab in immediate contact with the mockup pieces was 30.5 cm thick, 20.3 cm of which was a layer of lithiated paraffin while the remaining 10.2 cm was concrete. Throughout the experiment the lithiated paraffin side of the slab was placed next to the mockup. For the mockups studied in Items I through IV, there was 10.2 cm of lithiated paraffin placed on the lateral sides of each slab as it was added to the mockup. This was followed by an extended thickness of concrete. Both the lithiated paraffin and the concrete pieces usually protruded beyond the depth of the mockup, providing surfaces from which neutrons passing through the mockup slabs could be scattered back to the detector. The void space between the top of the slabs and the concrete roof was filled with 20-30 cm of lithiated paraffin. Again the sizes of the concrete roof slabs usually resulted in concrete protruding beyond the lithiated paraffin, providing another neutron reflection surface.

The same procedure was followed for the Japanese part of the program, Items V through X, except the term "mockup" in this series included the sodium and B_4C slabs placed parallel to the beam centerline on each side of the "usual" mockup slabs. As a result, the lithiated paraffin bricks on the sides were stacked outside the enlarged mockups, followed by a considerable thickness of concrete. The void spaces above the sodium and B_4C slabs on the sides were also filled with lithiated paraffin and this arrangement was maintained regardless of the number of sodium slabs present as the IHX mockup. Again the concrete roof slabs projected beyond the maximum mockup thickness and the space between it and the tops of each IHX slab as they were added to the mockup was filled with lithiated paraffin. Thus, when the sodium slabs were not present, the concrete slabs became one side of the mockup cavity that remained and, thus, an important reflective surface for neutrons.

4. MEASUREMENTS

The typical mockup consists of a series of slabs, 152.4 cm on a side, that are stacked in proper sequence for a particular measurement as called for in the program plan. The slabs are usually surrounded with lithiated paraffin bricks followed by concrete to provide both a reasonable boundary for calculation of the albedo neutrons reflected back into the mockup and a satisfactory shield for minimizing the effect of background contribution to the measurement. A 20.3 cm thickness of lithiated paraffin is preferred, but for this experiment the thickness along the lateral edges was limited to 10.16 cm because the number of bricks available to cover the larger mockups was inadequate. There was, however, 20.3 cm of lithiated paraffin beneath the mockup slabs as that amount is inherently part of the concrete slab that supports the mockup. The amount of lithiated paraffin between the top of the mockup slabs and the concrete slabs placed overhead for background suppression varied but was usually never less than 20-30 cm.

Concrete pieces beyond the lithiated paraffin at the sides of the mockups varied from small blocks 15.24 cm square by 30.5 cm alongside the SM to larger 61-cm-square by 30.5-cm-thick blocks beside the mockup slabs. Larger concrete blocks (91 cm x 91 cm) were used to extend the background attenuation but their presence did not contribute to the neutron flux reflected back into the mockup.

The spectrum modifier required in Item IA was the same slab arrangement of Fe, Al, boral, and Na used in the previous In-Vessel Fuel Storage (IVFS) experiment. The homogeneous vessel with fuel pins used in that experiment was also part of a mockup in this experiment (see Item III). The measurements in Item III of this IHX experiment were performed as part of the IVFS experiment to limit the number of changes of fuel pins and thus reduce personnel exposure to the radiation level of the fuel pins. The results, however, are included in this report.

One of the requests in Item III in the original program plan called for exposure of sodium foils, as Na_2CO_3 powder, between the last two sodium slabs in the mockup. Polystyrene capsules containing 5-6 grams of the powder were exposed for one hour at the maximum reactor power level of one megawatt. The resulting gamma-ray activity of the foils from this exposure was not sufficient to be counted by J. K. Dickens using a Ge (Li) detector. This result changed the exposure requests to what are now stated in the program plan.

As the experiment progressed, it was recognized that the thermal flux measurements requested in the original program plan were not as definitive as originally conceived. Hence, bare detector measurements were added: (1) inside a Cd hut on centerline at 30 cm, (2) with a Cd sheet behind the detector at both 30 and 150 cm when feasible, (3) with a Cd sheet over the face of the mockup, (4) with a Cd sheet beneath the concrete slabs covering the mockup, (5) background measurements with Cd over the face of the shadow shield, and (6) others as noted in the various data tables.

The background measurements were obtained in the usual manner by placing the lithiated paraffin shadow shield between the detector at 150 cm and the back face of the mockup in Items I through IV. For such measurements in the remaining items of the plan, V-X, it was requested by PNC that they be limited to just the 150 cm detector positions for which the shadow shield position would prevent the neutrons leaving the side B_4C and sodium tanks from reaching the detector unobstructed. In reality, this meant that the side B_4C and sodium tanks were to be considered as part of the mockup and for the thin mockups having one sodium tank or less, the background measurements would be physically impossible.

For the one spectral measurement requested in this plan, Item IB, it was necessary to place 7.62 cm of lead between the detector and the large cylindrical sodium tanks to reduce the gamma-ray flux at the detector. The addition of the lead permitted placing the detector close (25 cm) behind the lead, eliminating the need for a background measurement. The composition of the lead slab is given in Table 13.

The order in which the measurements were performed did not follow the order in which they were listed in the program plan. All of the mockups in Items II, III, and IV used the same spectrum modifier (Item IA) and these items were completed before changing modifiers to Item IB and doing measurements in Items V-X. The order in which the measurements were performed within each of the two groups did not follow the order of the listing in the program plan. The reporting of the data, however, will follow the order in which the program plan is written. The plan in Appendix A reflects only the measurements that were made, not what was originally planned. Throughout this report, the words *configuration*, *item*, and *mockup* are used interchangeably when referring to the contents of the program plan.

4.1 SPECTRUM MODIFIERS (Items IA, IAA, IB)

The program plan called for measurements behind two different spectrum modifiers, listed as SM-2 and SM-3 in Item I. The modifier SM-2 is the same modifier as was used in the previous IVFS experiment to provide a simulated spectrum incident upon the above core area where fuel pins were to be stored in the ALMR design for the U.S. At that time extensive measurements of the neutron flux and spectra were made behind it. Hence, at the start of this experiment, the measurements in IA were limited to those with the bare, Cd-covered, 3-, 5-, 8-, and 10-inch Bonner balls on centerline at 30 cm (foreground) and 150 cm (foreground and background) behind the modifier and the sodium activation measurements using Na_2CO_3 powder. The results of the Bonner ball measurements are listed in Tables 14 and 15.

The Na_2CO_3 foils were located in two voids between the sodium tanks as indicated by the letters X and Y, in Item IAA, and Z in Item IA, (see Figures 11 and 12). Locations of the vials within each void is shown to the left of those mockups in Figure 11. The results of the sodium activation measurements are expressed as nanocuries of activation per kilowatt of power and gram of sodium for each minute of exposure. These activation values can be found in Table 16.

The second modifier, SM-3, consisted of two 335.3-cm-diam sodium-filled tanks having 76 cm and 160.6 cm thicknesses as measured along the tank centerline. This thickness included the two aluminum faces of 1.27 cm each. The tanks were separated by a small void to allow insertion of the Na_2CO_3 capsules. These tanks provided a sodium pool-type modifier for the Japanese part of the IHX program. A description of the tanks was given earlier in section 3.1. A schematic of the modifier mockup can be found in Figure 4.

Since this modifier was new to the JASPER experiments, considerable effort was exerted to map the neutron spectrum and flux distribution behind it. Spectral measurements were made on centerline behind the bare tanks without presence of any of the mockup structure that was to follow. It was necessary to place two 3.81-cm-thick lead slabs between the sodium and the NE-213 spectrometer to obtain an acceptable gamma-ray to neutron count rate. Spectral data was obtained on centerline at 25 cm behind the lead with both the NE 213 and the hydrogen-filled detectors. At this location the detector was 35 cm behind the sodium modifiers as indicated in Figure 4. The resulting spectra are listed in Tables 17 and 18 and plotted in Figures 13 and 14 respectively. Integral flux measurements with the 3-, 5-, and 10-inch Bonner balls at this same location are listed in Table 19.

Measurements were made with the bare, Cd-covered, 3-, 5-, 8-, and 10-inch Bonner balls on centerline at 30 cm (foreground) and 150 cm (foreground and background) behind the mockup with the lead slab removed, and these results are given in Tables 14 and 15. A horizontal traverse was made with the 5-inch Bonner ball at 30 cm, as measured on centerline, behind the sodium tanks and these results are listed in Table 20.

The Na_2CO_3 capsules, three bare and two Cd-covered, were exposed on centerline at points 10 and 11 in the void XX between the two sodium tanks, Item IB, as shown in Figure 11. The resultant activation values are given in Table 16.

4.2 ALMR MOCKUPS BELOW SPENT FUEL REGION (ITEMS IIA-F)

The series of mockups in this group, IIA-F, represent a study of the shielding materials and their locations within the shield for the off-axial area below the spent fuel region in the ALMR concept. A schematic of the mockups can be seen in Figure 15. A series of measurements with the bare, Cd-covered, 3-, 5-, 8-, and 10-inch Bonner balls were made on centerline at 30 and 150 cm behind the last slab in each of the A through F mockups. Foreground measurements only were made at the 30 cm location, while both foreground and background data were obtained at 150 cm. The data at 30 cm are listed in Table 14, and that obtained at 150 cm are contained in Table 15.

Some additional measurements were added in this series that were not called for in the original data plan. These were included in an attempt to help define the foreground and background thermal neutron flux values at the 30 and 150 cm detector locations. As seen in the program plan, measurements with the bare detector were made on centerline at 30 cm behind the mockup when located inside a Cd hut that inhibited entry of the thermal neutrons from every direction except the back face of the mockup. A discussion of the Cd hut was given earlier in section 3.7. Subtracting the Cd-covered detector count rate from the bare detector measurement at 30 cm indicates the magnitude of the thermal flux leaving the face of the mockup.

An opposite approach was also employed throughout part of the experiment in which measurements were made with the bare detector when Cd was placed over the face of the mockup. In a way this may be considered a background-type measurement in that the Cd absorbs the thermal flux leaving the face of the mockup but allows the detector to respond to thermal neutrons from every other possible source. Subtracting the two bare detector runs, with and without Cd over the face of the mockup, again provides a measure of the thermal flux leaving the mockup. Results from the measurements at 30 cm using both approaches are given in Table 21, while those results from measurements made at 150 cm in the last method are in Table 22.

A series of Na_2CO_3 foil activation measurements were originally requested to be obtained in voids placed throughout the mockup. This part of the program plan was canceled for Item II following the results of such measurements obtained in Item III, which was the first Item in the IHX series for which these measurements were made. As discussed in section 3, the large neutron attenuation of that mockup reduced the activity in the foils to values below the sensitivity range of the foil counter. A similar attenuation would have occurred in Item II.

4.3 ALMR MOCKUPS IN SPENT FUEL REGION (ITEMS IIIA-E)

The mockups in this group are representative of the shielding materials and their locations within the shield for the off-axial region of the spent fuels. Measurements behind this series of mockups were performed as part of the IVFS experiment, but recorded here, since the use of fuel pins is called for in this series and to have delayed performing these measurements until the IHX experiment would have required another shuffling of the fuel pins into the homogeneous vessel which was already available in the previous IVFS experiment.

Measurements were made with the bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner balls on centerline at 30 and 150 cm behind the last slab in each of the mockups A through E as shown in Figure 16. The data at 30 cm is given in Table 14, that at 150 cm is included in Table 15. Measurements with the bare detector at 30 cm inside the Cd hut were included in the plan and these results are part of Table 21.

As seen in the mockup schematic, a void is shown to exist between sodium tank #4 and the 2.59-cm-thick stainless steel slab that followed it. The initial run in the IHX experiment was made with Na_2CO_3 powder in nine polystyrene capsules located within that void for one hour at a nominal one megawatt of reactor power. Each capsule contained approximately 6 grams of powder and following the run the combination of nine capsules failed to indicate enough activation to provide a count rate above the lower limit for the Ge (Li) detector of one-tenth nanocurie. Because the activation was so low, the exposure of foils as called for in Items I-IV in the original data plan was changed to those noted in the present plan, that is, only within the sodium tanks of the spectrum modifier. Thus no foil exposures were recorded for Item III.

4.4 ALMR MOCKUPS FOR FISSION GAS PLENUM REGION OF SPENT FUEL (ITEMS IVA-E)

The mockups chosen for measurements in this group are typical of the shield designs for the Fission Gas Plenum region of the spent fuels. The data plan calls for the homogeneous vessel, without fuel pins, to be placed behind the spectrum modifier. Use of the vessel would have required the presence of lithiated paraffin bricks on its sides to extend the vessel width to be the same as the other slabs, 152.4 cm, and beneath it to place the center of the vessel at the beam centerline. The presence of the bricks, 20.3 cm in thickness, would have changed the neutron flow in the outer area of the mockup in the slabs that followed it. To promote consistency, the homogeneous vessel was mocked up using slabs of aluminum and void spaces as seen in the schematics in Figure 17. This substitution is not noted in the data plan so that the original concept of the shields to be studied would be maintained.

Measurements with the bare, Cd-covered, 3-, 5-, 8-, and 10-inch Bonner balls were made on centerline at 30 and 150 cm behind the last slab in each of the five mockup changes called for in Item IV. These results are listed in Tables 14 and 15. Data was also obtained behind each of the mockups with the bare detector located at 30 cm inside a Cd hut and at 30 and 150 cm with Cd over the face of the shield mockup. These data are given in Tables 21 and 22. Foil activation measurements were not obtained in this series.

4.5 IHX MOCKUP (SODIUM WITH SODIUM SIDE SLABS) (ITEMS VA-E)

For the remainder of the mockups in this experiment, the spectrum modifier was changed from the combination of Fe, Al, boral, and Na to just large cylindrical sodium tanks as seen in Figure 4 and discussed earlier in section 4.1. The shield mockups that followed this SM were no longer composed of just those slabs placed perpendicular to the beam centerline as in the previous mockups, but they also included the sodium and B_4C slabs that were placed parallel to the beam centerline at the sides of the other slabs.

Concrete blocks were placed radially beyond these side tanks to support the concrete slabs that would be placed above the mockup. PNC had requested in the original program plan that two sodium tanks be placed on each side of the central sodium tanks. The use of two tanks at each side would have pushed the location of the concrete support blocks beyond the distance that could be spanned by the concrete slabs available at the TSF to cover the mockup. To correct this problem it was necessary to limit the sodium side tanks to just one on each side.

The IHX sodium in this mockup was represented by a maximum of four 155-cm-wide sodium tanks spaced to provide small voids between the tanks for placement of Na_2CO_3 capsules. This arrangement and the location of the foils within the voids is shown in Figure 11. A schematic of the actual mockup is shown in Figure 18.

Measurements were made with the bare, Cd-covered, 3-, 5-, 8-, and 10-inch Bonner balls on centerline at 30 and 150 cm behind the spectrum modifier and each sodium slab as it was added to the mockup. These results are given in Tables 14 and 15. Bare detector measurements were made at 30 cm in Items D and E with a small Cd sheet placed closely behind the detector so that it could see only the mockup and the side sodium tanks. The Cd was used in an attempt to eliminate background contributions. These results are placed in Table 21. Starting with this series of experiments, background measurements required placing the shadow shield closer to the detector so that the detector could not see the edges of the B_4C and the sodium tanks residing at the sides of the mockup tanks since these side tanks are to be considered as part of the mockup through the remainder of the program. This limited background measurements to Items C, D, and E as indicated in the program plan.

Na_2CO_3 capsules were exposed in each of the voids listed in Figure 18. Six capsules were placed in each void in the pattern shown in Figure 11 and exposed for one hour at a nominal reactor power of one megawatt. For this exposure the greater depth of void number one was due to the absence of the B_4C slab that will be inserted in the next series of mockups in Item VI, thus keeping the sodium tank locations the same for Na_2CO_3 capsule exposures in both V and VI. The values for the sodium activation at each of the voids is given in Table 23.

4.6 IHX MOCKUP (BORON CARBIDE FRONT SHIELD - SODIUM SIDE SLABS) (ITEMS VIA-E)

For this series of mockups the B_4C slab was placed in the void area in front of the sodium tanks while keeping the side shields the same as in Item V. Bare, Cd-covered, 3-, 5-, 8-, and 10-inch Bonner ball measurements were made on centerline at 30 and 150 cm behind the last slab in each mockup. These count rate values are part of Tables 14 and 15. Background measurements were made only behind mockups C, D, and E, and these results are also in Table 15. Bare detector measurements were made with Cd behind it at 30 cm in C and E and the data is in Table 21.

Placement of the B_4C slab in the mockup created another void (number 2) between it and the sodium slab that followed it as seen in Figure 19. Na_2CO_3 capsules were exposed in all six voids and the resulting activations are listed in Table 23.

4.7 IHX MOCKUP (BORON CARBIDE FRONT SHIELD - PARTIAL SIDE SHIELD) (ITEMS VIIA-F)

In this mockup the B_4C slab and sodium slabs in the IHX region were retained, but the sodium slab on each side was moved radially to allow insertion of half slabs of B_4C and aluminum next to the IHX slabs as seen in Figure 20. The bare, Cd-covered, 3-, 5-, 8-, and 10-inch Bonner ball measurements were made behind each of the IHX slabs as they were placed in the mockup. These results are located in Tables 14 and 15. Background measurements were limited to the thicker mockups, D, E, and F, at 150 cm only and these values are also in Table 15. A sheet of Cd was placed behind the bare detector at 30 cm in Items D, E, and F, and these results are contained in Table 21. Results from similar measurements at 150 cm for each mockup are given in Table 22. Background data were obtained with the same detector when a Cd sheet was placed over the back face (face closest to the detector) of the shadow shield and these data are also in Table 22.

A new measurement was added to the data plan for the mockups in Items A and B. Data was obtained with the bare detector at 30 and 150 cm when Cd was placed above the detector but below the concrete slabs covering the mockup area to eliminate the thermal neutron contribution leaving the concrete slab and reaching the detector. The results of these measurements are shown in Tables 21 and 22. A bare detector measurement was repeated at 150 cm with Cd both behind it and also above it as in the previous measurement and this result is in Table 22.

Na_2CO_3 foils were not exposed in void number 2 in this mockup because in the previous run, Item VI, it was necessary for personnel to be exposed to a high radiation field for an extended time to retrieve the foils from that void. The results of the measurements in the other five voids are given in Table 23.

4.8 IHX MOCKUP BORON CARBIDE FRONT SHIELD - BORON CARBIDE SIDE SHIELD) (ITEMS VIIIA-F)

A schematic of the slab arrangements in this mockup is given in Figure 21. The B_4C slab and four sodium slabs are enclosed on each side by a thin slab of B_4C followed by a slab of sodium, lithiated paraffin, and concrete. Measurements were made with the bare, Cd-covered, 3-, 5-, 8-, and 10-inch Bonner balls on centerline at 30 and 150 cm behind each slab as they were added to the mockup. These results are given in Tables 14 and 15 respectively. Again there were no background measurements in the first three mockups, Items A through C. For Items C, D, and F, measurements were obtained at 150 cm with Cd behind the bare detector. Similar measurements were made with the bare detector at 30 cm and Cd behind it in Items D, E, and F. A background measurement with the bare detector was included in Item F with Cd over the back face of the shadow shield. These extra data are in Tables 21 and 22.

Capsules of Na_2CO_3 were exposed in all voids except number 2 as in previous item and these activity values can be found in Table 23.

4.9 IHX MOCKUP (BORON CARBIDE FRONT SHIELD WITH ALUMINUM WINDOW - BORON CARBIDE SIDE SHIELD) (ITEMS IXA-E)

In this series of mockups the front B_4C slab in the previous mockup was replaced with one containing a 14.96-cm-diameter aluminum cylinder (see Figure 9) that represented the sodium entry pipe into the IHX vessel. Locations of this slab and sodium cylinder are shown in the schematic in Figure 22.

Results from the limited number of measurements in the previous Items V through VIII indicated that it might be helpful in doing the analysis if further studies were made in an attempt to define the neutron source areas within the mockup from which neutrons emerge and strike the detector. The mockup for Item IXA was selected as indicated in the program plan. Measurements were made at 30 and 150 cm with the bare detector when Cd was placed at different locations within the mockup and these results can be found in Tables 21 and 22.

The first measurement was obtained at 150 cm with a piece of Cd behind the bare detector to discriminate against background neutrons. That piece of Cd was removed and the face of the lithiated paraffin above the front B_4C slab (6W) was covered with Cd. To that configuration was then added a sheet of Cd above the detectors but beneath the concrete slab. The Cd above the detectors was removed in the next measurement and the face of the lithiated paraffin bricks above the side B_4C slabs (7W and 8W) was covered with Cd along with the bricks above the front B_4C slab. A piece of Cd was added over the aluminum insert in the front B_4C slab in addition to the previous Cd locations. In the next run the Cd was kept the same and a Cd sheet was placed again above the detectors. Then without changing any of the Cd, 10.2 cm of lithiated paraffin was placed behind the front B_4C slab and this time measurements were made using both the bare and Cd-covered detectors.

As in the previous mockups a series of bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements were made on centerline at 30 and 150 cm behind each of the slabs as they were added to the mockup. These results are contained in Tables 14 and 15. As noted in the program plan, measurements were made with the bare detector when Cd was placed at several locations for the other mockups also. In Items B and C, data were obtained with the Cd piece behind the detector and with a Cd sheet above the detector. Measurements were made in Items D and E when a Cd piece was placed behind the detector at both 30 and 150 cm and at 150 cm when the face of the shadow shield was covered with Cd. Results from these measurements are in Tables 21 and 22 also.

Na_2CO_3 capsules were exposed in just the five voids (number 2 omitted) and the resulting activations are listed in Table 23.

4.10 IHX MOCKUP WITH SOLID BORON CARBIDE/ALUMINUM FRONT SHIELD AND FULL BORON CARBIDE SIDE SHIELDS (Items XA-E)

A schematic for the last mockup is shown in Figure 23. The front slab in the mockup was a combination of one half B_4C and one half aluminum joined at the beam centerline. These are the same slabs used in Item VII that combined to form the two partial side shields. In this mockup the side shields were the two B_4C slabs (7W and 8W), each followed by a slab of sodium. The bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball data obtained on centerline at 30 and 150 cm behind each slab as they were added to the mockup are given in Tables 14 and 15. As in the previous items, the measurements made with the bare detector when Cd was placed behind the detector, above it, or over the face of the shadow shield are found in Tables 21 and 22.

Throughout the experiment little attention was paid to the contribution from neutrons being reflected from the floor of the mockup. The floor, described earlier, consisted of 20.3 cm of lithiated paraffin followed by concrete. One run in Item B was made with a bare detector at 30 and 150 cm when Cd was placed above and on the floor below the detector and these data are also in Tables 21 and 22. The effect of the Cd on the floor can be estimated when comparing this data with that in Item B where Cd was above the detector only.

It was possible to expose Na_2CO_3 capsules in all six voids in this mockup and the resultant activations for each of the capsules are listed in Table 23.

Another special measurement was included to aid in the analysis of the experiment. Radial traverses were made at 30 cm behind the mockup as measured on centerline. The mockup was the same one shown in Figure 23, but the schematic in Figure 24 relates the distances behind various slabs as the detector travels radially. Data were obtained to the left of centerline for the bare and Cd-covered Bonner balls, while full traverses were obtained with the 3-, 5-, and 10-in balls. All the data are reported in Table 24.

5. ANALYSIS OF EXPERIMENTAL ERRORS

The errors associated with the measurements are due to a number of uncertainties: (1) the sizes of the gaps between slabs, unavoidably introduced in the configurations, (2) the positions of the detectors, (3) the detector count rate statistics and calibrations, (4) the reactor power determinations, and (5) the effects of the exposure of the configurations to the weather. Of these, the uncertainty due to the weather is the least understood and probably beyond simple estimation. The uncertainty lies in the amount of moisture between the slabs and in the lithiated paraffin surrounding them. During this experiment the mockups were covered with a plastic tarpaulin that would limit the amount of moisture reaching the slabs. Thus, for this experiment, the effect of the weather was assumed to be negligible.

The TSR-II power level for each measurement was determined from the output of two fission chambers located in the reactor shield along the midplane of the reactor. The response of these chambers to the reactor source was monitored prior to the experiment through the use of gold foils and this ratio, detector response to gold foil results, agreed within about 5% with a history of earlier such comparisons. These detectors were calibrated on a daily basis using a ^{252}Cf source, with the calibration values lying within about a 6% spread (±3% of an average value). During any one detector traverse in a given day, the variation in the reactor power indicated by the monitor outputs was at most only 3%; however, during the several months the experiment was being performed, the monitors indicated a spread in any one power level of about ±5%. Thus, the uncertainty in the reactor power determination was assumed to be ±5%.

Count-rate statistics are expressed in a manner specific to each detector. For the NE-213 measurements, counting statistics and unfolding errors are included in the unfolding of the pulse-height spectra using the FERD code, with the resulting flux expressed in terms of lower and upper limits that represent a 68% confidence interval. Similar errors are expressed in the tabular data for the hydrogen measurements unfolded using SPEC4. Neither of the spectra, NE-213 or hydrogen counter, reflects the error in determining the reactor power since this error is not included in the unfolding program. This, as seen above, could be as much as ±5%.

The Bonner balls were calibrated on a daily basis using ^{252}Cf as a source, with the resulting count rates falling within about ±3% of an average value obtained throughout the years. Movement of the Bonner balls along a traversing mechanism can vary the detector location with respect to the configuration several millimeters on either side of a straight line. For the measurements perpendicular to the configuration centerline at 30 cm behind the configuration, such variations in the detector position could amount to a change in the count rate of about 2%. For the measurements on centerline beyond the 30 cm point, the error in positioning several millimeters either side of the selected location would lie within the statistics of the measurement. Rather than calculate probable errors for each measurement in a series of measurements during a traverse, we prefer, in general, to quote a value for the error in the measurements for a given experiment. Thus, assuming the estimated upper limit for all the errors, the errors assigned to the Bonner ball measurements should be less than ±10%.

An overall absolute counting uncertainty of ±5% was assigned to the sodium activity which included the geometry corrections in counting the capsules that had a large length-to-diameter ratio (L/D) and were placed in close proximity of the detector. This error does not include positioning of the capsules during exposure, nor does it account for the error in reactor power determination. Estimation of error in placement of the samples within the voids is hardly feasible since only one run was made for each mockup and each mockup was different. Error in the reactor power was assumed to be the same as quoted earlier, ±5%. Assigning an error of ±10% in foil activity due to placements of the foils, the overall estimated error would lie between ±10-15%.

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APPENDIX A

EXPERIMENTAL PROGRAM PLAN FOR THE JASPER INTERMEDIATE HEAT EXCHANGER (IHX) EXPERIMENT

I. Spectrum Modifier
- A. SM-2 (10 cm Fe + 9 cm Al + 2.54 cm boral + 180 cm Na)
  1. bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
     - a. at 30 cm behind shield mockup
     - b. at 150 cm behind shield mockup (foreground and background)
  2. Expose Na_2CO_3 capsules on centerline and at points where vertical and horizontal lines through center and 45.7 cm from center intersect behind the last Na slab.
- AA. SM-2 [10 cm Fe + 9 cm Al + 2.54 cm boral + 180 cm Na (include voids)]
  1. Between selected Na slabs, expose Na_2CO_3 capsules on centerline and at points where vertical and horizontal lines through center and 45.7 cm from center intersect.
  2. Bare Bonner ball measurements on centerline:
     - a. at 30 cm inside Cd hut
     - b. at 30 cm, with Cd over face of shield mockup
     - c. at 150 cm, with Cd over face of shield mockup
- B. SM-3 (76.2 cm Na + 152.4 cm Na)
  1. NE 213 and hydrogen counters measurements on centerline as close as feasible behind the shield mockup
  2. 3-, 5-, and 10-in Bonner ball measurements at location of NE 213 on centerline:
  3. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
     - a. at 30 cm behind shield mockup
     - b. at 150 cm behind shield mockup (foreground and background)
  4. 5-in Bonner ball traverse at 30 cm behind shield mockup
  5. Expose Na_2CO_3, bare and Cd-covered, on centerline between the two sodium tanks

II. ALMR (below spent fuels)
- A. SM-2 + 3.81 cm SS + 3.29 cm Al + 5.62 cm B_4C + 1.27 cm Al
  1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
     - a. at 30 cm behind shield mockup
     - b. at 150 cm behind shield mockup (foreground and background)

B. SM-2 + 3.81 cm SS + 3.29 cm Al + 5.62 cm B_4C + 1.27 cm Al + 5.08 cm SS + 3.81 cm Al + 15.61 cm B_4C + 2.54 cm Al
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground and background)

C. SM-2 + 3.81 cm SS + 3.29 cm Al + 5.62 cm B_4C + 1.27 cm Al + 5.08 cm SS + 3.81 cm Al + 15.61 cm B_4C + 2.54 cm Al + 30.48 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground and background)

D. SM-2 + 3.81 cm SS + 3.29 cm Al + 5.62 cm B_4C + 1.27 cm Al + 5.08 cm SS + 3.81 cm Al + 15.61 cm B_4C + 2.54 cm Al + 30.48 cm Na + 30.48 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground and background)
   2. Bare Bonner ball measurements on centerline:
      a. at 30 cm inside Cd hut
      b. at 30 cm, with Cd over face of shield mockup
      c. at 150 cm, with Cd over face of shield mockup

E. SM-2 + 3.81 cm SS + 3.29 cm Al + 5.62 cm B_4C + 1.27 cm Al + 5.08 cm SS + 3.81 cm Al + 15.61 cm B_4C + 2.54 cm Al + 30.48 cm Na + 30.48 cm Na + 30.48 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground and background)
   2. Bare Bonner ball measurements on centerline:
      a. at 30 cm inside Cd hut
      b. at 30 cm, with Cd over face of shield mockup
      c. at 150 cm, with Cd over face of shield mockup

F. SM-2 + 3.81 cm SS + 3.29 cm Al + 5.62 cm B_4C + 1.27 cm Al + 5.08 cm SS + 3.81 cm Al + 15.61 cm B_4C + 2.54 cm Al + 30.48 cm Na + 30.48 cm Na + 30.48 cm Na + 30.48 cm Na

1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground and background)
2. Bare Bonner ball measurements on centerline:
   a. at 30 cm inside Cd hut
   b. at 30 cm, with Cd over face of shield mockup
   c. at 150 cm, with Cd over face of shield mockup

III. ALMR (fuel region of spent fuel)

A. SM-2 + 16.04 cm IVFS (homogeneous) vessel (thin slab of fuel pins)

1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground and background)
2. Bare Bonner ball measurements on centerline:
   a. at 30 cm inside Cd hut

B. SM-2 + 16.04 cm IVFS (homogeneous) vessel (thin slab of fuel pins) + 5.15 cm B_4C + 5.08 cm SS

1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground and background)

C. SM-2 + 16.04 cm IVFS (homogeneous) vessel (thin slab of fuel pins) + 5.15 cm B_4C + 5.08 cm SS + 15.61 cm B_4C

1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground and background)
2. Bare Bonner ball measurements on centerline:
   a. at 30 cm inside Cd hut

D. SM-2 + 16.04 cm IVFS (homogeneous) vessel (thin slab of fuel pins) + 5.15 cm B_4C + 5.08 cm SS + 15.61 cm B_4C + 30.48 cm Na + 2.54 cm SS

1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground and background)
2. Bare Bonner ball measurements on centerline:
   a. at 30 cm inside Cd hut

E. SM-2 + 16.04 cm IVFS (homogeneous) vessel (thin slab of fuel pins) + 5.15 cm B_4C + 5.08 cm SS + 15.61 cm B_4C + 30.48 cm Na + 2.54 cm SS + 30.48 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground and background)
   2. Bare Bonner ball measurements on centerline:
      a. at 30 cm inside Cd hut

IV. ALMR (fission gas plenum region of spent fuel)
   A. SM-2 + empty 16.04 cm IVFS (homogeneous) vessel (no fuel) + 2.54 cm Al + 5.15 cm B_4C
      1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
         a. at 30 cm behind shield mockup
         b. at 150 cm behind shield mockup (foreground and background)
      2. Bare Bonner ball measurements on centerline:
         a. at 30 cm inside Cd hut
         b. at 30 cm, with Cd over face of shield mockup
         c. at 150 cm, with Cd over face of shield mockup
   B. SM-2 + empty 16.04 cm IVFS (homogeneous) vessel (no fuel) + 2.54 cm Al + 5.15 cm B_4C + 5.08 cm SS + 30.48 cm Na + 2.54 cm SS
      1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
         a. at 30 cm behind shield mockup
         b. at 150 cm behind shield mockup (foreground and background)
      2. Bare Bonner ball measurements on centerline:
         a. at 30 cm inside Cd hut
         b. at 30 cm, with Cd over face of shield mockup
         c. at 150 cm, with Cd over face of shield mockup
   C. SM-2 + empty 16.04 cm IVFS (homogeneous) vessel (no fuel) + 2.54 cm Al + 5.15 cm B_4C + 5.08 cm SS + 30.48 cm Na + 2.54 cm SS + 30.48 cm Na
      1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
         a. at 30 cm behind shield mockup
         b. at 150 cm behind shield mockup (foreground and background)
      2. Bare Bonner ball measurements on centerline:
         a. at 30 cm inside Cd hut
         b. at 30 cm, with Cd over face of shield mockup
         c. at 150 cm, with Cd over face of shield mockup

D. SM-2 + empty 16.04 cm IVFS (homogeneous) vessel (no fuel) + 2.54 cm Al + 5.15 cm B_4C + 5.08 cm SS + 30.48 cm Na + 2.54 cm SS + 30.48 cm Na + 30.48 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground and background)
   2. Bare Bonner ball measurements on centerline:
      a. at 30 cm inside Cd hut
      b. at 30 cm, with Cd over face of shield mockup
      c. at 150 cm, with Cd over face of shield mockup
E. SM-2 + empty 16.04 cm IVFS (homogeneous) vessel (no fuel) + 2.54 cm Al + 5.15 cm B_4C + 5.08 cm SS + 30.48 cm Na + 2.54 cm SS + 30.48 cm Na + 30.48 cm Na + 2.54 cm SS + 30.48 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground and background)
   2. Bare Bonner ball measurements on centerline:
      a. at 30 cm inside Cd hut
      b. at 30 cm, with Cd over face of shield mockup
      c. at 150 cm, with Cd over face of shield mockup

V. IHX Mockup (Na Shield - Na Side Shield)
A. SM-3 only
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground only)
B. SM-3 + 30.48 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground only)
C. SM-3 + 61 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground and background)

D. SM-3 + 91 cm Na
  1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
    a. at 30 cm behind shield mockup
    b. at 150 cm behind shield mockup (foreground and background)
  2. Bare Bonner ball measurements on centerline:
    a. at 30 cm, with Cd sheet behind detector

E. SM-3 + 122 cm Na
  1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
    a. at 30 cm behind shield mockup
    b. at 150 cm behind shield mockup (foreground and background)
  2. Bare Bonner ball measurements on centerline:
    a. at 30 cm, with Cd sheet behind detector
  3. Expose Na_2CO_3 capsules between mockup slabs on the horizontal centerline and on a parallel line 45.7 cm above the horizontal centerline

VI. IHX Mockup (B_4C Front Shield - Na Side Shields)

A. SM-3 + 13.05 cm B_4C
  1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
    a. at 30 cm behind shield mockup
    b. at 150 cm behind shield mockup (foreground only)

B. SM-3 + 13.05 cm B_4C + 30.48 cm Na
  1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
    a. at 30 cm behind shield mockup
    b. at 150 cm behind shield mockup (foreground only)

C. SM-3 + 13.05 cm B_4C + 61 cm Na
  1. bare, cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
    a. at 30 cm behind shield mockup
    b. at 150 cm behind shield mockup (foreground and background)
  2. Bare Bonner ball measurements on centerline:
    a. at 30 cm, with Cd sheet behind detector

D. SM-3 + 13.05 cm B_4C + 91 cm Na
  1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
    a. at 30 cm behind shield mockup
    b. at 150 cm behind shield mockup (foreground and background)

E. SM-3 + 13.05 cm B_4C + 122 cm Na
1. bare, cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground and background)
2. Bare Bonner ball measurements on centerline:
   a. at 30 cm, with Cd sheet behind detector
3. Expose Na_2CO_3 capsules between mockup slabs on the horizontal centerline and on a parallel line 45.7 cm above the horizontal centerline

VII. IHX Mockup (partial side shields)

A. SM-3 only
1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground only)
2. Bare Bonner ball measurements on centerline:
   a. at 150 cm, with Cd sheet behind detector

B. SM-3 + 13.05 cm B_4C
1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground only)
2. Bare Bonner ball measurements on centerline:
   a. at 150 cm, with Cd sheet behind detector

C. SM-3 + 13.05 cm B_4C + 30.48 cm Na
1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground only)
2. Bare Bonner ball measurements on centerline:
   a. at 150 cm, with Cd sheet behind detector

D. SM-3 + 13.05 cm B_4C + 61 cm Na
1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground and background)
2. Bare Bonner ball measurements on centerline:
   a. at 30 cm, with Cd sheet behind detector
   b. at 150 cm, with Cd sheet behind detector
   c. at 150 cm, Cd sheet over face of background shadow shield

E. SM-3 + 13.05 cm B_4C + 91 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground and background)
   2. Bare Bonner ball measurements on centerline:
      a. at 30 cm, with Cd sheet behind detector
      b. at 150 cm, with Cd sheet behind detector
      c. at 150 cm, Cd sheet over face of background shadow shield

F. SM-3 + 13.05 cm B_4C + 122 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground and background)
   2. Bare Bonner ball measurements on centerline:
      a. at 30 cm, with Cd sheet behind detector
      b. at 150 cm, with Cd sheet behind detector
      c. at 150 cm, Cd sheet over face of background shadow shield
   3. Expose Na_2CO_3 capsules between mockup slabs on the horizontal centerline and on a parallel line 45.7 cm above the horizontal centerline

VIII. IHX Mockup (full side shields)

A. SM-3 only
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground only)

B. SM-3 + 13.05 cm B_4C
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground only)

C. SM-3 + 13.05 cm B_4C + 30.48 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground only)
   2. Bare Bonner ball measurements on centerline:
      a. at 150 cm, with Cd sheet behind detector

D. SM-3 + 13.05 cm B_4C + 61 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground and background)
   2. Bare Bonner ball measurements on centerline:
      a. at 30 cm, with Cd sheet behind detector
      b. at 150 cm, with Cd sheet behind detector

E. SM-3 + 13.05 cm B_4C + 91 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground and background)
   2. Bare Bonner ball measurements on centerline:
      a. at 30 cm, with Cd sheet behind detector
      b. at 150 cm, Cd sheet over face of background shadow shield

F. SM-3 + 13.05 cm B_4C + 122 cm Na
   1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
      a. at 30 cm behind shield mockup
      b. at 150 cm behind shield mockup (foreground and background)
   2. Bare Bonner ball measurements on centerline:
      a. at 30 cm, with Cd sheet behind detector
      b. at 150 cm, with Cd sheet behind detector
      c. at 150 cm, Cd sheet over face of background shadow shield
   3. Expose Na_2CO_3 capsules between mockup slabs on the horizontal centerline and on a parallel line 45.7 cm above the horizontal centerline

IX. IHX Mockup (window in front shield - full side shields)

A. SM-3 + 13.05 cm B_4C (with Al window)

1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground only)
2. Bonner ball measurements on centerline (foreground only):
   a. bare, at 150 cm, Cd piece behind detector
   b. bare, at 30 and 150 cm, Cd over Li-Par face above front B_4C slab
   c. bare, at 30 and 150 cm, Cd over Li-Par face above front B_4C slab + Cd directly beneath concrete over detectors
   d. bare, at 30 and 150 cm, Cd over Li-Par face above both front and side B_4C slabs
   e. bare, at 30 and 150 cm, Cd over Li-Par face above both front and side B_4C slabs and over cylindrical Al insert
   f. bare, at 30 and 150 cm, Cd over Li-Par face above both front and side B_4C slabs, also over cylindrical Al insert + Cd directly beneath concrete slabs overhead
   g. bare and Cd-covered, at 30 and 150 cm, Cd over Li-Par face above both front and side B_4C slabs, also over cylindrical Al insert + Cd directly beneath concrete slabs overhead + 10.16 cm Li-Par covering front B_4C face

B. SM-3 + 13.05 cm B_4C (with Al window) + 30.48 cm Na

1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground only)
2. Bare Bonner ball measurements on centerline:
   a. at 30 and 150 cm, Cd sheet beneath concrete roof above detectors
   b. at 30 and 150 cm, Cd piece behind detectors

C. SM-3 + 13.05 cm B_4C (with Al window) + 61 cm Na

1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground and background)
2. Bare Bonner ball measurements on centerline:
   a. at 30 and 150 cm, Cd sheet beneath concrete roof above detectors
   b. at 30 and 150 cm, Cd piece behind detectors
   c. at 150 cm (background), Cd over face of shadow shield

D. SM-3 + 13.05 cm B_4C (with Al window) + 91 cm Na

1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
    a. at 30 cm behind shield mockup
    b. at 150 cm behind shield mockup (foreground and background)
2. Bare Bonner ball measurements on centerline:
    a. at 30 and 150 cm, Cd piece behind detectors
    b. at 150 cm (background), Cd over the face of the shadow shield

E. SM-3 + 13.05 cm B_4C (with Al window) + 122 cm Na

1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
    a. at 30 cm behind shield mockup
    b. at 150 cm behind shield mockup (foreground and background)
2. Bare Bonner ball measurements on centerline:
    a. at 30 and 150 cm, Cd piece behind detectors
    b. at 150 cm (background), Cd over face of shadow shield
3. Expose Na_2CO_3 capsules between mockup slabs on the horizontal centerline and on a parallel line 45.7 cm above the horizontal centerline

X. IHX Mockup (partial front shield - full side shields)

A. SM-3 + 13.5 cm B_4C/Al

1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
    a. at 30 cm behind shield mockup
    b. at 150 cm behind shield mockup (foreground only)
2. Bare Bonner ball measurements on centerline:
    a. at 150 cm, Cd piece behind detector
    b. at 30 and 150 cm, Cd sheet beneath concrete roof above detector

B. SM-3 + 13.5 cm B_4C/Al + 30.48 cm Na

1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
    a. at 30 cm behind shield mockup
    b. at 150 cm behind shield mockup (foreground only)
2. Bare Bonner ball measurements on centerline:
    a. at 150 cm, Cd piece behind detector
    b. at 30 and 150 cm, Cd sheet beneath concrete roof above detector
    c. at 30 and 150 cm, Cd sheet beneath concrete roof above detector and on the floor beneath detector

C. SM-3 + 13.5 cm B_4C/Al + 61 cm Na
1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground and background)
2. Bare Bonner ball measurements on centerline:
   a. at 150 cm, Cd piece behind detector
   b. at 150 cm (background), Cd over the face of the shadow shield
   c. at 30 and 150 cm, Cd sheet beneath concrete roof above detector

D. SM-3 + 13.5 cm B_4C/Al + 91 cm Na
1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground and background)
2. Bare Bonner ball measurements on centerline:
   a. at 30 cm, Cd piece behind detector
   b. at 150 cm (background), Cd over the face of the shadow shield

E. SM-3 + 13.5 cm B_4C/Al + 122 cm Na
1. Bare, Cd-covered, 3-, 5-, 8-, and 10-in Bonner ball measurements on centerline:
   a. at 30 cm behind shield mockup
   b. at 150 cm behind shield mockup (foreground and background)
2. Bare Bonner ball measurements on centerline:
   a. at 30 cm, Cd piece behind detector
   b. at 150 cm (background), Cd over the face of the shadow shield
3. Horizontal traverses with the bare, Cd-covered, 3-, 5-, and 10-in Bonner balls at 30 cm behind shield mockup
4. Expose Na_2CO_3 capsules between mockup slabs on the horizontal centerline and on a parallel line 45.7 cm above the horizontal centerline

APPENDIX B

TABLES OF DATA

Table 1. Analysis of iron slabs (ρ = 7.86 g/cc) used in spectrum modifier

Element	wt %
Fe	98.4
C	.25
Cr	.15
Cu	.03
Mn	1.0
Mo	.02
Ni	.05
Si	.25

Table 2. Analysis of 6061 aluminum (ρ = 2.70 g/cc)

Element	wt %	ppm
Al	97.5	
Cr	.22	
Cu	.23	
Fe	.47	
Mg	.86	
Mn	.01	
Si	.63	
Ti	.042	
Zn	.07	
Li		3
Ni		50
Sn		<10
V		150

Table 3. Composition of boral slabs used in spectrum modifier

	(B_4C - 40-43 vol % in B_4C-Al mixture)		
Component	Density (g/cc)	Elemental Composition (wt %)	With Al Cladding (wt %)
B_4C	2.3		
Al	2.70	65	~75
B		27.5	~19.6
C		7.5	~5.4

Table 4. Composition of rectangular sodium slabs (ρ = 0.945 g/cc)

Element	wt %
Na	99.7
Ca, Zn	0.3

Table 5. Composition of the small concrete blocks on each side of the spectrum modifier (ρ = 2.39 g/cc)

Element	wt %
C	10.36
O	49.03
Ca	38.05
Fe	0.37
Si	0.78
Mg	0.23
S	0.17
P	0.04
Na	0.03
K	0.04
H	0.42
R*	0.47
	99.99

*R is an unspecified mix of Al, Ti, Cr, and possibly other trace metals.

Table 6. Analysis of 61-cm x 61-cm x 30.5-cm (ρ = 2.40 g/cc) concrete blocks used to surround configuration

Component	wt%	Component	wt%
CO_3	41.9	Al_2O_3	2.2
Ca	27.4	Fe_2O_3	.60
SiO_2	18.1	SO_3	.32
H_2O	4.0	P_2O_5	.035
Mg	3.66	K	.30
O_2	1.4		

Table 7. Analysis of concrete slabs on top of the mockup (ρ = 2.68 g/cc)

Element	Wt%
MgO	14.11
SiO_2	9.17
CaO	34.18
Al_2O_3	2.02
Fe_2O_3	1.0
SO_3	.52
Na_2O	.24
K_2O	.58
P_2O_5	.06
LOI*	38.54

*LOI (Lost on ignition) includes the free and bound H_2O, SO_3, and CO_2.

Table 8. Composition of lithiated paraffin bricks (ρ = 1.15 g/cc)

Component	wt %
C_nH_{2n+2}	60
Li_2CO_3	40

Table 9. Maximum impurities in the cylindrical sodium slab (ρ = 0.945 g/cc)

Element	ppm
Hydrogen	60
Oxygen	200
Potassium	150
Calcium	400

Table 10. Analysis of concrete around the cylindrical sodium tanks

Element	Wt%
LOI*	33.2
CaO	39.9
MgO	4.1
SO_3	.48
SiO_2	16.4
P_2O_5	.09
K_2O	7.84
Na_2O	.06

*LOI (Lost on ignition) includes the free and bound H_2O, SO_3, and CO_2.

Table 11. Analysis of boron carbide used in shield mockups

Element	wt%	ppm
B	76.7	
C	19.52	
Al		50
Ca		800
Cl		10
Co		<1
Cr		2
Cu		<1
Fe		600
Mg		25
Mn		10
Na		1
P		2
S		5
Si		50
Ti		225

Table 12. Analysis of type 304 stainless steel in boron carbide containers (6W, 7W, 8W) (ρ = 7.92 g/cc)

Element	Wt%
As	.008
Co	.20
Cr	18.3
Cu	.40
Fe	70.0
Ga	.01
Mn	1.40
Mo	.20
Nb	.03
Ni	8.7
Si	.35
Ti	.033
V	.23

Table 13. Analysis of lead slabs (ρ = 11.35 g/cc)

Element	wt%	PPM
Pb	99.9	
Al		<3
Ag		30
B		<1
Ca		1
Cr		10
Cu		800
Fe		1
Li		20
Mg		<3
Mn		5
Na		1
Ni		30
P		5
Si		<3
Sn		30

Table 14. Bonner ball measurements on centerline at 30 cm behind a series of configurations

	Bonner ball count rate ($s^{-1}W^{-1}$)					
Configuration[a]	Bare Detector	Cd-Covered Detector	3-inch-Diam Ball	5-inch-Diam Ball	8-inch-Diam Ball	10-inch-Diam Ball
IA	7.33 (0)[b]	3.10 (0)	3.57 (1)	5.75 (1)	2.16 (1)	8.53 (0)
IB	4.87 (1)	2.40 (1)	2.34 (2)	3.39 (2)	1.23 (2)	4.91 (1)
IIA	1.30 (-2)	3.84 (-3)	1.97 (-1)	8.73 (-1)	5.39 (-1)	2.57 (-1)
IIB	1.13 (-3)	1.11 (-4)	3.04 (-3)	1.49 (-2)	1.12 (-2)	6.05 (-3)
IIC	1.01 (-3)	9.88 (-5)	1.83 (-3)	6.18 (-3)	3.94 (-3)	1.97 (-3)
IID	8.07 (-4)	7.41 (-5)	1.08 (-3)	2.78 (-3)	1.40 (-3)	6.61 (-4)
IIE	2.97 (-4)	3.50 (-5)	4.84 (-4)	1.04 (-3)	4.82 (-4)	2.16 (-4)
IIF	1.86 (-4)	1.81 (-5)	2.21 (-4)	4.15 (-4)	1.79 (-4)	7.31 (-5)
IIIA	1.13 (0)	4.49 (-1)	6.09 (0)	2.04 (1)	1.65 (1)	1.00 (1)
IIIB	5.77 (-2)	1.03 (-2)	6.36 (-1)	4.55 (0)	4.41 (0)	2.70 (0)
IIIC	3.62 (-3)	6.65 (-4)	5.61 (-2)	4.40 (-1)	4.25 (-1)	2.53 (-1)
IIID	2.07 (-3)	4.78 (-4)	2.17 (-2)	1.14 (-1)	8.74 (-2)	4.79 (-2)
IIIE	2.24 (-3)	5.02 (-4)	1.36 (-2)	4.73 (-2)	2.81 (-2)	1.38 (-2)
IVA	3.73 (-2)	7.09 (-3)	2.89 (-1)	1.10 (0)	6.56 (-1)	3.11 (-1)
IVB	2.23 (-2)	3.89 (-3)	7.27 (-2)	1.83 (-1)	9.10 (-2)	4.03 (-2)
IVC	1.41 (-2)	2.43 (-3)	3.65 (-2)	7.40 (-2)	3.12 (-2)	1.29 (-2)
IVD	6.15 (-3)	1.21 (-3)	1.51 (-2)	2.66 (-2)	1.06 (-2)	4.23 (-3)
IVE	1.53 (-3)	3.57 (-4)	3.91 (-3)	6.18 (-3)	2.29 (-3)	9.15 (-4)
VA	7.96 (1)	3.07 (1)	2.91 (2)	4.07 (2)	1.43 (2)	5.49 (1)
VB	2.72 (1)	1.02 (1)	9.02 (1)	1.19 (2)	4.04 (1)	1.56 (1)
VC	1.03 (1)	3.96 (0)	3.20 (1)	4.22 (1)	1.36 (1)	5.25 (0)
VD	3.88 (0)	1.44 (0)	1.14 (1)	1.40 (1)	4.48 (0)	1.72 (0)
VE	1.41 (0)	5.13 (-1)	3.79 (0)	4.47 (0)	1.45 (0)	5.52 (-1)
VIA	4.97 (0)	1.31 (0)	1.19 (1)	1.84 (1)	7.48 (0)	3.26 (0)
VIB	1.93 (0)	5.74 (-1)	4.86 (0)	6.93 (0)	2.75 (0)	1.14 (0)
VIC	8.12 (-1)	2.62 (-1)	2.18 (0)	2.96 (0)	1.05 (0)	4.24 (-1)

Table 14. (continued)

Configuration	Bonner ball count rate ($s^{-1}W^{-1}$)					
	Bare Detector	Cd-Covered Detector	3-inch-Diam Ball	5-inch-Diam Ball	8-inch-Diam Ball	10-inch-Diam Ball
VID	3.04 (-1)	9.85 (-2)	7.99 (-1)	1.04 (0)	3.61 (-1)	1.41 (-1)
VIE	1.29 (-1)	3.71 (-2)	2.89 (-1)	3.54 (-1)	1.18 (-1)	4.71 (-2)
VIIA	6.42 (1)	2.62 (1)	2.50 (2)	3.60 (2)	1.28 (2)	5.16 (1)
VIIB	9.20 (-1)	8.87 (-2)	1.33 (0)	4.38 (0)	2.89 (0)	1.51 (0)
VIIC	2.19 (-1)	5.64 (-2)	7.18 (-1)	1.81 (0)	9.70 (-1)	4.66 (-1)
VIID	1.56 (-1)	4.30 (-2)	4.61 (-1)	8.79 (-1)	3.96 (-1)	1.74 (-1)
VIIE	7.19 (-2)	1.88 (-2)	1.97 (-1)	3.50 (-1)	1.43 (-1)	5.96 (-2)
VIIF	4.04 (-2)	8.17 (-3)	8.30 (-2)	1.35 (-1)	5.20 (-2)	2.13 (-2)
VIIIA	6.31 (1)	2.60 (1)	2.49 (2)	3.66 (2)	1.28 (2)	5.17 (1)
VIIIB	5.76 (-1)	5.42 (-2)	1.07 (0)	4.02 (0)	2.75 (0)	1.47 (0)
VIIIC	9.89 (-2)	2.50 (-2)	4.60 (-1)	1.37 (0)	8.61 (-1)	4.27 (-1)
VIIID	5.10 (-2)	1.33 (-2)	2.25 (-1)	5.65 (-1)	2.92 (-1)	1.33 (-1)
VIIIE	3.70 (-2)	7.33 (-3)	1.06 (-1)	2.25 (-1)	1.03 (-1)	4.46 (-2)
VIIIF	3.14 (-2)	4.39 (-3)	5.33 (-2)	9.72 (-2)	4.00 (-2)	1.68 (-2)
IXA	1.63 (0)	5.69 (-1)	6.00 (0)	1.11 (1)	5.18 (0)	2.41 (0)
IXB	1.97 (-1)	8.00 (_2)	1.02 (0)	2.23 (0)	1.10 (0)	5.24 (-1)
IXC	7.92 (-2)	2.91 (-2)	3.62 (-1)	7.44 (-1)	3.46 (-1)	1.56 (-1)
IXD	4.29 (-2)	1.30 (-2)	1.53 (-1)	2.83 (-1)	1.20 (-1)	5.20 (-2)
IXE	3.17 (-2)	6.05 (-3)	6.57 (-2)	1.12 (-1)	4.44 (-2)	1.87 (-2)
XA	1.77 (1)	7.55 (0)	7.06 (1)	1.08 (2)	3.74 (1)	1.49 (1)
XB	6.18 (0)	2.68 (0)	2.40 (1)	3.26 (1)	1.13 (1)	4.41 (0)
XC	2.40 (0)	1.01 (0)	8.44 (0)	1.08 (1)	3.69 (0)	1.43 (0)
XD	8.70 (-1)	3.55 (-1)	2.84 (0)	3.53 (0)	1.16 (0)	4.39 (-1)
XE	3.28 (-1)	1.25 (-1)	9.48 (-1)	1.16 (0)	3.67 (-1)	1.40 (-1)

[a]See experimental program plan in Appendix A for description of configurations.
[b]Read: 7.33×10^0.

Table 15. Bonner ball measurements on centerline at 150 cm behind a series of configurations

	Bonner ball count rate ($s^{-1}W^{-1}$)					
	Bare Detector		Cd-Covered Detector		3-inch-Diam Ball	
Configuration[a]	Foreground[b]	Background[c]	Foreground	Background	Foreground	Background
IA	2.18 (0)[d]	5.44 (-1)	7.15 (-1)	7.43 (-2)	7.76 (0)	5.98 (-1)
IB	1.93 (1)	3.63 (0)	8.21 (0)	7.34 (-1)	7.91 (1)	6.26 (0)
IIA	8.59 (-3)	4.34 (-3)	1.79 (-3)	4.30 (-4)	5.25 (-2)	6.10 (-3)
IIB	1.35 (-3)	1.10 (-3)	9.99 (-5)	5.84 (-5)	1.45 (-3)	6.07 (-4)
IIC	1.16 (-3)	1.07 (-3)	7.53 (-5)	5.30 (-5)	9.03 (-4)	5.51 (-4)
IID	1.14 (-3)	1.05 (-3)	6.38 (-5)	5.08 (-5)	6.81 (-4)	4.92 (-4)
IIE	2.74 (-4)	2.03 (-4)	1.80 (-5)	8.59 (-6)	1.89 (-4)	7.73 (-5)
IIF	1.82 (-4)	1.67 (-4)	9.52 (-6)	5.18 (-6)	9.34 (-5)	4.86 (-5)
IIIA	3.55 (-1)	1.86 (-1)	9.31 (-2)	1.93 (-2)	1.14 (0)	2.09 (-1)
IIIB	2.52 (-2)	2.21 (-2)	3.14 (-3)	2.01 (-3)	1.09 (-1)	2.91 (-2)
IIIC	2.54 (-3)	2.38 (-3)	2.47 (-4)	1.70 (-4)	1.04 (-2)	2.26 (-3)
IIID	1.62 (-3)	1.48 (-3)	1.73 (-4)	9.51 (-5)	4.54 (-3)	1.06 (-3)
IIIE	1.73 (-3)	1.31 (-3)	1.83 (-4)	7.19 (-5)	3.49 (-3)	7.64 (-4)
IVA	3.40 (-2)	2.33 (-2)	4.83 (-3)	2.03 (-3)	9.89 (-2)	2.53 (-2)
IVB	1.85 (-2)	1.14 (-2)	1.83 (-3)	8.22 (-4)	2.46 (-2)	8.45 (-3)
IVC	1.04 (-2)	5.88 (-3)	1.02 (-3)	4.04 (-4)	1.19 (-2)	3.80 (-3)
IVD	4.34 (-3)	2.45 (-3)	4.57 (-4)	1.53 (-4)	4.71 (-3)	1.35 (-3)
IVE	1.10 (-3)	6.53 (-4)	1.21 (-4)	4.08 (-5)	1.19 (-3)	3.31 (-4)
VA	3.51 (1)		1.06 (1)		9.60 (1)	
VB	9.70 (0)		2.98 (0)		2.58 (1)	
VC	3.40 (0)	5.83 (-1)	1.05 (0)	6.66 (-2)	8.27 (0)	5.18 (-1)
VD	1.20 (0)	2.51 (-1)	3.61 (-1)	2.62 (-2)	2.81 (0)	1.90 (-1)
VE	4.77 (-1)	1.20 (-1)	1.35 (-1)	9.83 (-3)	9.73 (-1)	6.81 (-2)
VIA	2.56 (0)		6.22 (-1)		5.50 (0)	
VIB	8.68 (-1)		2.32 (-1)		1.91 (0)	

Table 15. (continued)

	Bonner ball count rate ($s^{-1}W^{-1}$)					
	Bare Detector		Cd-Covered Detector		3-inch-Diam Ball	
Configuration	Foreground	Background	Foreground	Background	Foreground	Background
VIC	3.30 (-1)	7.48 (-2)	8.42 (-2)	5.82 (-3)	7.03 (-1)	4.55 (-2)
VID	1.31 (-1)	5.33 (-2)	3.00 (-2)	3.31 (-3)	2.32 (-1)	2.66 (-2)
VIE	6.91 (-2)	1.79 (-3)	1.17 (-2)	4.15 (-2)	8.88 (-2)	1.46 (-2)
VIIA	2.78 (1)		8.72 (0)		8.07 (1)	
VIIB	6.49 (-1)		7.85 (-2)		8.25 (-1)	
VIIC	1.42 (-1)		2.91 (-2)		3.05 (-1)	
VIID	7.96 (-2)	3.49 (-2)	1.47 (-2)	2.11 (-3)	1.48 (-1)	1.88 (-2)
VIIE	5.01 (-2)	3.32 (-2)	7.23 (-3)	1.60 (-3)	6.98 (-2)	1.32 (-2)
VIIF	3.80 (-2)	3.09 (-2)	3.70 (-3)	1.31 (-3)	3.42 (-2)	1.11 (-2)
VIIIA	2.52 (1)		7.94 (0)		7.42 (1)	
VIIIB	3.72 (-1)		3.94 (-2)		5.09 (-1)	
VIIIC	8.02 (-2)		1.36 (-2)		1.77 (-1)	
VIIID	4.39 (-2)	3.28 (-2)	5.42 (-3)	1.43 (-3)	6.96 (-2)	1.34 (-2)
VIIIE	3.99 (-2)	3.39 (-2)	3.06 (-3)	1.30 (-3)	3.52 (-2)	1.12 (-2)
VIIIF	3.65 (-2)	3.02 (-2)	2.23 (-3)	1.16 (-3)	2.25 (-2)	1.05 (-2)
IXA	5.47 (-1)		8.48 (-2)		9.16 (-1)	
IXB	8.57 (-2)		2.01 (-2)		2.52 (-1)	
IXC	4.60 (-2)	2.77 (-2)	8.39 (-3)	1.54 (-3)	9.50 (-2)	1.43 (-2)
IXD	3.48 (-2)	2.70 (-2)	4.12 (-3)	1.24 (-3)	4.37 (-2)	1.15 (-2)
IXE	3.35 (-2)	2.93 (-2)	2.57 (-3)	1.20 (-3)	2.46 (-2)	1.08 (-2)
XA	6.88 (0)		2.21 (0)		2.00 (1)	
XB	2.10 (0)		7.10 (-1)		6.11 (0)	
XC	7.33 (-1)	1.19 (-1)	2.44 (-1)	1.26 (-2)	1.95 (0)	1.01 (-1)
XD	2.60 (-1)	6.93 (-2)	8.11 (-2)	5.49 (-3)	6.52 (-1)	4.08 (-2)
XE	1.05 (-1)	4.31 (-2)	2.86 (-2)	2.81 (-3)	2.21 (-1)	2.21 (-2)

Table 15. (continued)

	Bonner ball count rate ($s^{-1}W^{-1}$)					
	5-inch-Diam Ball		8-inch-Diam Ball		10-inch-Diam Ball	
Configuration	Foreground	Background	Foreground	Background	Foreground	Background
IA	1.20 (1)	9.49 (-1)	4.59 (0)	3.34 (-1)	1.81 (0)	1.38 (-1)
IB	1.10 (2)	8.37 (0)	3.82 (1)	2.56 (0)	1.55 (1)	1.09 (0)
IIA	2.04 (-1)	1.42 (-2)	1.23 (-1)	6.93 (-3)	5.90 (-2)	3.27 (-3)
IIB	4.75 (-3)	1.36 (-3)	3.20 (-3)	6.47 (-4)	1.70 (-3)	3.06 (-4)
IIC	2.22 (-3)	1.05 (-3)	1.27 (-3)	4.83 (-4)	6.16 (-4)	2.16 (-4)
IID	1.46 (-3)	9.32 (-4)	6.75 (-4)	4.06 (-4)	3.11 (-4)	1.78 (-4)
IIE	3.53 (-4)	1.30 (-4)	1.56 (-4)	5.20 (-5)	6.93 (-5)	2.22 (-5)
IIF	1.61 (-4)	7.59 (-5)	6.63 (-5)	2.89 (-5)	2.72 (-5)	1.28 (-5)
IIIA	3.27 (0)	4.94 (-1)	2.41 (0)	2.99 (-1)	1.43 (0)	1.54 (-1)
IIIB	6.85 (-1)	8.83 (-2)	6.51 (-1)	5.72 (-2)	3.95 (-1)	2.94 (-2)
IIIC	7.19 (-2)	6.74 (-3)	7.39 (-2)	4.15 (-3)	4.20 (-2)	2.17 (-3)
IIID	2.08 (-2)	2.48 (-3)	1.58 (-2)	1.26 (-3)	8.71 (-3)	6.13 (-4)
IIIE	1.05 (-2)	1.52 (-3)	6.07 (-3)	6.94 (-4)	2.94 (-3)	3.02 (-4)
IVA	3.01 (-1)	5.26 (-2)	1.71 (-1)	2.33 (-2)	7.82 (-2)	1.02 (-2)
IVB	5.34 (-2)	1.50 (-2)	2.53 (-2)	6.21 (-3)	1.10 (-2)	2.58 (-3)
IVC	2.20 (-2)	5.98 (-3)	8.95 (-3)	2.24 (-3)	3.65 (-3)	9.02 (-4)
IVD	7.66 (-3)	1.98 (-3)	3.00 (-3)	7.11 (-4)	1.20 (-3)	2.85 (-4)
IVE	1.78 (-3)	4.63 (-4)	6.62 (-4)	1.66 (-4)	2.61 (-4)	6.53 (-5)
VA	1.31 (2)		4.62 (1)		1.78 (1)	
VB	3.33 (1)		1.13 (1)		4.37 (0)	
VC	1.07 (1)	6.28 (-1)	3.47 (0)	1.46 (-1)	1.31 (0)	5.97 (-2)
VD	3.44 (0)	2.22 (-1)	1.11 (0)	5.85 (-2)	4.19 (-1)	2.29 (-2)
VE	1.14 (0)	8.23 (-2)	3.68 (-1)	2.59 (-2)	1.41 (-1)	1.03 (-2)
VIA	8.01 (0)		3.11 (0)		1.32 (0)	
VIB	2.64 (0)		9.88 (-1)		4.01 (-1)	

Table 15. (continued)

	Bonner ball count rate ($s^{-1}W^{-1}$)					
	5-inch-Diam Ball		8-inch-Diam Ball		10-inch-Diam Ball	
Configuration	Foreground	Background	Foreground	Background	Foreground	Background
VIC	9.34 (-1)	5.92 (-2)	3.20 (-1)	2.08 (-2)	1.31 (-1)	8.42 (-3)
VID	3.00 (-1)	3.59 (-2)	1.05 (-1)	1.18 (-2)	4.08 (-2)	4.75 (-3)
VIE	1.08 (-1)	2.08 (-2)	3.83 (-2)	7.76 (-3)	1.47 (-2)	3.20 (-3)
VIIA	1.12 (2)		4.01 (1)		1.58 (1)	
VIIB	1.82 (0)		1.05 (0)		5.18 (-1)	
VIIC	6.24 (-1)		3.10 (-1)		1.46 (-1)	
VIID	2.59 (-1)	2.96 (-2)	1.12 (-1)	9.92 (-3)	4.92 (-2)	4.19 (-3)
VIIE	1.11 (-1)	2.19 (-2)	4.47 (-2)	7.21 (-3)	1.85 (-2)	2.92 (-3)
VIIF	5.28 (-2)	1.78 (-2)	2.01 (-2)	7.17 (-3)	8.17 (-3)	2.97 (-3)
VIIIA	1.05 (2)		3.78 (1)		1.49 (1)	
VIIIB	1.43 (0)		8.78 (-1)		4.38 (-1)	
VIIIC	4.51 (-1)		2.51 (-1)		1.21 (-1)	
VIIID	1.57 (-1)	2.24 (-2)	7.81 (-2)	7.65 (-3)	3.59 (-2)	3.23 (-3)
VIIIE	6.65 (-2)	1.84 (-2)	2.97 (-2)	6.53 (-3)	1.27 (-2)	2.70 (-3)
VIIIF	3.76 (-2)	1.63 (-2)	1.53 (-2)	6.67 (-3)	6.36 (-3)	2.79 (-3)
IXA	1.97 (0)		1.06 (0)		5.16 (-1)	
IXB	5.43 (-1)		2.82 (-1)		1.35 (-1)	
IXC	1.89 (-1)	2.39 (-2)	8.96 (-2)	8.15 (-3)	3.93 (-2)	3.48 (-3)
IXD	7.76 (-2)	1.80 (-2)	3.26 (-2)	6.48 (-3)	1.38 (-2)	2.74 (-3)
IXE	3.99 (-2)	1.71 (-2)	1.58 (-2)	6.69 (-3)	6.72 (-3)	2.81 (-3)
XA	2.95 (1)		1.06 (1)		4.14 (0)	
XB	8.30 (0)		2.81 (0)		1.11 (0)	
XC	2.49 (0)	1.29 (-1)	8.66 (-1)	3.51 (-2)	3.27 (-1)	1.38 (-2)
XD	8.03 (-1)	5.22 (-2)	2.64 (-1)	1.56 (-2)	9.90 (-2)	6.24 (-3)
XE	2.72 (-1)	3.01 (-2)	8.78 (-2)	1.03 (-2)	3.31 (-2)	4.21 (-3)

[a]See experimental program plan in Appendix A for description of experiment.
[b]Count rates without shadow shield between detector and configuration.
[c]Count rates with shadow shield between detector and configuration.
[d]Read: 2.18×10^0.

Table 16. Sodium foil measurements in voids located in the spectrum modifiers

Foil Location[a]		S(nCi)/kW/g(Na)/minute of exposure		
Void	Position	Item IA[c]	Item IAA[e]	Item IB
X	1		5.44 (-2)	
	2		6.18 (-2)	
	3		5.58 (-2)	
	4		5.83 (-2)	
	5		5.99 (-2)	
	6		5.94 (-2)	
	7		5.65 (-2)	
	8		5.48 (-2)	
	9			
Y	1		1.52 (-2)	
	2		1.84 (-2)	
	3		1.44 (-2)	
	4		1.73 (-2)	
	5		1.89 (-2)	
	6		1.65 (-2)	
	7		1.55 (-2)	
	8		1.72 (-2)	
	9		1.54 (-2)	
Z	1	1.63 (-3)[d]		
	2	1.64 (-3)		
	3	1.70 (-3)		
	4	1.79 (-3)		
	5	1.84 (-3)		
	6	1.72 (-3)		
	7	1.59 (-3)		
	8	1.64 (-3)		
	9	1.51 (-3)		
XX	10			1.26 (0)
	10			1.32 (0)
	10			1.21 (0)
	11[b]			3.25 (-1)
	11			3.39 (-1)

[a]See Figure 11 for location of capsules.
[b]Cd-covered capsules.
[c]See experimental program plan in Appendix A for description of configurations.
[d]Read: 1.63×10^{-3}.
[e]Same configuration as IA with voids placed between tanks.

Table 17. Fast neutron spectrum (>0.8 MeV) on centerline at 25 cm behind the lead slabs (Item IB) Run 7923.A

Neutron Energy (MeV)	Flux (neutrons cm^{-2}MeV^{-1}kW^{-1}s^{-1}) Lower Limit	Upper Limit	Neutron Energy (MeV)	Flux (neutrons cm^{-2}MeV^{-1}kW^{-1}s^{-1}) Lower Limit	Upper Limit
8.11E - 01	6.65E + 02	6.91E + 02	5.94E + 00	1.44E + 01	1.60E + 01
9.07E - 01	7.63E + 02	7.76E + 02	6.25E + 00	1.05E + 01	1.24E + 01
1.01E + 00	7.50E + 02	7.62E + 02	6.55E + 00	9.02E + 00	1.06E + 01
1.11E + 00	7.00E + 02	7.11E + 02	6.84E + 00	8.94E + 00	1.01E + 01
1.20E + 00	6.54E + 02	6.64E + 02	7.24E + 00	8.22E + 00	9.20E + 00
1.31E + 00	6.12E + 02	6.22E + 02	7.74E + 00	5.56E + 00	6.76E + 00
1.41E + 00	5.71E + 02	5.80E + 02	8.24E + 00	3.75E + 00	4.97E + 00
1.51E + 00	5.25E + 02	5.33E + 02	8.76E + 00	3.47E + 00	4.16E + 00
1.61E + 00	4.68E + 02	4.75E + 02	9.26E + 00	2.90E + 00	3.52E + 00
1.71E + 00	4.06E + 02	4.13E + 02	9.74E + 00	2.41E + 00	2.95E + 00
1.81E + 00	3.49E + 02	3.56E + 02	1.03E + 01	2.32E + 00	2.82E + 00
1.93E + 00	2.93E + 02	2.99E + 02	1.08E + 01	2.24E + 00	2.67E + 00
2.10E + 00	2.24E + 02	2.30E + 02	1.12E + 01	1.89E + 00	2.27E + 00
2.30E + 00	1.65E + 02	1.70E + 02	1.18E + 01	1.32E + 00	1.61E + 00
2.50E + 00	1.32E + 02	1.36E + 02	1.24E + 01	7.29E - 01	9.82E - 01
2.70E + 00	1.11E + 02	1.15E + 02	1.32E + 01	3.35E - 01	5.09E - 01
2.90E + 00	9.71E + 01	1.01E + 02	1.40E + 01	8.78E - 02	2.31E - 01
3.10E + 00	8.24E + 01	8.66E + 01	1.48E + 01	9.66E - 02	2.03E - 01
3.30E + 00	6.64E + 01	6.98E + 01	1.56E + 01	1.05E - 01	2.08E - 01
3.50E + 00	5.44E + 01	5.82E + 01	1.65E + 01	3.51E - 02	1.01E - 01
3.71E + 00	4.80E + 01	5.09E + 01	1.75E + 01	-5.39E - 04	4.45E - 02
3.91E + 00	4.32E + 01	4.58E + 01	1.85E + 01	-1.09E - 02	2.53E - 02
4.15E + 00	3.81E + 01	4.05E + 01	1.95E + 01	-1.88E - 02	1.38E - 02
4.45E + 00	3.29E + 01	3.49E + 01	2.05E + 01	-2.57E - 02	2.40E - 02
4.75E + 00	2.77E + 01	2.96E + 01	2.16E + 01	-2.36E - 02	2.86E - 02
5.04E + 00	2.40E + 01	2.57E + 01	2.26E + 01	-1.54E - 02	1.90E - 02
5.34E + 00	2.14E + 01	2.30E + 01	2.35E + 01	-1.52E - 02	1.50E - 02
5.64E + 00	1.83E + 01	2.01E + 01			

E1 (MeV)	E2 (MeV)	Integral neutrons cm^{-2}kW^{-1}s^{-1}	Error neutrons cm^{-2}kW^{-1}s^{-1}
0.811	1.000	1.42E + 02	1.45E + 00
1.000	1.200	1.42E + 02	1.07E + 00
1.200	1.600	2.31E + 02	1.76E + 00
1.600	2.000	1.45E + 02	1.28E + 00
2.000	3.000	1.48E + 02	2.32E + 00
3.000	4.000	6.06E + 01	1.67E + 00
4.000	6.000	5.36E + 01	1.88E + 00
6.000	8.000	1.81E + 01	1.33E + 00
8.000	10.000	7.10E + 00	7.56E - 01
10.000	12.000	4.29E + 00	4.00E - 01
12.000	16.000	1.42E + 00	3.10E - 01
16.000	20.000	1.03E - 01	9.22E - 02
3.000	10.000	1.39E + 02	5.65E + 00
1.500	15.000	4.89E + 02	1.03E + 01
3.000	12.000	1.43E + 02	6.05E + 00

Table 18. Neutron spectrum (50 keV to 1.4 MeV) on centerline at 25 cm behind the lead slabs (Item VB) Runs 1593.C, 1593.A, 1593.B

N	Energy Boundary (MeV)		Flux (neutrons $cm^{-2}MeV^{-1}kW^{-1}s^{-1}$)	Error (%)
		RUN 1593.C		
1	0.0389	0.0455	6.85E + 04	2.19
2	0.0455	0.0538	5.19E + 04	2.48
3	0.0538	0.0637	4.94E + 04	2.32
4	0.0637	0.0737	4.86E + 04	2.52
5	0.0737	0.0869	3.53E + 04	2.63
6	0.0869	0.1034	2.22E + 04	3.47
7	0.1034	0.1200	2.22E + 04	3.83
8	0.1200	0.1415	1.90E + 04	3.47
9	0.1415	0.1680	1.27E + 04	4.32
		RUN 1593.A		
1	0.1191	0.1436	1.93E + 04	1.13
2	0.1436	0.1680	1.34E + 04	1.77
3	0.1680	0.1985	1.01E + 04	2.03
4	0.1985	0.2352	8.16E + 03	2.29
5	0.2352	0.2718	8.78E + 03	2.32
6	0.2718	0.3207	7.52E + 03	2.07
7	0.3207	0.3818	4.28E + 03	2.98
8	0.3818	0.4490	3.12E + 03	4.02
9	0.4490	0.5284	2.60E + 03	4.27
		RUN 1593.B		
1	0.3759	0.4521	3.03E + 03	1.95
2	0.4521	0.5284	2.81E + 03	2.24
3	0.5284	0.6156	1.74E + 03	3.24
4	0.6156	0.7245	8.33E + 02	5.74
5	0.7245	0.8553	8.02E + 02	5.46
6	0.8553	1.0078	7.34E + 02	5.56
7	1.0078	1.1821	6.46E + 02	5.88
8	1.1821	1.4000	6.00E + 02	5.07

Table 19. Bonner ball measurements on centerline at NE-213 location behind spectrum modifier (Item IB)

	Bonner ball count rates ($s^{-1}W^{-1}$)					
	3-inch-Diam Ball		5-inch-Diam Ball		10-inch-Diam Ball	
Configuration[a]	Foreground[d]	Background	Foreground	Background	Foreground	Background
Item IB[b,c]	1.33 (2)[e]		1.91 (2)		2.73 (1)	

[a]See experimental program plan in Appendix A for description of configurations.
[b]Lead slab (7.62 cm) between configuration and detector (see Figure 4).
[c]Detectors at 25 cm behind the lead.
[d]Count rates without shadow shield between detector and configuration.
[e]Read: 1.33×10^2.

Table 20. 5-inch Bonner ball horizontal traverse through midplane at 30 cm behind spectrum modifier (Item IB)

Distance from centerline (cm)	Bonner ball count rate ($s^{-1}W^{-1}$) Item IB[a]
195 S	5.89 (1)[b]
180	8.36 (1)
150	1.21 (2)
120	1.82 (2)
90	2.40 (2)
75	2.71 (2)
60	2.96 (2)
45	3.14 (2)
30	3.30 (2)
15	3.38 (2)
0	3.44 (2)
0[c]	3.49 (2)
15	3.49 (2)
30	3.29 (2)
45	3.20 (2)
60	2.98 (2)
75	2.58 (2)
90	2.34 (2)
120	1.72 (2)
150	1.15 (2)
180	7.68 (1)
195 N	5.35 (1)

[a]See experimental program plan in Appendix A for description of configuration.
[b]Read: 5.89×10^1.
[c]Repeat.

Table 21. Bare Bonner ball measurements on centerline at 30 cm behind a series of configurations

	count rate ($s^{-1}W^{-1}$)							
Detection Modes[a]	Item IIC[b]	Item IID	Item IIE	Item IIF	Item IIIA	Item IIIC	Item IIID	Item IIIE
inside Cd hut	2.15 (-4)[c]	1.47 (-4)	7.92 (-5)	4.12 (-5)	6.91 (-1)	1.51 (-3)	7.25 (-4)	1.01 (-3)
Cd sheet over face of mockup	6.86 (-4)	5.79 (-4)	1.84 (-4)	1.17 (-4)				
Cd sheet behind detector								

Table 21. (continued)

	count rate ($s^{-1}W^{-1}$)							
Detection Modes	Item IVA	Item IVB	Item IVC	Item IVD	Item IVE	Item VD	Item VE	Item VIC
inside Cd hut	1.05 (-2)	5.19 (-3)	3.94 (-3)	2.29 (-3)	6.01 (-4)			
Cd sheet over face of mockup	2.81 (-2)	1.61 (-2)	9.22 (-3)	3.67 (-3)	9.68 (-4)			
Cd sheet behind detector						3.50 (0)	1.27 (0)	7.59 (-1)

Table 21. (continued)

	count rate ($s^{-1}W^{-1}$)					
Detection Modes	Item VIE	Item VIIA	Item VIIB	Item VIID	Item VIIE	Item VIIF
Cd sheet above detector		4.97 (1)	2.34 (-1)			
Cd sheet behind detector	1.04 (-1)			1.50 (-1)	5.35 (-2)	2.54 (-2)

Table 21. (continued)

	count rate ($s^{-1}W^{-1}$)							
Detection Modes	Item VIIID	Item VIIIE	Item VIIIF	Item IXA	Item IXB	Item IXC	Item IXD	Item IXE
Cd sheet behind detector	4.36 (-2)	2.53 (-2)	2.62 (-2)		1.95 (-1)	7.41 (-2)	3.04 (-2)	1.75 (-2)
Cd sheet above detector					1.57 (-1)	6.46 (-2)		
see footnote (1)				1.29 (0)				
see footnote (2)				9.86 (-1)				
see footnote (3)				1.24 (0)				
see footnote (4)				9.15 (-1)				
see footnote (5)				6.41 (-1)				
see footnote (6)				1.24 (-1)				
see footnote (7)				4.17 (-2)				

Table 21. (continued)

	count rate ($s^{-1}W^{-1}$)				
Detection Modes	Item XA	Item XB	Item XC	Item XD	Item XE
Cd sheet behind detector				8.63 (-1)	3.12 (-1)
Cd sheet above detector	1.45 (1)	5.36 (0)	2.17 (0)		
Cd sheet above and below detector		5.04 (0)			

[a,b]See experimental program plan in Appendix A for description of configurations.
[c]Read: 2.15×10^{-4}.
[1]Cd covering face of Li-Par above the front B_4C slab (6W).
[2]Cd covering face of Li-Par above the front B_4C slab (6W) plus Cd sheet beneath concrete slab covering top of the mockup.
[3]Cd covering face of Li-Par above the front B_4C slab (6W) and the Li-Par above both side B_4C slabs (7W and 8W).
[4]Cd covering face of Li-Par above the front B_4C slab (6W) and the two side B_4C slabs (7W and 8W), plus Cd over the aluminum plug insert.
[5]Cd covering face of Li-Par above the front B_4C slab (6W) and the two side B_4C slabs (7W and 8W), Cd over the aluminum insert and beneath the concrete slab covering the top of the mockup.
[6]Cd covering face of Li-Par above the front B_4C slab (6W) and the two side B_4C slabs (7W and 8W), Cd over the aluminum insert and beneath the concrete slab covering the top of the mockup, 10.2 cm of Li-Par covering the face of the front B_4C slab (6W).
[7]Cd-covered detector, Cd covering face of Li-Par above the front B_4C slab (6W) and the two side B_4C slabs (7W and 8W), Cd over the aluminum insert and beneath the concrete slab covering the top of the mockup, 10.2 cm of Li-Par covering the face of the front B_4C slab (6W).

Table 22. Bare Bonner ball measurements on centerline at 150 cm behind a series of configurations

	count rate ($s^{-1}W^{-1}$)											
	Item IIB[b]		Item IIC		Item IID		Item IIE		Item IIF		Item IVA	
Detection Modes[a]	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background
Cd over face of mockup	1.24 (-3)[e]		1.07 (-3)		1.07 (-3)		2.20 (-4)		1.44 (-4)		2.92 (-2)	
Cd sheet behind detector												
Cd sheet over face of shadow shield												

Table 22. (continued)

	count rate ($s^{-1}W^{-1}$)											
	Item IVB		Item IVC		Item IVD		Item IVE		Item VIIA		Item VIIB	
Detection Modes	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background
Cd over face of mockup	1.55 (-2)		8.27 (-3)		3.13 (-3)		8.31 (-4)					
Cd sheet behind detector									2.59 (1)		5.85 (-1)	
Cd sheet above detector									1.82 (1)		2.22 (-1)	
Cd sheet above detector with Cd sheet behind detector											1.93 (-1)	

Table 22. (continued)

	count rate ($s^{-1}W^{-1}$)											
	Item VIIC		Item VIID		Item VIIE		Item VIIF		Item VIIIC		Item VIIID	
Detection Modes	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background
Cd over face of mockup												
Cd sheet behind detector	1.14 (-1)		5.44 (-2)		2.69 (-2)		1.45 (-2)		5.55 (-2)		2.23 (-2)	
Cd sheet over face of shadow shield				2.96 (-2)		2.91 (-2)		2.81 (-2)				

Table 22. (continued)

	count rate ($s^{-1}W^{-1}$)											
	Item VIIIE		Item VIIIF		Item IXA		Item IXB		Item IXC		Item IXD	
Detection Modes	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background
Cd sheet behind detector			8.87 (-3)		4.80 (-1)		6.80 (-2)		2.79 (-2)		2.33 (-2)	
Cd sheet over face of shadow shield		3.04 (-2)		2.79 (-2)						2.41 (-2)		2.46 (-2)
Cd sheet above detector							6.09 (-2)		3.89 (-2)			
See footnote (1)					3.55 (-1)							
See footnote (2)					1.74 (-1)							
See footnote (3)					3.29 (-1)							
See footnote (4)					3.04 (-1)							
See footnote (5)					1.39 (-1)							
See footnote (6)					6.33 (-2)							
See footnote (7)					2.66 (-2)							

Table 22. (continued)

	count rate ($s^{-1}W^{-1}$)											
	Item IXE		Item XA		Item XB		Item XC		Item XD		Item XE	
Detection Modes	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background	Foreground	Background
Cd sheet behind detector	1.93 (-2)		6.59 (0)		1.98 (0)		6.77 (-1)					
Cd sheet over face of shadow shield		2.74 (-2)						9.62 (-2)		5.72 (-2)		3.96 (-2)
Cd sheet above detector			4.68 (0)		1.66 (0)		7.10 (-1)					
Cd sheet above and below detector					1.49 (0)							

[a]See experimental program plan in Appendix A for description of configurations.
[b]See experimental program plan in Appendix A for description of configurations.
[c]Count rates without shadow shield between detector and configuration.
[d]Count rates with shadow shield between detector and configuration.
[e]Read: 1.24×10^{-3}.
[1]Cd covering face of Li-Par above the front B_4C slab (6W).
[2]Cd covering face of Li-Par above the front B_4C slab (6W) plus Cd sheet beneath concrete slab covering top of the mockup.
[3]Cd covering face of Li-Par above the front B_4C slab (6W) and the Li-Par above both side B_4C slabs (7W and 8W).
[4]Cd covering face of Li-Par above the front B_4C slab (6W) and the two side B_4C slabs (7W and 8W), plus Cd over the aluminum plug insert.
[5]Cd covering face of Li-Par above the front B_4C slab (6W) and the two side B_4C slabs (7W and 8W), Cd over the aluminum insert and beneath the concrete slab covering the top of the mockup.
[6]Cd covering face of Li-Par above the front B_4C slab (6W) and the two side B_4C slabs (7W and 8W), Cd over the aluminum insert and beneath the concrete slab covering the top of the mockup, 10.2 cm of Li-Par covering the face of the front B_4C slab (6W).
[7]Cd-covered detector, Cd covering face of Li-Par above the front B_4C slab (6W) and the two side B_4C slabs (7W and 8W), Cd over the aluminum insert and beneath the concrete slab covering the top of the mockup, 10.2 cm of Li-Par covering the face of the front B_4C slab (6W).

Table 23. Sodium foil measurements in voids located throughout configuration mockups

Foil Location[a]		S (nCi)/kW/g (Na)/minute of exposure)					
Void	Position	Item VE[b]	Item VIE	Item VIIF	Item VIIIF	Item IX	Item X
1	A	2.39 (-2)[c]	2.04 (-2)	1.86 (-2)	1.94 (-2)	1.55 (-2)	1.62 (-2)
	B	2.58 (-2)	2.22 (-2)	2.17 (-2)	2.13 (-2)	1.72 (-2)	2.04 (-2)
	C	2.40 (-2)	2.02 (-2)	1.98 (-2)	1.89 (-2)	1.66 (-2)	2.36 (-2)
	D	2.55 (-2)	2.21 (-2)	2.03 (-2)	2.05 (-2)	1.73 (-2)	1.75 (-2)
	E	2.78 (-2)	2.32 (-2)	2.33 (-2)	2.37 (-2)	1.86 (-2)	2.27 (-2)
	F	2.54 (-2)	2.14 (-2)	2.18 (-2)	2.05 (-2)	1.54 (-2)	2.30 (-2)
2	A		1.01 (-3)				8.33 (-4)
	B		4.64 (-4)				6.54 (-3)
	C		8.18 (-4)				1.31 (-2)
	D		9.69 (-4)				4.42 (-4)
	E		4.11 (-4)				5.24 (-3)
	F		7.52 (-4)				1.52 (-2)
3	A	1.08 (-2)	9.04 (-4)	7.64 (-5)	5.67 (-5)	5.86 (-5)	1.12 (-3)
	B	1.20 (-2)	4.33 (-4)	5.77 (-5)	5.58 (-5)	6.09 (-5)	3.16 (-3)
	C	1.11 (-2)	7.25 (-4)	7.32 (-5)	6.31 (-5)	5.33 (-5)	4.31 (-3)
	D	1.14 (-2)	9.91 (-4)	5.75 (-5)	4.35 (-5)	6.17 (-5)	1.24 (-3)
	E	1.31 (-2)	4.42 (-4)	4.03 (-5)	3.06 (-5)	1.21 (-4)	3.63 (-3)
	F	1.18 (-2)	7.97 (-4)	4.14 (-5)	3.94 (-5)	5.45 (-5)	5.22 (-3)
4	A	4.48 (-3)	4.16 (-4)	5.87 (-5)	2.28 (-5)	2.94 (-5)	7.39 (-4)
	B	4.87 (-3)	2.76 (-4)	3.86 (-5)	2.56 (-5)	3.10 (-5)	1.40 (-3)
	C	4.48 (-3)	3.46 (-4)	5.04 (-5)	2.74 (-5)	2.48 (-5)	1.57 (-3)
	D	4.79 (-3)	4.27 (-4)	5.59 (-5)	1.93 (-5)	2.99 (-5)	7.97 (-4)
	E	5.38 (-3)	2.85 (-4)	3.38 (-5)	2.03 (-5)	3.67 (-5)	1.57 (-3)
	F	4.81 (-3)	4.09 (-4)	4.64 (-5)	1.98 (-5)	2.47 (-5)	1.70 (-3)
5	A	1.65 (-3)	1.49 (-4)	2.93 (-5)	1.09 (_5)	1.26 (_5)	2.99 (-4)
	B	1.93 (-3)	1.28 (-4)	2.23 (-5)	1.26 (-5)	1.48 (-5)	4.66 (-4)
	C	1.77 (-3)	1.12 (-4)	2.50 (-5)	1.14 (-5)	1.14 (-5)	4.95 (-4)
	D	1.79 (-3)	1.62 (-4)	3.02 (-5)	8.09 (-6)	1.26 (_5)	3.25 (-4)
	E	1.91 (-3)	1.40 (-4)	2.00 (-5)	1.12 (-5)	1.51 (-5)	5.31 (-4)
	F	1.83 (-3)	1.45 (-4)	2.34 (-5)	9.56 (-6)	1.07 (-5)	5.33 (-4)
6	A	3.15 (-4)	4.26 (-5)	9.20 (-6)	4.38 (-6)	5.36 (-6)	5.61 (-5)
	B	3.83 (-4)	3.45 (-5)	7.93 (-6)	6.15 (-6)	5.81 (-6)	8.94 (-5)
	C	3.14 (-4)	3.37 (-5)	8.63 (-6)	4.45 (-6)	5.21 (-6)	8.75 (-5)
	D	3.22 (-4)	3.62 (-5)	8.89 (-6)	5.23 (-6)	5.19 (-6)	5.64 (-5)
	E	3.69 (-4)	5.48 (-5)	7.73 (-6)	5.07 (-6)	5.42 (-6)	9.32 (-5)
	F	3.17 (-4)	3.48 (-5)	8.64 (-6)	3.82 (-6)	5.25 (-6)	9.02 (-5)

[a]See Figure 11 for location of capsules.
[b]See experimental program plan in Appendix A for description of configurations.
[c]Read 2.39×10^{-2}.

Table 24. Bonner ball horizontal traverses through midplane at 30 cm behind the shield mockup (Item XE)[a]

Distance from centerline (cm)	Bonner ball count rates ($s^{-1}W^{-1}$) Bare Ball	Cd-covered Ball	3-inch-Diam Ball	5-inch-Diam Ball	10-inch-Diam Ball
186 N			4.73 (-2)	6.28 (-2)	
176			5.87 (-2)	7.68 (-2)	
166			7.85 (-2)	1.04 (-1)	
156			1.08 (-1)	1.36 (-1)	1.60 (-2)
146			1.35 (-1)	1.66 (-1)	2.04 (-2)
136			1.68 (-1)	2.12 (-1)	2.57 (-2)
126			2.09 (-1)	2.62 (-1)	3.18 (-2)
116			2.62 (-1)	3.28 (-1)	4.09 (-2)
106			3.26 (-1)	4.06 (-1)	4.89 (-2)
96			4.09 (-1)	5.10 (-1)	6.16 (-2)
86			5.10 (-1)	6.48 (-1)	7.82 (-2)
76			6.37 (-1)	7.84 (-1)	9.39 (-2)
66			6.96 (-1)	8.42 (-1)	1.04 (-1)
56			7.91 (-1)	9.57 (-1)	1.14 (-1)
46			8.79 (-1)	1.06 (0)	1.27 (-1)
36			9.40 (-1)	1.13 (0)	1.36 (-1)
26			9.74 (-1)	1.16 (0)	1.40 (-1)
16			9.83 (-1)	1.17 (0)	1.41 (-1)
6			9.70 (-1)	1.15 (0)	1.41 (-1)
0			9.54 (-1)	1.13 (0)	1.37 (-1)
0	3.21 (-1)[b]	1.24 (-1)	9.41 (-1)	1.15 (0)	1.39 (-1)
10			9.01 (-1)	1.11 (0)	1.31 (-1)
20	2.91 (-1)	1.10 (-1)	8.68 (-1)	1.02 (0)	1.23 (-1)
30			7.71 (-1)	9.41 (-1)	1.12 (-1)
40	2.47 (-1)	9.02 (-2)	6.96 (-1)	8.41 (-1)	1.01 (-1)
50			5.99 (-1)	7.22 (-1)	8.87 (-2)
60			5.08 (-1)	6.17 (-1)	7.47 (-2)
70			4.34 (-1)	5.15 (-1)	6.34 (-2)
72	1.63 (-1)	5.44 (-2)			
80			3.66 (-1)	4.46 (-1)	5.37 (-2)
81	1.48 (-1)	4.62 (-2)			
90			3.03 (-1)	3.54 (-1)	4.43 (-2)
100			2.37 (-1)	2.92 (-1)	3.56 (-2)
101	1.13 (-1)	3.09 (-2)			
110			1.94 (-1)	2.39 (-1)	2.92 (-2)
120			1.55 (-1)	1.92 (-1)	2.39 (-2)
130			1.23 (-1)	1.53 (-1)	1.90 (-2)
135	7.92 (-2)	1.49 (-2)			
140			1.00 (-1)	1.20 (-1)	1.48 (-2)
145 S					1.28 (-2)

[a]See experimental program plan in Appendix A for description of configurations.
[b]Read: 3.21×10^{-1}.

APPENDIX C

FIGURES

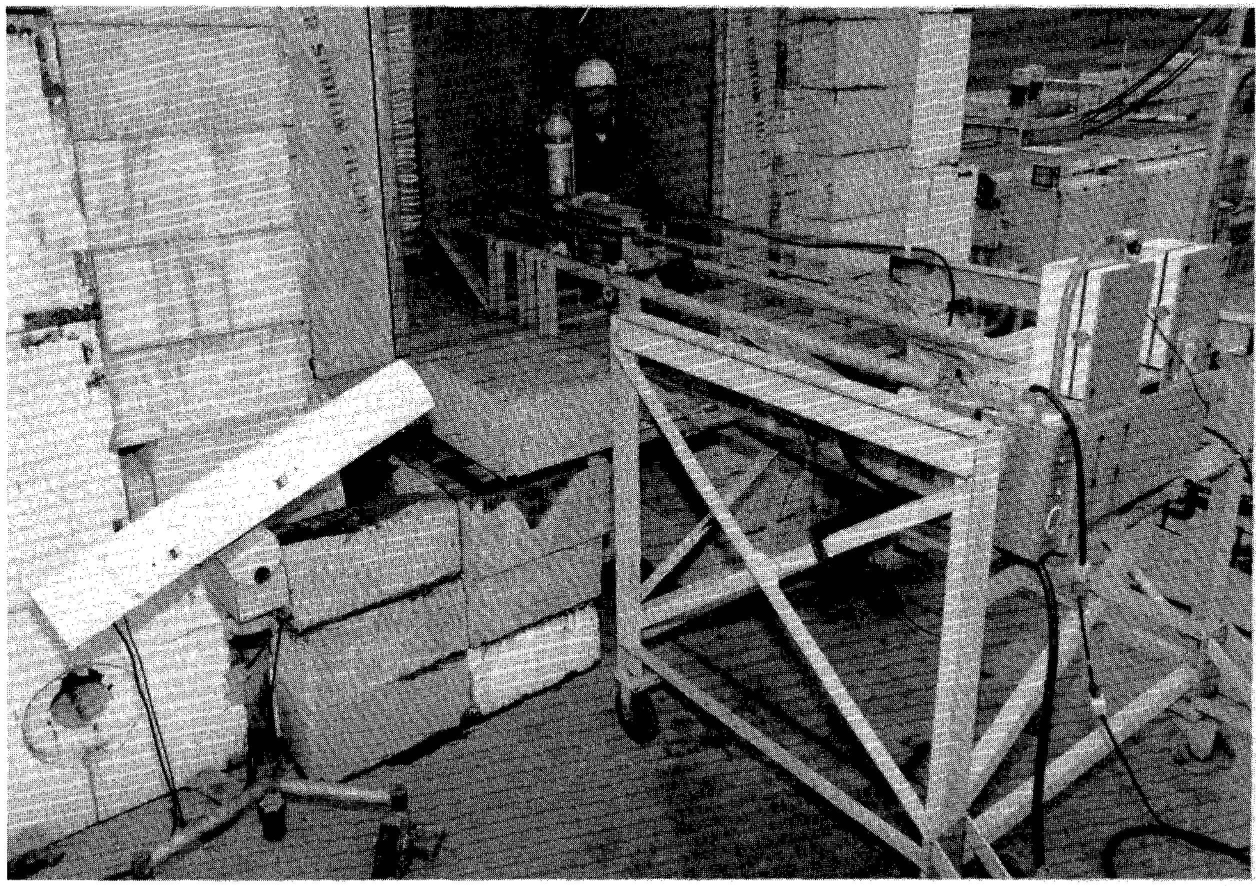


Figure 1. A photograph of a typical IHX shield mockup.

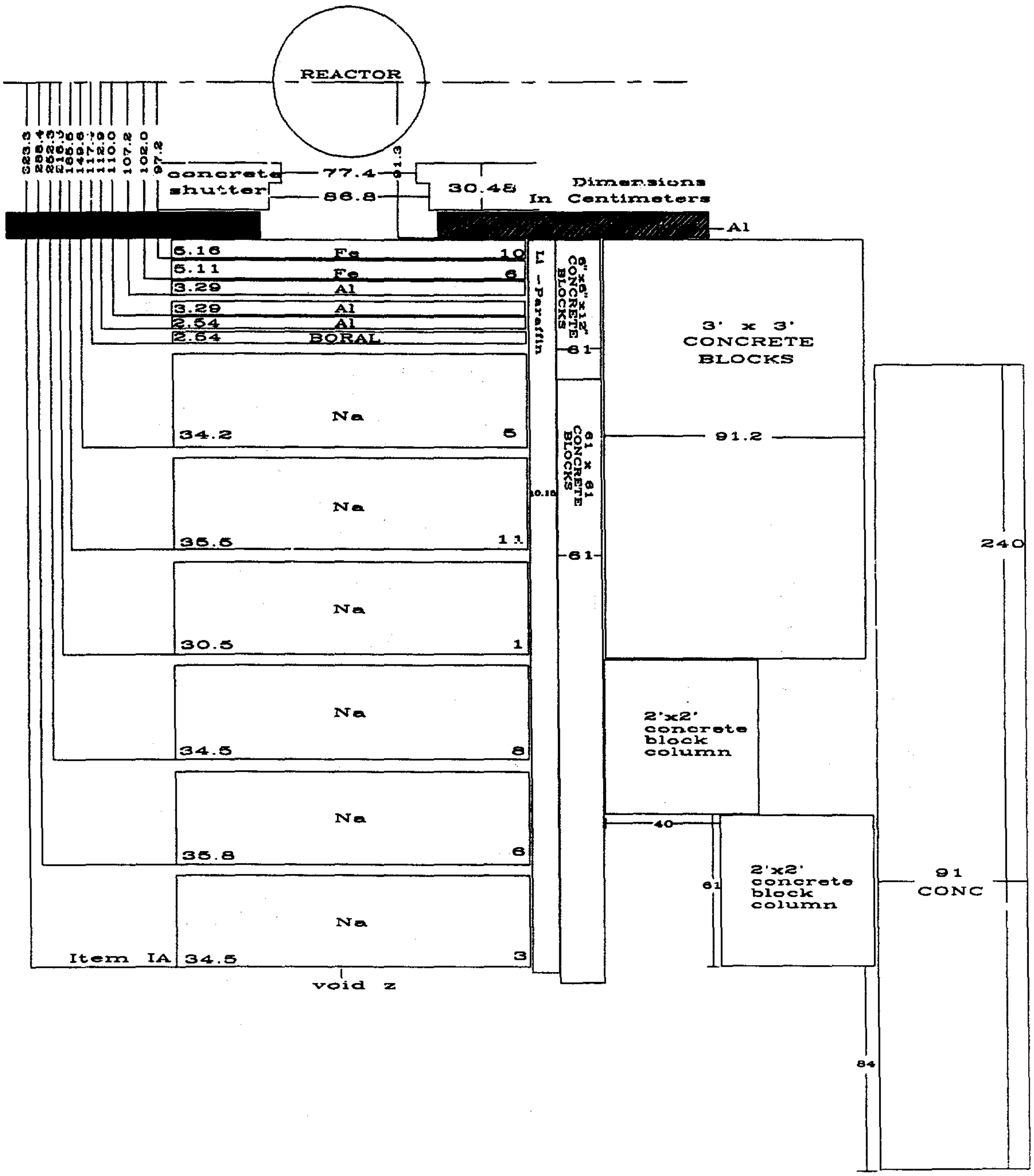


Figure 2. Schematic of SM-2 (iron + aluminum + boral + sodium). Item IA.

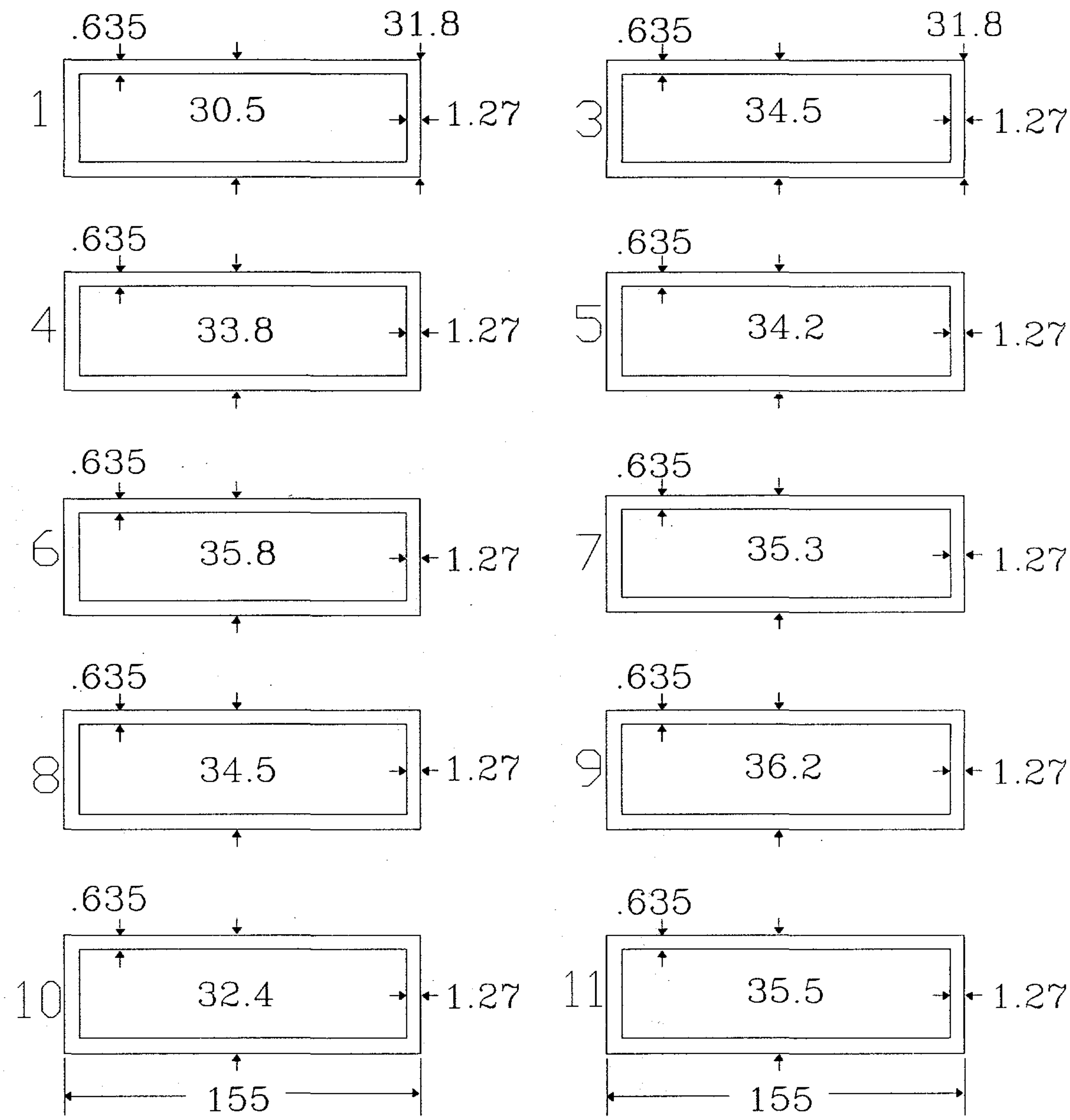


Figure 3. Schematic of aluminum containers filled with sodium.

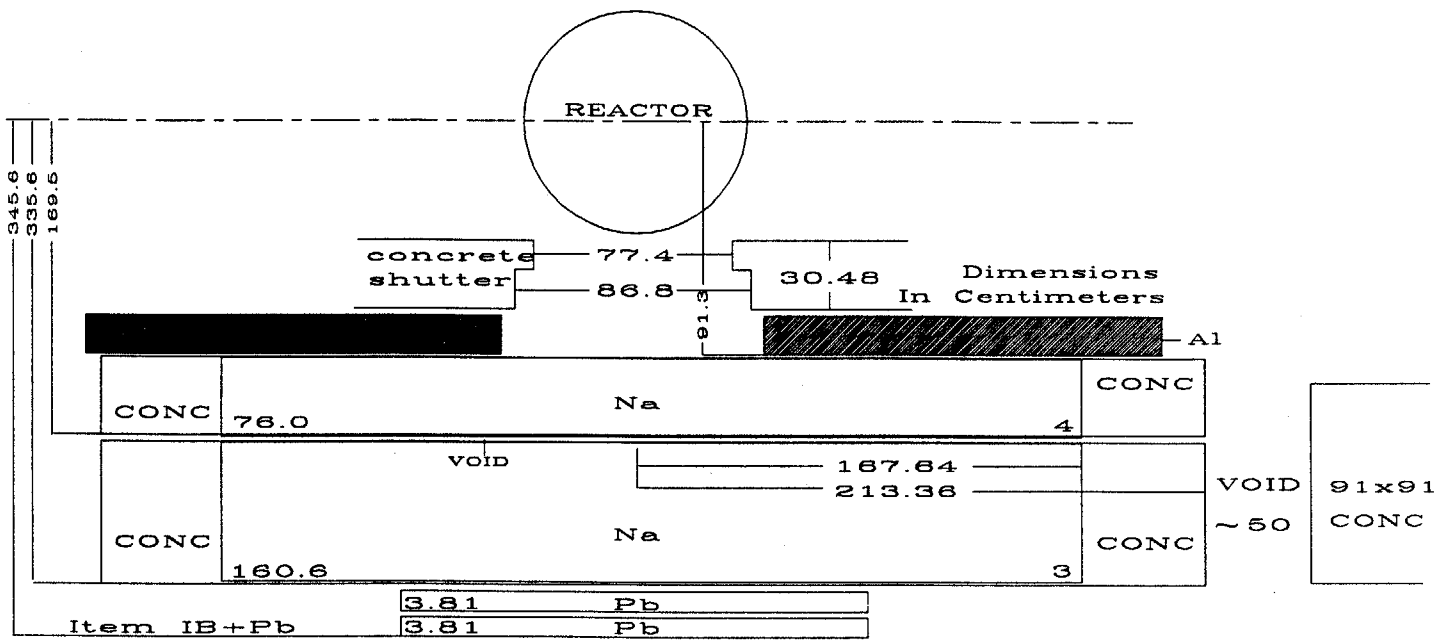


Figure 4. Schematic of SM-3 (sodium) plus lead. Item IB.

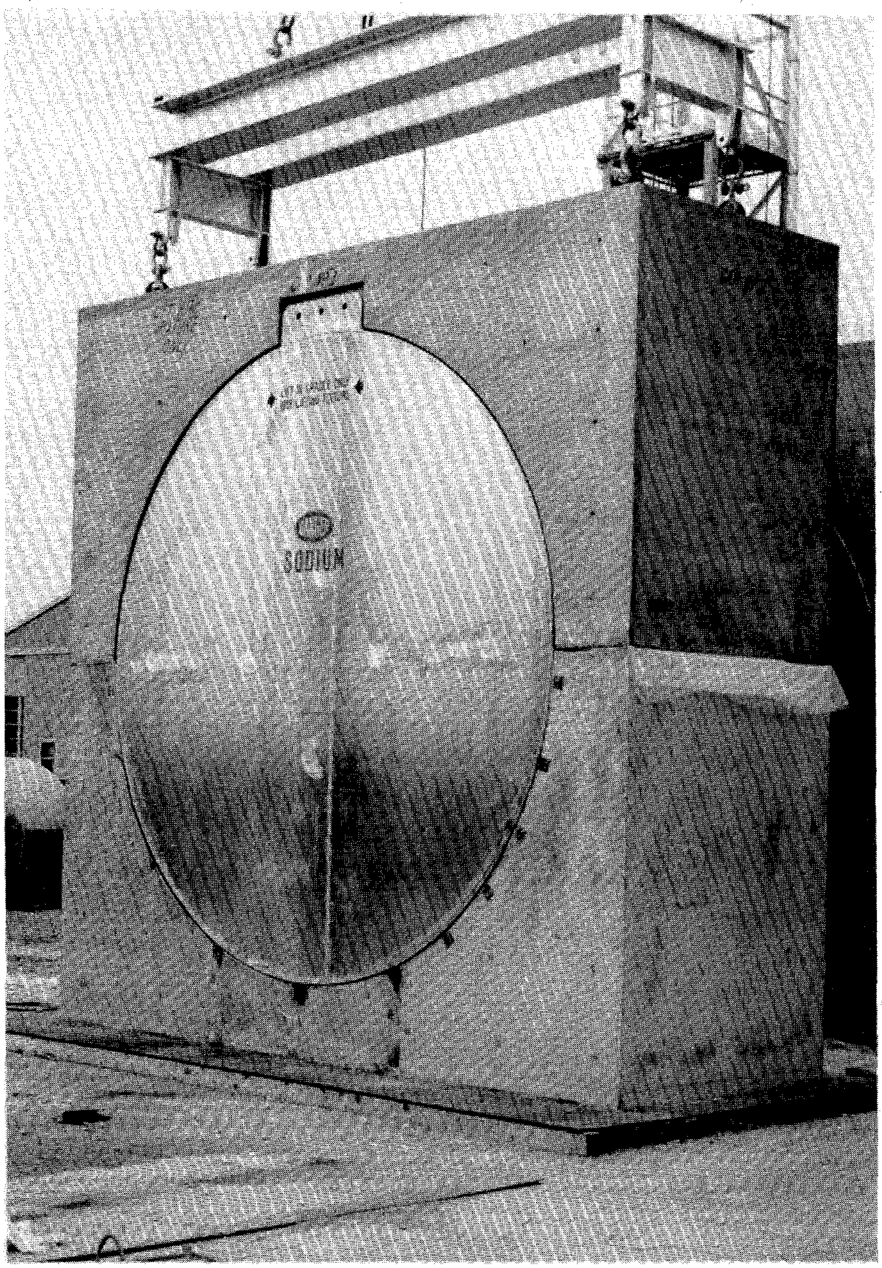
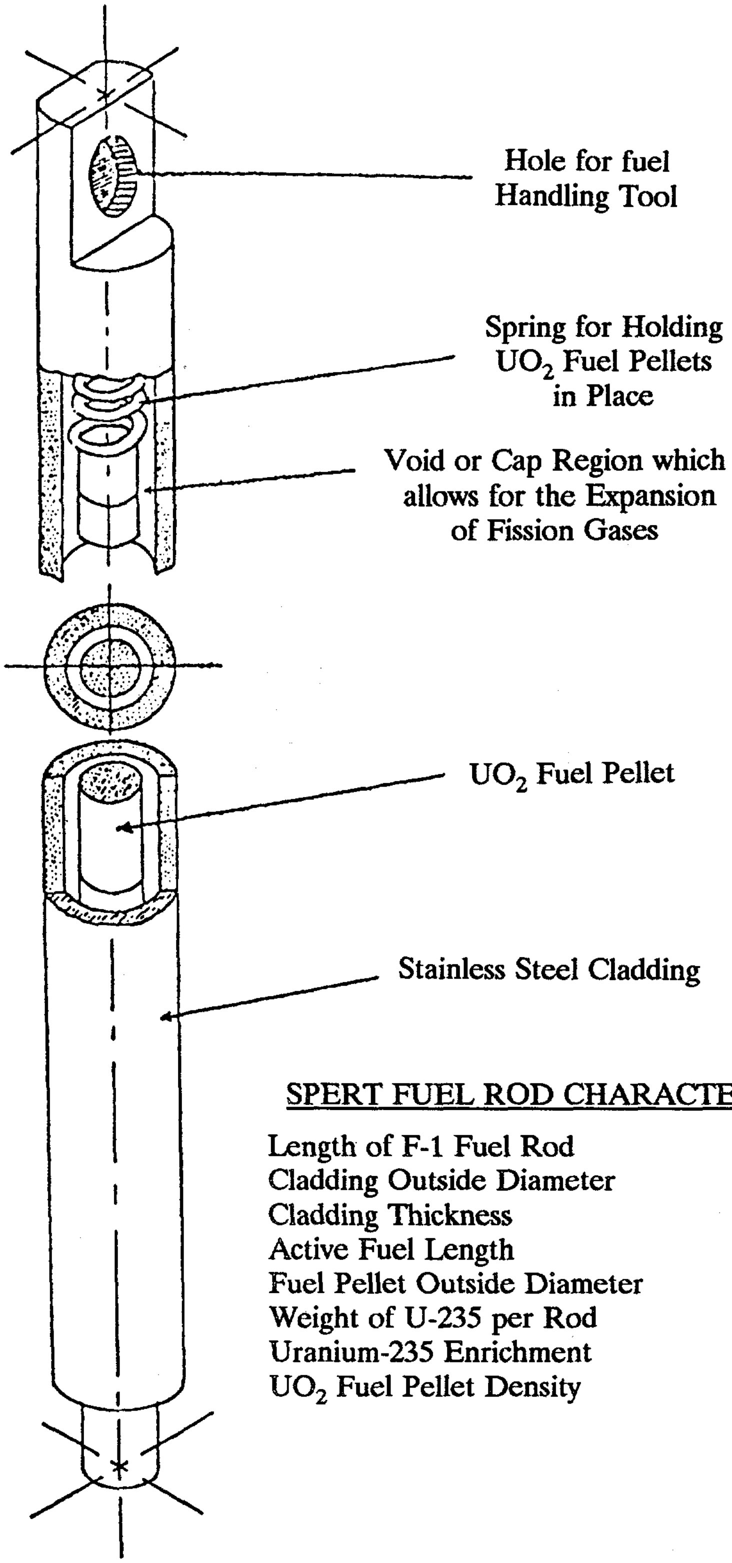


Figure 5. A photograph of a typical sodium-filled, aluminum-walled cylindrical vessel used in SM-3.



SPERT FUEL ROD CHARACTERISTICS

Length of F-1 Fuel Rod	106.05 cm
Cladding Outside Diameter	1.184 cm
Cladding Thickness	0.051 cm
Active Fuel Length	91.44 cm
Fuel Pellet Outside Diameter	1.067 cm
Weight of U-235 per Rod	35.2 gm
Uranium-235 Enrichment	4.81 wt%
UO_2 Fuel Pellet Density	10.08 g/cc

Figure 6. Isometric of the SPERT fuel rod containing Uranium-Dioxide fuel pellets.

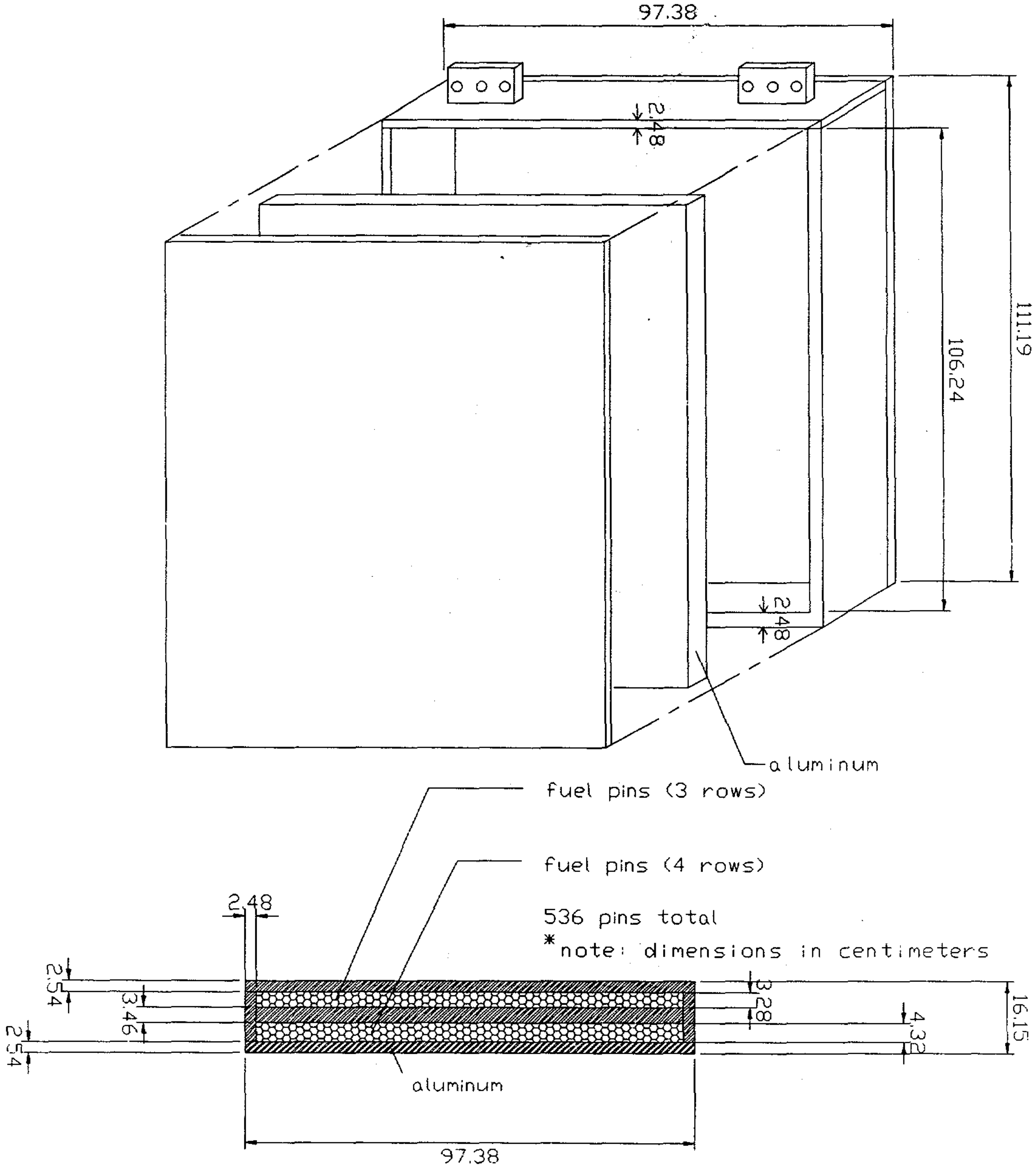


Figure 7. Schematic of Homogeneous IVFS Mockup (Slab #3).

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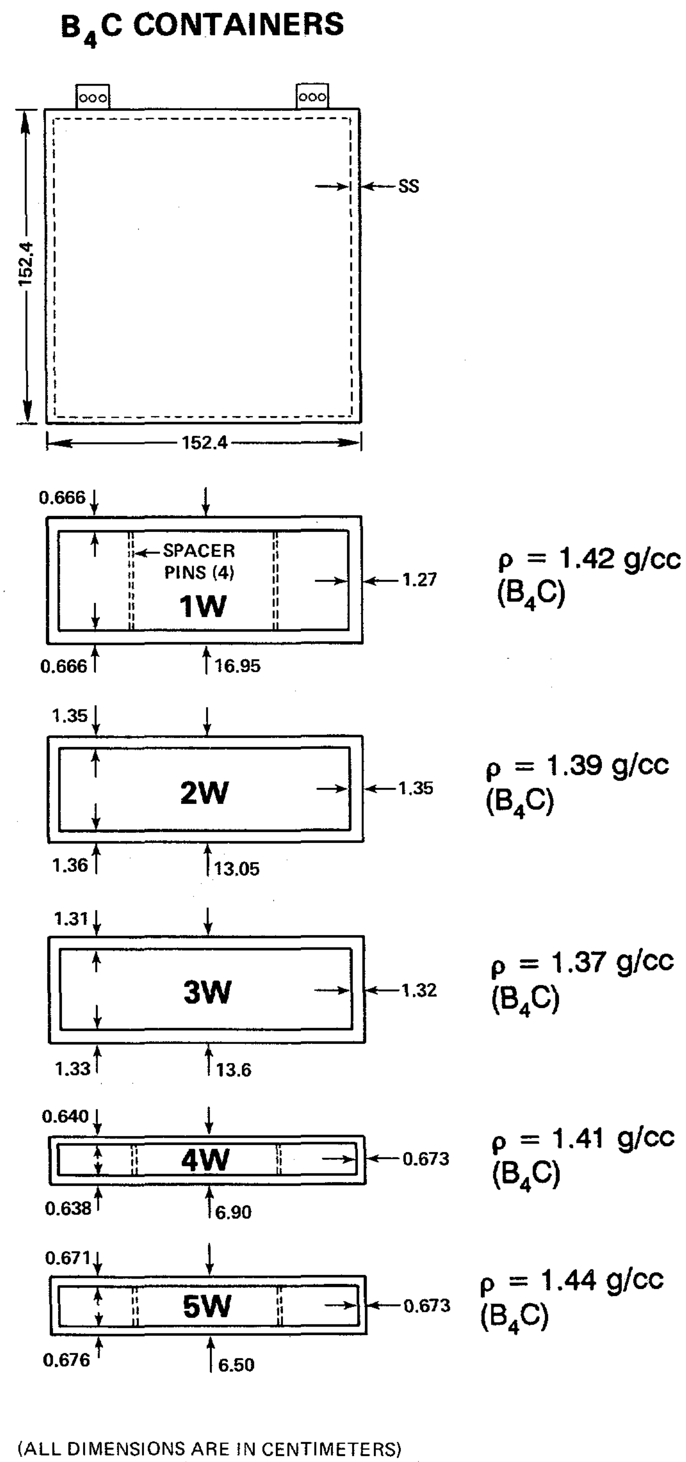

Figure 8. Schematic of stainless steel containers used for boron-carbide-filled shield slabs.

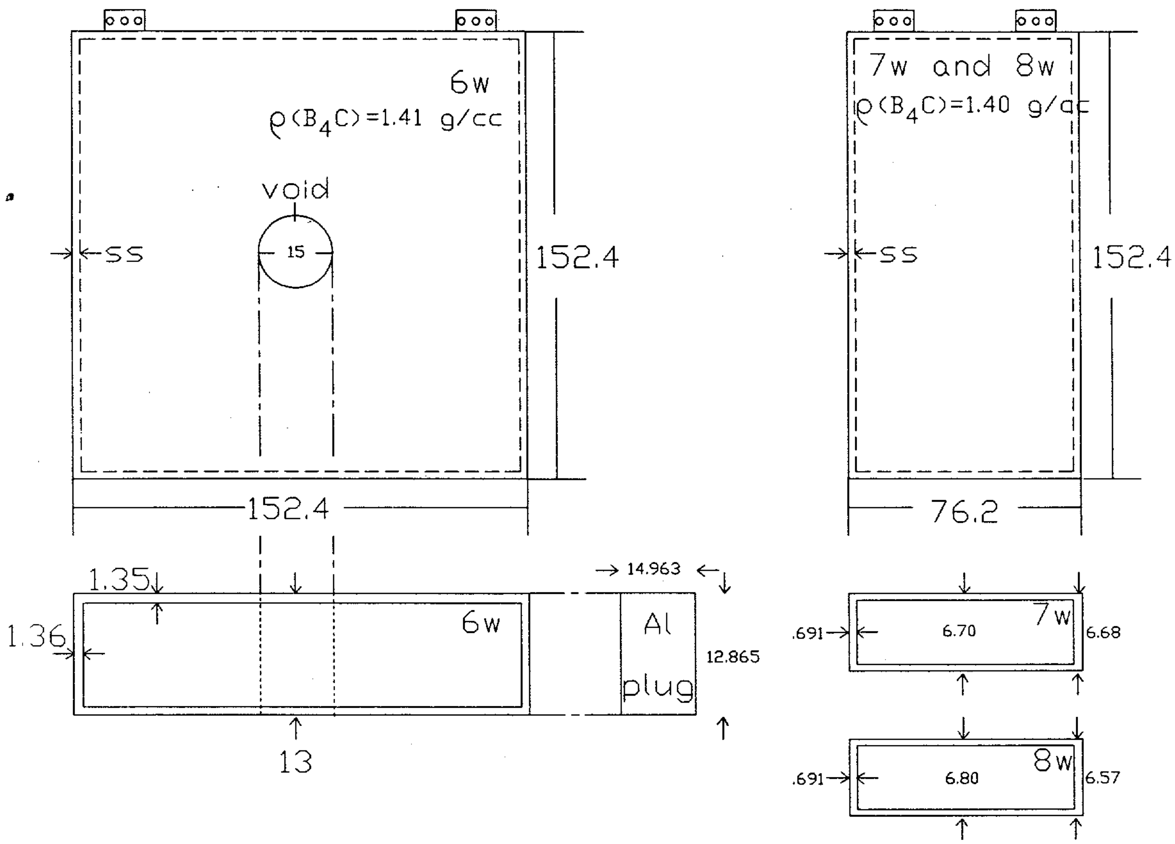

Figure 9. Schematic of stainless steel containers used for boron-carbide-filled shield slabs.

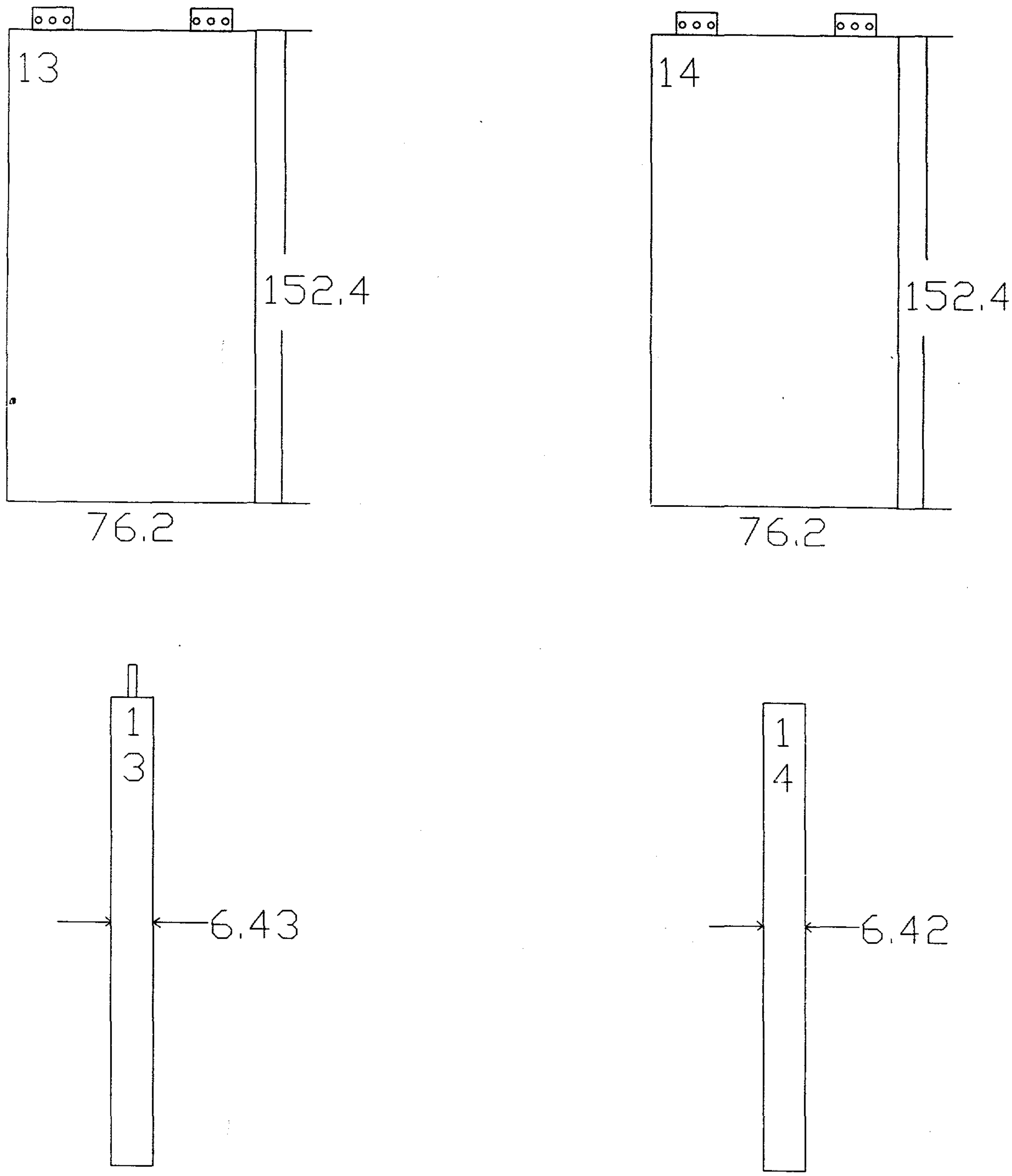

Figure 10. Schematic of aluminum slabs (dimensions in cm).

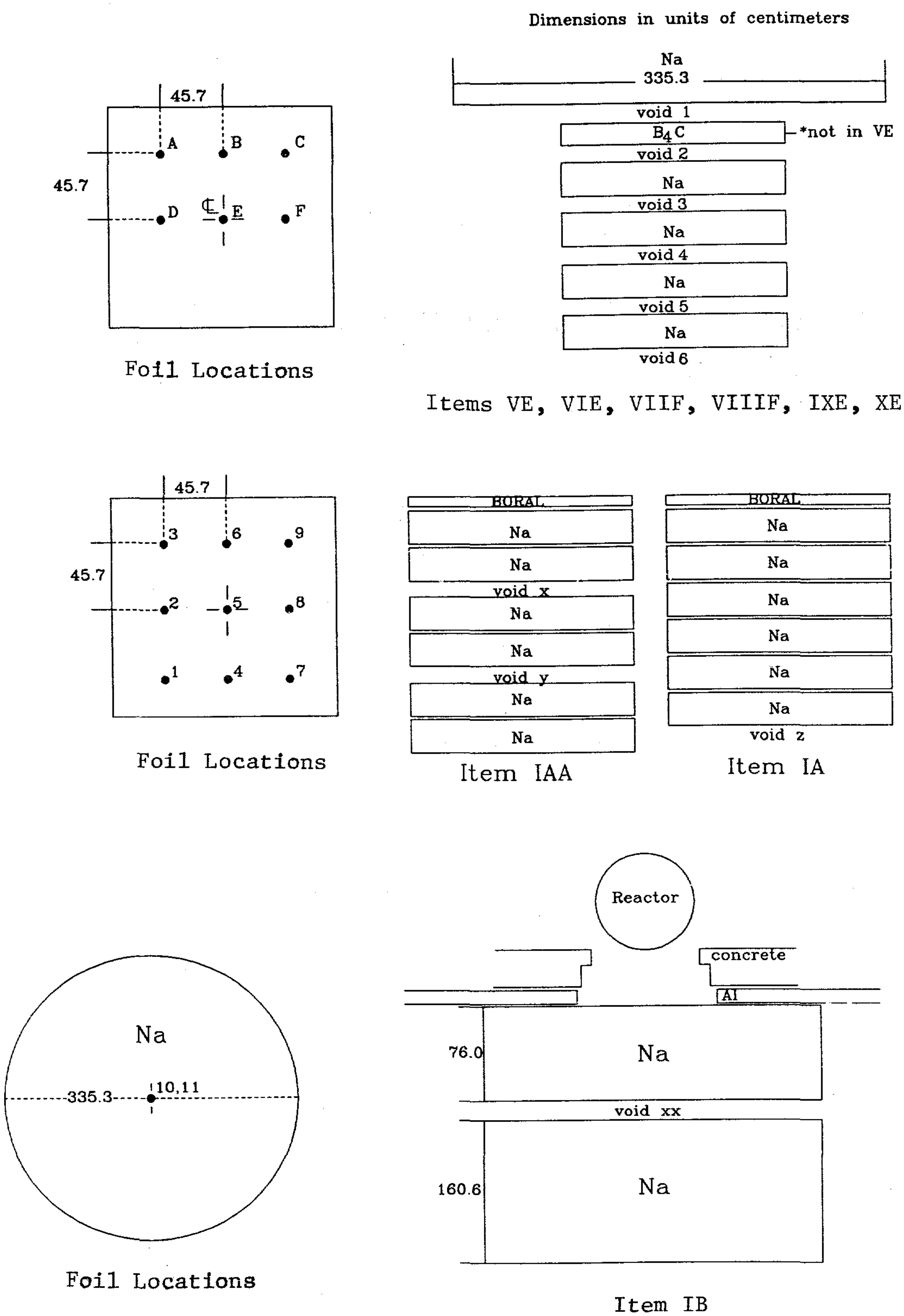

Figure 11. Schematic of sodium foil locations within mockups. Items IA, IAA, IB, VE, VIE, VIIF, VIIIF, IXE, XE.

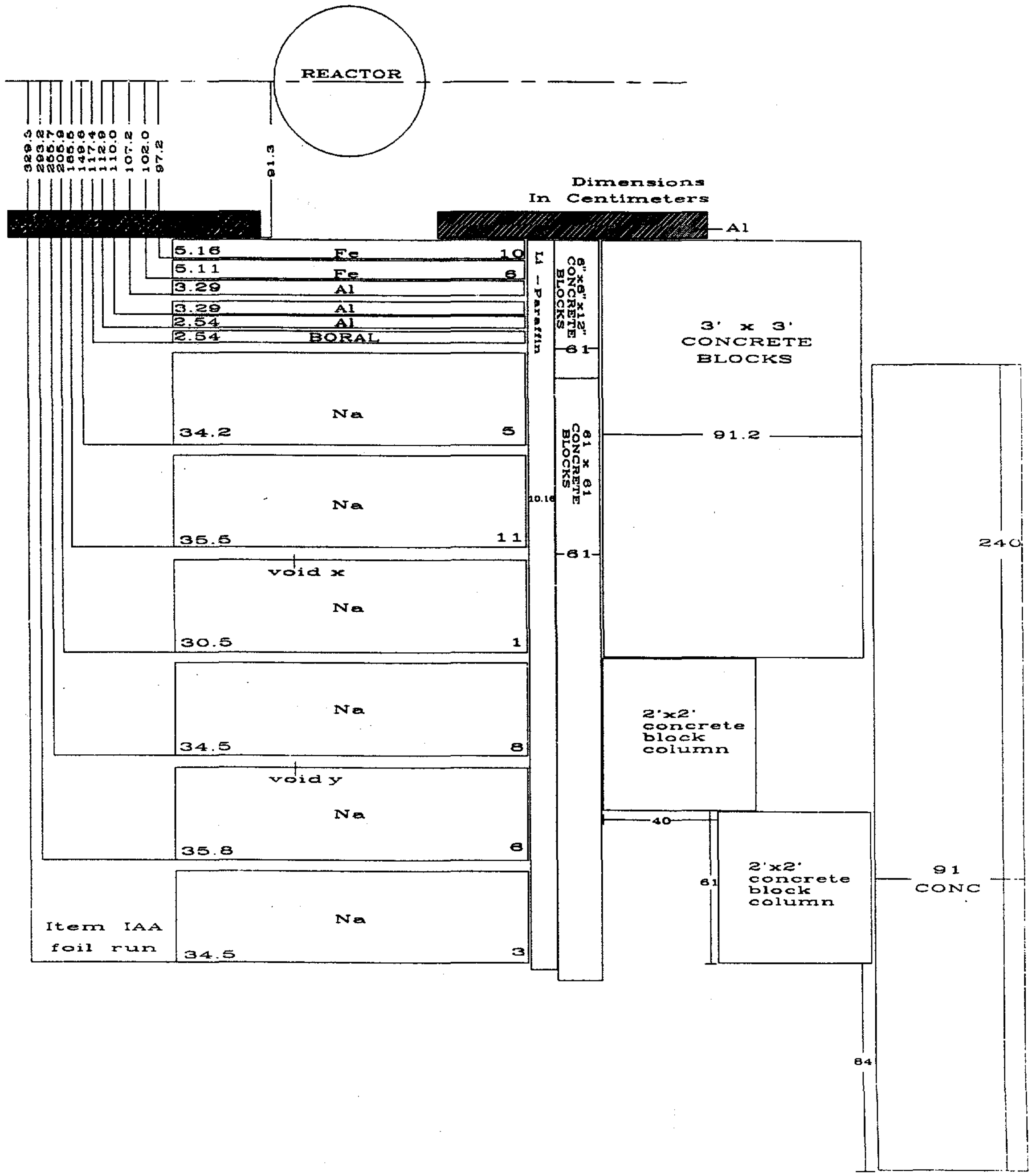

Figure 12. Schematic of SM-2 (iron + aluminum + boral + sodium) for foil run. Item IAA.

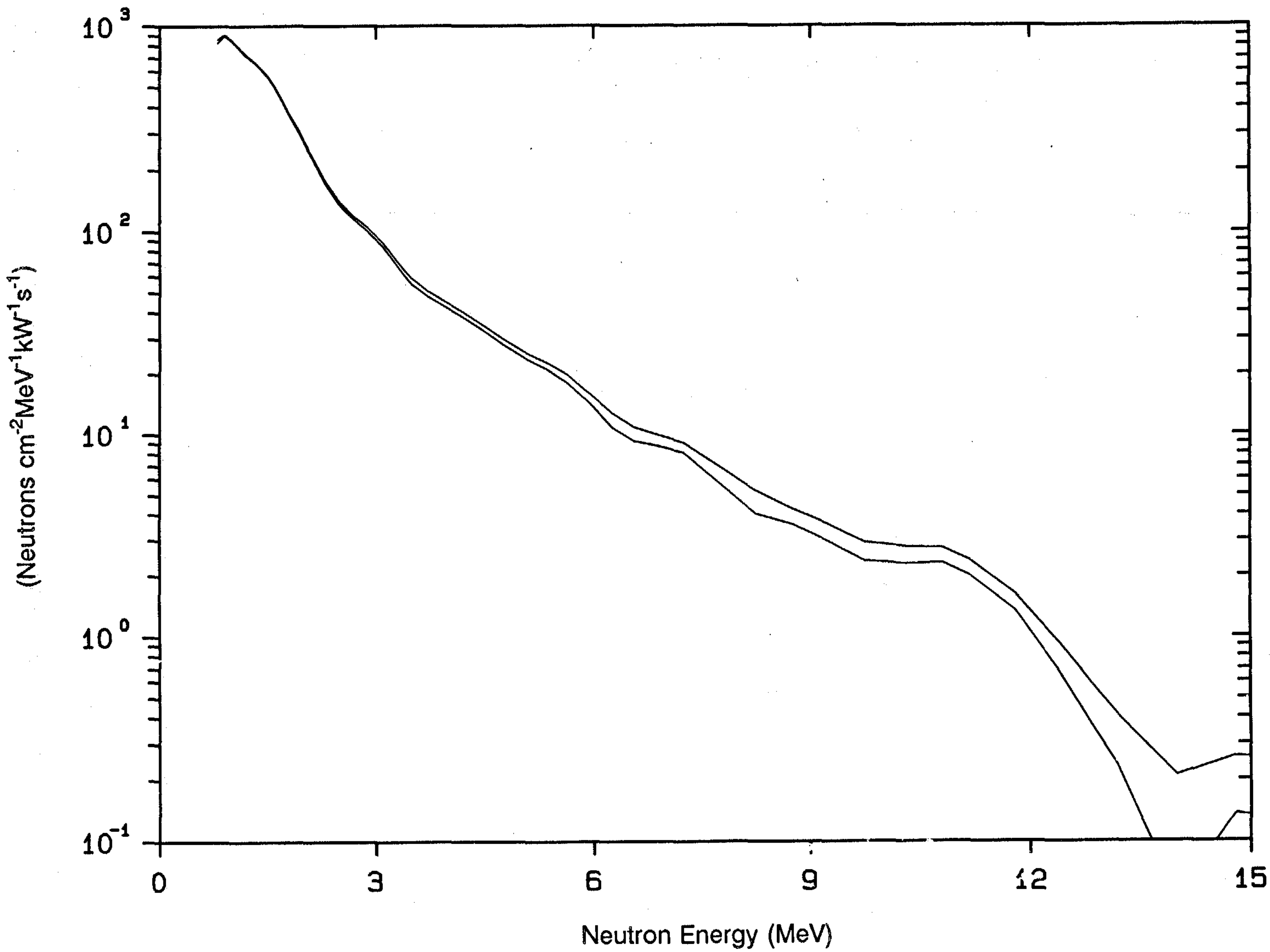

Figure 13. Spectrum of high-energy neutrons (>0.8 MeV) on centerline at 25 cm behind the lead slab (Item IB) Run 7923A.

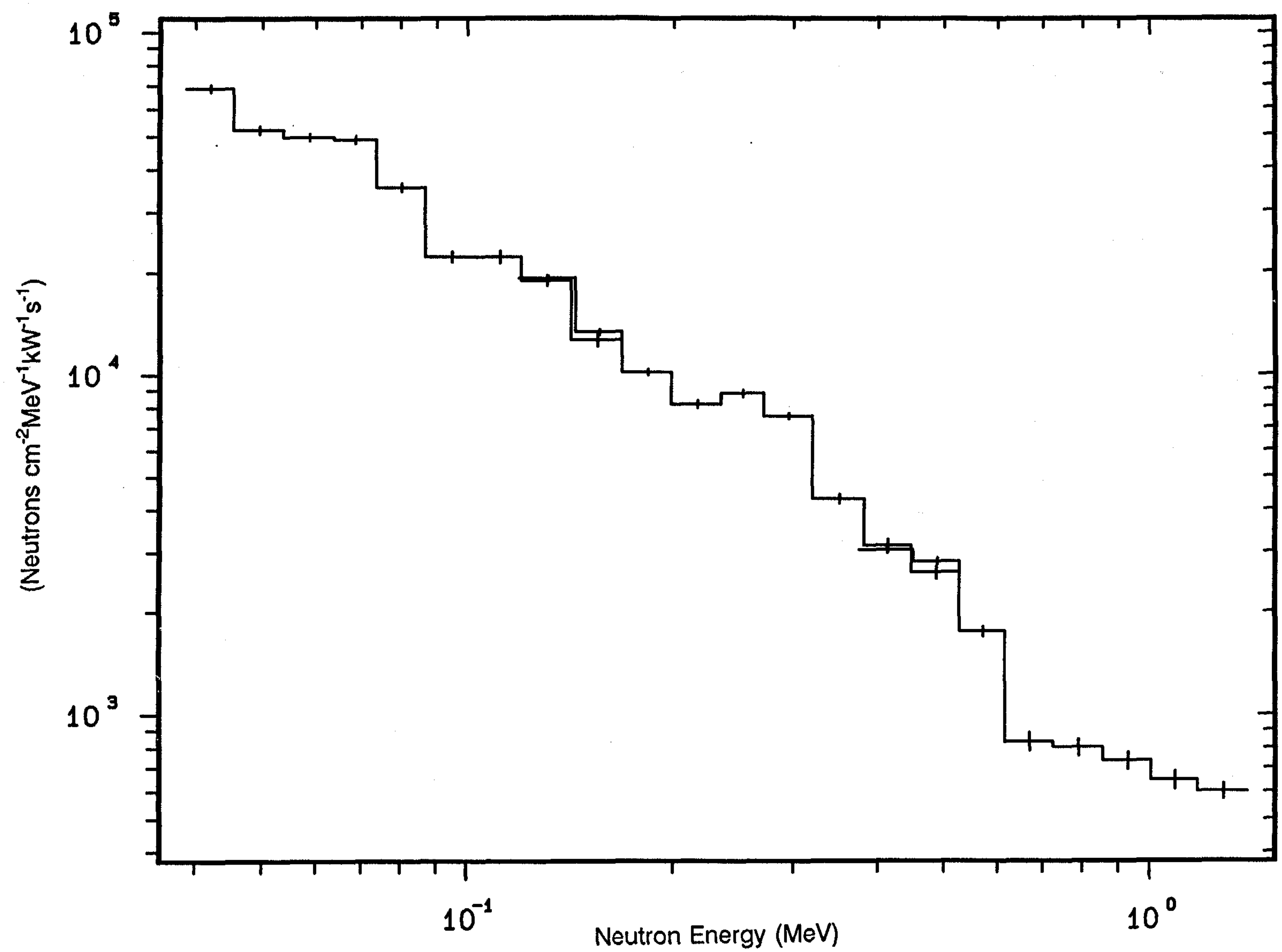

Figure 14. Neutron spectrum (50 keV to 1.4 MeV) on centerline at 25 cm behind the lead slabs (Item IB) Runs 1593C, 1593A, 1593B.

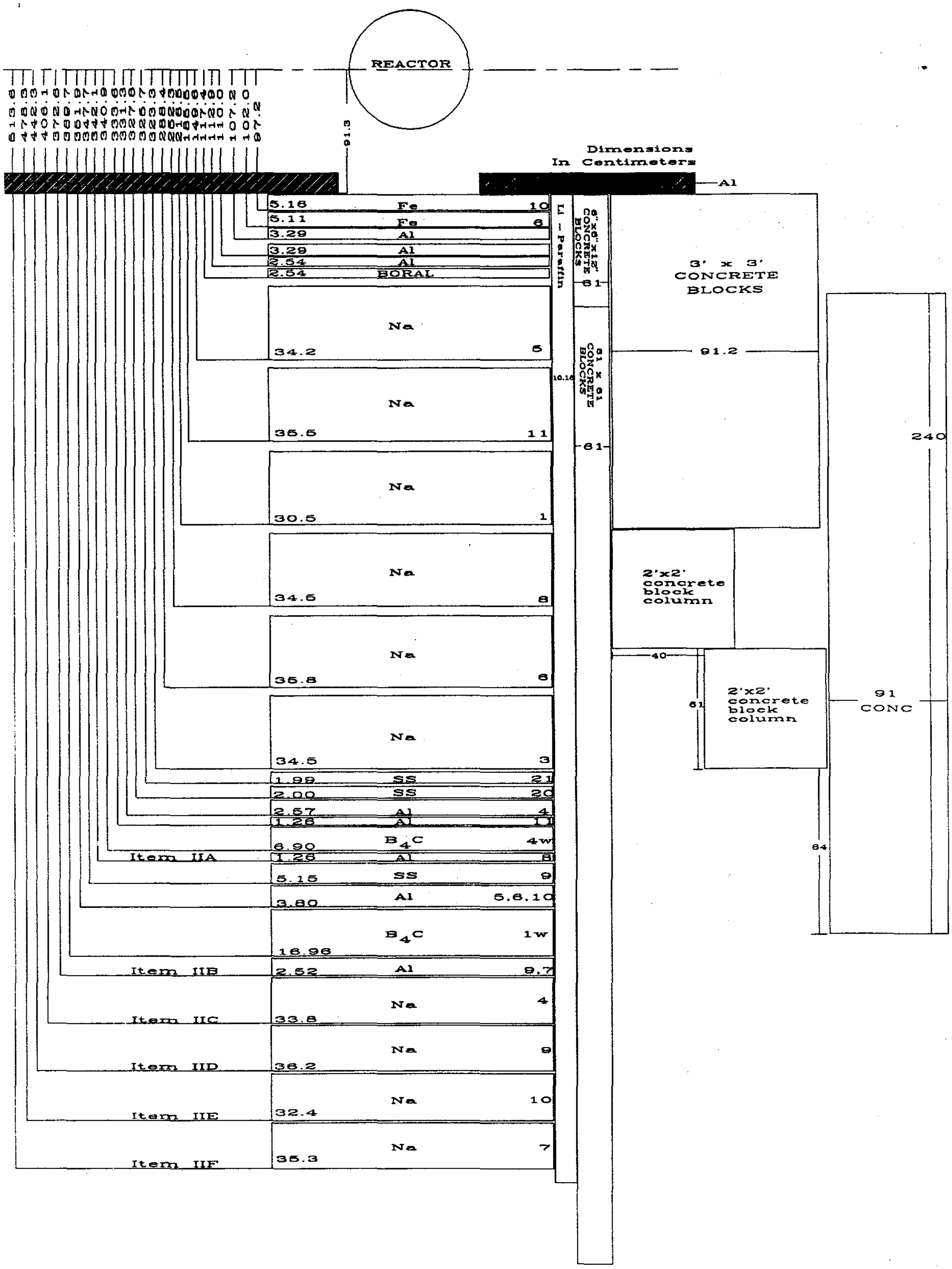

Figure 15. Schematic of SM-2 plus shield configurations for Item II.

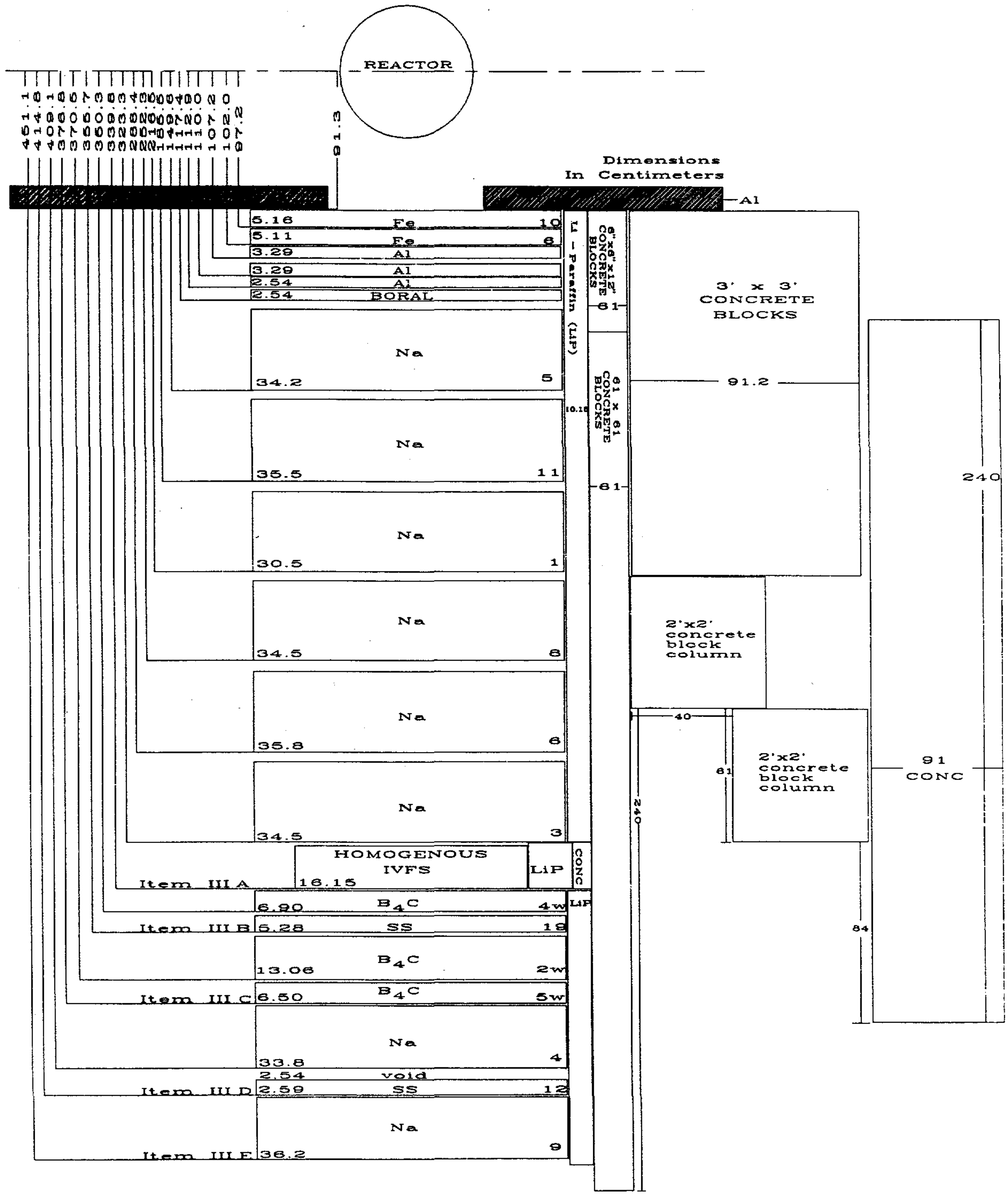

Figure 16. Schematic of SM-2 plus shield configurations for Item III.

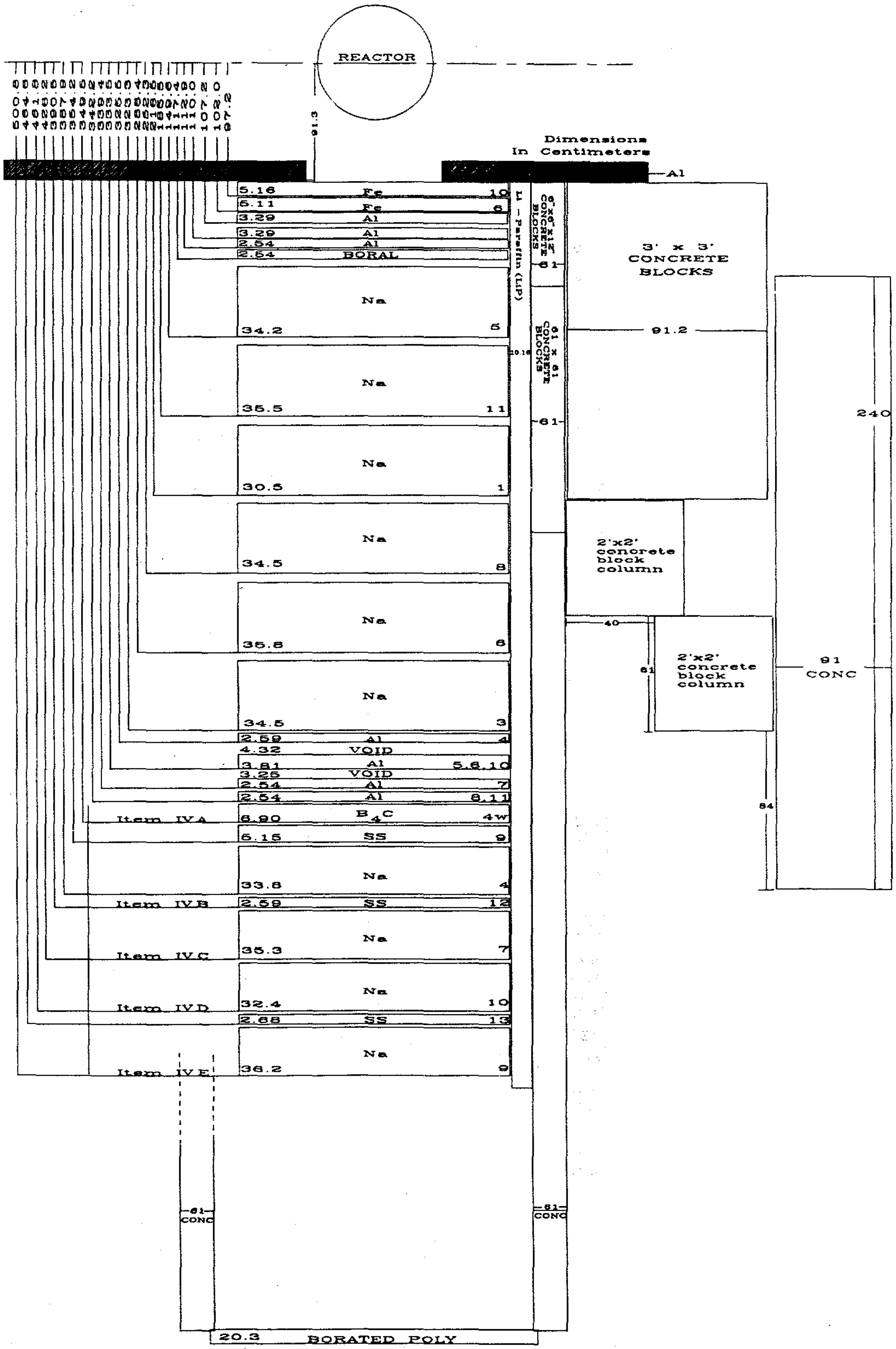

Figure 17. Schematic of SM-2 plus shield configurations for Item IV.

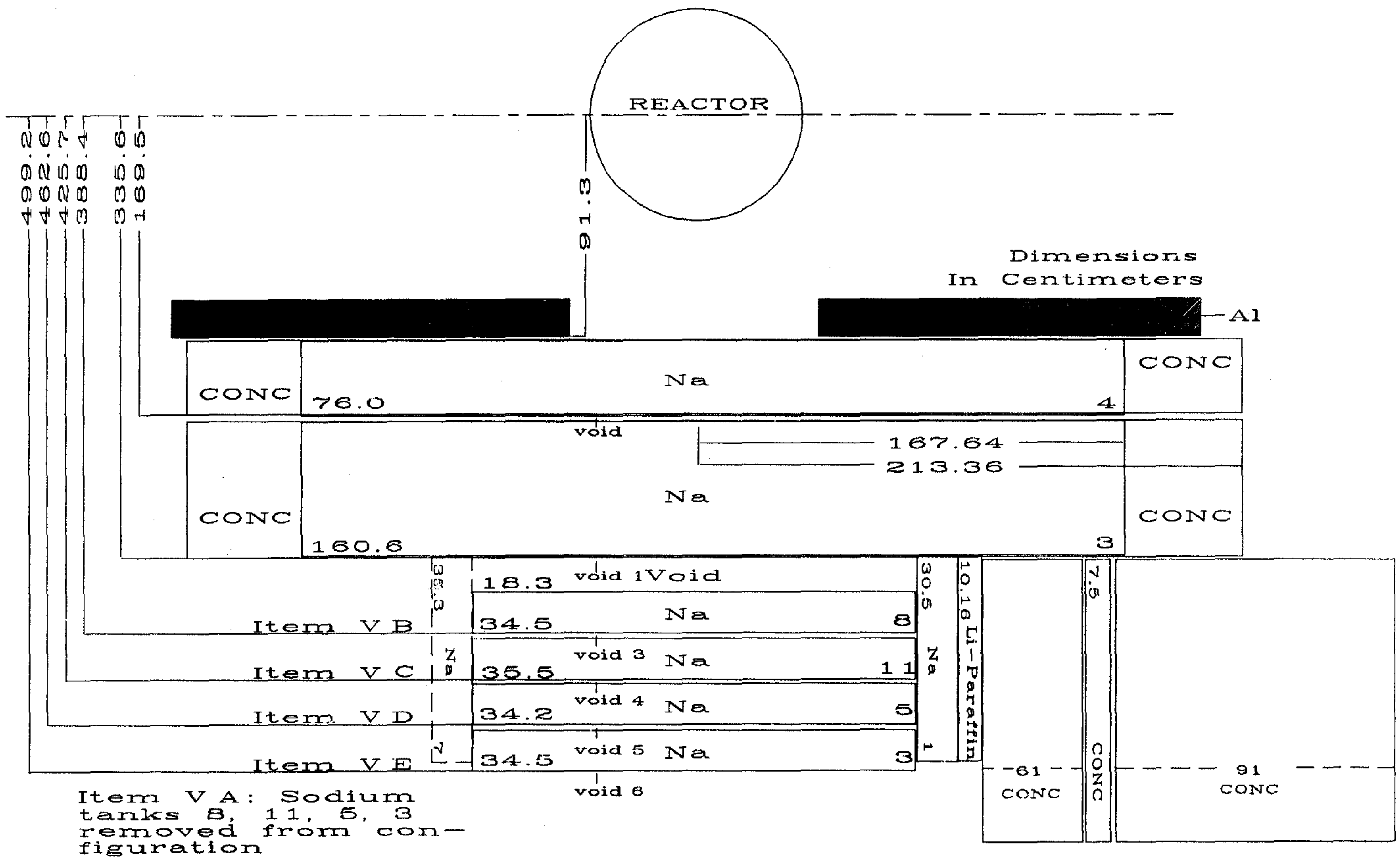

Figure 18. Schematic of SM-3 plus shield configurations for Item V.

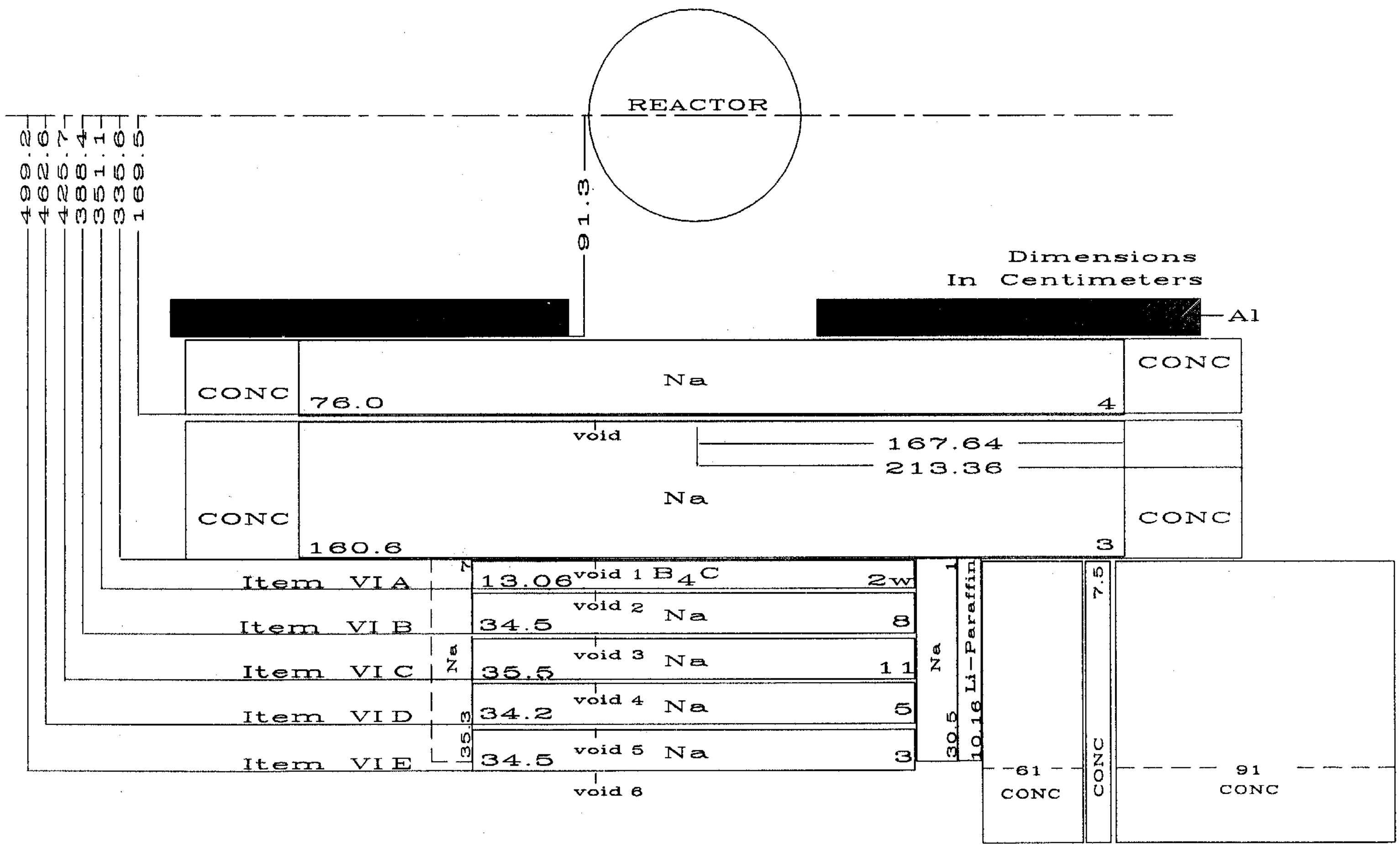

Figure 19. Schematic of SM-3 plus shield configurations for Item VI.

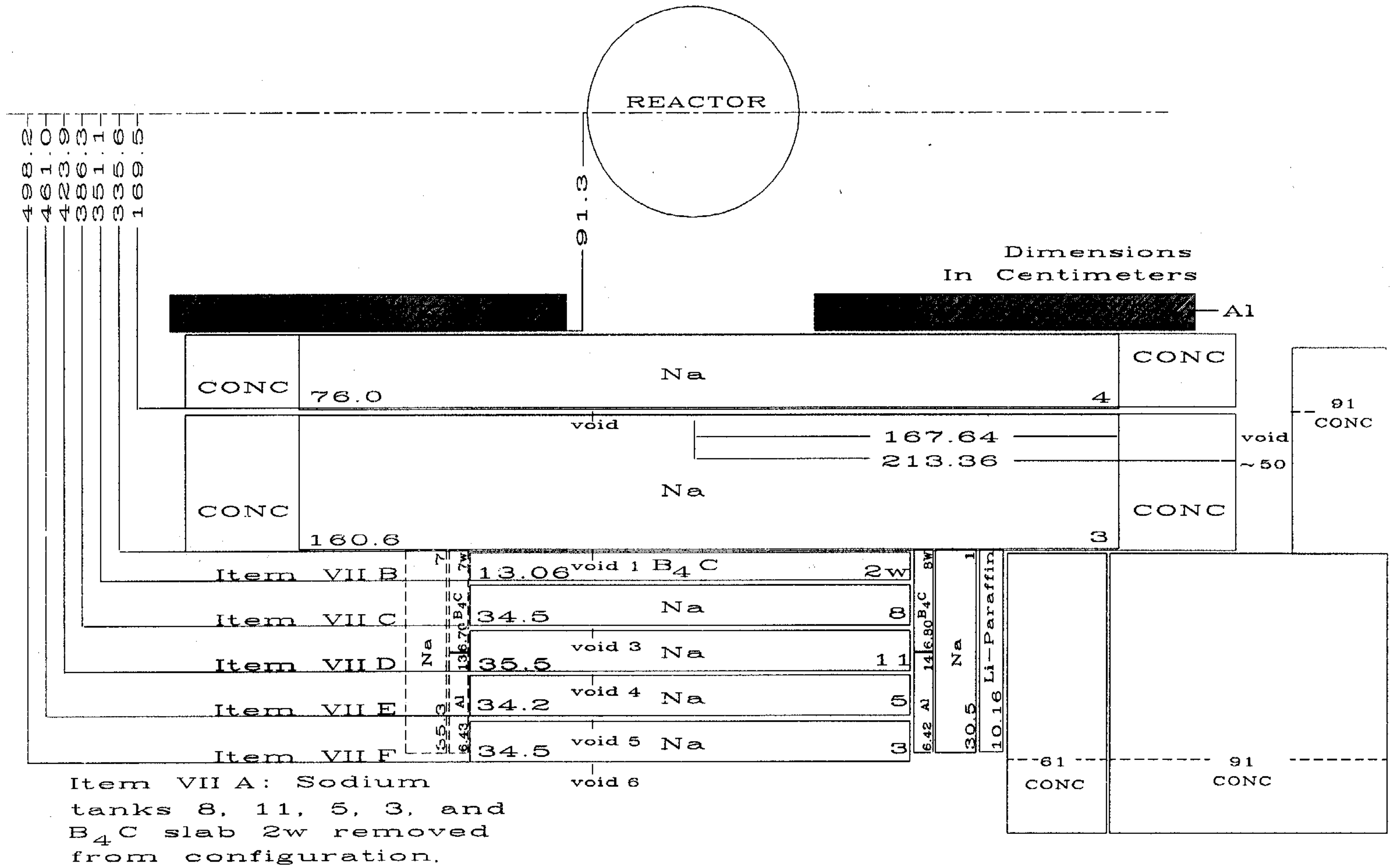

Figure 20. Schematic of SM-3 plus shield configurations for Item VII.

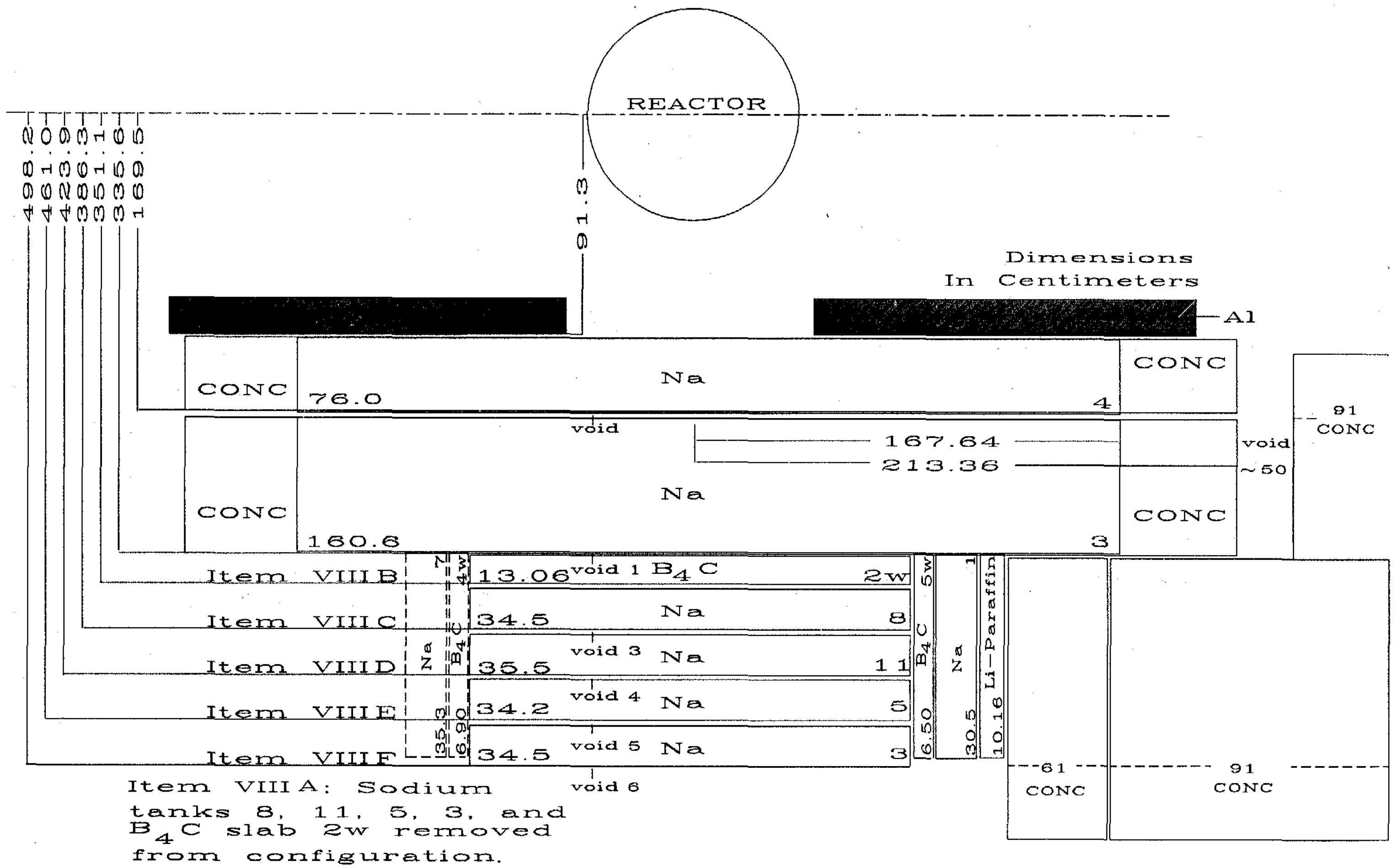

Figure 21. Schematic of SM-3 plus shield configurations for Item VIII.

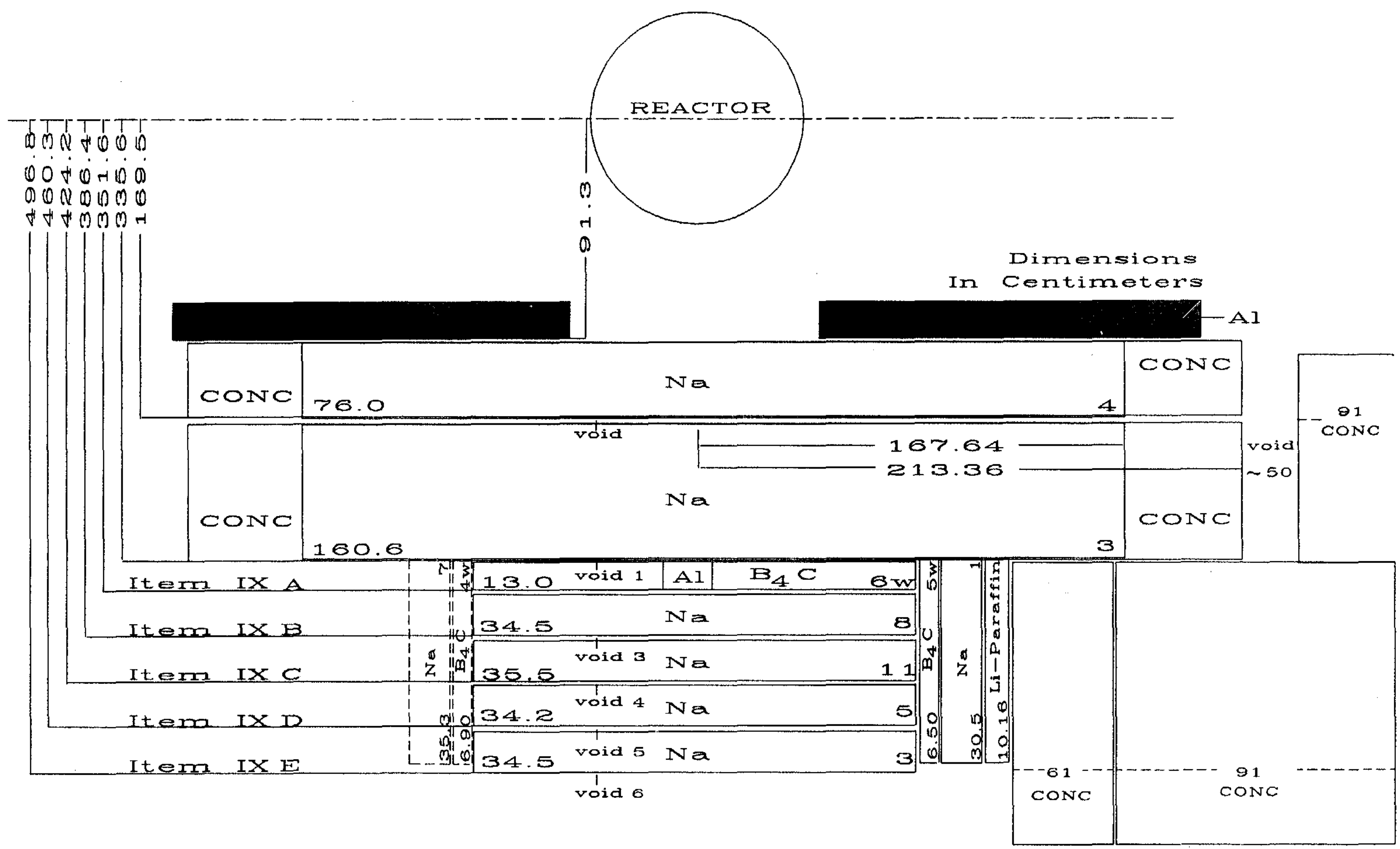

Figure 22. Schematic of SM-3 plus shield configurations for Item IX.

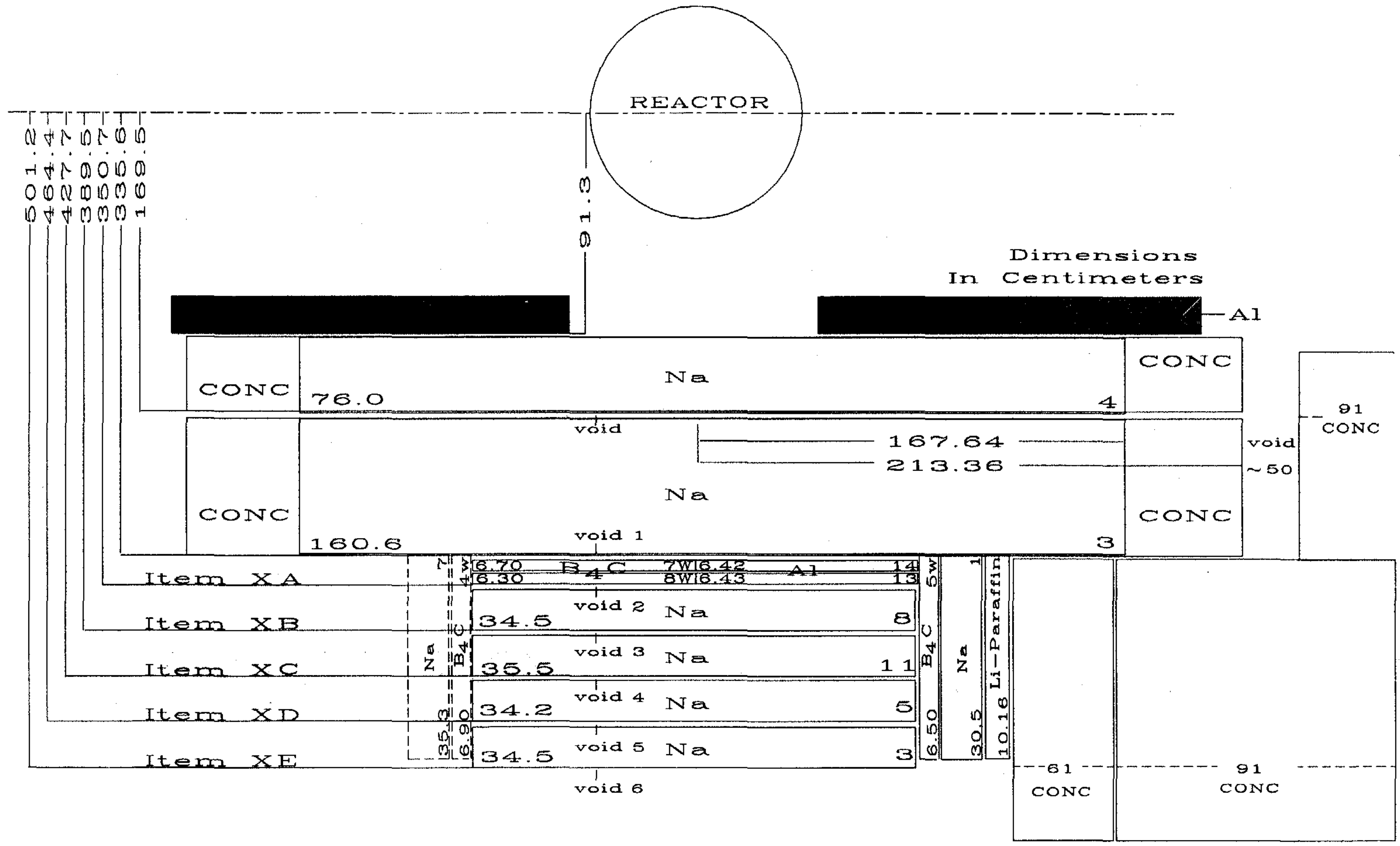

Figure 23. Schematic of SM-3 plus shield configurations for Item X.

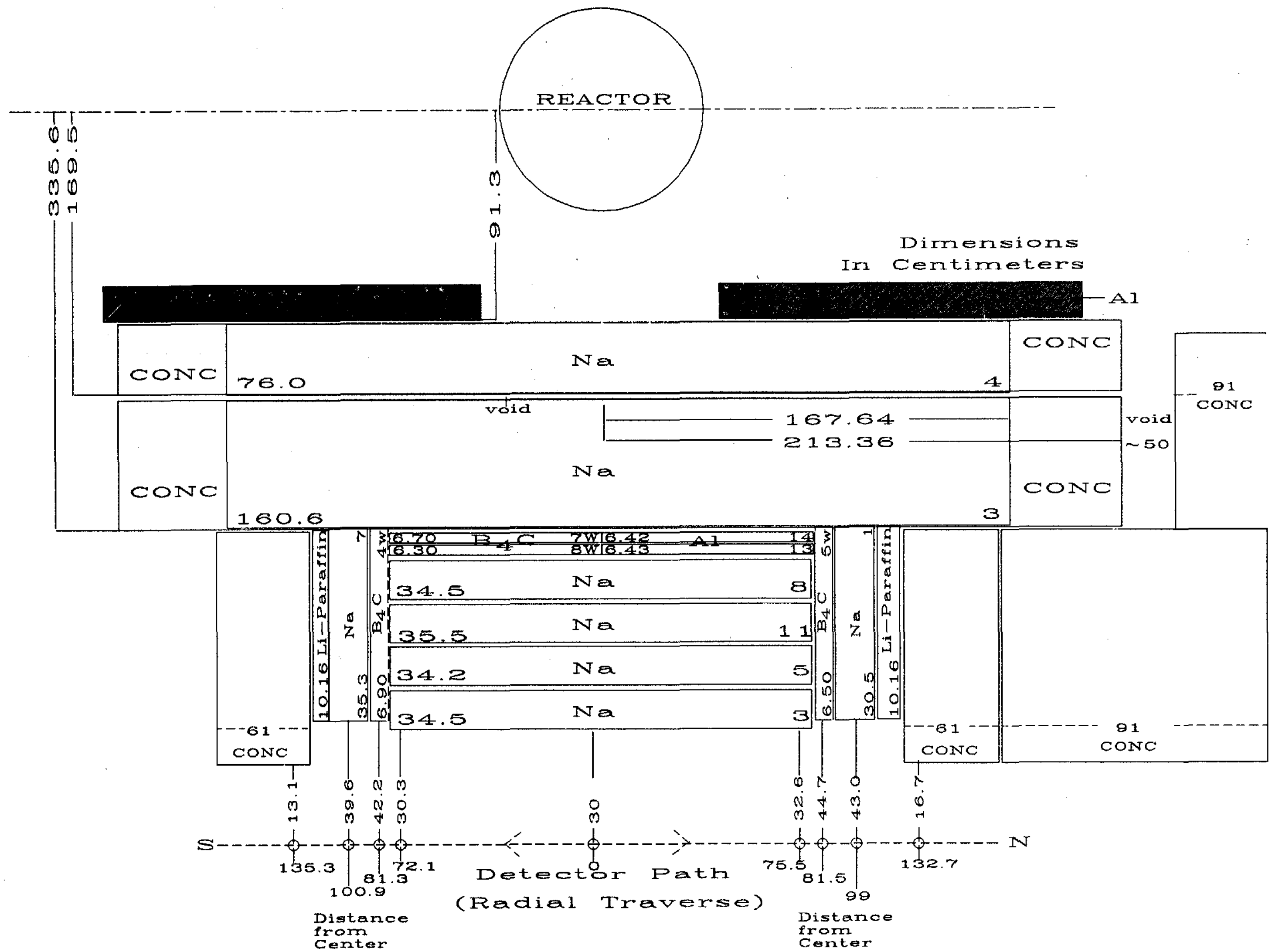

Figure 24. Schematic of SM-3 plus shield configuration for radial traverses beyond mockup in Item X.

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