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OAK RIDGE Y-12 PLANT

MARTIN MARIETTA

MONTE CARLO STUDY OF NEUTRONICS PROPERTIES OF THE MODULAR STORAGE GEOMETRY

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Table of Contents

Executive Summary	1
Introduction	1
MSV Geometry	2
MCNP Input File	5
Results	8
Aluminum v. ZAMAK	9
Effect of Detectors	10
ZAMAK3 v. ZAMAK5	10
Center of MSV v. Edge	10
Conclusions	11
Appendix A - MCNP Input Files	12
Z300M2.INP	12
Z3G00M2.INP	15
APPENDIX B - Neutron Point Spread Functions	20
AL00M2	20
ALG00M2	29
Z300M2	38
Z3G00M2	47
Z3GND00M2	56
Z3ND00M2	65
Z3000	74
Z5G00M2	80

Monte Carlo Study of Neutronics Properties of the Modular Storage Vault Geometry
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Executive Summary

The modular storage vault (MSV) geometry was investigated for its effects on the spectrum of neutrons from the spontaneous and induced fission of plutonium. Zinc alloy and aluminum alloy plates that will house neutron detectors and weight sensors were included. It was found that because of the large number of captures by plutonium, and the steel and concrete MSV structure, only 12% of the neutron spectrum in the vicinity of the detector position was thermalized and over half of the neutrons incident on the detector position have energy in excess of 100 keV. Based on this, it is recommended that both fast and slow neutron detectors be included in the instrumentation package if plutonium is to be stored in an MSV structure. No differences in the neutron spectra were found with different zinc alloys. In addition, insufficient differences in the spectra were found when aluminum was substituted for zinc to warrant any recommendation for one material over the other.

Introduction

Modular storage vaults are presently under evaluation as a storage environment for enriched uranium. However, it also may be possible to use them for the storage of plutonium. Since this material is a natural neutron emitter (by spontaneous fission) and fissile, it will be useful to have neutron sensors in the suite of instrumentation to be included in the storage cells. Therefore, it was necessary to ascertain the effects of geometry and construction materials on the neutron spectrum at the proposed sensor locations.

The Monte Carlo code MCNP (produced at Los Alamos National Laboratory) was used to simulate neutron transport through the MSV geometry. Engineering drawings for the concrete structures were consulted for dimensions and materials, and an actual structure was inspected to ensure the accuracy of the modeling. The geometry of the metal plates to be used to hold the neutron detector and weight sensor was similarly obtained from engineering drawings.

Spectra were calculated for plutonium, both as a bare metal sphere and a cast-in-graphite cylindrical annulus, placed in a concrete and steel rectangular array 4 by 5, horizontally, by 5 layers high. Zinc alloy and aluminum alloy plates, having slots for the detectors, were placed under the plutonium. Transport through the matrix included the effects of induced fission, capture, (n, xn) reactions, and elastic and inelastic scattering in all materials. In those simulations where graphite was present, the MCNP thermal neutron treatment of that material was used.

Neutrons were tallied as they crossed into the detector position and were sorted by energy and direction (inbound or outbound) of travel. Energies were tallied by decades by MCNP from 0.01 eV to 20 MeV. For analysis, however, tallies were organized as thermal neutrons ($E_n \leq$

1 eV), intermediate energy neutrons ($1 \text{ eV} < E_n \leq 100 \text{ keV}$), and fast neutrons ($100 \text{ keV} < E_n \leq 20 \text{ MeV}$). Tallies were recorded in a 3 by 3 by 3 set of cells surrounding and including a single cell of the array containing a fission source to determine the extent of "cross-talk" between cells. Source cells were placed at the top of the array and close to the center of the array.

In the remaining sections, detailed descriptions of the geometry of the array, and tallies are given. A discussion of the tallies and recommendations for detectors are also given. The MCNP input files as well as processed data from the output files are found in the appendices. The entire set of output files are available, on request, on a set of 3½ inch floppy disks.

MSV Geometry

Figures 1 and 2 show the layout of the MSV cells for the two arrangements of plutonium that were run. The basic MSV structure is a stack of 5 poured concrete slabs each containing a 4 by 5 array of cells for the storage of fissile material, with the entire stack being capped with 8 inches of concrete. Each cell was 20 inches high by 21 inches long by 14.5 inches wide. Centered in the top 21 by 14.5 inch face of the cell was a 11.75 inch long, 8 inch inner diameter, 8.25 inch outer diameter steel pipe. Underneath the pipe and covering its lower end, was a plexiglas plate, 0.25 inch thick, 8.25 inches in diameter. Inside the pipe, in direct contact with the plexiglas, was an alloy plate, 7.5 inches in diameter by 0.97 inch high, containing an L-shaped channel to accommodate a neutron detector and its wiring. Note that the cell boundaries lie outside the figures but within the concrete surrounding the pipe and plexiglas. Calculations were performed for zinc alloys ZAMAK3 and ZAMAK5, and aluminum alloy 360. The entire structure contained 100 cells.

Simulations were run with plutonium in each cell first as a 4 kg bare metal sphere (Figure 1), 7.26 cm in diameter, and then as 4 kg of metal cast in an annular graphite crucible (Figure 2). The crucible was 15.52 cm high and 7.76 cm in diameter. The plutonium annulus was 13.2 cm high with an internal diameter of 1.56 cm and outside diameter of 4.66 cm. No supporting structures were included for either the plutonium sphere or the annulus.

Reinforcing steel bars embedded within the concrete and wiring in the channels in the top and bottom surfaces of the slabs were neglected. In addition, the air space of the wiring channels themselves was also neglected. The effects of none of these were expected to be significant compared to the other materials in the MSV structure.

A right-handed coordinate system was imposed on the arrays as follows: The height of the array was 108 inches, being composed of 5 layers of 20 inches each, capped by 8 inches of concrete. The layers were numbered from $Z = 0$ (topmost layer just below the 8 inch thick cap) to $Z = -4$ (lowermost layer). Each layer was 84 inches (4×21 inches) by 78 inches (5×14.5 inches). The X-axis was along the 84 inch length and the four cells were numbered from $X = -1$ (with outside surface at coordinate value -42 inches) to $X = +2$ (with outside surface at coordinate value +42 inches). The Y-axis was along the 78 inch dimension with the cells numbered $Y = -2$ to $Y = +2$.

The coordinate value of 0 was in the center of the $Y = 0$ cell. The numbering and dimensions are shown in Figure 3.

Figure 1. Plutonium sphere geometry.

Figure 2. Plutonium in graphite crucible geometry.

Figure 3. Coordinates and numbering scheme (concrete cap not shown).

MCNP Input File

Calculations were carried out for the combinations of mounting plates, source position, detector, and shape shown in Table 1. The column labeled Source Position indicates the cell (see figure 3, above) in which the source was located. The 0,0,0 position is in the topmost layer, while 0,0,-2 is directly below in the middle layer.

A representative MCNP input file for both types of source shapes is given in Appendix A. The MSV geometries was generated as an MCNP universe defining the 84 by 74 by 108 inch concrete structure filled by a lattice of cells of the types shown in either Figures 1 or 2. Each cell was constructed so that the steel pipe terminated at the top of the cell and there were 8 inches of concrete between the bottom of the plexiglas and the bottom of the cell. The lattice was positioned so that the top of the top row of cells (the $Z = 0$ row in Figure 3) was 8 inches below the top of the concrete. Thus, the 8 inch concrete cap was, for the purposes of MCNP, the lower 8 inches of concrete of a row $Z = 1$ (not shown in Figure 3).

Table 1. List of Calculations

Data Set	Al / ZAMAK	Source Position	Shape	Detector
AL00M2	360 Al	0,0,-2	Sphere	Yes
ALG00M2	360 Al	0,0,-2	Annulus	Yes
Z3000	ZAMAK3	0,0,0	Sphere	Yes
Z300M2	ZAMAK3	0,0,-2	Sphere	Yes
Z3G00M2	ZAMAK3	0,0,-2	Annulus	Yes
Z3ND00M2	ZAMAK3	0,0,-2	Sphere	No
Z3GND00M2	ZAMAK3	0,0,-2	Annulus	No
Z5G00M2	ZAMAK5	0,0,-2	Annulus	Yes

The tally specifications reflect the lattice nature of the geometry. Tallies were accumulated for neutrons crossing the top and bottom surfaces of the detectors. The sides were ignored because they were only 1 mm thick. Neutrons were characterized as incoming if they crossed the top surface while heading in the -Z direction or if they crossed the bottom surface while heading in the +Z direction. They were characterized as outgoing in the other two cases.

The tally specification for the lower surface is complicated by the fact that that surface is common to more than one structure. Consequently, it was necessary to break up that tally into segments, defined by the vertical sides of the detector, that divided the surface into segments outside the detector and a single segment inside the detector boundaries.

Neutron histories were calculated for the source of neutrons placed in cell 0,0,0 (X, Y, Z) or in cell 0,0,-2. These were considered to be "representative" positions within the lattice at which a source's influence would be felt the most. Since the main purpose of placing a neutron detector under a mass of plutonium is to verify the presence of that mass, it is important to know how many neutrons that start out in at the source induce events at nearby detectors. If this number is large, then it is possible for the direct signal, due to the plutonium in the cell with the detector, to be overwhelmed by leakage neutrons (including induced fission events) from other cells.

The source was taken to be uniformly distributed within a 4 kg sphere or annulus of plutonium. The annulus was contained in a graphite crucible, while the sphere was bare. Although only a single source was used in all problems, induced fissions augmented the number of neutrons significantly. The source spectrum was taken to be a Watt fission spectrum with the parameters as suggested by the MCNP manual, Appendix H.

Each cell of the MSV was constructed of concrete. In the absence of a chemical analysis of the actual material used, and the fact that the very nature of concrete makes its composition extremely variable, the "Los Alamos" formulation from the MCNP manual was used.

The composition of the steel pipe was taken as that of cold rolled steel as found in the CRC Handbook of Chemistry and Physics. The formulation of the plexiglas plate was taken from the Johnson Matthey Alfa Aesar chemicals catalog. The composition of 360 aluminum was found in the Reynolds Metals Aluminum Data Book, Table 14. The composition of the ZAMAK plates was supplied by Cambridge Tool and Manufacturing Company, a manufacturer of die-cast aluminum and zinc parts. Both ZAMAK 3 and ZAMAK 5 were run because both materials were contemplated for use in mounting the detectors. The ZAMAK and aluminum compositions are shown in Table 2.

The detector in each cell was modeled as a 1 mm thick plate containing a uniform mixture of 75%, by weight, ZnS(1% Ag) and 25%, by weight, ^6LiF . This is an approximation to an actual thermal neutron detector whose use in a plutonium-loaded MSV is contemplated. Because ^6Li is a strong neutron absorber, computations were performed both with and without the detectors to determine the effect, if any, of the detectors themselves on the neutron fluence.

Table 2. Elemental Composition of Alloy Plates

	ZAMAK 3	ZAMAK 5	360 ALUMINUM
Mg	0.00035	0.00045	0.006
Al	0.039	0.039	0.871
Si			0.095
Mn			0.003
Fe	0.001	0.001	0.008
Ni			0.005
Cu	0.0025	0.01	0.006
Zn	0.95703	0.94943	0.005
Cd	0.00004	0.00004	
Sn	0.00003	0.00003	0.001
Pb	0.00005	0.00005	

Results

Although MCNP was programmed to bin neutrons incident on the detector position by energy by decades from 0.1 eV to 20 MeV, for ease of analysis the neutrons were rebinned as thermals, $E_n \leq 1$ eV, intermediate energy neutrons, $1 \text{ eV} < E_n \leq 100 \text{ keV}$, and fast neutrons $100 \text{ keV} < E_n \leq 20 \text{ MeV}$. The detector, as modeled in this calculation, was found to be nearly 100% efficient for the capture of thermal neutrons, and nearly 100% inefficient for fast neutrons. This, of course, is a not unexpected consequence of the properties of the ^6Li in the detector.

In general, it was found that for each source neutron launched, approximately 0.16 neutrons were incident on the detector position from either above or below. Of these, thermal neutrons accounted for only about 12% of the incident neutrons (0.02 per source neutron). This was true regardless of the shape of the plutonium, the position of the source, the material in the plates, or even of the presence of the detector. Approximately 60% of all incident neutrons were fast. Thus it is obvious that the addition of a fast neutron detector could significantly enhance the signal. Unfortunately, this benefit is somewhat offset by the relatively poor efficiency and probable gamma sensitivity of fast neutron detectors. Alternatively, the addition of a small amount of moderator placed under the thermal detector might enhance the signal by reflecting some non-thermal neutrons back into the detector.

Almost all neutrons were captured in the MSV array, regardless of the position of the source. It was found that concrete accounted for the vast majority of captures, and most of those were in the silicon (0.86 per source neutron) and hydrogen (0.62 per source neutron). (The fractions sum to greater than unity because of multiplication by induced fission neutrons and (n, xn) reactions.) However, significant capture also occurred in calcium, potassium, aluminum, and sodium. In addition, in the plates were used to house the detector, 0.02 captures per source neutron in the case of aluminum, and 0.08 captures per source neutron in the case of ZAMAK (3 or 5) were found. This indicates that whatever detector is placed under the plutonium, it will need to be either insensitive to beta/gamma radiation (both from the plutonium itself and also from the tremendous amount of activation and capture gamma rays) or at least be able to discriminate between neutron events and beta/gamma events.

The probability (per source neutron) of a neutron entering the detector volume for the data sets enumerated in Table 1 can be found in Appendix B in both tabular and graphical form. The rows of the tables correspond to the cell's Y designation while the columns correspond to the cell's X designation. Each table and graph set corresponds to a specific layer in the MSV. The reader should note that the vertical scales, indicating probability, change from graph to graph.

Probabilities were accumulated in the 27 (or 18, in the case of set Z3000) cells in the 3 by 3 by 3 (or 2) cell region surrounding the source for each energy group (fast, intermediate, and thermal). These data sets represent the "point spread function" for the MSV array and the ratio of the probability in the source cell to the sum of the probabilities gives the fraction of the signal that is

caused by the source in the detector directly under it. In other words, this ratio gives the decrease in signal that might be expected in a cell if the source in that cell were to be removed while a source remained in each of the adjacent cells. Note that this is **not** the fraction of each energy group emanating from the plutonium in the source cell; there was no distinction made regarding the birth cell of the neutron. The results are summarized in Table 3, sorted by neutron energy group.

Table 3. Direct contribution

Data Set	Thermal	Intermediate	Fast
AL00M2	0.293	0.532	0.730
ALG00M2	0.299	0.552	0.737
Z300M2	0.299	0.535	0.735
Z3G00M2	0.306	0.557	0.744
Z3GND00M2	0.304	0.555	0.745
Z3ND00M2	0.294	0.530	0.745
Z5G00M2	0.304	0.561	0.731
Z3000	0.388	0.624	0.791

It is apparent that the fraction of thermal neutrons is the least indicative measure from any energy group, while sensitivity increases with increasing neutron energy. This occurs because faster neutrons, while not readily captured in the materials of the MSV (although they do cause some fissions and (n, xn) reactions), penetrate the concrete and thermalize in distant cells where they become part of a sea of thermal neutrons. In addition, a much greater number of faster neutrons thermalize than do thermal neutrons cause fissions. Although there is higher sensitivity to a loss of fast neutrons, the 30 - 40% loss of signal from a thermal detector should still be noticeable.

Aluminum v. ZAMAK

The differences between 360 aluminum and ZAMAK3 with both a spherical and annular source were examined with the source placed at 0,0,-2. Comparing the spherical source data (AL00M2 and Z300M2) first, Table 3 indicates the use of ZAMAK3 will result in an insignificantly higher sensitivity to the loss of direct contribution. However, the tabular data in Appendix B for these sets indicate an approximately 10% higher absolute event rate would be seen in a thermal detector if aluminum plates were used. This effect decreases as the neutron energy increases, implying that captures in the plates themselves have some effect on the local spectrum. This

observation is consistent with the increased absorption noted in the ZAMAK plates and is attributable to the higher thermal neutron absorption cross section of zinc. These same observations apply to the crucible data sets ALG00M2 and Z3G00M2, with the exception that the absolute event rates, at all neutron energies is, approximately 60% that of the bare sphere rates. This occurs because of the increased moderation of neutrons immediately upon exiting the plutonium. That is, because the spectrum of neutrons entering the concrete is softer when the crucible is used, more neutrons are captured in the concrete before they can reach a detector.

Based on these results, no conclusion concerning a preference for either material can be drawn. The decision should probably be made either on economic grounds or after consideration of the effects of the different activation products on the detector.

Effect of Detectors

Two calculations were performed with ZAMAK3 plates to examine the effects, if any, of the $\text{ZnS(Ag)}+^6\text{LiF}$ detector on the neutron spectrum. Plutonium was treated in both the spherical geometry and crucible geometry, with the source taken to be at the 0,0,-2 position. As expected, the presence of the detector decreased only the thermal neutron component of the spectrum. The effect was observed in both geometries and in all 27 cells tallied and varied between 10% and 16%. It can be concluded that the removal of some of the detectors would cause a noticeable increase in the thermal fluence in the vicinity of the remaining detectors.

ZAMAK3 v. ZAMAK5

The difference between the ZAMAK3 and ZAMAK5 alloys is the slight increase in the amount of copper in ZAMAK5 at the expense of the zinc content. Since the constitutive differences are so minuscule, no significant changes in neutron fluence were expected, and only a single calculation using ZAMAK5 in the crucible geometry was done. This expectation was borne out in the results, and can be seen by comparing the tables for Z3G00M2 and Z5G00M2. Qualitatively, the graphs are very similar, while the quantitative differences are all within statistics.

Center of MSV v. Edge

It was expected that the neutron spectrum seen by detectors might be affected by the detectors' location. The spherical geometry was run with the source cell at 0,0,0 and 0,0,-2 to estimate the magnitude of the effect. It was found that the differences between the two cases were usually less than 10% between any pair of corresponding cells, with no apparent pattern discernible. Thus it is concluded that the absolute fluence in the corresponding cells are probably equal, and the differences are probably due to statistical fluctuations in the Monte Carlo process.

However, because the edge cell at 0,0,0 has no neighbors above it contributing to the fluence in the detector in that cell, the neutron fluence there is somewhat more sensitive to the removal of the source. Table 3, above, shows that the sensitivity to thermals is 30% greater in the Z3000 set

than in the other sets. This occurs because there is no contribution to the fluence at 0,0,0 from neighbors in the level $Z = 1$.

Conclusions

The calculations indicate that an optimum detector suite will contain a thermal neutron detector and a fast neutron detector. Although the signal from the thermal detector is sensitive to presence of the plutonium in its cell, greater sensitivity can probably be achieved with a fast neutron signal. In addition, the greatest sensitivity to the presence of plutonium in a cell is likely to occur in cells near a face of the MSV array.

No significant differences were detected in the behavior of the array as a function of ZAMAK alloy. This is to be expected because of the similarities of the compositions. However, more captures were found to occur in ZAMAK (because of the higher capture cross section) than in aluminum. Thus, it would behoove detector designers to determine which are the more benign: the capture products of ZAMAK or aluminum.

Appendix A MCNP Input Files

Z300M2.INP

Pu in MSV in concrete room with 100 cm thick walls, 4kg ball, ZAMAK3 plate

```

1 1 -2.505 1 -2 5 -8 9 -12 imp:n = 1 $ concrete room walls
2 1 -2.505 3 -4 5 -8 9 -12 imp:n = 1
3 1 -2.505 2 -3 5 -6 9 -12 imp:n = 1
4 1 -2.505 2 -3 7 -8 9 -12 imp:n = 1
5 1 -2.505 2 -3 6 -7 11 -12 imp:n = 1
6 1 -2.505 2 -3 6 -7 9 -10 imp:n = 1
c
7 0 2 -13 14 -15 16 -17 imp:n = 1 fill = 1 $ entire msv
8 0 -23 22 -21 20 -19 18 imp:n = 1 u = 1 lat = 1 fill = 2
c
9 2 -7.86 24 27 -28 imp:n = 1 u = 2 $ steel liner
10 3 -1.60 -36 35 -31 32 33 -34 imp:n = 1 u = -2 $ ZnS(Ag)+LiF
11 5 -1.188 -24 25 -28 imp:n = 1 u = -2 $ plexiglas
12 1 -2.505 28 imp:n = 1 u = 2 $ concrete
13 1 -2.505 -28 -25 imp:n = 1 u = 2
14 6 -19.8 -29 imp:n = 1 u = -2 $ Pu
15 4 -0.00129 26 -27 29 imp:n = 1 u = 2 $ Air
16 4 -0.00129 24 -26 30 -27 imp:n = 1 u = -2
17 4 -0.00129 36 -26 -31 32 33 -34 imp:n = 1 u = -2
18 4 -0.00129 35 -37 -32 -30 33 -34 imp:n = 1 u = -2
19 7 -6.60 24 -35 -30 imp:n = 1 u = -2 $ ZAMAK
20 7 -6.60 35 -26 -30 31 imp:n = 1 u = -2
21 7 -6.60 35 -26 -30 -31 34 imp:n = 1 u = -2
22 7 -6.60 35 -26 -30 -31 -33 imp:n = 1 u = -2
23 7 -6.60 37 -26 -30 -32 33 -34 imp:n = 1 u = -2
c
24 4 -0.00129 2 -3 6 -7 10 -11 #7 imp:n = 1 $ air outside msv
25 0 -1: 4: -5: 8: -9: 12 imp:n = 0 $ beyond room

1 pz -350.00 $ room
2 pz -250.00
3 pz 250.00
4 pz 350.00
5 py -350.00
6 py -250.00
7 py 250.00
8 py 350.00
9 px -350.00
10 px -250.00
11 px 250.00
12 px 350.00
c
13 pz 24.32 $ msv boundary
14 py -99.06
15 py 99.06
16 px -106.68
17 px 106.68
c
18 pz -46.81 $ cell
19 pz 3.99
20 py -18.415

```

```

21 py 18.415
22 px 0.01
23 px 53.35
c
24 pz -25.22 $ bottom of steel sleeve
25 pz -25.855 $ bottom of plexiglas
26 pz -22.7562 $ top of ZAMAK top plate
27 c/z 26.68 0.00 10.16
28 c/z 26.68 0.00 10.4775
29 s 26.68 0.00 -10.615 3.62783
30 c/z 26.68 0.00 9.525
31 py 4.445 $ slot is 3.5" in y
32 py -4.445
33 px 24.4575 $ by 1.75" in x centered on (26.68, 0)
34 px 28.9025
35 pz -24.712 $ bottom of ZnS
36 pz -24.612 $ top of ZnS
37 pz -23.7087 $ top of bottom plate

m1 1001.50c -0.004532 $ concrete
    8016.50c -0.512597
    11023.50c -0.011553
    12000.50c -0.003666
    13027.50c -0.035548
    14000.50c -0.360364
    19000.50c -0.014219
    20000.50c -0.043546
    26000.55c -0.013775
m2 26000.55c -0.985 $ cold-rolled steel
    6000.50c -0.015
m3 3006.50c -0.06 $ ZnS(.01Ag) + LiF
    9019.50c -0.19
    16032.50c -0.2443
    30000.40c -0.4982
    47000.55c -0.0075
m4 7014.50c -0.78 $ air
    8016.50c -0.21
    18000.35c -0.01
m5 1001.50c 8 $ plexiglas
    6000.50c 5
    8016.50c 2
m6 94238.50c 0.00012 $ Pu
    94239.55c 0.93826
    94240.50c 0.05820
    94241.50c 0.00340
    94242.50c 0.00024
m7 12000.50c -0.00035 $ ZAMAK 3
    13027.50c -0.039
    26000.55c -0.001
    29000.50c -0.0025
    30000.40c -0.95703
    48000.50c -0.00004
    50000.35c -0.00003
    82000.50c -0.00005
sdef pos 26.68 0.0 -112.215 rad d1 erg d2 $ 240-Pu source
sil 3.62783
sp2 -3 0.799 4.903
c0 0.0 1.0

```

e0	1.0e-8	1.0e-7	1.0e-6	1.0e-5	1.0e-4	0.001	0.01	0.1	1.0	10.0	20.0
f1:n	(36 < 8 [0 0 -2])										
f11:n	(35 < 8 [0 0 -2])										
fs11	-32 -33 31 34										
f21:n	(36 < 8 [1 0 -2])										
f31:n	(35 < 8 [1 0 -2])										
fs31	-32 -33 31 34										
f41:n	(36 < 8 [0 1 -2])										
f51:n	(35 < 8 [0 1 -2])										
fs51	-32 -33 31 34										
f61:n	(36 < 8 [1 1 -2])										
f71:n	(35 < 8 [1 1 -2])										
fs71	-32 -33 31 34										
f81:n	(36 < 8 [-1 -1 -2])										
f91:n	(35 < 8 [-1 -1 -2])										
fs91	-32 -33 31 34										
f101:n	(36 < 8 [-1 0 -2])										
f111:n	(35 < 8 [-1 0 -2])										
fs111	-32 -33 31 34										
f121:n	(36 < 8 [0 0 -3])										
f131:n	(35 < 8 [0 0 -3])										
fs131	-32 -33 31 34										
f141:n	(36 < 8 [1 0 -3])										
f151:n	(35 < 8 [1 0 -3])										
fs151	-32 -33 31 34										
f161:n	(36 < 8 [0 1 -3])										
f171:n	(35 < 8 [0 1 -3])										
fs171	-32 -33 31 34										
f181:n	(36 < 8 [1 1 -3])										
f191:n	(35 < 8 [1 1 -3])										
fs191	-32 -33 31 34										
f201:n	(36 < 8 [-1 -1 -3])										
f211:n	(35 < 8 [-1 -1 -3])										
fs211	-32 -33 31 34										
f221:n	(36 < 8 [-1 0 -3])										
f231:n	(35 < 8 [-1 0 -3])										
fs231	-32 -33 31 34										
f241:n	(36 < 8 [0 0 -1])										
f251:n	(35 < 8 [0 0 -1])										
fs251	-32 -33 31 34										
f261:n	(36 < 8 [1 0 -1])										
f271:n	(35 < 8 [1 0 -1])										
fs271	-32 -33 31 34										
f281:n	(36 < 8 [0 1 -1])										
f291:n	(35 < 8 [0 1 -1])										
fs291	-32 -33 31 34										
f301:n	(36 < 8 [1 1 -1])										
f311:n	(35 < 8 [1 1 -1])										
fs311	-32 -33 31 34										
f321:n	(36 < 8 [-1 -1 -1])										
f331:n	(35 < 8 [-1 -1 -1])										
fs331	-32 -33 31 34										
f341:n	(36 < 8 [-1 0 -1])										
f351:n	(35 < 8 [-1 0 -1])										
fs351	-32 -33 31 34										
f361:n	(36 < 8 [-1 1 -2])										
f371:n	(35 < 8 [-1 1 -2])										
fs371	-32 -33 31 34										

```

f381:n (36 < 8 [ 0 -1 -2])
f391:n (35 < 8 [ 0 -1 -2])
fs391 -32 -33 31 34
f401:n (36 < 8 [ 1 -1 -2])
f411:n (35 < 8 [ 1 -1 -2])
fs411 -32 -33 31 34
f421:n (36 < 8 [-1 1 -3])
f431:n (35 < 8 [-1 1 -3])
fs431 -32 -33 31 34
f441:n (36 < 8 [ 0 -1 -3])
f451:n (35 < 8 [ 0 -1 -3])
fs451 -32 -33 31 34
f461:n (36 < 8 [ 1 -1 -3])
f471:n (35 < 8 [ 1 -1 -3])
fs471 -32 -33 31 34
f481:n (36 < 8 [-1 1 -1])
f491:n (35 < 8 [-1 1 -1])
fs491 -32 -33 31 34
f501:n (36 < 8 [ 0 -1 -1])
f511:n (35 < 8 [ 0 -1 -1])
fs511 -32 -33 31 34
f521:n (36 < 8 [ 1 -1 -1])
f531:n (35 < 8 [ 1 -1 -1])
fs531 -32 -33 31 34
nps 250000
phys:n 20.0 20.0
print

```

Z3G00M2.INP

Pu in MSV in concrete room with 100 cm thick walls, 4kg in graphite crucible,
C and ZAMAK3 plate

1	1	-2.505	1	-2	5	-8	9	-12	imp:n = 1	\$ concrete room walls
2	1	-2.505	3	-4	5	-8	9	-12	imp:n = 1	
3	1	-2.505	2	-3	5	-6	9	-12	imp:n = 1	
4	1	-2.505	2	-3	7	-8	9	-12	imp:n = 1	
5	1	-2.505	2	-3	6	-7	11	-12	imp:n = 1	
6	1	-2.505	2	-3	6	-7	9	-10	imp:n = 1	
c										
7	0		2	-13	14	-15	16	-17	imp:n = 1	fill = 1 \$ entire msv
8	0		-23	22	-21	20	-19	18	imp:n = 1	u = 1 lat = 1 fill = 2
c										
9	2	-7.86	24	27	-28				imp:n = 1	u = 2 \$ steel liner
10	3	-1.60	-36	35	-31	32	33	-34	imp:n = 1	u = -2 \$ ZnS(Ag)+LiF
11	5	-1.188	-24	25	-28				imp:n = 1	u = -2 \$ plexiglas
12	1	-2.505	28						imp:n = 1	u = 2 \$ concrete
13	1	-2.505	-28	-25					imp:n = 1	u = 2
14	6	-19.8	-42	43	-40	39			imp:n = 1	u = -2 \$ Pu
15	4	-0.00129	42	-41	-40	39			imp:n = 1	u = -2 \$ Air
16	4	-0.00129	24	-26	30	-27			imp:n = 1	u = -2
17	4	-0.00129	36	-26	-31	32	33	-34	imp:n = 1	u = -2
18	4	-0.00129	35	-37	-32	-30	33	-34	imp:n = 1	u = -2
19	4	-0.00129	41	-27					imp:n = 1	u = 2
20	4	-0.00129	38	-27	-41	26			imp:n = 1	u = -2
21	4	-0.00129	26	-44	-38				imp:n = 1	u = -2
22	7	-6.60	24	-35	-30				imp:n = 1	u = -2 \$ ZAMAK
23	7	-6.60	35	-26	-30	31			imp:n = 1	u = -2
24	7	-6.60	35	-26	-30	-31	34		imp:n = 1	u = -2

```

25  7  -6.60    35 -26 -30 -31 -33    imp:n = 1 u = -2
26  7  -6.60    37 -26 -30 -32  33 -34  imp:n = 1 u = -2
27  8  -1.55   -38  40  43 -41    imp:n = 1 u = -2 $ C
28  8  -1.55   -39  43 -41    imp:n = 1 u = -2
29  8  -1.55   -43 -38  44    imp:n = 1 u = -2
c
30  4  -0.00129  2  -3   6  -7  10 -11 #7 imp:n = 1 $ air outside msv
31  0          -1:  4:  -5:   8: -9: 12 imp:n = 0 $ beyond room

1   pz -350.00    $ room
2   pz -250.00
3   pz  250.00
4   pz  350.00
5   py -350.00
6   py -250.00
7   py  250.00
8   py  350.00
9   px -350.00
10  px -250.00
11  px  250.00
12  px  350.00
c
13  pz  24.32    $ msv boundary
14  py -99.06
15  py  99.06
16  px -106.68
17  px  106.68
c
18  pz -46.81    $ cell
19  pz   3.99
20  py -18.415
21  py  18.415
22  px   0.01
23  px  53.35
c
24  pz -25.22    $ bottom of steel sleeve
25  pz -25.855   $ bottom of plexiglas
26  pz -22.7562  $ top of ZAMAK top plate
27  c/z 26.68    0.00 10.16
28  c/z 26.68    0.00 10.4775
29  s   26.68    0.00 -10.615  3.62783
30  c/z 26.68    0.00 9.525
31  py   4.445   $ slot is 3.5" in y
32  py  -4.445
33  px  24.4575  $ by 1.75" in x centered on (26.68, 0)
34  px  28.9025
35  pz -24.712   $ bottom of ZnS
36  pz -24.612   $ top of ZnS
37  pz -23.7087  $ top of bottom plate
38  c/z 26.68    0.00 3.88225  $ outer C wall
39  c/z 26.68    0.00 0.77645  $ inner C rod
40  c/z 26.68    0.00 2.32935  $ inner C wall
41  pz -2.85     $ top of C
42  pz -3.6270   $ top of Pu
43  pz -16.8266  $ bottom of Pu
44  pz -18.3795  $ bottom of C

ml   1001.50c -0.004532 $ concrete

```



```

      8016.50c -0.512597
      11023.50c -0.011553
      12000.50c -0.003666
      13027.50c -0.035548
      14000.50c -0.360364
      19000.50c -0.014219
      20000.50c -0.043546
      26000.55c -0.013775
m2      26000.55c -0.985      $ cold-rolled steel
      6000.50c -0.015
m3      3006.50c -0.06      $ ZnS(.01Ag) + LiF
      9019.50c -0.19
      16032.50c -0.2443
      30000.40c -0.4982
      47000.55c -0.0075
m4      7014.50c -0.78      $ air
      8016.50c -0.21
      18000.35c -0.01
m5      1001.50c 8      $ plexiglas
      6000.50c 5
      8016.50c 2
m6      94238.50c 0.00012      $ Pu
      94239.55c 0.93826
      94240.50c 0.05820
      94241.50c 0.00340
      94242.50c 0.00024
m7      12000.50c -0.00035      $ ZAMAK 3
      13027.50c -0.039
      26000.55c -0.001
      29000.50c -0.0025
      30000.40c -0.95703
      48000.50c -0.00004
      50000.35c -0.00003
      82000.50c -0.00005
m8      6000.50c 1      $ carbon
mt8      grph.01t      $ graphite @ 300K
sdef pos 26.68 0.0 -111.8268 axs 0 0 1 ext d3 rad d1 erg d2 $ 240-Pu source
si1      0.77645 2.32935
sp2      -3 0.799 4.903
si3      6.59
c0      0.0 1.0
e0      1.0e-8 1.0e-7 1.0e-6 1.0e-5 1.0e-4 0.001 0.01 0.1 1.0 10.0 20.0
f1:n      (36 < 8 [ 0 0 -2])
f11:n     (35 < 8 [ 0 0 -2])
fs11      -32 -33 31 34
f21:n     (36 < 8 [ 1 0 -2])
f31:n     (35 < 8 [ 1 0 -2])
fs31      -32 -33 31 34
f41:n     (36 < 8 [ 0 1 -2])
f51:n     (35 < 8 [ 0 1 -2])
fs51      -32 -33 31 34
f61:n     (36 < 8 [ 1 1 -2])
f71:n     (35 < 8 [ 1 1 -2])
fs71      -32 -33 31 34
f81:n     (36 < 8 [-1 -1 -2])
f91:n     (35 < 8 [-1 -1 -2])
fs91      -32 -33 31 34
f101:n    (36 < 8 [-1 0 -2])

```

```

f111:n (35 < 8 [-1 0 -2])
fs111 -32 -33 31 34
f121:n (36 < 8 [ 0 0 -3])
f131:n (35 < 8 [ 0 0 -3])
fs131 -32 -33 31 34
f141:n (36 < 8 [ 1 0 -3])
f151:n (35 < 8 [ 1 0 -3])
fs151 -32 -33 31 34
f161:n (36 < 8 [ 0 1 -3])
f171:n (35 < 8 [ 0 1 -3])
fs171 -32 -33 31 34
f181:n (36 < 8 [ 1 1 -3])
f191:n (35 < 8 [ 1 1 -3])
fs191 -32 -33 31 34
f201:n (36 < 8 [-1 -1 -3])
f211:n (35 < 8 [-1 -1 -3])
fs211 -32 -33 31 34
f221:n (36 < 8 [-1 0 -3])
f231:n (35 < 8 [-1 0 -3])
fs231 -32 -33 31 34
f241:n (36 < 8 [ 0 0 -1])
f251:n (35 < 8 [ 0 0 -1])
fs251 -32 -33 31 34
f261:n (36 < 8 [ 1 0 -1])
f271:n (35 < 8 [ 1 0 -1])
fs271 -32 -33 31 34
f281:n (36 < 8 [ 0 1 -1])
f291:n (35 < 8 [ 0 1 -1])
fs291 -32 -33 31 34
f301:n (36 < 8 [ 1 1 -1])
f311:n (35 < 8 [ 1 1 -1])
fs311 -32 -33 31 34
f321:n (36 < 8 [-1 -1 -1])
f331:n (35 < 8 [-1 -1 -1])
fs331 -32 -33 31 34
f341:n (36 < 8 [-1 0 -1])
f351:n (35 < 8 [-1 0 -1])
fs351 -32 -33 31 34
f361:n (36 < 8 [-1 1 -2])
f371:n (35 < 8 [-1 1 -2])
fs371 -32 -33 31 34
f381:n (36 < 8 [ 0 -1 -2])
f391:n (35 < 8 [ 0 -1 -2])
fs391 -32 -33 31 34
f401:n (36 < 8 [ 1 -1 -2])
f411:n (35 < 8 [ 1 -1 -2])
fs411 -32 -33 31 34
f421:n (36 < 8 [-1 1 -3])
f431:n (35 < 8 [-1 1 -3])
fs431 -32 -33 31 34
f441:n (36 < 8 [ 0 -1 -3])
f451:n (35 < 8 [ 0 -1 -3])
fs451 -32 -33 31 34
f461:n (36 < 8 [ 1 -1 -3])
f471:n (35 < 8 [ 1 -1 -3])
fs471 -32 -33 31 34
f481:n (36 < 8 [-1 1 -1])
f491:n (35 < 8 [-1 1 -1])

```

```
fs491 -32 -33 31 34
f501:n (36 < 8 [ 0 -1 -1])
f511:n (35 < 8 [ 0 -1 -1])
fs511 -32 -33 31 34
f521:n (36 < 8 [ 1 -1 -1])
f531:n (35 < 8 [ 1 -1 -1])
fs531 -32 -33 31 34
nps 250000
phys:n 20.0 20.0
print
```

APPENDIX B
Neutron Point Spread Functions

AL00M2

Y\X	-1	0	1
-1	5.20E-04	2.64E-03	5.20E-04
0	1.04E-03	6.46E-03	9.56E-04
1	5.04E-04	2.75E-03	4.44E-04

Y\X	-1	0	1
-1	1.11E-03	7.51E-03	1.20E-03
0	2.41E-03	2.00E-02	2.51E-03
1	1.18E-03	7.07E-03	1.12E-03

Thermal Neutrons, Z = -2

Y\X	-1	0	1
-1	3.04E-04	1.37E-03	3.60E-04
0	6.24E-04	2.89E-03	4.96E-04
1	3.48E-04	1.42E-03	3.16E-04

Y\X	-1	0	1
-1	1.76E-04	1.58E-03	2.04E-04
0	5.44E-04	6.00E-03	3.88E-04
1	2.48E-04	1.49E-03	1.64E-04

Intermediate Energy Neutrons, Z = -1

Y\X	-1	0	1
-1	5.12E-04	7.40E-03	6.00E-04
0	1.35E-03	4.13E-02	1.42E-03
1	6.12E-04	7.41E-03	5.48E-04

Y\X	-1	0	1
-1	1.80E-04	9.36E-04	1.28E-04
0	2.64E-04	2.52E-03	3.56E-04
1	1.28E-04	1.00E-03	1.36E-04

Y\X	-1	0	1
-1	2.20E-04	1.33E-03	2.92E-04
0	4.08E-04	5.23E-03	4.84E-04
1	1.92E-04	1.58E-03	2.36E-04

Y\X	-1	0	1
-1	7.44E-04	7.18E-03	5.24E-04
0	1.58E-03	9.86E-02	1.56E-03
1	5.88E-04	7.47E-03	6.20E-04

Y\X	-1	0	1
-1	1.84E-04	1.03E-03	2.08E-04
0	3.44E-04	2.62E-03	3.92E-04
1	1.96E-04	1.09E-03	1.88E-04

ALG00M2

Y\X	-1	0	1
-1	3.56E-04	2.01E-03	4.20E-04
0	7.92E-04	4.95E-03	7.24E-04
1	3.48E-04	1.84E-03	4.04E-04

Thermal Neutrons, Z = -1

Y\X	-1	0	1
-1	8.08E-04	5.57E-03	7.92E-04
0	1.84E-03	1.48E-02	1.78E-03
1	8.52E-04	5.36E-03	7.68E-04

Y\X	-1	0	1
-1	2.00E-04	8.80E-04	1.96E-04
0	2.72E-04	1.80E-03	3.32E-04
1	2.36E-04	9.00E-04	1.60E-04

Y\X	-1	0	1
-1	1.36E-04	1.17E-03	1.36E-04
0	3.76E-04	4.33E-03	2.80E-04
1	1.72E-04	1.14E-03	1.56E-04

Intermediate Energy Neutrons, Z = -1

Y\X	-1	0	1
-1	3.64E-04	5.03E-03	3.52E-04
0	1.10E-03	3.13E-02	1.22E-03
1	4.68E-04	5.30E-03	4.04E-04

Intermediate Energy Neutrons, Z = -2

Y\X	-1	0	1
-1	1.08E-04	6.68E-04	7.20E-05
0	1.24E-04	1.30E-03	2.32E-04
1	1.00E-04	5.92E-04	9.20E-05

Intermediate Energy Neutrons, Z = -3

Y\X	-1	0	1
-1	1.64E-04	1.01E-03	1.56E-04
0	3.36E-04	3.17E-03	3.20E-04
1	1.52E-04	9.04E-04	1.04E-04

Y\X	-1	0	1
-1	4.84E-04	4.58E-03	3.32E-04
0	1.12E-03	6.40E-02	1.05E-03
1	5.32E-04	4.77E-03	3.88E-04

Fast Neutrons, Z = -2

Y\X	-1	0	1
-1	1.24E-04	6.00E-04	1.16E-04
0	1.24E-04	1.31E-03	1.92E-04
1	1.00E-04	5.52E-04	1.00E-04

Z300M2

Y\X	-1	0	1
-1	4.08E-04	2.35E-03	4.32E-04
0	8.24E-04	5.87E-03	7.44E-04
1	4.92E-04	2.49E-03	3.92E-04

Y\X	-1	0	1
-1	1.06E-03	6.54E-03	1.08E-03
0	2.09E-03	1.79E-02	2.05E-03
1	9.76E-04	6.17E-03	9.64E-04

Y\X	-1	0	1
-1	2.80E-04	1.24E-03	2.80E-04
0	5.32E-04	2.55E-03	4.48E-04
1	3.04E-04	1.18E-03	2.40E-04

Thermal Neutrons, Z = -3

Y\X	-1	0	1
-1	2.08E-04	1.46E-03	2.00E-04
0	4.24E-04	5.73E-03	3.96E-04
1	1.92E-04	1.43E-03	2.04E-04

Intermediate Energy Neutrons, Z = -1

Y\X	-1	0	1
-1	6.44E-04	7.14E-03	5.36E-04
0	1.32E-03	4.07E-02	1.38E-03
1	5.96E-04	7.44E-03	6.00E-04

Intermediate Energy Neutrons, Z = -2

Y\X	-1	0	1
-1	1.60E-04	8.80E-04	1.08E-04
0	4.04E-04	2.31E-03	2.92E-04
1	1.84E-04	9.00E-04	1.92E-04

Intermediate Energy Neutrons, $Z = -3$

Y\X	-1	0	1
-1	2.24E-04	1.36E-03	3.04E-04
0	4.28E-04	5.02E-03	4.84E-04
1	2.04E-04	1.34E-03	2.32E-04

Y\X	-1	0	1
-1	8.40E-04	6.96E-03	5.12E-04
0	1.66E-03	9.86E-02	1.63E-03
1	6.32E-04	7.02E-03	5.80E-04

Fast Neutrons, Z = -2

Y\X	-1	0	1
-1	2.00E-04	9.96E-04	1.52E-04
0	4.12E-04	2.52E-03	3.36E-04
1	2.40E-04	1.04E-03	1.96E-04

Z3G00M2

Y\X	-1	0	1
-1	2.80E-04	1.70E-03	3.36E-04
0	6.68E-04	4.42E-03	5.52E-04
1	2.84E-04	1.54E-03	3.56E-04

Y\X	-1	0	1
-1	7.00E-04	4.78E-03	6.52E-04
0	1.60E-03	1.31E-02	1.57E-03
1	6.92E-04	4.76E-03	6.64E-04

Y\X	-1	0	1
-1	1.44E-04	7.80E-04	1.96E-04
0	2.20E-04	1.57E-03	2.60E-04
1	1.84E-04	7.00E-04	1.40E-04

Y\X	-1	0	1
-1	8.00E-05	1.12E-03	1.00E-04
0	2.72E-04	4.16E-03	2.92E-04
1	1.60E-04	9.88E-04	8.00E-05

Intermediate Energy Neutrons, Z = -1

Intermediate Energy Neutrons, $Z = -2$

Y\X	-1	0	1
-1	1.00E-04	5.04E-04	1.00E-04
0	1.36E-04	1.17E-03	2.32E-04
1	5.60E-05	5.28E-04	8.40E-05

Intermediate Energy Neutrons, Z = -3

Y\X	-1	0	1
-1	1.12E-04	8.80E-04	1.64E-04
0	2.60E-04	3.11E-03	3.20E-04
1	7.20E-05	9.60E-04	1.60E-04

Fast Neutrons, Z = -1

Y\X	-1	0	1
-1	4.16E-04	4.39E-03	4.08E-04
0	1.01E-03	6.44E-02	1.03E-03
1	4.56E-04	4.78E-03	3.84E-04

Fast Neutrons, Z = -2

Y\X	-1	0	1
-1	7.60E-05	4.96E-04	1.24E-04
0	2.16E-04	1.26E-03	2.56E-04
1	9.60E-05	5.56E-04	1.12E-04

Z3GND00M2

Y\X	-1	0	1
-1	3.36E-04	2.06E-03	4.32E-04
0	6.76E-04	4.99E-03	6.60E-04
1	3.60E-04	1.73E-03	4.36E-04

Y\X	-1	0	1
-1	7.88E-04	5.72E-03	8.16E-04
0	1.70E-03	1.51E-02	1.81E-03
1	8.52E-04	5.39E-03	7.72E-04

Thermal Neutrons, Z = -2

Y\X	-1	0	1
-1	1.56E-04	8.52E-04	2.12E-04
0	2.48E-04	1.82E-03	3.24E-04
1	2.32E-04	8.76E-04	2.08E-04

Y\X	-1	0	1
-1	8.40E-05	1.18E-03	1.56E-04
0	3.00E-04	4.14E-03	2.48E-04
1	1.88E-04	1.05E-03	1.20E-04

Intermediate Energy Neutrons, Z = -1

Y\X	-1	0	1
-1	3.68E-04	5.33E-03	3.56E-04
0	9.68E-04	3.07E-02	1.07E-03
1	4.32E-04	5.33E-03	3.56E-04

Intermediate Energy Neutrons, Z = -2

Y\X	-1	0	1
-1	9.60E-05	5.08E-04	9.20E-05
0	1.28E-04	1.40E-03	2.24E-04
1	6.00E-05	4.20E-04	8.80E-05

Y\X	-1	0	1
-1	8.80E-05	9.36E-04	2.04E-04
0	2.76E-04	3.11E-03	2.72E-04
1	1.20E-04	9.36E-04	1.04E-04

Y\X	-1	0	1
-1	4.32E-04	4.64E-03	5.24E-04
0	1.04E-03	6.53E-02	9.72E-04
1	5.08E-04	4.58E-03	3.88E-04

Fast Neutrons, Z = -2

Y\X	-1	0	1
-1	1.12E-04	5.72E-04	1.16E-04
0	1.32E-04	1.28E-03	2.24E-04
1	7.60E-05	5.96E-04	1.64E-04

Z3ND00M2

Y\X	-1	0	1
-1	4.40E-04	2.64E-03	5.32E-04
0	1.09E-03	6.77E-03	9.16E-04
1	5.32E-04	2.58E-03	4.52E-04

Y\X	-1	0	1
-1	1.17E-03	7.19E-03	1.19E-03
0	2.59E-03	2.01E-02	2.30E-03
1	1.12E-03	7.06E-03	1.22E-03

Y\X	-1	0	1
-1	3.16E-04	1.64E-03	2.96E-04
0	5.68E-04	3.10E-03	5.84E-04
1	3.60E-04	1.25E-03	3.56E-04

Y\X	-1	0	1
-1	1.76E-04	1.42E-03	1.92E-04
0	4.84E-04	5.79E-03	4.00E-04
1	1.44E-04	1.53E-03	2.12E-04

Y\X	-1	0	1
-1	6.88E-04	7.54E-03	4.88E-04
0	1.31E-03	4.07E-02	1.56E-03
1	6.56E-04	7.62E-03	5.52E-04

Intermediate Energy Neutrons, Z = -2

Y\X	-1	0	1
-1	2.12E-04	8.60E-04	1.68E-04
0	3.20E-04	2.38E-03	2.72E-04
1	1.12E-04	9.60E-04	1.52E-04

Y\X	-1	0	1
-1	2.28E-04	1.48E-03	3.16E-04
0	5.16E-04	5.19E-03	3.80E-04
1	2.28E-04	1.36E-03	2.28E-04

Y\X	-1	0	1
-1	8.00E-04	7.68E-03	6.60E-04
0	1.76E-03	1.00E-01	1.50E-03
1	7.00E-04	7.10E-03	5.52E-04

YX	-1	0	1
-1	2.08E-04	1.00E-03	1.96E-04
0	3.64E-04	2.69E-03	3.64E-04
1	1.88E-04	8.64E-04	1.88E-04

Z3000

Y\X	-1	0	1
-1	9.60E-04	6.32E-03	9.32E-04
0	2.02E-03	1.75E-02	2.08E-03
1	1.02E-03	6.09E-03	1.00E-03

Y\X	-1	0	1
-1	2.84E-04	1.18E-03	2.88E-04
0	5.08E-04	2.67E-03	4.80E-04
1	2.84E-04	1.12E-03	2.88E-04

Y\X	-1	0	1
-1	5.28E-04	7.18E-03	6.52E-04
0	1.39E-03	4.07E-02	1.38E-03
1	5.28E-04	7.22E-03	5.48E-04

Intermediate Energy Neutrons, $Z = 0$

Y\X	-1	0	1
-1	1.60E-04	9.72E-04	1.60E-04
0	3.04E-04	2.02E-03	2.60E-04
1	1.36E-04	9.00E-04	2.20E-04

Intermediate Energy Neutrons, Z = -1

Y\X	-1	0	1
-1	6.96E-04	6.92E-03	5.96E-04
0	1.74E-03	9.82E-02	1.48E-03
1	6.76E-04	7.20E-03	6.20E-04

Y\X	-1	0	1
-1	1.88E-04	8.28E-04	1.76E-04
0	3.92E-04	2.67E-03	3.04E-04
1	2.00E-04	9.44E-04	2.44E-04

Z5G00M2

Y\X	-1	0	1
-1	2.44E-04	1.72E-03	3.36E-04
0	6.92E-04	4.32E-03	5.76E-04
1	2.84E-04	1.60E-03	3.64E-04

Y\X	-1	0	1
-1	7.20E-04	4.76E-03	6.60E-04
0	1.65E-03	1.31E-02	1.54E-03
1	7.04E-04	4.88E-03	6.76E-04

Thermal Neutrons, Z = -2

Y\X	-1	0	1
-1	1.52E-04	7.76E-04	1.80E-04
0	2.40E-04	1.65E-03	2.52E-04
1	1.68E-04	7.80E-04	1.32E-04

Y\X	-1	0	1
-1	7.60E-05	1.14E-03	1.24E-04
0	3.24E-04	4.08E-03	2.64E-04
1	1.24E-04	1.04E-03	8.80E-05

Intermediate Energy Neutrons, Z = -1

Y\X	-1	0	1
-1	4.08E-04	5.30E-03	4.20E-04
0	1.04E-03	3.13E-02	1.04E-03
1	4.12E-04	5.28E-03	3.80E-04

Intermediate Energy Neutrons, Z = -2

Y\X	-1	0	1
-1	1.08E-04	4.92E-04	9.60E-05
0	1.80E-04	1.19E-03	2.28E-04
1	4.80E-05	4.92E-04	9.60E-05

Intermediate Energy Neutrons, Z = -3

Y\X	-1	0	1
-1	1.40E-04	8.48E-04	1.68E-04
0	2.48E-04	3.13E-03	3.36E-04
1	8.00E-05	8.96E-04	1.52E-04

Y\X	-1	0	1
-1	3.80E-04	4.36E-03	3.88E-04
0	1.02E-03	6.46E-02	1.02E-03
1	4.48E-04	4.58E-03	3.40E-04

Fast Neutrons, Z = -2

Y\X	-1	0	1
-1	5.20E-05	5.24E-04	1.24E-04
0	2.16E-04	1.30E-03	2.36E-04
1	1.04E-04	5.16E-04	8.80E-05

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