APPENDIX E

THERMAL ANALYSIS OF NLI 10/24 CASK

Introduction

The results of the thermal analysis outlined in this Appendix were used for the final stress analysis calculations concerning containment safety. The 2-D axial model of the cask reported in this Appendix is slightly more conservative than the similar model reported in Appendix D, i.e., resulting temperatures produce higher stress in the shells. The modeling difference is found in the treatment of the axial conduction of heat in the basket. The thermal model used here assumes an additional thermal impedence component based on the interface between the axial section of the basket and, hence, heat does not flow axially as well as the Appendix D model. This change results in slightly higher midplane shell temperatures and cooler conditions on the ends of the cask.

In addition to the 2-D axial model of the cask, a 2-D circumferential model was developed to estimate the magnitude of circumferential gradients in the inner shell, lead, and outer shell. The circumferential temperature differences calculated were used in the normal cycle stress range evaluations.

Top and Bottom Section Analyses

Detailed two-dimensional heat transfer analyses of the top and bottom sections of the NLI 10/24 cask were performed for use for the stress analysis calculations. The operating conditions analyzed include:

1. Normal operation with 40 and 70 kw thermal inventory at ambient temperatures of -40 and 130 F
2. Post-fire operation (loss of coolant) with 40 and 70 kw thermal inventory at ambient temperatures of -40 and 130 F

The discussion which follows outlines the analytical models used as well as the computed temperature profiles corresponding to the above cases.

Development of Thermal Model

The thermal models used in the heat transfer analysis of the top and bottom sections of the cask are shown in Figure E-1 and E-2, respectively. These thermal models incorporate the following assumptions and simplifications:

1. Ambient (air) temperatures of -40F and 130F with solar heat load
2. Temperature dependent thermophysical properties for all materials including water/glycol solution for temperatures ranging from -40 to 300F

3. Radiation is assumed to be diffuse between gray surfaces
4. The following hemispherical emissivities were used: .5 for stainless steel and .7 for carbon steel within the neutron shield; .25 for stainless steel of the external cask shielding fin
5. Temperature of internal steel fins assumed to be equal to that of the adjacent shell
6. Circumferential components of heat transport neglected
7. Lead bonding at inner shell is assumed at contact pressurer for the yield strength of lead; at the outer shell only 75 percent of the contact area is accounted for in heat conduction due to shrinkage gaps
8. The fuel basket was modeled as a simplified lumped parameter in the radial direction with radial gradients restricted to conform to prior basket analysis in this SAR
9. The axial conduction area of the fuel basket materials was lumped into a single effective conduction area of aluminum for simplicity
10. Longitudinal axis of cask oriented horizontally

11. The heat transfer between the fuel baskets and the bottom end includes a conductance of 2.80 for the helium filled cavity and the stainless steel basket supports plus a radiation exchange factor of .333
12. Interface thermal conductance of 500 Btu/hr ft^2f at stainless steel/uranium interfaces in bottom section of cask
13. Cavities and gaps within inner shell and fuel baskets are filled with helium at atmospheric pressure
14. Neutron shield cavity is filled with air during post-fire operation of cask
15. An effective emissivity of .58 for radiative exchange within the finned neutron shield was calculated for post-fire conditions with the aid of the CONFAC* radiation interchange computer
16. A convective heat transfer function ($h = 0.82\Delta T^{.278}$) was incorporated into the thermal analysis of the finned neutron shield for post-fire conditions. This heat transfer function was developed from Lia-Mueller-Landis** correlations

* K. A. Toups, "CONFAC A GENERAL COMPUTER PROGRAM FOR THE DETERMINATION OF RADIANT-INTERCHANGE CONFIGURATION AND FORM FACTORS", SID65-1043-2, October 1965.

** "NATURAL CONVECTION HEAT TRANSFER IN LONG HORIZONTAL CYLINDRICAL ANNULI", International Developments in Heat Transfer. Paper 117. Boulder, Colorado, August 1961.

Summary of Input and Output Data

The TRUMP finite-differencing heat transfer computer program was used for these thermal analyses. In these models, the node centers are located at the geometric centers of the subregions as shown in Figures E-1 and E-2. The assumptions outlined in the previous section, together with the physical dimensions and thermophysical properties, were translated into the required input data formats as summarized in Exhibit E-1 for the top section of the cask. These input data sets correspond to the top and bottom ends of the cask with a thermal inventory of 70 kw and an ambient temperature of 130 F.

The calculated temperatures for the top and bottom sections of the cask are summarized in Figure E-3 to E-18 for the normal and post-fire conditions. These temperatures are representative of a point at the geometric center of the nodes.

Circumferential Thermal Analysis

A detailed two-dimensional heat transfer analysis of the NLI 10/24 cask was performed in order to estimate the magnitude of circumferential temperature gradients in the inner shell, lead shield, and outer shell. Circumferential gradients in these members are possible when the longitudinal axis of the cask is oriented horizontally since the basket will be in good thermal contact with the inner shell over a fraction of the total circumferential surface area. As a result, a significant fraction of the heat transferred from the basket to the inner shell will flow through the lower portion of the circumferential interface. The discussion which follows outlines the analytical model used as well as the computer circumferential temperature profile. These results were the basis for circumferential thermal stress analyses.

Development of Thermal Model

The thermal model used in the circumferential heat-transfer analysis incorporates the following assumptions and simplifications:

1. Uniform heat generation in basket region
2. 88 percent of 70 kw thermal inventory dissipated over 10-foot-long fuel basket
3. The bottom one-sixth of the circumference of the fuel basket is in contact with the inner shell assuming an average heat transfer coefficient of 500 Btu/hr ft^2F

4. Maximum gap of 0.060 inch occurs at top of basket/ inner shell interface and is occupied by helium at atmospheric pressure
5. Surface of outer shell coupled to "ambient" with constant heat transfer coefficient (i.e., temperature "smearing" effect of naturally convecting water/ glycol mixture neglected)
6. "Ambient" boundary condition adjusted to simulate radial thermal impedance of water jacket and external fins dissipating to air at 130 F.

Summary of Input and Output Data

The TRUMP finite-differencing heat transfer computer program was used for this steady-state thermal analysis. The assumptions outlined in the previous section, together with the physical dimensions and thermo-physical properties, were translated into the required input data formats as summarized in Exhibit E-3.

The calculated steady-state, circumferential temperature profiles for the NLI 10/24 cask are summarized in Figure E-19. These temperatures are representative of a point at the geometric center of the nodes. The computer temperature profiles indicate a larger circumferential gradient than would actually occur in the presence of connecting heat transfer fluids in the water jacket and over the outer-finned surface of the water jacket.

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 1. CALCULATIONAL MODEL FOR TOP END OF NLI 10/24 CASK INDICATING NODE NUMBERS USED IN TRUMP HEAT TRANSFER COMPUTER PROGRAM

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 2. CALCULATIONAL MODEL FOR BOTTOM END OF NLI 10/24 CASK INDICATING NODE NUMBERS USED IN TRUMP HEAT TRANSFER COMPUTER PROGRAM

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MODEL IS 1/2 AXIAL AND  60 DEG. CIRCUM.. HENCE 1/6 OF WHOLE CASK IS MODELED
T1031 .1875 THICK.X 3.014 HIGH S. STL. EXT. FINS
E=.4 S.STL AND CU.  GLYCOL
**NLITOPD** 2/2/76    3-D MODELOF THERMAL
BLOCK01   1111/1111122222222223333/3333334444/4444455557555556666/666667777/
            -1                    1          1   66  20.      .083333333
        3 .15                 10.                    60.       -45.     2000.
250.
BLOCK02   1111/111112222/222223333/333334444/444445555/555556666/666667777/
301SS     1                 4    8       493.                          2600.      120.
        .100       -60.      .108       40.       .115       140.       .121      240.
        .133       540.      .135      640.       .137       740.       .156     1640.
         7.7       -60.      8.35       40.       8.95       140.       9.55      240.
        11.1       540.     11.55      640.      11.95       740.      15.8      1690.
LEAD      2                 6    8       705.                          621.       10.5
   3.03E-02        32.  3.15E-02       212.  3.38E-02       572.  3.37E-02       621.
   3.26E-02       621.  3.26E-02     10000.
       20.1        32.      14.6       212.       18.0       572.       8.8       621.
        8.8       621.       8.9       900.        9.6      1200.      11.5      1500.
CORE      3                          125.0       .109       100.      1200.      167.
CU        4                 8    8       558.                          2440.       40.
       .075      -210.  8.45E-02      -110.       .088       -60.       .091       15.
       .093        90.      .101       665.  1.215E-01      1965.       .160     4875.
     243.5       -60.      233.        90.       221.       390.      214.5      600.
       209.       800.      204.      1000.       199.      1200.      184.5     1900.
CDCU      5                 3    4     555.                          1890.     2240.
.089      -40.      .13      400.       .115      1475.
154.      -40.      181.     400.       190.       550.      190.      1475.
URANI     6                 6    5    1190.0                         2070.0     408.
 0.026    -100.0    0.027    0.0        0.029     100.0     0.0345    600.
 0.042    1000.0    0.0495   1240.0
 15.2     -100.0    13.3     0.0        15.0      200.0     18.0      600.
 24.7     1500.0
RICOR     7                          55.        .55       .15       1500.     1.
BALSA     8                          15.        .5        .034      1500.     1.

BLOCK04   1111/111112222/222223333/333334444/444445555/555556666/666667777/
 3111                 3          20.       22.50      11.78
 3211                 3          20.       22.50      11.78
 3311                 3          20.       22.50      11.78
 3411                 3           9.       22.50      11.78
 3511                 3           6.       22.50      11.78
 1111                 1          20.        .75       23.95
 1211                 1          20.        .75       23.95
 1311                 1          20.        .75       23.95
 1411                 1           9.        .75       23.95
 1511                 1           9.        .75       23.95
 2111                 2          20.        1.        24.87
 2211                 2          20.        1.        24.87
 2311                 2          20.        1.        24.87
 2411                 2           9.        1.        24.87
 2511                 2           9.        1.        24.87
 2121                 2          20.        1.        25.92
 2221                 2          20.        1.        25.92
 2321                 2          20.        1.        25.92
 2421                 2           9.        1.        25.92
 2521                 2           9.        1.        25.92
 2131                 2          20.        1.        26.97
 2231                 2          20.        1.        26.97
 2331                 2          20.        1.        26.97
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EXHIBIT 1. INPUT DATA FOR TOP SECTION THERMAL ANALYSIS

2141			2	20.	1.	28.01
2241			2	20.	1.	28.01
2341			2	20.	1.	28.01
2441			2	9.	1.	28.01
2541			2	9.	1.	28.01
2151			2	20.	1.	29.06
2251			2	20.	1.	29.06
2351			2	20.	1.	29.06
2451			2	9.	1.	29.06
2551			2	9.	1.	29.06
2161			2	20.	1.	30.1
2261			2	20.	1.	30.1
2361			2	20.	1.	30.1
2461			2	9.	1.	30.1
2561			2	9.	1.	30.1
1121			1	20.	1.	31.67
1221			1	20.	1.	31.67
1321			1	20.	1.	31.67
1421			1	9.	1.	31.67
1521			1	9.	1.	31.67
1131			1	20.	1.	17.725
1231			1	20.	1.	17.725
1331			1	20.	1.	17.725
1431			1	9.	1.	17.725
1531			1	9.	1.	17.725
1132			1	20.	1.	15.00
1232			1	20.	1.	15.00
1332			1	20.	1.	15.00
1432			1	9.	1.	15.00
1532			1	9.	1.	15.00
1141			1	20.	.375	21.17
1241			1	20.	.375	21.17
1341			1	20.	.375	21.17
1441			1	9.	.375	21.17
1541			1	9.	.375	21.17
1142			1	20.	.375	21.17
1242			1	20.	.375	21.17
1342			1	20.	.375	21.17
1442			1	9.	.375	21.17
1542			1	9.	.375	21.17
1151			1	17.47	.375	42.7388
1251			1	17.47	.375	42.7388
1351			1	17.47	.375	42.7388
1451			1	7.97	.375	42.7388
1551			1	7.97	.375	42.7388
1152			1	2.53	.375	42.7388
1252			1	2.53	.375	42.7388
1352			1	2.53	.375	42.7388
1452			1	1.03	.375	42.7388
1552			1	1.03	.375	42.7388
1161	2	100	1	3.333	.125	42.935
1461	1	100	1	1.50	.125	42.935
1162	2	100	1	2.53	1.	43.46
1462	1	100	1	1.03	1.	43.46
1171			1	2.531	1.	44.51
1271			1	2.531	1.	44.51
1371			1	2.531	1.	44.51
1471			1	1.03	1.	44.51
1571			1	1.03	1.	44.51
1181			1	2.53	1.	45.55
1281			1	2.53	1.	45.55
1381			1	2.53	1.	45.55
1481			1	1.03	1.	45.55
1581			1	1.03	1.	[illegible]

5			1		3.	5.89	2.813			
6		1	1		3.	5.89	-4.438			
9			7		3.	5.89	2.813			
10	2	1	7		3.	5.89	-4.438			
13			1		2.5	5.89	2.813			
14	2	1	1		2.5	5.89	-4.438			
17			1		8.	5.24	24.6			
18			1		11.75	7.07	25.9			
19			1		3.	7.07	25.9			
20			1		3.	7.07	25.9			
21			7		3.	7.07	25.9			
22			1		2.5	7.07	25.9			
23			6		8.	1.83	28.4			
24			1		8.	2.09	30.3			
25			1		7.	4.45	31.4			
26			1		11.75	5.54	32.4			
27			1		11.5	6.54	32.4			
28			1		3.	5.76	38.3			
29			7		13.	1.57	36.3			
30			3		5.	5.89	2.813			
31	3	1	3		5.	5.89	-4.44			

BLOCK05 1111/11111222/22222333/33333444/44444555/55555666/66667777/

3111	1111			87.5	.5	20.	23.56			
3211	1211			87.5	.5	20.	23.56			
3311	1311			87.5	.5	20.	23.56			
3411	1411			87.5	.5	9.	23.56			
3511	1511			87.5	.5	5.	23.56			
1111	2111			.375	.5	20.94	23.25	500.		
2111	2121	4	10	10	.5	.5	20.94	-24.25		
1211	2211				.375	.5	20.94	23.25	500.	
2211	2221	4	10	10	.5	.5	20.94	-24.25		
1311	2311				.375	.5	20.94	23.25	500.	
2311	2321	4	10	10	.5	.5	20.94	-24.25		
1411	2411				.375	.5	9.425	23.25	500.	
2411	2421	4	10	10	.5	.5	9.425	-24.25		
1511	2511				.375	.5	9.425	23.25	500.	
2511	2521	4	10	10	.5	.5	9.425	-24.25		
2161	1121				.5	.5	20.0	22.973		
2261	1221				.5	.5	20.0	22.973		
2361	1321				.5	.5	20.0	22.973		
2461	1421				.5	.5	9.0	22.973		
2561	1521				.5	.5	9.0	22.973		
1121	1131	2	1	12	.5	.5	20.0	17.158		
1421	1431	1	1	12	.5	.5	9.0	17.158		
1121	1132	2	1	12	.5	.5	20.0	14.52		
1421	1432	1	1	12	.5	.5	9.0	14.52		
1131	1132	2	1	12	.872	.738	20.	10.		
1431	1432	1	1	12	.872	.738	.9	10.		
1132	1141	2	1	12			20.	3.2	31.0	-.278
1432	1441	1	1	12			9.	3.2	31.0	-.278
1131	1141	2	1	12			10.	37.44	31.0	-.278
1131	1142	2	1	12			10.	37.44	31.0	-.278
1431	1442	1	1	12			4.5	37.44	31.0	-.278
1431	1441	1	1	12			4.5	37.44	31.0	-.278
1141	1151	2	1	12	.188	.188	17.47	21.07		
1142	1151	2	1	12	.188	.189	17.47	21.07		
1141	1152	2	1	12	.188	.189	2.53	21.07		
1142	1152	2	1	12	.188	.189	2.53	21.07		
1441	1451	1	1	12	.188	.186	7.969	21.07		
1442	1	1	1	12	.188	.186	7.969	21.07		
1441	2	1	1	12	.188	.186	1.031	21.07		
1442	1452	1	1	12	.188	.186	1.031	21.07		

1452	14[illegible]		1	12	.188	.5	1.031	42.94	
1162	117[illegible]				.5	.5	2.53	43.98	
1262	12[illegible]				.5	.5	2.53	41.[illegible]	
1362	1371				.5	.5	2.53	43.98	
1462	1471				.5	.5	1.031	43.98	
1562	1571				.5	.5	1.031	41.98	
1171	1181				.5	.5	2.53	45.03	
1271	1281				.5	.5	2.53	45.03	
1371	1381				.5	.5	2.53	45.03	
1471	1481				.5	.5	1.031	45.03	
1571	1581				.5	.5	1.031	45.03	
3111	3211	1	1	12	10.	10.	3.85	22.5	20.8
3311	3411				10.	4.5	3.85	22.5	20.8
3411	3511				4.5	3.	3.85	22.5	20.8
1111	1211				10.	10.	.785	22.87	
1211	1311				10.	10.	.785	22.87	
1311	1411				10.	4.5	.785	22.87	
1411	1511				4.5	4.5	.785	22.87	
2111	2211				10.	10.	1.047	23.75	
2211	2311				10.	10.	1.047	23.75	
2311	2411				10.	4.5	1.047	23.75	
2411	2511				4.5	4.5	1.047	23.75	
2121	2221				10.	10.	1.047	24.75	
2221	2321				10.	10.	1.047	24.75	
2321	2421				10.	4.5	1.047	24.75	
2421	2521				4.5	4.5	1.047	24.75	
2131	2231				10.	10.	1.047	25.75	
2231	2331				10.	10.	1.047	25.75	
2331	2431				10.	4.5	1.047	25.75	
2431	2531				4.5	4.5	1.047	25.75	
2141	2241				10.	10.	1.047	26.75	
2241	2341				10.	10.	1.047	26.75	
2341	2441				10.	4.5	1.047	26.75	
2441	2541				4.5	4.5	1.047	26.75	
2151	2251				10.	10.	1.047	27.75	
2251	2351				10.	10.	1.047	27.75	
2351	2451				10.	4.5	1.047	27.75	
2451	2551				4.5	4.5	1.047	27.75	
2161	2261				10.	10.	1.047	28.75	
2261	2361				10.	10.	1.047	28.75	
2361	2461				10.	4.5	1.047	28.75	
2461	2561				4.5	4.5	1.047	28.75	
1121	1221				10.	10.	1.047	29.75	
1221	1321				10.	10.	1.047	29.75	
1321	1421				10.	4.5	1.047	29.75	
1421	1521				4.5	4.5	1.047	29.75	
1131	1231				10.	10.	1.	17.441	
1231	1331				10.	10.	1.	17.441	
1331	1431				10.	4.5	1.	17.441	
1431	1531				4.5	4.5	1.	17.441	
1132	1232				10.	10.	1.	14.76	
1232	1332				10.	10.	1.	14.76	
1332	1432				10.	4.5	1.	14.76	
1432	1532				4.5	4.5	1.	14.76	
1141	1241				10.	10.	.375	21.17	
1241	1341				10.	10.	.375	21.17	
1341	1441				10.	4.5	.375	21.17	
1441	1541				4.5	4.5	.375	21.17	
1142	1242				10.	10.	.375	21.17	
1242	1342				10.	10.	.375	21.17	
1342	1442				10.	4.5	.375	21.17	
1442	1542				4.5	4.5	.375	21.17	
1151	1152				.656	.094	5.00	42.719	

1551	1552			.056	.094	2.25	42.734		
1161	116			.052	.094	3.333	43.066		
1261	1			.052	.094	3.333	43.066		
1361	1.			.052	.094	3.333	43.066		
1461	1462			.052	.094	1.50	43.066		
1561	1562			.052	.094	1.50	43.066		
1151	1251			10.	10.	.375	21.37		
1251	1351			10.	10.	.375	21.37		
1351	1451			10.	4.5	.375	21.37		
1451	1551			4.5	4.5	.375	21.37		
1152	1252			10.	10.	.375	21.37		
1252	1352			10.	10.	.375	21.37		
1352	1452			10.	4.5	.375	21.37		
1452	1552			4.5	4.5	.375	21.37		
1162	1151					26.667	43.46		.170
1262	1251					26.667	43.46		.170
1362	1351					26.667	43.46		.170
1462	1451					12.0	43.46		.170
1562	1551					12.0	43.46		.170
1171	1151					26.667	44.51		.139
1271	1251					26.667	44.51		.139
1371	1351					26.667	44.51		.139
1471	1451					12.0	44.51		.139
1571	1551					12.0	44.51		.139
1181	1151					26.667	45.55		.078
1281	1251					26.667	45.55		.078
1381	1351					26.667	45.55		.078
1481	1451					12.0	45.55		.078
1581	1551					12.0	45.55		.078
1162	1171					26.667	43.46		.106
1262	1271					26.667	43.46		.106
1362	1371					26.667	43.46		.106
1462	1471					12.0	43.46		.106
1562	1571					12.0	43.46		.106
1162	1181					26.667	43.46		.007
1262	1281					26.667	43.46		.007
1362	1381					26.667	43.46		.007
1462	1481					12.0	43.46		.007
1562	1581					12.0	43.46		.007
1171	1181					26.667	44.51		.233
1271	1281					26.667	44.51		.233
1371	1381					26.667	44.51		.233
1471	1481					12.0	44.51		.233
1571	1581					12.0	44.51		.233
1	5			1.5	1.5	5.89	2.813	500.	.32
2	6	2	1	1	1.5	1.5	5.89	-4.438	500.	.32
5	9				1.5	1.5	5.89	2.813	500.	.15
6	10	2	1	1	1.5	1.5	5.89	-4.438	500.	.15
9	13				1.5	1.25	5.89	2.813	25.	.15
10	14	2	1	1	1.5	1.25	5.89	-4.438	25.	.15
13	30				1.25	2.5	5.89	2.813	25.	.1
14	31	2	1	1	1.25	2.5	5.89	-4.438	25.	.1
1	2				2.81	2.81	3.14	5.625		
2	3	1	1	1	2.81	2.81	3.14	-11.25		
5	6				2.81	2.81	3.14	5.625		
6	7	1	1	1	2.81	2.81	3.14	-11.25		
9	10				2.81	2.81	3.14	5.625		
10	11	1	1	1	2.81	2.81	3.14	-11.25		
13	14				2.81	2.81	2.62	5.625		
14	15	1	1	1	2.81	2.81	2.62	-11.25		
30					2.81	2.81	5.24	5.625		
31		2	1	1	2.81	2.81	5.24	-11.25		
17	23				2.5	.88	8.38	27.5		
23	24				[illegible]	[illegible]	[illegible]	[illegible]		

VIII-E14

```
 25                    2.25      .75       3.14      35.8      25.        .15
  4                    2.81      3.5       3.14      22.5      25         .32
  8                    2.81      3.5       3.14      22.5
 12                    2.81      3.5       3.14      22.5      25.        .15
 16   22               2.81      3.5       2.62      22.5
 19   27               3.5       1.2       3.14      24.3      25.        .25
 20   27               3.5       1.2       3.14      24.3      25.        .25
 21   27               3.5       1.2       3.14      24.3      25.        .15
 22   27               5.        1.5       2.62      32.2      25.        .25
 17 1511               4.        4.5       .79       22.4
 17 2511               4.        4.5       1.047     23.75     25.        .32
 17 2521   2    10     4.        4.5       1.047     -24.75    25.        .32
 17 2551               4.        4.5       .25       25.9      25.        .32
 23 2551               4.        4.5       1.047     27.8      25.        .32
 23 2561               4.        4.5       1.047     29.8      25.        .32
 24 1521               4.        4.5       1.047     29.8
 24   26               4.        5.        2.09      30.2
 25   26               4.        6.        4.71      33.5
 26   27               6.        5.75      5.81      32.5
 28   29               1.5       5.5       1.57      35.5      25.        .15
 18   26               3.38      3.25      12.3      29.3
 17   18               4.        5.88      7.07      25.
 18   23               5.88      4.        1.93      28.4      25.        .15
 18   19                                   7.07      26.7      250.
 19   20               1.5       1.5       7.07      26.7
 20   21               1.5       1.5       7.07      26.7      25.        .15
 21   22               1.5       1.25      7.07      26.7      25.        .15
 22   34               1.25      2.5       7.07      26.7      50.        .1
  1 3511                                   5.89      2.813                .25
  2 3511   2    1                          5.89      -4.438               .25
 17 3511                                   4.38      22.5                 .25
 18 3511                                   12.3      22.5                 .15
  1 3511                                   5.89      2.813     .6         -.333
  2 3511   2    1                          5.89      -4.438    .6         -.333
 17 3511                                   4.38      22.5      .6         -.333
 18 3511                                   12.3      22.5      .6         -.333

BLOCK06   1111/11111222/22222333/33333444/44444555/55555666/66666777///
 1162 1000                    6 26.667   43.46                   .0619   .333
 .258      -40.      .212     100.       .171      300.      .139      600.
 .112      1000.     .093     1475.
 1262 1000                    6 26.667   43.46                   .0619   .333
 .258      -40.      .212     100.       .171      300.      .139      600.
 .112      1000.     .093     1475.
 1362 1000                    6 26.667   43.46                   .0619   .333
 .258      -40.      .212     100.       .171      300.      .139      600.
 .112      1000.     .093     1475.
 1462 1000                    6 12.0     43.46                   .0619   .333
 .258      -40.      .212     100.       .171      300.      .139      600.
 .112      1000.     .093     1475.
 1562 1000                    6 12.0     43.46                   .0619   .333
 .258      -40.      .212     100.       .171      300.      .139      600.
 .112      1000.     .093     1475.
 1171 1000                    6 26.667   44.51                   .0463   .333
 .258      -40.      .212     100.       .171      300.      .139      600.
 .112      1000.     .093     1475.
 1271 1000                    6 26.667   44.51                   .0463   .333
 .258      -40.      .212     100.       .171      300.      .139      600.
 .112      1000.     .093     1475.
 1371 1000                    6 26.667   44.51                   .0463   .333
 .258      -40.      .212     100.       .171      300.      .139      600.
 .112      1000.     .093     1475.
 1471 1000                    612.0      44.51                   .0463   .333
```

```
 .258      -40.      .212      100.      .171      300.      .139      600.
 .112      1[illegible].      .093      1475.
 1181 100[illegible]                 6 26.667   49.87                          .333
 .258      [illegible]      .212      100.      .171      300.      .139      600.
 .112      1000.     .093      1475.
 1281 1000                     6 26.667   49.87                    .1031 .333
 .258      -40.      .212      100.      .171      300.      .139      600.
 .112      1000.     .093      1475.
 1381 1000                     6 26.667   49.87                    .1031 .333
 .258      -40.      .212      100.      .171      300.      .139      600.
 .112      1000.     .093      1475.
 1481 1000                     612.0      49.87                    .1031 .333
 .258      -40.      .212      100.      .171      300.      .139      600.
 .112      1000.     .093      1475.
 1581 1000                     612.0      49.87                    .1031 .333
 .258      -40.      .212      100.      .171      300.      .139      600.
 .112      1000.     .093      1475.
 1151 1000                     6 17.47    42.94                    .1350 .333
 .258      -40.      .212      100.      .171      300.      .139      600.
 .112      1000.     .093      1475.
 1251 1000                     6 17.47    42.94                    .1350 .333
 .258      -40.      .212      100.      .171      300.      .139      600.
 .112      1000.     .093      1475.
 1351 1000                     6 17.47    42.94                    .1350 .333
 .258      -40.      .212      100.      .171      300.      .139      600.
 .112      1000.     .093      1475.
 1451 1000                     6 17.47    42.94                    .1350 .333
 .258      -40.      .212      100.      .171      300.      .139      600.
 .112      1000.     .093      1475.
 1551 1000                     6 17.47    42.94                    .1350 .333
 .258      -40.      .212      100.      .171      300.      .139      600.
 .112      1000.     .093      1475.
   30 1000                     4 5.89     2.81                   .6        .333
 .129      -40.      .106      100.      .085      300.      .07       600.
   31 1000                     4 5.89     8.44                   .6        .333
 .129      -40.      .106      100.      .085      300.      .07       600.
   32 1000                     4 5.89     14.1                   .6        .333
 .129      -40.      .106      100.      .085      300.      .07       600.
   33 1000                     4 5.89     19.7                   .6        .333
 .129      -40.      .106      100.      .086      300.      .07       600.
   34 1000                     4 6.2      25.3                   .6        .333
 .129      -40.      .106      100.      .085      300.      .07       600.
   27 1000                     6 1.047    692.                   .4        .333
 .258      -40.      .212      100.      .171      300.      .139      600.
 .112      1000.     .093      1475.
   28 1000                     6 4.19     39.                    .4        .333
 .258      -40.      .212      100.      .171      300.      .139      600.
 .112      1000.     .093      1475.
   29 1000                     6 14.2     36.3                   .4        .333
 .258      -40.      .212      100.      .171      300.      .139      600.
 .112      1000.     .093      1475.

BLOCK07
 1000                 130.

BLOCK08   1111/111112222/222223333/333334444/444445555/555556666/6666677777
 1181    2  100   -2 281.      .0        281.      10000.
 1481    1  100   -2 281.      .0        281.      10000.
 1151    2  100   -2  1964.    .0        1964.     10000.
 1451    1  100   -2  1964.    .0        1964.     10000.

BLOCK 9
 3111                 6.672E+02 1.000E+00 0.          1903.1
 3211                 6.507E+02 1.000E+00 0.          1903.1
```

3511	5.340E+02	1.000E+00	0.	-0.
1111	5.547E+02	1.000E+00	0.	-0.
1211	5.456E+02	1.000E+00	0.	-0.
1311	5.140E+02	1.000E+00	0.	-0.
1411	4.775E+02	1.000E+00	0.	-0.
1511	4.437E+02	1.000E+00	0.	-0.
2111	5.495E+02	1.000E+00	0.	-0.
2211	5.364E+02	1.000E+00	0.	-0.
2311	5.066E+02	1.000E+00	0.	-0.
2411	4.694E+02	1.000E+00	0.	-0.
2511	4.345E+02	1.000E+00	0.	-0.
2121	5.430E+02	1.000E+00	0.	-0.
2221	5.302E+02	1.000E+00	0.	-0.
2321	5.094E+02	1.000E+00	0.	-0.
2421	4.637E+02	1.000E+00	0.	-0.
2521	4.352E+02	1.000E+00	0.	-0.
2131	5.364E+02	1.000E+00	0.	-0.
2231	5.243E+02	1.000E+00	0.	-0.
2331	4.954E+02	1.000E+00	0.	-0.
2431	4.584E+02	1.000E+00	0.	-0.
2531	4.318E+02	1.000E+00	0.	-0.
2141	5.310E+02	1.000E+00	0.	-0.
2241	5.195E+02	1.000E+00	0.	-0.
2341	4.903E+02	1.000E+00	0.	-0.
2441	4.542E+02	1.000E+00	0.	-0.
2541	4.293E+02	1.000E+00	0.	-0.
2151	5.254E+02	1.000E+00	0.	-0.
2251	5.132E+02	1.000E+00	0.	-0.
2351	4.854E+02	1.000E+00	0.	-0.
2451	4.497E+02	1.000E+00	0.	-0.
2551	4.249E+02	1.000E+00	0.	-0.
2161	5.200E+02	1.000E+00	0.	-0.
2261	5.090E+02	1.000E+00	0.	-0.
2361	4.807E+02	1.000E+00	0.	-0.
2461	4.455E+02	1.000E+00	0.	-0.
2561	4.212E+02	1.000E+00	0.	-0.
1121	5.109E+02	1.000E+00	0.	-0.
1221	4.992E+02	1.000E+00	0.	-0.
1321	4.726E+02	1.000E+00	0.	-0.
1421	4.391E+02	1.000E+00	0.	-0.
1521	4.140E+02	1.000E+00	0.	-0.
1131	4.999E+02	1.000E+00	0.	-0.
1231	4.887E+02	1.000E+00	0.	-0.
1331	4.630E+02	1.000E+00	0.	-0.
1431	4.255E+02	1.000E+00	0.	-0.
1531	4.040E+02	1.000E+00	0.	-0.
1132	5.053E+02	1.000E+00	0.	-0.
1232	4.939E+02	1.000E+00	0.	-0.
1332	4.677E+02	1.000E+00	0.	-0.
1432	4.352E+02	1.000E+00	0.	-0.
1532	4.129E+02	1.000E+00	0.	-0.
1141	3.230E+02	1.000E+00	0.	-0.
1241	3.174E+02	1.000E+00	0.	-0.
1341	3.045E+02	1.000E+00	0.	-0.
1441	2.779E+02	1.000E+00	0.	-0.
1541	2.674E+02	1.000E+00	0.	-0.
1142	3.226E+02	1.000E+00	0.	-0.
1242	3.170E+02	1.000E+00	0.	-0.
1342	3.042E+02	1.000E+00	0.	-0.
1442	2.774E+02	1.000E+00	0.	-0.
1542	2.676E+02	1.000E+00	0.	-0.
1151	3.203E+02	1.000E+00	0.	-0.
1251	3.148E+02	1.000E+00	0.	-0.
1351	3.022E+02	1.000E+00	0.	-0.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1152	3.197E+02	1.000E+00	0.	-0.
1252	3.143E+02	1.000E+00	0.	-0.
1352	3.017E+02	1.000E+00	0.	-0.
1452	2.753E+02	1.000E+00	0.	-0.
1552	2.657E+02	1.000E+00	0.	-0.
1161	3.160E+02	1.000E+00	0.	-0.
1261	3.107E+02	1.000E+00	0.	-0.
1361	2.944E+02	1.000E+00	0.	-0.
1461	2.726E+02	1.000E+00	0.	-0.
1561	2.631E+02	1.000E+00	0.	-0.
1162	3.174E+02	1.000E+00	0.	-0.
1262	3.082E+02	1.000E+00	0.	-0.
1362	2.951E+02	1.000E+00	0.	-0.
1462	2.707E+02	1.000E+00	0.	-0.
1562	2.515E+02	1.000E+00	0.	-0.
1171	2.908E+02	1.000E+00	0.	-0.
1271	2.854E+02	1.000E+00	0.	-0.
1371	2.752E+02	1.000E+00	0.	-0.
1471	2.543E+02	1.000E+00	0.	-0.
1571	2.469E+02	1.000E+00	0.	-0.
1181	2.790E+02	1.000E+00	0.	-0.
1281	2.750E+02	1.000E+00	0.	-0.
1381	2.653E+02	1.000E+00	0.	-0.
1481	2.455E+02	1.000E+00	0.	-0.
1581	2.394E+02	1.000E+00	0.	-0.
1	4.505E+02	1.000E+00	0.	-0.
2	4.474E+02	1.000E+00	0.	-0.
3	4.414E+02	1.000E+00	0.	-0.
4	4.320E+02	1.000E+00	0.	-0.
5	4.354E+02	1.000E+00	0.	-0.
6	4.331E+02	1.000E+00	0.	-0.
7	4.259E+02	1.000E+00	0.	-0.
8	4.130E+02	1.000E+00	0.	-0.
9	3.599E+02	1.000E+00	0.	-0.
10	3.542E+02	1.000E+00	0.	-0.
11	3.545E+02	1.000E+00	0.	-0.
12	3.480E+02	1.000E+00	0.	-0.
13	2.944E+02	1.000E+00	0.	-0.
14	2.848E+02	1.000E+00	0.	-0.
15	2.848E+02	1.000E+00	0.	-0.
16	2.950E+02	1.000E+00	0.	-0.
17	4.103E+02	1.000E+00	0.	-0.
18	3.941E+02	1.000E+00	0.	-0.
19	3.923E+02	1.000E+00	0.	-0.
20	3.863E+02	1.000E+00	0.	-0.
21	3.352E+02	1.000E+00	0.	-0.
22	2.866E+02	1.000E+00	0.	-0.
23	3.989E+02	1.000E+00	0.	-0.
24	3.927E+02	1.000E+00	0.	-0.
25	3.742E+02	1.000E+00	0.	-0.
26	3.771E+02	1.000E+00	0.	-0.
27	3.221E+02	1.000E+00	0.	-0.
28	3.551E+02	1.000E+00	0.	-0.
29	2.370E+02	1.000E+00	0.	-0.
30	2.765E+02	1.000E+00	0.	-0.
31	2.767E+02	1.000E+00	0.	-0.
32	2.769E+02	1.000E+00	0.	-0.
33	2.774E+02	1.000E+00	0.	-0.
34	2.780E+02	1.000E+00	0.	-0.

ENDED-1

AFTER FIRE

3

BLOCK058

VIII-E18

2/76

```
 1131 11[illegible]  2  1  12                    10.      37.44     .82      -.278
 1431 144[illegible]  1  1  12                    4.5      37.44     .82      -.278
 1431 144[illegible]  2  1  12                    4.5      37.44     .82      -.278

BLOCK#5A
   24 1531              4.        4.5            1.047    30.3
   25 1531                                       4.71     33.5                .12
   28 1531                                       4.71     38.                 .12
 1132 1141  2  1  12                             20.      3.2                 0.290
 1432 1441  1  1  12                             9.       3.2                 0.290
 1131 1141  2  1  12                             10.      37.44               0.290
 1131 1142  2  1  12                             10.      37.44               0.290
 1431 1442  1  1  12                             4.5      37.44               0.290
 1431 1441  1  1  12                             4.5      37.44               0.290

ENDED-1
*SPLIT
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```
MODEL IS 1/2 AXIAL AND 60 DEG. CIRCUM.. HENCE 1/12 OF WHOLE CASE IS MODELED
(103) .1875 THICK.X 3.0PF HIGH S. STL. EXT. FINS
E=.25 S.STL AND CU. GLYCOL
**NLINOTD** 2/22/76    NLI 3-D MODEL OF THERMAL
BLOCK01  S1111/11111/2222/2222/3333/3333/4444/4444/5555/5555/6666/6666/7777/7777
            -1                    1          1   66  20.      .053333333
         3 .15                   10.                   50.        -45.      2000.
250.
BLOCK 2   1111/11111/2222/2222/3333/3333/4444/4444/5555/5555/6666/6666/7777/
30155     1                 4    5      493.                          2600.      120.
      .100       -50.       .109       40.       .115       140.       .121       240.
      .133       540.       .135      640.       .137       740.       .155      1640.
      7.7        -60.       8.35       40.       8.95       140.       9.55       240.
     11.1        540.      11.55      640.      11.58       740.      15.8       1640.
LEAD      2                 4    5      493.                           621.       10.5
  3.03E-02        32.  3.19E-02       212.  3.36E-02       572.  3.37E-02       621.
  3.25E-02       621.  3.28E-02     19000.
     20.1         32.      19.6       212.      19.0       572.       4.8       621.
      4.8        621.       0.9       910.       4.6      1200.      11.5      1500.
CORE      3                        125.       .108       100.      1200.      167.
CU        4                 4    5      550.                           2440.       40.
      .075      -210.  8.45E-02      -110.       .088       -60.       .091       15.
      .093        90.       .101      555. 1.215E-01      1965.       .160     4875.
    243.5        -60.      233.       40.      221.       390.      214.5      600.
      209.       800.      204.     1000.      190.      1200.      184.5     1900.
COCU      5                 3    4      555.                           1890.     2240.
.089      -40.       .13       400.       .115      1475.
154.      -40.      181.       400.       190.       550.       190.      1475.
URANI     6                 6    5 1130.0                            2070.0     494.
  0.026   -100.0    0.027      0.0       0.029      100.0      0.0345     500.
  0.042   1000.0    0.0495    1240.0
  15.2    -100.0    13.3       0.0       15.0       200.0      18.0       500.
  24.7    1500.0
RI109     7                        55.        .55        .15       1500.      1.
BALSA     8                        15.        .5         .034      1500.      1.

BLOCK04   1111/11111/2222/2222/3333/3333/4444/4444/5555/5555/6666/6666/7777/7777
  3111                3          20.       22.50      11.78
  3211                3          20.       22.50      11.78
  3311                3          20.       22.50      11.78
  3411                3           9.       22.50      11.78
  3511                3           6.       22.50      11.78
  1111                1          20.        .75      23.95
  1211                1          20.        .75      23.95
  1311                1          20.        .75      23.95
  1411                1           9.        .75      23.95
  1511                1           9.        .75      23.95
  2111                2          20.       1.        24.87
  2211                2          20.       1.        24.87
  2311                2          20.       1.        24.87
  2411                2           9.       1.        24.87
  2511                2           9.       1.        24.87
  2121                2          20.       1.        25.92
  2221                2          20.       1.        25.92
  2321                2          20.       1.        25.92
  2421                2           9.       1.        25.92
  2521                2           9.       1.        25.92
  2131                2          20.       1.        25.97
  2231                2          20.       1.        25.97
```

EXHIBIT 2. INPUT DATA FOR BOTTOM SECTIONS THERMAL ANALYSIS

2141			2	20.	1.	24.01
2241			2	20.	1.	24.01
2341			2	20.	1.	24.01
2441			2	9.	1.	24.01
2541			2	9.	1.	24.01
2151			2	20.	1.	29.05
2251			2	20.	1.	29.05
2351			2	20.	1.	29.05
2451			2	9.	1.	29.05
2551			2	9.	1.	29.05
2161			2	20.	1.	30.1
2261			2	20.	1.	30.1
2361			2	20.	1.	30.1
2461			2	9.	1.	30.1
2561			2	9.	1.	30.1
1121			1	20.	1.	31.67
1221			1	20.	1.	31.67
1321			1	20.	1.	31.67
1421			1	9.	1.	31.67
1521			1	9.	1.	31.67
1131			1	20.	1.	17.725
1231			1	20.	1.	17.725
1331			1	20.	1.	17.725
1431			1	9.	1.	17.725
1531			1	9.	1.	17.725
1132			1	20.	1.	15.00
1232			1	20.	1.	15.00
1332			1	20.	1.	15.00
1432			1	9.	1.	15.00
1532			1	9.	1.	15.00
1141			1	20.	.375	21.17
1241			1	20.	.375	21.17
1341			1	20.	.375	21.17
1441			1	9.	.375	21.17
1541			1	9.	.375	21.17
1142			1	20.	.375	21.17
1242			1	20.	.375	21.17
1342			1	20.	.375	21.17
1442			1	9.	.375	21.17
1542			1	9.	.375	21.17
1151			1	17.47	.375	42.7388
1251			1	17.47	.375	42.7388
1351			1	17.47	.375	42.7388
1451			1	7.97	.375	42.7388
1551			1	7.97	.375	42.7388
1152			1	2.53	.375	42.7388
1252			1	2.53	.375	42.7388
1352			1	2.53	.375	42.7388
1452			1	1.03	.375	42.7388
1552			1	1.03	.375	42.7388
1161	2	100	1	3.333	.125	42.935
1461	1	100	1	1.50	.125	42.935
1162	2	100	1	2.53	1.	43.45
1462	1	100	1	1.03	1.	43.45
1171			1	2.531	1.	44.51
1271			1	2.531	1.	44.51
1371			1	2.531	1.	44.51
1471			1	1.03	1.	44.51
1571			1	1.03	1.	44.51
1141			1	2.53	1.	45.55
1241			1	2.53	1.	45.55
1341			1	2.53	1.	45.55
1441			1	1.03	1.	45.55

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5			1		2.5	5.14	2.414		
6	2	1	1		2.5	5.59	-4.414		
9			1		4.	5.32	2.413		
10	2	1	1		4.	5.34	-4.434		
13			1		3.54	5.54	2.414		
14	1	1	1		3.53	5.57	-3.438		
16			1		3.45	5.34	14.54		
17			1		5.5	.755	22.84		
18			1		7.	.755	22.88		
19			1		2.5	.755	22.88		
20			1		4.	.785	22.44		
21			1		3.54	.785	22.44		
22			1		5.5	2.55	24.25		
23			1		6.75	2.55	24.25		
24			1		5.	2.50	24.25		
25			1		12.25	5.	31.4		
26			1		6.	3.95	19.4		
27			1		3.	5.76	17.3		
28			1		7.25	1.14	17.		
BLOCKS	1111/1111	2222/2222	3333/3333	4444/4444	5555/5555	6666/6666	7777/7777		
3111	1111		87.5	.5	20.	23.56			
3211	1211		87.5	.5	20.	23.56			
3311	1311		87.5	.5	20.	23.56			
3411	1411		87.5	.5	3.	23.56			
3511	1511		87.5	.5	3.	23.56			
1111	2111		.375	.5	20.44	23.25	500.		
2111	2121	4 10 10	.5	.5	20.44	-24.25			
1211	2211		.375	.5	20.44	23.25	500.		
2211	2221	4 10 10	.5	.5	20.44	-24.25			
1311	2311		.375	.5	20.44	23.25	500.		
2311	2321	4 10 10	.5	.5	20.44	-24.25			
1411	2411		.375	.5	9.425	23.25	500.		
2411	2421	4 10 10	.5	.5	9.425	-24.25			
1511	2511		.375	.5	9.425	23.25	500.		
2511	2521	4 10 10	.5	.5	9.425	-24.25			
2101	1121		.5	.5	20.00	22.973			
2201	1221		.5	.5	20.00	22.973			
2301	1321		.5	.5	20.00	22.973			
2401	1421		.5	.5	9.0	22.973			
2501	1521		.5	.5	9.0	22.973			
1121	1131	2 1 12	.5	.5	20.00	17.158			
1421	1431	1 1 12	.5	.5	9.0	17.159			
1121	1132	2 1 12	.5	.5	20.00	14.52			
1421	1432	1 1 12	.5	.5	9.0	14.52			
1131	1132	2 1 12	.072	.734	20.	10.			
1431	1432	1 1 12	.072	.738	9.	10.			
1132	1141	2 1 12			20.	3.2	37.0	-.278	
1432	1441	1 1 12			9.	3.2	37.0	-.278	
1131	1141	2 1 12			10.	37.44	37.0	-.278	
1131	1142	2 1 12			10.	37.44	37.0	-.278	
1431	1442	1 1 12			4.5	37.44	37.0	-.278	
1431	1441	1 1 12			4.5	37.44	37.0	-.278	
1141	1151	2 1 12	.188	.188	17.47	21.07			
1142	1151	2 1 12	.188	.188	17.47	21.07			
1141	1152	2 1 12	.188	.188	2.53	21.07			
1142	1152	2 1 12	.188	.188	2.53	21.07			
1441	1451	1 1 12	.188	.188	7.464	21.07			
1442	1451	1 1 12	.188	.188	7.464	21.07			
1441	1452	1 1 12	.188	.188	1.031	21.07			
1442	[illegible]	1 1 12	.188	.188	1.031	21.07			
1151	[illegible]	2 1 12	.188	.188	4.22	42.94			
1451	[illegible]	1 1 12	.188	.188	1.719	42.94			
1152	1162	2 1 12	[illegible]	[illegible]	[illegible]	[illegible]			

1162	1				.5	.5	2.53	43.98	
1262	1				.5	.5	2.53	43.98	
1362	13				.5	.5	2.53	43.98	
1462	14				.5	.5	1.031	43.98	
1562	1571				.5	.5	1.031	43.98	
1171	1181				.5	.5	2.53	45.03	
1271	1281				.5	.5	2.53	45.03	
1371	1381				.5	.5	2.53	45.03	
1471	1481				.5	.5	1.031	45.03	
1571	1581				.5	.5	1.031	45.03	
3111	3211	1	1	12	10.	10.	3.85	22.5	20.8
3311	3411				10.	4.5	3.85	22.5	20.8
3411	3511				4.5	3.	3.85	22.5	20.8
1111	1211				10.	10.	.785	22.47	
1211	1311				10.	10.	.785	22.47	
1311	1411				10.	4.5	.785	22.47	
1411	1511				4.5	4.5	.785	22.47	
2111	2211				10.	10.	1.047	23.75	
2211	2311				10.	10.	1.047	23.75	
2311	2411				10.	4.5	1.047	23.75	
2411	2511				4.5	4.5	1.047	23.75	
2121	2221				10.	10.	1.047	24.75	
2221	2321				10.	10.	1.047	24.75	
2321	2421				10.	4.5	1.047	24.75	
2421	2521				4.5	4.5	1.047	24.75	
2131	2231				10.	10.	1.047	25.75	
2231	2331				10.	10.	1.047	25.75	
2331	2431				10.	4.5	1.047	25.75	
2431	2531				4.5	4.5	1.047	25.75	
2141	2241				10.	10.	1.047	26.75	
2241	2341				10.	10.	1.047	26.75	
2341	2441				10.	4.5	1.047	26.75	
2441	2541				4.5	4.5	1.047	26.75	
2151	2251				10.	10.	1.047	27.75	
2251	2351				10.	10.	1.047	27.75	
2351	2451				10.	4.5	1.047	27.75	
2451	2551				4.5	4.5	1.047	27.75	
2161	2261				10.	10.	1.047	28.75	
2261	2361				10.	10.	1.047	28.75	
2361	2461				10.	4.5	1.047	28.75	
2461	2561				4.5	4.5	1.047	28.75	
1121	1221				10.	10.	1.047	29.75	
1221	1321				10.	10.	1.047	29.75	
1321	1421				10.	4.5	1.047	29.75	
1421	1521				4.5	4.5	1.047	29.75	
1131	1231				10.	10.	1.	17.441	
1231	1331				10.	10.	1.	17.441	
1331	1431				10.	4.5	1.	17.441	
1431	1531				4.5	4.5	1.	17.441	
1132	1232				10.	10.	1.	14.76	
1232	1332				10.	10.	1.	14.76	
1332	1432				10.	4.5	1.	14.76	
1432	1532				4.5	4.5	1.	14.76	
1141	1241				10.	10.	.375	21.17	
1241	1341				10.	10.	.375	21.17	
1341	1441				10.	4.5	.375	21.17	
1441	1541				4.5	4.5	.375	21.17	
1142	1242				10.	10.	.375	21.17	
1242	1342				10.	10.	.375	21.17	
1342	1442				10.	4.5	.375	21.17	
1442	1542				4.5	4.5	.375	21.17	
1151	1152				.555	.094	5.0	42.739	
1251	1252				.555	.094	5.0	42.739	
1351	1352				.555	.094	5.0	42.739	

1251	1262				.052	.094	3.33	43.066			
1361	1362				.052	.094	3.33	43.066			
1461					.052	.094	1.50	43.066			
1561					.052	.094	1.50	43.066			
1151	1251				10.	10.	.375	21.37			
1251	1351				10.	10.	.375	21.37			
1351	1451				10.	4.5	.375	21.37			
1451	1551				4.5	4.5	.375	21.37			
1152	1252				10.	10.	.375	21.37			
1252	1352				10.	10.	.375	21.37			
1352	1452				10.	4.5	.375	21.37			
1452	1552				4.5	4.5	.375	21.37			
1162	1151						26.667	43.46			.170
1262	1251						26.667	43.46			.170
1362	1351						26.667	43.46			.170
1462	1451						12.0	43.46			.170
1562	1551						12.0	43.46			.170
1171	1151						26.667	44.51			.139
1271	1251						26.667	44.51			.139
1371	1351						26.667	44.51			.139
1471	1451						12.0	44.51			.139
1571	1551						12.0	44.51			.139
1181	1151						26.667	45.55			.078
1281	1251						26.667	45.55			.078
1381	1351						26.667	45.55			.078
1481	1451						12.0	45.55			.078
1581	1551						12.0	45.55			.078
1162	1171						26.667	43.46			.106
1262	1271						26.667	43.46			.106
1362	1371						26.667	43.46			.106
1462	1471						12.0	43.46			.106
1562	1571						12.0	43.46			.106
1162	1181						26.667	43.46			.007
1262	1281						26.667	43.46			.007
1362	1381						26.667	43.46			.007
1462	1481						12.0	43.46			.007
1562	1581						12.0	43.46			.007
1171	1181						26.667	44.51			.233
1271	1281						26.667	44.51			.233
1371	1381						26.667	44.51			.233
1471	1481						12.0	44.51			.233
1571	1581						12.0	44.51			.233
1	2				2.81	2.81	2.09	5.625			
2	3	1	1	1	2.81	2.81	2.09	-11.25			
5	6				2.81	2.81	2.52	5.625			
6	7	1	1	1	2.81	2.81	2.52	-11.25			
9	10				2.81	2.81	4.19	5.625			
10	11	1	1	1	2.81	2.81	4.19	-11.25			
13	14				2.81	2.81	4.06	5.625			
14	15				2.81	2.81	4.06	11.25			
15	16				2.81	2.81	4.06	16.88	25.	.15	
4	18				2.81	.38	2.09	22.5			
8	19				2.81	.38	2.52	22.5	25.	.12	
12	20				2.81	.75	4.19	22.5			
16	21				2.81	.75	4.06	22.5			
17	22				.38	1.38	5.78	23.3	25.	.32	
18	23				.38	1.38	2.09	23.3	25.	.32	
19	23				.38	1.38	2.52	23.3	25.	.32	
20	24				.38	1.38	1.83	23.3			
21	24				.38	1.38	4.06	23.3			
22	5				1.75	2.25	5.75	26.	.0	.25	
23	5				1.75	2.25	7.07	26.	.0	.25	
24	26				1.35	4.73	5.25	25.			

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```
   1                  0.1        4.25       1.047     24.75
25  31                0.1        4.25       1.        30.2
25                    0.1        4.25       1.        2.
25                    0.1        1.         0.11      30.8
27 1531                                     4.45      48.                    .12
27   28               1.5        1.0        3.14      37.1      25.          .15
27 1551                1.5        4.5        .785      40.62
 1 3511                                     5.89      2.813     2.80         .333
 2 3511  2  1                               5.89      -9.438    2.80         .333
17 3511                                     5.76      22.5      2.80         .333
 1    5                1.        1.25       5.89      2.813     500.         .32
 2    6  2  1  1       1.        1.25       5.89      -9.438    500.         .32
 5    9                1.25      2.         5.89      2.813     500.         .32
 6   10  2  1  1       1.25      2.         5.89      -9.438    500.         .32
 9   13                2.        1.94       5.89      2.813     25.          .15
10   14  1  1  1       2.        1.94       5.89      -9.438    25.          .15
12   16                2.        1.94       5.89      19.69
17   18                2.75      1.         .785      22.98
18   19                1.        1.25       .785      22.98
19   20                1.25      2.         .785      22.98
20   21                2.        1.94       .785      22.98
17 1511                2.75      4.5        .785      22.98     25.          .32
22 2521                2.75      4.5        1.047     24.75     25.          .32
22 2531                2.75      4.5        .785      25.1      25.          .32
22   23                2.75      3.38       2.88      24.6
23   24                3.35      3.         2.88      24.6      25.          .32

BLOCK06   1111/1111122222/22222333333/33333444444/44444555555/55555666666/66666777777
1162 1000                          6 26.667   43.46                .0619   .333
.258     -40.      .212            100.       .171      300.       .139    600.
.112     1000.     .093            1475.
1262 1000                          6 26.667   43.46                .0619   .333
.258     -40.      .212            100.       .171      300.       .139    600.
.112     1000.     .093            1475.
1362 1000                          6 26.667   43.46                .0619   .333
.258     -40.      .212            100.       .171      300.       .139    600.
.112     1000.     .093            1475.
1462 1000                          6 12.0     43.46                .0619   .333
.258     -40.      .212            100.       .171      300.       .139    600.
.112     1000.     .093            1475.
1562 1000                          6 12.0     43.46                .0619   .333
.258     -40.      .212            100.       .171      300.       .139    600.
.112     1000.     .093            1475.
1171 1000                          6 26.667   44.51                .0463   .333
.258     -40.      .212            100.       .171      300.       .139    600.
.112     1000.     .093            1475.
1271 1000                          6 26.667   44.51                .0463   .333
.258     -40.      .212            100.       .171      300.       .139    600.
.112     1000.     .093            1475.
1371 1000                          6 26.667   44.51                .0463   .333
.258     -40.      .212            100.       .171      300.       .139    600.
.112     1000.     .093            1475.
1471 1000                          612.0      44.51                .0463   .333
.258     -40.      .212            100.       .171      300.       .139    600.
.112     1000.     .093            1475.
1571 1000                          612.0      44.51                .0463   .333
.258     -40.      .212            100.       .171      300.       .139    600.
.112     1000.     .093            1475.
1181 1000                          6 26.667   49.87                .1031   .333
.258     -40.      .212            100.       .171      300.       .139    600.
.112     1000.     .093            1475.
1281 1000                          6 26.667   49.87                .1031   .333
.258     -40.      .212            100.       .171      300.       .139    600.
.112     1000.     .093            1475.
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1441 1000                    612.0     49.87                    .1031   .333
.258      -40.     .212      100.      .171      300.      .139      600.
.112      1000.    .093      1475.
1541 1000                    612.0     49.87                    .1031   .333
.258      -40.     .212      100.      .171      300.      .139      600.
.112      1000.    .093      1475.
1151 1000                    6 17.47   42.94                    .1350   .333
.258      -40.     .212      100.      .171      300.      .139      600.
.112      1000.    .093      1475.
1251 1000                    5 17.47   42.94                    .1350   .333
.258      -40.     .212      100.      .171      300.      .139      600.
.112      1000.    .093      1475.
1351 1000                    6 17.47   42.94                    .1350   .333
.258      -40.     .212      100.      .171      300.      .139      600.
.112      1000.    .093      1475.
1451 1000                    6 17.47   42.94                    .1350   .333
.258      -40.     .212      100.      .171      300.      .139      600.
.112      1000.    .093      1475.
1551 1000                    6 17.47   42.94                    .1350   .333
.258      -40.     .212      100.      .171      300.      .139      600.
.112      1000.    .093      1475.
  13 1000                    4 5.49    2.81                     .6      .333
.129      -40.     .106      100.      .085      300.      .07       600.
  14 1000                    4 5.89    4.64                     .6      .333
.129      -40.     .106      100.      .085      300.      .07       600.
  15 1000                    4 5.49    14.1                     .6      .333
.129      -40.     .105      100.      .085      300.      .07       600.
  16 1000                    4 5.49    19.69                    .6      .333
.129      -40.     .106      100.      .085      300.      .07       600.
  24 1000                    4 2.75    24.3                     .6      .333
.129      -40.     .106      100.      .085      300.      .07       600.
  26 1000                    4 1.      515.                     .77     .333
.129      -40.     .106      100.      .086      300.      .07       600.
  27 1000                    5 1.      354.                     .4      .333
.258      -40.     .212      100.      .171      300.      .139      600.
.112      1000.    .093      1475.
  28 1000                    5 1.      273.                     .4      .333
.258      -40.     .212      100.      .171      300.      .139      600.
.112      1000.    .093      1475.

BLOCK07   1111/11111222/22222333/33333444/44444555/55555666/66666777/7/
 1000                 130.

BLOCK08
 1141     2  100   -2 281.      .0        281.      10000.
 1441     1  100   -2 281.      .0        281.      10000.
 1151     2  100   -2  1964.    .0        1964.     10000.
 1451     1  100   -2  1964.    .0        1964.     10000.

BLOCK09
    1                 4.504E+02 1.000E+00 0.        -0.
    2                 4.464E+02 1.000E+00 0.        -0.
    3                 4.404E+02 1.000E+00 0.        -0.
    4                 4.297E+02 1.000E+00 0.        -0.
    5                 4.243E+02 0.        0.        -0.
    6                 4.202E+02 0.        0.        -0.
    7                 4.171E+02 0.        0.        -0.
    8                 4.014E+02 0.        0.        -0.
    9                 4.014E+02 1.000E+00 0.        -0.
   10                 3.954E+02 1.000E+00 0.        -0.
   11                 3.851E+02 1.000E+00 0.        -0.
   12                 3.472E+02 1.000E+00 0.        -0.
   13                 2.777E+02 1.000E+00 0.        -0.
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  16                 3.431E+02 1.000E+00 0.        -0.
  17                 4.450E+02 1.000E+00 0.        -0.
  18                 4.168E+02 1.000E+00 0.        -0.
  19                 3.955E+02 1.000E+00 0.        -0.
  20                 3.513E+02 1.000E+00 0.        -0.
  21                 3.359E+02 1.000E+00 0.        -0.
  22                 4.210E+02 0.        0.        -0.
  23                 3.474E+02 0.        0.        -0.
  24                 3.311E+02 1.000E+00 0.        -0.
  25                 2.990E+02 1.000E+00 0.        -0.
  26                 2.913E+02 1.000E+00 0.        -0.
  27                 2.737E+02 1.000E+00 0.        -0.
  28                 2.418E+02 1.000E+00 0.        -0.
 3111                5.240E+02 1.0       0.        1903.1
 3211                5.142E+02 1.0       0.        1903.1
 3311                4.917E+02 1.0       0.        1903.1
 3411                4.613E+02 1.0       0.        1903.1

ENDED-1
*                                                                  3
BLOCK05B
 1132 1141  2  1  12                  20.        3.2       .82      -.278
 1432 1441  1  1  12                  9.         3.2       .82      -.278
 1131 1141  2  1  12                  10.        37.44     .82      -.278
 1131 1142  2  1  12                  10.        37.44     .82      -.278
 1431 1442  1  1  12                  4.5        37.44     .82      -.278
 1431 1441  1  1  12                  4.5        37.44     .82      -.278

BLOCK05A
 1132 1141  2  1  12                  20.        3.2                0.290
 1432 1441  1  1  12                  9.         3.2                0.290
 1131 1141  2  1  12                  10.        37.44              0.290
 1131 1142  2  1  12                  10.        37.44              0.290
 1431 1442  1  1  12                  4.5        37.44              0.290
 1431 1441  1  1  12                  4.5        37.44              0.290

ENDED-1
*SPLIT
```

VIII-E27

FIGURE WITHHELD UNDER 10 CFR 2.390

RE 3. STEADY STATE TEMPERATURE PROFILE OF CASK UNDER NORMAL CONDITIONS

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 4. STEADY STATE TEKPERATURE PROFILE OF CASK UNDER POST-FIRE. CONDITIONS

1.

FIGURE WITHHELD UNDER 10 CFR 2.390

N•

AURE So STEADY STATE TEMPERATURE PROFILE OF CAS'1. aDER HORfAL CONDMTTOIS

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE **6.** STEADY STATE TEMPERATURE PROFILE OF CASK UNDER POST-FIRE CONDITIONS

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE *7.* STEADY STATE TEHPERATURE PROFL.E OF CASK UNDER NORMAL CnNDTTMn.'

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 8. STEADY STATE TEMPERATURE PROFILE OF CASK UNDER POST-FIRE CONDITIONS

FIGURE WITHHELD UNDER 10 CFR 2.390

'RE 9. STEADY STATE TEMPERATURE PROFILE OF CASK•)ER NOIFIAL CONDITIONS

FIGURE WITHHELD UNDER 10 CFR 2.390

2. Boundary conditionM: te e a u e. j

External ambient temperature=.-..F

Internal coolant temperature- F

3. Internal heat generation in center 10-foot axial section, qO KILO01ATTS

FIGURE 10. STEADY STATE TEHPERATURE PROFILE OF CASK UNDER POST-FIRE CONDITIONS

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 12. **STEAMY- STATE** IDWERATURR PROFILE **0? CA3%** WXDER POST-71P.E COM(DI1ONS

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 12. **STEAMY- STATE** IDWERATURR PROFILE **0? CA3%** WXDER POST-71P.E COM(DI1ONS

0

FIGURE WITHHELD UNDER 10 CFR 2.390

fIGURE 13. STEADY STATE TEMPERATURE PROFILE OF C/ UNDER NORM4,L CONDITIONS

p.

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 14. STEADY STATE TEMPERATURE PROFILE OF CASK UNDER POST-FLUE CONDITIONS

1.

FIGURE WITHHELD UNDER 10 CFR 2.390

'RE **15.** STEADY STATE TEMPERATURE PROFILE OF CA.S 16LR NORMAL CONDITIONS

(

FIGURE WITHHELD UNDER 10 CFR 2.390

z

FIGURE 16. STEADX.STATE TEMPERATURE PROFILE OF CASK UNDER POST-FIRE **CONDITIONS**

FIGURE WITHHELD UNDER 10 CFR 2.390

FIWJRE **17.** STEADY STATE TEMPERATURE PROFILE OF CASK UNDER NORMAL. CONDITTONS

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 18. STEADY **STATE** TEHPERAURE PROFILE **OF** CASK **UNDER** POST-FIRE **CONDITIONS**

```
*CIRCUMFERENTIAL MODEL OF NLI CASK  CASE 1
BLOCK 1
          -1                                        1.        .083333
   2    3                                          20.
  400.

BLOCK 2
30155    1                 8    8      443.                                  2600.      120.
       .100       -60.      .108       40.       .115      140.       .121      240.
       .133       540.      .145      640.       .137      740.       .155     1640.
       7.7        -60.      8.35       40.      8.95       140.      9.55      240.
      11.1        540.     11.55      640.     11.48       740.     15.8      1640.
LEAD     2                 5    8      795.                                   621.      10.5
  3.03E-02        32.  3.15E-02      212.  3.39E-02       572.  3.37E-02      621.
  3.26E-02       621.  3.20E-02    10000.
      20.1        32.     17.5       212.     14.0       572.      8.8       621.
       4.8       621.      4.9       900.      4.6      1200.     11.5      1500.
ALAL1    3                 2    2   83.3       .210      121.     1112.     167.4
   0.2        32.       0.23       342.
  60.5        32.      61.7        342.

BLOCK 4
  101    5    1    3                .08333    4.0        8.0
  201    5    1    3                .08333    4.0       12.0
  301    5    1    3                .08333    4.0       15.0
  401    5    1    3                .08333    4.38      20.14
  601    5    1    1                .08333     .75      22.875
 7101    5   10    2                0.0833               23.75
 7102    5   10    2                0.0833    1.0        24.75
 7103    5   10    2                0.0833    1.0        25.75
 7104    5   10    2                0.0833    1.0        26.75
 7105    5   10    2                0.0833    1.0        27.75
 7106    5   10    2                0.0833    1.0        28.75
  801    5    1    1                .08333    2.00       30.25

BLOCK 5
  101  102    4    1    1    2.09      2.09      .15916    4.00
  201  202    4    1    1    3.14      4.14      .15916    4.00
  301  302    4    1    1    4.19      4.19      .15916    4.00
  401  402    4    1    1    5.23      5.23      .15916    4.38
  601  602    4    1    1    5.49      5.49      .15916     .75
  601 7101    5    1   10    0.375     0.5       0.0833    23.25
 7101 7102    5   10   10    0.5       0.5       0.0833    24.25
 7102 7103    5   10   10    0.5       0.5       0.0833    25.25
 7103 7104    5   10   10    0.5       0.5       0.0833    26.25
 7104 7105    5   10   10    0.5       0.5       0.0833    27.25
 7105 7106    5   10   10    0.5       0.5       0.0833    28.25
 7106  801    5   10    1    0.5       1.0       0.0833    29.25
 7101 7111    4   10   10    5.22      5.22      0.15916     1.0
 7102 7112    4   10   10    5.48      5.48      0.15916     1.0
 7103 7113    4   10   10    5.74      5.74      0.15916     1.0
 7104 7114    4   10   10    6.00      6.00      0.15916     1.0
 7105 7115    4   10   10    6.25      6.25      0.15916     1.0
 7106 7116    4   10   10    6.51      6.51      0.15916     1.0
  601  602    4    1    1    7.92      7.92      .15916    2.00
  101    1    5    1    1    2.0       2.0       .08333   10.0
  201    1    5    1    1    2.0       2.0       .08333   14.
  301  401    5    1    1    2.0       2.0       .08333   18.
```

EXHIBIT 3. INPUT DATA FOR CIRCUMFERENTIAL ANALYSIS OF NLI 10/24 CASK

```
 405  [illegible]          2.19     2.175     .08333   22.5    50[illegible]      .21
 406  60                   2.19     2.175     .08333   22.5    50[illegible]      .2

BLOCK 6
 801 1001    5    1    1          .08333  31.25        1000.

BLOCK 7
 1001                  36[illegible].
 1002                  36[illegible].
 1003                  35[illegible].
 1004                  35[illegible].
 1005                  34[illegible].
 1006                  34[illegible].

BLOCK 9
 101    5    1                                  2072.0
 201    5    1                                  2072.0
 301    5    1                                  2072.0
 401    5    1                                  2072.0

ENDED-1
*SPLIT
```

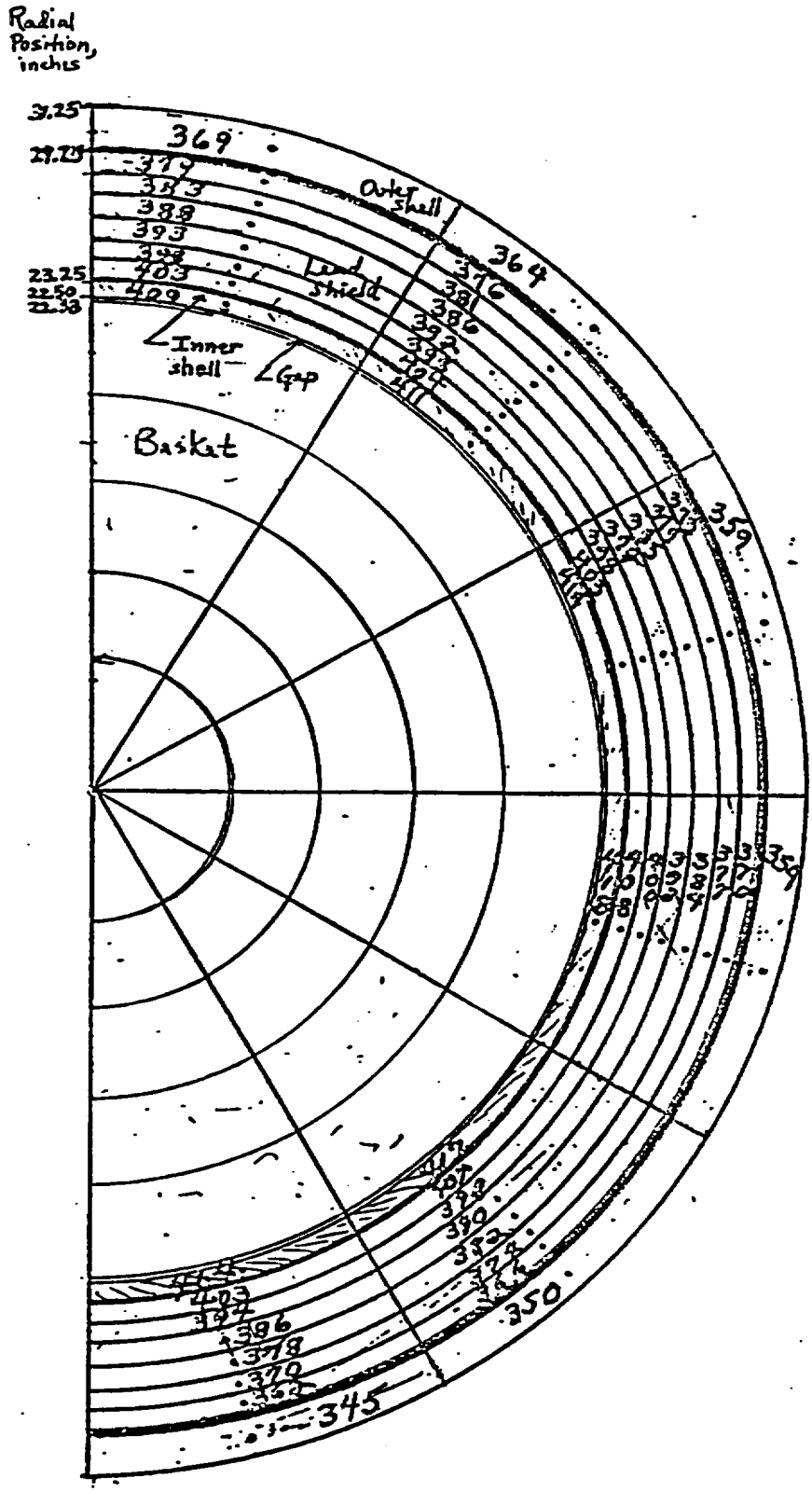

FIGURE E-19. STEADY-STATE, CIRCUMFERENTIAL TEMPERATURE PROFILE OF NLI 10/24 CASK WITH THERMAL INVENTORY OF 70KW.

Section IX

SECTION IX

SHIELDING

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Section IX

SHIELDING

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Section IX

SHIELDING

1.0 INTRODUCTION AND SUMMARY

The purpose of this section is to define the total gamma and neutron dose rates to be expected outside the NLI 10/24 spent fuel shipping cask. The fuel to be shipped and the corresponding fission product source inventories are discussed in Section III. Detailed dose rate calculations have been performed for the fuel parameters identified in Section III for the 10 PWR cask loading with an average burnup of 35,500 MWD/MTU, an average operating specific power of 36.3 kw/kgU, and an initial enrichment of 3.35 w/o U-235 in 4.54 MT of uranium. Calculations were not performed for the BWR sources, since as shown in Section III, the PWR source loading presents the limiting design conditions.

The NLI spent fuel rail shipping cask shield has been designed to insure that the radiation emanating from the cask is effectively reduced to levels equal to or less than those levels currently specified by the DOT or AEC hazardous materials shipping regulations. The pertinent radiation standards controlling the shield design are:

From Section 173.393 of Reference 1 for normal conditions of transport:

"(j)...

(1) 1000 millirem per hour at 3 feet from the external surface of the package (closed transport vehicle only);

(2) 200 millirem per hour at any point on the external surface of the car or vehicle (closed transport vehicle only);

(3) 10 millirem per hour at 6 feet from the external surface of the car or vehicle; and

(4) 2 millirem per hour in any normally occupied position in the car or vehicle, except that this provision does not apply to private motor carriers."

From Section 71.35 of Reference 2 which specifies the standards for hypothetical accident conditions for a single package:

"(a)...

(1) The reduction of shielding would not be sufficient to increase the external radiation dose rate to more than 1000 millirems per hour at 3 feet from the external surface of the package."

The shield materials used in the cask design have been selected and arranged to minimize the cask weight while maintaining overall shield effectiveness. Lead and depleted uranium were chosen as effective gamma radiation shields, and a water jacket and Ricorad on the ends of the cask was provided to efficiently moderate the neutron radiation.

The dose rate calculations are summarized in Table IX-1 and Figure IX-1. Table IX-1 shows the dose rates for:

(1) normal conditions at the cask surface and 6 feet from the vehicle surface at the fuel midplane
(2) accident conditions at 3 ft from the cask surface at the fuel midplane
(3) the ratio of accident to normal dose rate at 3 feet from the cask surface at the fuel midplane.

Figure IX-1 shows the dose profile around the cask surface and indicates a local maximum dose rate near the bottom of the cask. This area of maximum surface dose rate does not contribute significantly to the maximum dose rate 10 feet from the vehicle surface under normal conditions or at 3 feet from the cask surface in accident conditions.

Dose rates off the top of the cask are less than off the bottom of the cask for both normal and accident conditions. In addition the ratio of accident-to-normal dose rates is also less for the top than for the bottom.

TABLE IX-1

NLI 10/24 SHIPPING CASK
SUMMARY OF MAXIMUM DOSE RATES

DOSE RATE IN MREM/HR

Location	SIDE						BOTTOM					
	Normal Ship. Cond.			Accident Cond.			Normal Ship. Cond.			Accident Cond.		
	γ	n	Total	γ	n	Total	γ	n	Total	γ	n	Total
Cask Surface	36.7	1.5	38.2	48.3	1019	1067	24.2	13.1	37.3	44.0	1900	1944
3' Off Cask Surface	10.0	1.0	11.0	25	625	650	13.6	7.54	21.1	26.1	861	887
6' Off Personnel Barrier	4.86	0.62	5.48	--	--	--	0.94	0.65	1.59	--	--	--
3' Accident To Normal Shipping Condition Dose Rate Ratio				2.5	625	59				1.92	114	42

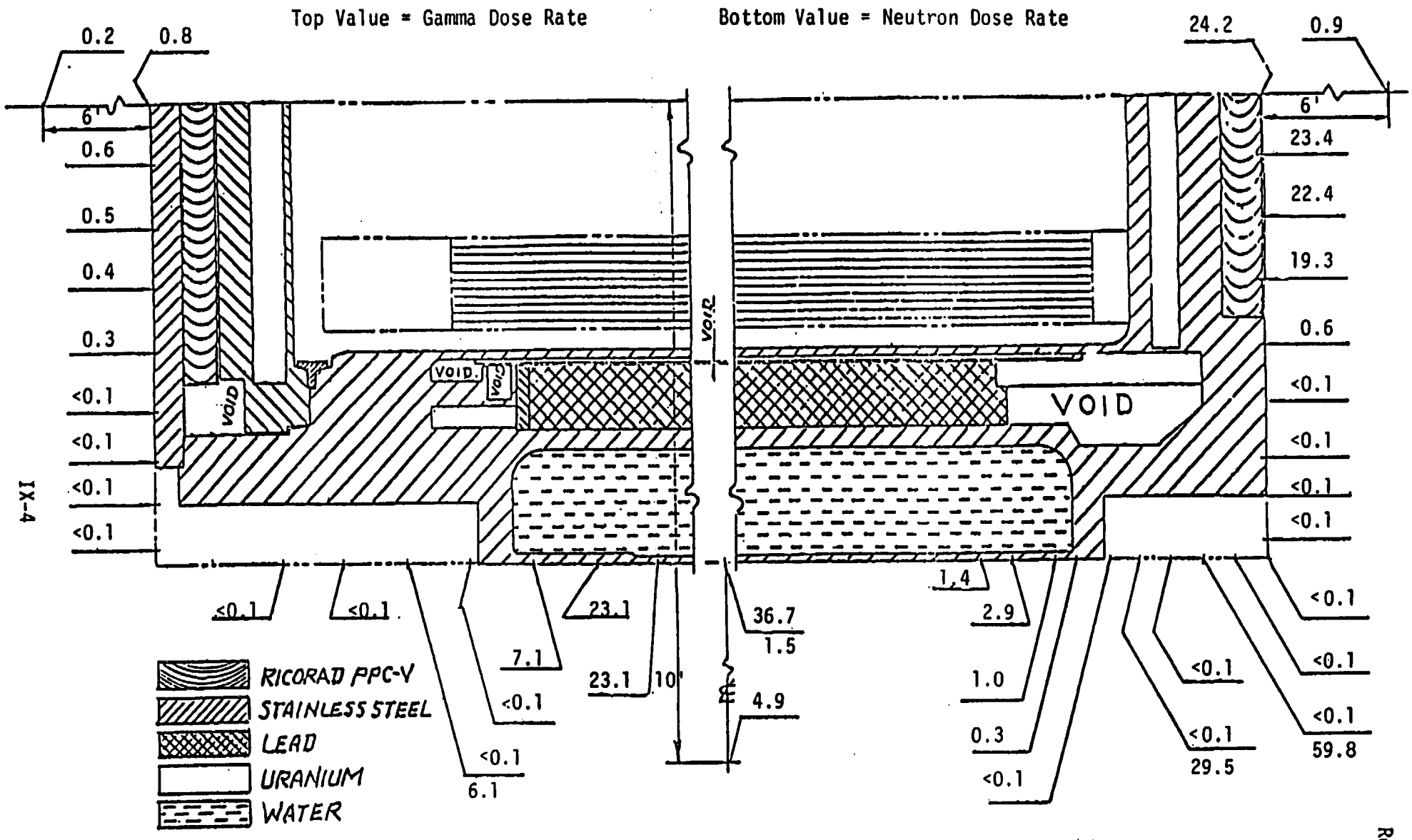


FIGURE IX-1. NEUTRON AND PRIMARY GAMMA DOSE RATES AT THE CASK SURFACE (mRem/hr)

The dose rates given in Table IX-1 include those from neutrons and gammas originating in the fuel, from neutrons and gammas scattered from the ground, radiation due to subcritical multiplication in the spent fuel and uranium shielding regions, and from secondary gammas resulting from neutron capture in the shield. All other sources of dose are insignificant. The details of the calculations and results are described in the following sections.

2.0 DESIGN FUEL SOURCE TERMS

Section III of this report defines the PWR and BWR fuel design and operating conditions on which the cask design is based and develops the corresponding neutron and gamma source strengths. The results, summarized in Table III-3, indicate that both source terms are larger for the 10 PWR assembly cask loading than for the 24 BWR assembly cask loading. Detailed gamma and neutron dose rate calculations were therefore performed only for the 10 PWR loading.

Table IX-2 gives the PWR design information used as a basis for the cask shield design. The energy distributions of the primary gamma and neutron sources are given in Table IX-3 and IX-4, respectively. The basis for these distributions is given in Section III. In addition to the primary neutron and gamma sources originating in the spent fuel being shipped, secondary gamma sources occur because of interactions of the primary neutron radiation with the cask materials. These sources and the resulting doses are discussed later in this section.

3.0 METHODS OF ANALYSIS

Presented below is a discussion of the techniques used to perform gamma and neutron dose rate calculations leading to the design of the NLI spent fuel shipping cask. Included is a definition of the various computer codes used in the cask design, a description of the configuration and composition of the source and shield materials used, and the location of the various dose points considered.

3.1 Shield - Dose Point Description

The shield overlay shown in Figure IX-2, whose dimensions are defined in Table IX-5, was used to represent the NLI 10/24 rail cask for normal shipping conditions. Table IX-6 defines the material overlay densities and elemental compositions.

All materials thus defined conform with standard material compositions specified in References 3, 4, 5 and 6 for the materials of construction specified in Section VI. For example, the U-235 content of the depleted uranium shield, taken as 0.22 w/o U-235, is in accordance with depleted uranium material composition specifications given in Reference 3. The water density in the neutron shield tank was based on a water temperature of 250°F. The maximum expected temperature for the shield tank is 232°F.

TABLE IX-2

PWR REFERENCE DESIGN INFORMATION

Loading	4540 kgU
Initial Enrichment	3.35 w/o
Average Specific Power	36.3 kw/kgU
Average Burnup	35,500 MWD/MTU
Cooling Time	150 days
Total Gamma Energy	2.79×10^{17} MeV/sec
Neutron Source	4.85×10^{9} n/sec

FIGURE IX-2

NLI 10/24 REFERENCE DESIGN SHIELD MODEL
NORMAL TRANSPORTATION MODE

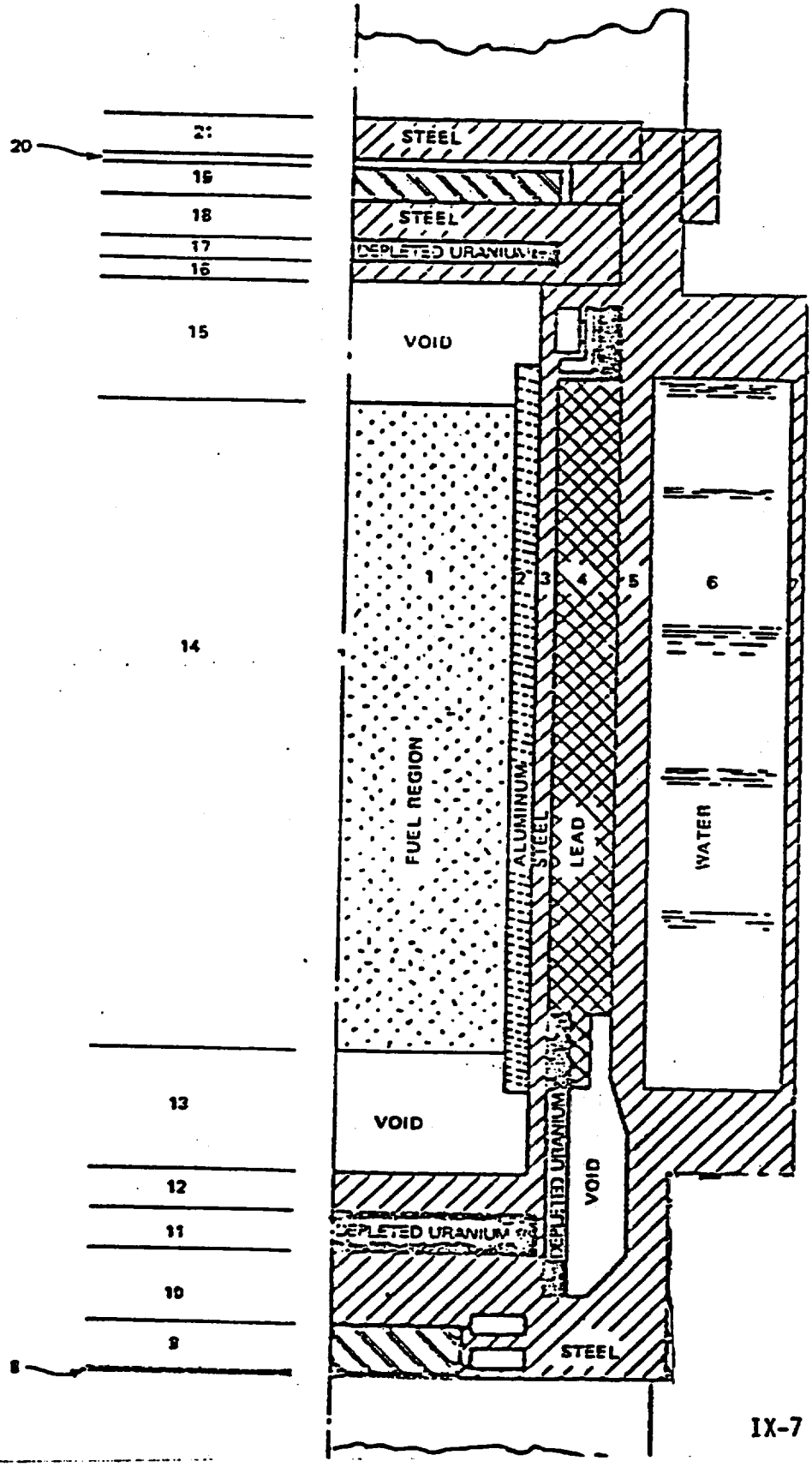


TABLE IX-3

DESIGN BASIS PWR GAMMA ENERGY DISTRIBUTION 150 DAYS AFTER SHUTDOWN

Gamma Energy, Max MeV	Group	Associated Section III Group (WAPD-BT-24)	Relative Distribution 150 Days After Shutdown	Gamma Decay Source, MeV/sec
2.0	30	5 (1.8-2.2 MeV)	1.0×10^{-2}	$2.79 \times 10^{+15}$
1.66	31	4 (1.35-1.8 MeV)	9.4×10^{-4}	$2.90 \times 10^{+14}$
1.33	32	3 (0.9-1.35 MeV)	1.8×10^{-3}	$2.51 \times 10^{+14}$
1.0	33			$2.51 \times 10^{+14}$
0.8	34	2 (0.4-0.9 MeV)	0.97526	$1.36 \times 10^{+17}$
0.6	35			$1.36 \times 10^{+17}$
0.4	36	1 (0.1-0.4 MeV)	1.2×10^{-2}	$1.116 \times 10^{+15}$
0.3	37			$1.116 \times 10^{+15}$
0.2	38			$1.116 \times 10^{+15}$
			Total =	$2.79 \times 10^{+17}$

TABLE IX-4

DESIGN BASIS PWR NEUTRON
ENERGY DISTRIBUTION 150 DAYS
AFTER SHUTDOWN

Energy Group, Max. MeV	NEUTRON SOURCE n/sec
15.0	--
12.2	$3.057 \times 10^{+6}$
10.0	$1.4366 \times 10^{+7}$
8.18	$5.0352 \times 10^{+7}$
6.36	$1.6319 \times 10^{+8}$
4.96	$2.29 \times 10^{+8}$
4.06	$8.6364 \times 10^{+8}$
3.01	$7.7224 \times 10^{+8}$
2.46	--
2.35	$7.6286 \times 10^{+8}$
1.83	$7.6868 \times 10^{+8}$
1.11	$8.038 \times 10^{+8}$
0.55	$4.1884 \times 10^{+8}$
	Total = $4.85 \times 10^{+9}$

TABLE IX-5

SHIELD REGION AND IDENTIFICATION

REGION	MATERIAL	THICKNESS cm
1	Fuel Region	54.13375
2	Aluminum	3.01625
3	Steel	1.905
4	Lead	15.24
5	Steel	5.08
6	Water	22.86
7	Steel	1.905
8	Steel	0.3175
9	Ricorad	9.8425
10	Steel	10.16
11	Uranium	6.36
12	Steel	5.08
13	Void	20.32
14	Fuel Region	365.76
15	Void	69.85
16	Steel	1.905
17	Uranium	7.62
18	Steel	7.62
19	Ricorad	7.62
20	Void	0.635
21	Steel	6.35

TABLE IX-6

NLI 10/24 REFERENCE RAIL CASK SHIELD DENSITIES
USED IN THE SHIELD DESIGN

Fuel Region	Element	Number Density (atoms/cc) x 10^{-24}
Source Region	Oxygen	6.431×10^{-3}
	Aluminum	2.9762×10^{-2}
	Chromium	4.213×10^{-6}
	Iron	1.5216×10^{-5}
	Nickel	7.7619×10^{-5}
	Zirconium	2.0074×10^{-3}
	U-235	1.9578×10^{-5}
	U-238	2.9987×10^{-3}
	Pu-239	1.5018×10^{-5}
	Pu-240	4.11388×10^{-6}
Aluminum Region	Aluminum	5.901×10^{-2}
Stainless Steel Region	Chromium	1.674×10^{-2}
	Iron	6.06×10^{-2}
	Nickel	9.88×10^{-3}
Lead Shield Region*	Lead	3.3×10^{-2}
Water in Shield Tank**	Hydrogen	6.31×10^{-2}
	Oxygen	3.15×10^{-2}
Depleted Uranium	U-235	1.05×10^{-4}
	U-238	4.785×10^{-2}
Ricorad	Hydrogen	7.57×10^{-2}
	Carbon	4.11×10^{-2}

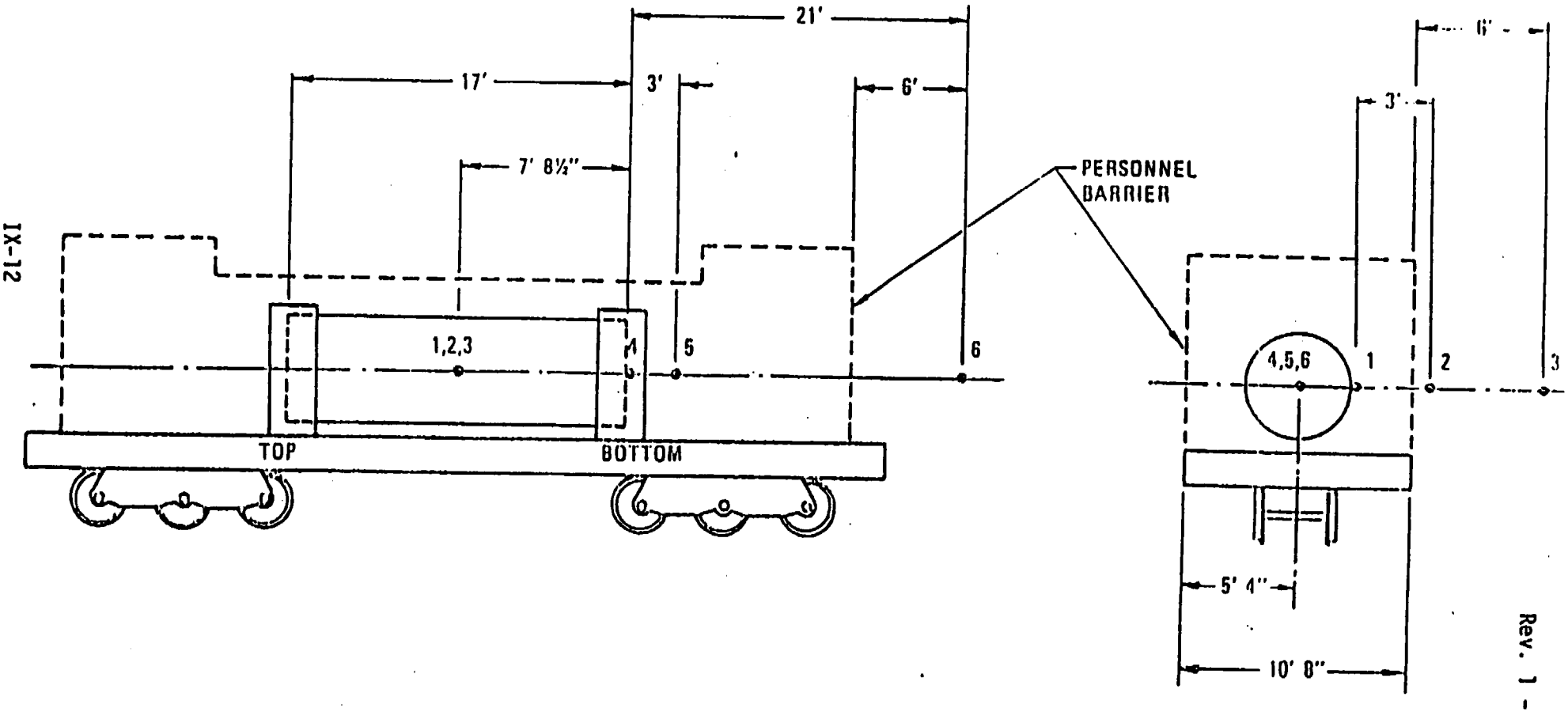
See Figure IX-1 for Shield Arrangement

* Lead taken at 70°F. For accident conditions, lead was taken at 850°F and a density of 10.511 g/cc(ρ=0.030555 x 10^{23} atoms/cc)

** Water taken at 250°F

FIGURE IX-3

DESIGN DOSE POINT LOCATIONS FOR NLI 10/24 REFERENCE RAIL CASK



Dose points for the shielding analysis were chosen and placed in accordance with conditions specified in 49 CFR 173[1] discussed in Section 1.0 previously. Dose points were placed (1) along the surface of the shield jacket, (2) at the fuel midplane, 3 feet off the surface, and 6 feet off the external surface of the personnel barrier, and (3) on the cask centerline on the surface of the Ricorad placed on the cask bottom. The surface dose points are shown in Figure IX-1, and the remaining dose points are shown in Figure IX-3.

3.2 Primary Gamma Dose Rates

The ANISN 2[7] computer code was used for calculating the primary gamma dose rates on the cask surface at the fuel midplane. ANISN is a one-dimensional multigroup code which solves the Boltzmann transport equation, including anisotropic scattering, by the discrete ordinate method. The ANISN code was developed by ORNL for use in calculating flux through shield media. This code has been checked with several simple experiments described in Reference 8 and 9.

For the present analysis, the P_3 - S_8 approximation to the transport equation was used with a 40 group coupled neutron-gamma energy spectrum for all elements of interest obtained from information presented in References 10 and 11. Table IX-7 defines the gamma energy spectrum (last 18 groups of the 40 group set) for the primary gamma dose rate calculations along with the flux-to-dose rate conversion factors were obtained from Reference 12. These data are consistent with information presented in References 13 and 14.

The dose rates along the cask surface and off the surface of the cask were obtained by using the QAD-P 5 computer program. The QAD-P 5 computer code, a version of the QAD-IV computer code (Reference 15) calculates both uncollided and collided gamma (and neutron) dose rates, energy deposition and fluxes for a volumetric source represented by a number of point isotropic sources in a user specified shield configuration. For each dose point the straight distance and attenuation in each shield material is calculated for each source point.

The total dose is obtained by summing the contributions from each source point.

The code QAD has had extensive use in industry for dose rate calculations and has been shown to yield satisfactory results.[16, 17] Calculation performed on similar shield configurations with hand methods and other computer codes have shown agreement with results generated by the QAD code. The gamma cross sections used in the QAD code were obtained from Reference 18, whereas the neutron removal cross sections were obtained from Reference 19.

The buildup factors used to calculate the ratios of uncollided-to-collided dose rates were obtained from Reference 20. The general equation used for the buildup factor calculation is

$$B(\mu_o r, E) = \sum_{i=0}^{3} \sum_{j=0}^{4} C_{ij} \left[\mu_o r\right]^{i} \left[E\right]^{j} + \varepsilon_{ij} (\mu_o r, E)$$

TABLE IX-7

GAMMA FLUX-TO-DOSE RATE CONVERSION FACTORS

Particle Group* Number	Gamma Energy, Max. MeV	Flux-To-Dose Rate Conversion Factor mr/hr/photon/cm^2-sec
23	10.0	9.79199×10^{-3}
24	8.0	8.28×10^{-3}
25	6.5	6.84×10^{-3}
26	5.0	5.76×10^{-3}
27	4.0	4.752×10^{-3}
28	3.0	3.96×10^{-3}
29	2.5	3.492×10^{-3}
30	2.0	2.988×10^{-3}
31	1.66	2.412×10^{-3}
32	1.33	1.908×10^{-3}
33	1.0	1.602×10^{-3}
34	0.8	1.26×10^{-3}
35	0.6	9.216×10^{-4}
36	0.4	6.372×10^{-4}
37	0.3	4.392×10^{-4}
38	0.2	2.376×10^{-4}
39	0.1	1.404×10^{-4}
40	0.05	3.024×10^{-4}

*Position in 40 group coupled neutron-gamma cross section table.

for the ranges $0 \leq \mu_0 r \leq 15$ and $0.5 \text{ MeV} \leq E \leq 10 \text{ MeV}$.

E is the energy and $\mu_0 r$ is the optical thickness of the shield material traversed by the gamma photon. The coefficients C_{ij} and correction terms ε_{ij} were obtained from Reference 20.

The source and shield configuration described in Figure IX-1 and Tables IX-5 and IX-6 was input into the ANISN and QAD codes and dose rates were calculated at dose points specified in Figure IX-2.

The QAD results were normalized to the ANISN surface calculation to obtain proper dose rates off the surface of the cask. The source given in Table IX-3 was considered to be uniformly distributed over the active fuel volume.

All of the above calculations were performed assuming the source to be distributed uniformly throughout the fuel region. In addition, dose rates were determined for an axial gamma source distribution taken to be the same as typical 300 day burnup distribution. This is a conservative representation of specific power and therefore of gamma source strength distribution for the reference fuel conditions. The results show that the midplane surface, 3 foot and 6 foot dose rates will increase by about 10%, 8% and 5% respectively for the 18% increase in peak source. These increases were included in the final result. The bottom dose rates would decrease by approximately 55%; however, no credit was taken for this decrease.

The ANISN 2 and QAD-P5 calculations were performed using the 6 inch thick lead defined in Figure IX-2. However, around the cooling channels the gamma shielding will be reduced by approximately 1/2". Additional calculations show that this local loss of lead shielding will increase the computer calculated gamma dose rates on the surface of the cask adjacent to the cooling channels by approximately 17%. This increase has been included in the final primary gamma result on the surface and conservatively off the surface.

3.3 Neutron Dose Rates

The ANISN 2 computer code was used for calculating the primary neutron dose rates on the cask surface at the fuel midplane. The MORSE code was used to calculate neutron dose rates along the cask surface at points other than the fuel midplane. For this portion of the analysis the first 22 groups of the 40 group coupled set was used in conjunction with the source and shield configuration described in Figure IX-2, Table IX-4, Table IX-5, and Table IX-6 to calculate the cask surface dose rates. Table IX-8 defines the neutron group energy structure and corresponding flux-to-dose rate conversion factor data as obtained from Reference 12. As in the case of primary gamma, the QAD-P5 computer program was used to calculate the off surface neutron fall-off factors. This option uses neutron removal cross sections to calculate neutron flux distributions.

TABLE IX-8

NEUTRON FLUX-TO-DOSE CONVERSION FACTORS

Particle Group Number	Neutron Energy, Max. MeV	Flux-To-Dose Rate Conversion Factor mr/hr/neutron/cm^2-sec
1	15.0	0.208
2	12.2	0.1656
3	10.0	0.1476
4	8.18	0.1476
5	6.36	0.1404
6	4.96	0.1332
7	4.06	0.1296
8	3.01	0.126
9	2.46	0.126
10	2.35	0.1296
11	1.83	0.1332
12	1.11	0.1188
13	0.55	5.4×10^{-2}
14	0.111	6.48×10^{-3}
15	3.35×10^{-3}	4.32×10^{-3}
16	5.83×10^{-4}	4.68×10^{-3}
17	1.01×10^{-4}	4.68×10^{-3}
18	2.90×10^{-5}	4.5×10^{-3}
19	1.07×10^{-5}	4.32×10^{-3}
20	3.06×10^{-6}	4.14×10^{-3}
21	1.12×10^{-6}	3.96×10^{-3}
22	4.14×10^{-7}	3.78×10^{-3}

As in the case of the primary gamma calculations, the neutron source was considered to be uniformly distributed throughout the cylindrical fuel region. The radial ANISN 2 problems used a buckling height of 12 feet. The x-y extrapolated buckling dimensions used in the axial calculations were chosen such that the fuel assembly centerline fluxes were consistent with the same fluxes obtained with the radial ANISN problems. This resulted in x-y buckling dimensions of 200 x 200 cm.

Based on the end of life axial burnup distribution given in Figure III-1 and the specific source strength of Figure III-3, the axial neutron source distribution has a peak to average ration of 1.25. While earlier in life burnup distributions would have greater peak to average ratios, the average burnup, andtherefore total neutron source, would be considerably less than at end of life. The neutron source axial peaking factor of 1.25 was conservatively applied directly to the off the side neutron dose rates.

Hand calculations were performed to define the neutron dose rate contribution off the ends from neutrons streaming through the cask cavity. The calculations were performed for the dry fuel assembly for (1) direct radiation emanating from fuel pins through the assembly interior to a worst point as compared to the computerized homogeneous system, (2) radiation scattering through the fuel assembly channels interior to the assembly, and (3) radiation scattering through the assembly-aluminum gap. The calculations were performed using equations defined in References 13 and 21. It was calculated that the direct neutron dose rates off the ends should be increased by approximately 100% to account for neutron streaming. These results are included in the reported bottom neutron dose rates in Section 4.0.

3.4 Secondary Gamma Dose Rates

The secondary capture gamma dose rates on the side and bottom surfaces of the NLI spent fuel rail shipping cask were obtained simultaneously with the primary neutron dose rate calculations using the 40 group coupled set in ANISN 2. Hand calculations were used to predict the capture gamma fall-off from the cask side and bottom surfaces. For these calculations the source was taken to be located near the cask outer shell since this was found to be a major source of secondary gammas. These results are reported in Section 4.0.

3.5 Ground Scatter

Scattering of neutrons and gamma photons from the ground may contribute to an increase in the total dose rate off the cask surface. The amount of this contribution has been estimated for both gamma photons and neutrons using the NUSALB code; NUSALB is a portion of the SOSC code which was developed for NASA-Goddard Space Flight Center.[22] The NUSALB code integrates radiation scattered to a receptor by a differential area of the scattering material, as for example, the ground. The code determines angular-differential scattering according to the albedo formulae. The

code uses empirical relationships for determining the gamma photon and neutron albedos. The code considers source angular emission distribution. The results are in good agreement with graphic data published by A.B. Chilton.[23]

The dose points of interest are 3 feet above the ground, 6 feet from the personnel barrier and 3 feet from the cask outer surface for both normal and accident conditions. In normal transport conditions, the cask axis is 7.9 feet above ground, while in accident conditions with the cask lying on the ground, the axis is 3.4 feet above ground. For calculational purposes, except for secondary gammas, the cask was defined as eight point sources spaced at 1.5 foot intervals along the cask axis each having 12.5% of the total source strength. For secondary gammas in normal transport conditions (negligibly small for accident conditions), each of the above 8 sources is further redefined as 2 point sources of 1/2 the original source strength each 82.5 cm from the cask axis in the cross sectional plan of the single source, one located azimuthally toward the ground and the other parallel to the ground. The energy spectral distributions (normalized to 1 mRem/hr total) used in the ground scatter calculations are given in Tables IX-9 and IX-10. These distributions were obtained from the primary and secondary gamma and neutron radial shielding analysis of the cask with water inside the cavity rather than the can and aluminum blocks.

The neutron differential scattering was determined according to the empirical relationship of Y. T. Song[24] which was derived from an analysis of the Monte Carlo data of F. J. Allen.[25] For thermal neutrons, the relationship of R. L. French and M. B. Wells[26] was used. The angular differential dose albedo for gamma photons was obtained from the work of A. B. Chilton.[23] The source angular emission distribution was obtained by separate cask evaluations using the QAD code.

3.6 Hypothetical Accident Conditions

In order to show compliance with the requirements of 10 CFR 71, calculations similar to those described in Section 3.2 and 3.5 were performed for the expected post-hypothetical accident conditions of the cask. These conditions are loss of shield jacket water and loss of Ricorad on the bottom.

Primary gamma and neutron doses at the cask side and bottom surfaces and 3 feet off these surfaces were determined using the techniques previously described. The shield configuration was as described in Figure IX-2 and Table IX-5 except that the shield jacket water was omitted for the radial calculations and the Ricorad was omitted for the axial calculations. The bottom dose points were placed on the outer surface of the cask shell. It was further assumed that the water jacket was left intact during the accident.

The highest dose rate at the cask surface was found to be near the bottom of the cask. The total area where the high dose rate occurs is small. This localized high surface dose rate does not significantly contribute to the dose rate at the 3 and 6 foot off the surface maximum dose rate locations

TABLE IX-9

NORMALIZED NEUTRON DOSE DISTRIBUTION

Group	$E_{max.}$ (Mev)	Normal	Accident
1	.111	3.12 E-2*	5.90 E-2
2	.55	1.30 -1	5.57 -1
3	1.11	2.34 -1	2.97 -1
4	1.83	2.45 -1	5.05 -2
5	2.46	1.48 -1	1.97 -2
6	4.06	1.37 -1	1.31 -2
7	8.18	7.13 -2	2.16 -3
8	12.2	6.68 -3	1.13 -3

* 3.12 E-2 = 3.12×10^{-2}

TABLE IX-10

NORMALIZED GAMMA DOSE DISTRIBUTIONS

Group	$E_{max.}$ (MeV)	Normal primary γ	Normal secondary γ	Accident primary γ
1	10	0	2.05 E-1*	2.18 E-2
2	5	0	7.81 -2	9.15 -3
3	2.5	1.91 E-1	3.91 -1	2.09 -1
4	1.66	3.43 -1	1.27 -1	3.44 -1
5	1	2.14 -1	7.48 -2	2.00 -1
6	.6	2.52 -1	1.23 -1	2.15 -1

* 2.05 E-1 = 2.05×10^{-1}

4.0 RESULTS

4.1 Normal Conditions of Transport

The highest dose rate on the surface of the cask is calculated to be 60.0 mRem/hr. The calculated dose rates off of the sides, at the fuel midplane, and at the ends of the cask for normal conditions are given in Table IX-11 and are discussed below.

The primary gamma dose rates on the fuel midplane calculated by ANISN 2 are 6.9 mRem/hr on the cask surface, 3.65 mRem/hr 3 feet from the cask surface, and 2 mRem/hr 6 feet off the personnel barrier. To conservatively obtain the maximum dose rate, these must be increased by the appropriate amounts to account for the effective loss of lead shielding due to the presence of the cooling channels and the axial peaking of the actual source distribution. These factors were discussed previously and are 17% for the cooling channel factor, and 10%, 8%, and 5% for the axial effect at the cask surface, 3 feet off the cask surface, and 6 feet off the personnel barrier, respectively. The results are 8.88 mRem/hr on the surface, 4.61 mRem/hr 3 feet off the surface, and 2.46 mRem/hr 6 feet off the personnel barrier.

The ground scatter calculations described in Section 3.5 yield back scatter dose factors of 0.0112 for primary photons, 0.00891 for secondary photons, and 0.235 for neutrons at the distance of 3 feet from the cask side. At a distance of 6 feet from the cask, the back scatter dose factors are 0.0247 for primary photons, 0.0211 for secondary photons and 0.404 for neutrons, Applying these factors (0.01 and 0.023 were used at the two dose points for total gamma instead of the individual factors for primary and secondary gamma) to the dose described above yield total ground scattered gamma dose rates of 0.1 and 0.11 mRem/hr at 3 and 6 feet off the cask, and total ground scattered neutron dose rates of 0.19 and 0.18 mRem/hr at 3 and 6 feet off the cask, respectively.

Adding all the components gives combined dose rates on the midplane of the fuel of 38.2 mRem/hr on the cask surface, 11.0 mRem/hr 3 feet from the cask surface, and 5.48 mRem/hr 6 feet from the cask personnel barrier. Table IX-12 summarizes the detailed derivation of the 6 foot dose rate.

Off the bottom the gamma dose rates are 19.7, 11.0, and 0.75 mRem/hr on the Ricorad surface, 3 feet off the surface, and 6 feet off the personnel barrier, respectively. The above numbers are based on a uniform axial source distribution. If the actual axial source distribution was utilized, the dose off of the bottom would decrease by about a factor of 2.

Including a 100% increase for streaming, the neutron dose rates off the bottom would be 13.10, 6.75, and 0.46 mRem/hr on the Ricorad surface, 3 feet off the Ricorad surface, and 6 feet off the personnel barrier, respectively.

The results of the secondary gamma dose rate calculations yield bottom dose rates of 4.45, 2.48, and 0.17 mRem/hr on the Ricorad surface, 3 feet off the Ricorad surface, and 6 feet off the personnel barrier, respectively. Ground scatter off of the ends was not directly calculated. A conservative estimate was made, however, by applying the back scatter factors off the side to the direct uncorrected gamma and neutron dose rates at the point of interest. The results are given in Table IX-11.

TABLE IX-11

NLI 10/24 RAIL CASK MAXIMUM DOSE RATES
(Normal Conditions of Transport)
mRem/hr

Source Category	Fuel Midplane			Off Bottom On Axial Centerline		
	Cask Surface	3' Off Cask Surface	6 Foot Off Cask Personnel Barrier	Cask Surface	3' Off Cask Surface	6 Foot Off Cask Personnel Barrier
Primary Gamma	8.88	4.61	2.46	19.7	11.00	0.75
Neutron	1.52	0.8	0.44	13.1	6.75	0.46
Secondary Gamma	27.8	5.32	2.29	4.45	2.48	0.17
Ground Scatter Gamma	--	0.1	0.11	--	0.14	0.02
Ground Scatter Neutron	--	0.19	0.18	--	0.79	0.19
Total Gamma	36.7	10.0	4.86	24.2	13.6	0.94
Total Neutron	1.5	1.0	0.62	13.1	7.54	0.65
Total	38.2	11.0	5.48	37.3	21.1	1.59

TABLE IX-12

DETAILED DERIVATION OF DOSE RATES
FUEL MIDPLANE 6 FEET FROM PERSONNEL BARRIER
(normal conditions of transport)

	Percent Correction	Dose Rate mRem/hr
Primary Gamma		
Base Calculated Value	2.00	
Channel Correction Factor	17%	
Axial Peaking Correction	5%	
Total	23%	2.46
Primary Neutron		
Base Calculated Value	0.35	
Axial Peak Correction	25%	
Total	25%	0.44
Secondary Gamma		2.29
Ground Scatter Gamma		
Direct Gamma Dose	4.75	
Back Scatter	2.3%	0.11
Ground Scatter Neutron		
Direct Neutron Dose	0.44	0.18
Back Scatter	40.4%	
Total		5.48

The total fuel centerline bottom dose rates on the Ricorad surface, 3 feet off the Ricorad surface, and 6 feet off the Ricorad surface are 37.3, 21.1, and 1.59 mRem/hr, respectively.

Considering the relative amounts of shield materials and the source to shield distances, the dose rates off the top of the cask are estimated to be approximately two thirds of the dose rates off the bottom of the cask for normal conditions. For accident conditions, the top dose rates would be an even smaller fraction of those off the bottom. Because the top dose rates are always less than the bottom dose rates, no detailed analysis of the top is necessary to show compliance with the regulations.

4.2 Hypothetical Accident Conditions

The results of the shielding analysis for post-hypothetical accident conditions are summarized in Table IX-13. The primary gamma dose rates off the side of the cask are 46.6 mRem/hr on the surface and 24.1 mRem/hr three feet off of the surface, including a 17% increase for the channel factor and an axial peaking increase of 10% and 8% at the shield tank surface and 3 feet off the surface, respectively.

The neutron dose rates increase significantly because of the assumed loss of all water. The ANISN results are 1019 and 529 mRem/hr at the surface and three feet from the surface, respectively. Each of these are conservatively increased by 25 % due to axial peaking of the neutron source. The secondary gamma dose rate is 1.68 mRem/hr on the surface and 0.88 mRem/hr at three feet.

The ground scatter calculations yielded back scatter factors of 0.0128 for gammas and 0.182 for neutrons. These were applied to the direct 3 foot dose rates given above.

Adding all the components yields a maximum dose rate 3 feet off of the surface of 650 mRem/hr. The detailed derivation of this number is summarized in Table IX-14.

Comparison of dose rates in Table IX-11 and of Table IX-13 3 feet off the cask side shows that the total dose rate will increase by a factor of 59 under accident conditions.

The primary gamma and neutron doses off the bottom are given in Table IX-13. These were obtained in a manner similar to these for normal shipping conditions except that the accident dose rates were obtained at 3 feet off the surface with the Ricorad removed from the cask.

The maximum dose rate three feet from the cask surface is seen to be off the cask bottom. This result is less than the 10 CFR 71 limit of 1000 mRem/hr.

Comparison of dose rates in Table IX-11 and IX-13 shows that after the accident the total dose rates 3 feet off the cask surface will increase by a factor of 59 at the midplane and 42 off the bottom. While the end dose rate after the accident is greater than at the midplane, the accident to normal ratio is greatest at the midplane.

TABLE IX-13

NLI 10/24 RAIL CASK MAXIMUM DOSE RATES
(Hypothetical Accident Conditions)
mRem/hr

Source Category	Fuel Midplane		Off Bottom On Axial Centerline	
	Cask Surface	3' Off Cask Surface	Cask Surface	3' Off Cask Surface
Primary Gamma	46.6	24.1	40.5	23.6
Neutron	1019	529	1900	728
Secondary Gamma	1.68	0.88	3.7	2.14
Ground Scatter Gamma	--	0.32	--	0.33
Ground Scatter Neutron	--	96.3	--	132.5
Total Gamma	48.3	25	44	26.1
Total Neutron	1019	625	1900	861
Total	1067	650	1944	887

TABLE IX-14

DETAILED DERIVATION OF DOSE RATE
FUEL MIDPLANE 3 FEET FROM SURFACE
(Hypothetical Accident Conditions)

	Base Value or Percent Correction	Dose Rate mRem/hr
Primary Gamma		
Base Calculated Value	19.1	
Channel Correction Factor	17%	
Axial Peaking Factor	8%	
Total	26%	24.1
Primary Neutron		
Base Calculate Value	423	
Axial Peaking Correction	25%	
Total	25%	529
Secondary Gamma		0.88
Ground Scatter Gamma		
Direct Gamma Dose	25	
Back Scatter	1.28%	0.32
Ground Scatter Neutron		
Direct Neutron Dose	529	
Back Scatter	18.2%	96.3
Total		650

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Section IX

Appendix A

Effects of Internal Water Jacket Fins on Shielding

The change in neutron shielding effectiveness due to the addition of steel fins inside the neutron water jacket can be shown by comparing $\sum$T's (macroscopic cross section X shield thickness) as a function of energy:

E (mev)	Without Fins (9" H_2O)	With Fins (5" H_2O + 4" F_e)
0.026	29.5	16.8
1	18.1	12.1
2	5.7	5.8
4	4.3	5.6
8	2.5	4.4
10	2.3	3.9

It can be seen that the attenuation with steel fins will be reduced appreciably at about 0.026 mev (due to the negative spike in the cross section vs. energy curve for steel at this energy) but the total attenuation at 0.026 mev will still be relatively high. There will be some "streaming" at this energy in steel, but this will be outweighed by the increased effectiveness of steel at energies above 2 mev, where the relative biological effectiveness is much greater. The steel will also provide better gamma protection than an equivalent thickness of water.

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SECTION IX

APPENDIX B

LOSS OF SHIELDING THICKNESS EFFECT

In Section XIV, paragraph 3.1, it is stated that a loss of 5% in shielding thickness over an area of less than 25% of the surface is considered acceptable.

Consider a case with a 5% shielding thickness loss over 100% of the lead surface area. A 5% loss for a 6 inch thick shield is 0.3 inch (0.762 cm) and virtually all of the primary gamma spectra is between 0.5 and 2.0 mev (See Table IX-3). The attenuation factors as a function of energy will be:

E(mev)	$u(cm^{-1})$	x(cm)	ux	Attenuation e^{ux}
0.5	1.8	.762	1.372	3.94
1.0	0.78	.762	0.595	1.82
1.5	0.58	.762	0.442	1.56
2.0	0.52	.762	0.396	1.49
			Avg.	= 2.2

A conservative estimate of the overall attenuation factor provided by 0.3" of Pb is to use the average attenuation (2.2) for an energy span of 0.5 to 2.0 mev. This is conservative because very little of the primary gamma with an energy as low as 0.5 mev will penetrate the shield. The average loss of attenuation would increase the primary

gamma dose rate six (6) feet off the cask personnel barrier (See Table IX-11) to 5.41 mrem/hr and the total to 8.43 mrem/hr which is still under the 10 mrem/hr limit. This estimate was based on a 0.3" shielding loss over the entire lead surface area. For only a 25% area, the effects should be appreciably less.

Section X

SECTION X

CRITICALITY ANALYSIS

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CRITICALITY ANALYSIS

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1.0 INTRODUCTION

This section describes the criticality safety analysis performed for the NLI 10/24 spent fuel shipping cask designed for rail transport. The cask accommodates up to 10 PWR fuel assemblies or 24 BWR fuel assemblies. Criticality control is maintained through the use of Ag-In-Cd poison.

The NLI 10/24 cask is designed to ship the wide variety of LWR fuel types which have been designed over the years. This section presents a detailed study of the most reactive type and configuration for both PWR and BWR fuels. This is accomplished by using 2x2 fuel assembly calculation models which closely resemble a portion of the PWR and BWR baskets. Using this model variations in rod size, array size, rod pitch, enrichment and total uranium loading are studied. Using the most reactive fuel type and fuel configurations, the reactivity of the full cask with PWR and BWR fuel is determined. These reactivity studies were carried out at Oak Ridge National Laboratory (ORNL) using the ORNL version of AMPX[1] and the 123 group GAM-THERMOS[2] cross sections.

The exhibits found in Appendix A of this section show the output from selected cases studied including the final cask calculations.

2.0 SUMMARY AND CONCLUSIONS

An extensive investigation of the most reactive type and configuration and loading of PWR and BWR fuels was made. The analysis was made using a relatively simple KENO model which allowed discrete representations of each fuel rod. The KENO reflective boundary condition option allowed the simulation of a 2x2 array of fuel assemblies in a geometry which closely resembles the full basket. From these analyses the following conclusions were drawn:

(1) The most reactive configuration for the fuel assemblies is the uniform distribution of the fuel rods in the fuel cavity.

(2) No statistical difference could be seen in the reactivity of the 14x14, 15x15, 16x16 and 17x17 type PWR fuels or the 7x7 and 8x8 BWR fuels when they were assumed to be in their most reactive configuration.

(3) The reactivity of the fuel assemblies increased as the total uranium loading was increased. No peak in reactivity is found as the total uranium loading in the fuel rods is increased to 100% of the theoretical density of UO_2

The KENO calculations were made for the full cask with the PWR and BWR baskets loaded with the most reactive of the respective fuel assemblies in the most reactive configurations. These calculations along with the 2x2 fuel assembly calculations show that fuels of the following type and range of parameters can be safely shipped in the NLI 10/24 spent fuel shipping cask:

	PWR	BWR
Fuel Form	Clad UO_2 Pellets	Clad UO_2 Pellets
Cladding Material	Zr or SS	Zr or SS
Maximum initial U content/assembly, Kg	475	200
Maximum initial U-235 enrichment, w/o	3.5	2.8
Maximum bundle cross section, inches	9.0	5.75
Fuel pin array types	14x14/15x15	7x7/8x8
Maximum active fuel length, inches	144	144

3.0 MOST REACTIVE FUEL AND FUEL CONFIGURATION

Both the PWR and BWR baskets use the Ag-In-Cd (80-15-5w/%) neutron poison to control reactivity. The silver and indium have strong resonance absorption cross sections. It was felt that the determination of the most reactive fuel and fuel configuration might be dependent on the neutron spectrum. To avoid uncertainty in this regard, the determination of the most reactive fuel and fuel configuration was made using 2x2 fuel assembly models with geometry that is similar to that of the BWR and PWR baskets. The calculations were performed with the KENO IV[3] code using the 123 group GAM-THERMOS cross sections. Each fuel rod is modeled discretely in the models. The 14x14, 15x15, 16x16 and 17x17 type PWR fuel rod arrays are examined

as are the 7x7 and 8x8 type BWR fuel rod arrays. The fuel rod spacing is varied from the typical "as built" pitch to a pitch that allows the rods to fill the fuel cavity uniformly. The effect of total uranium loading is also examined as is the case of uniform loading of all rods in the arrays compared to actual fuel assemblies where several of the rods in the array are empty.

3.1 The 2x2 Fuel Assembly Calculation Model

3.1.1 Cross Sections

The NITAWL module from AMPX was used to prepare the 123 group GAM-THERMOS cross sections. For the cases where the fuel was homogenized both the NITAWL and XSDRNPM modules were used.

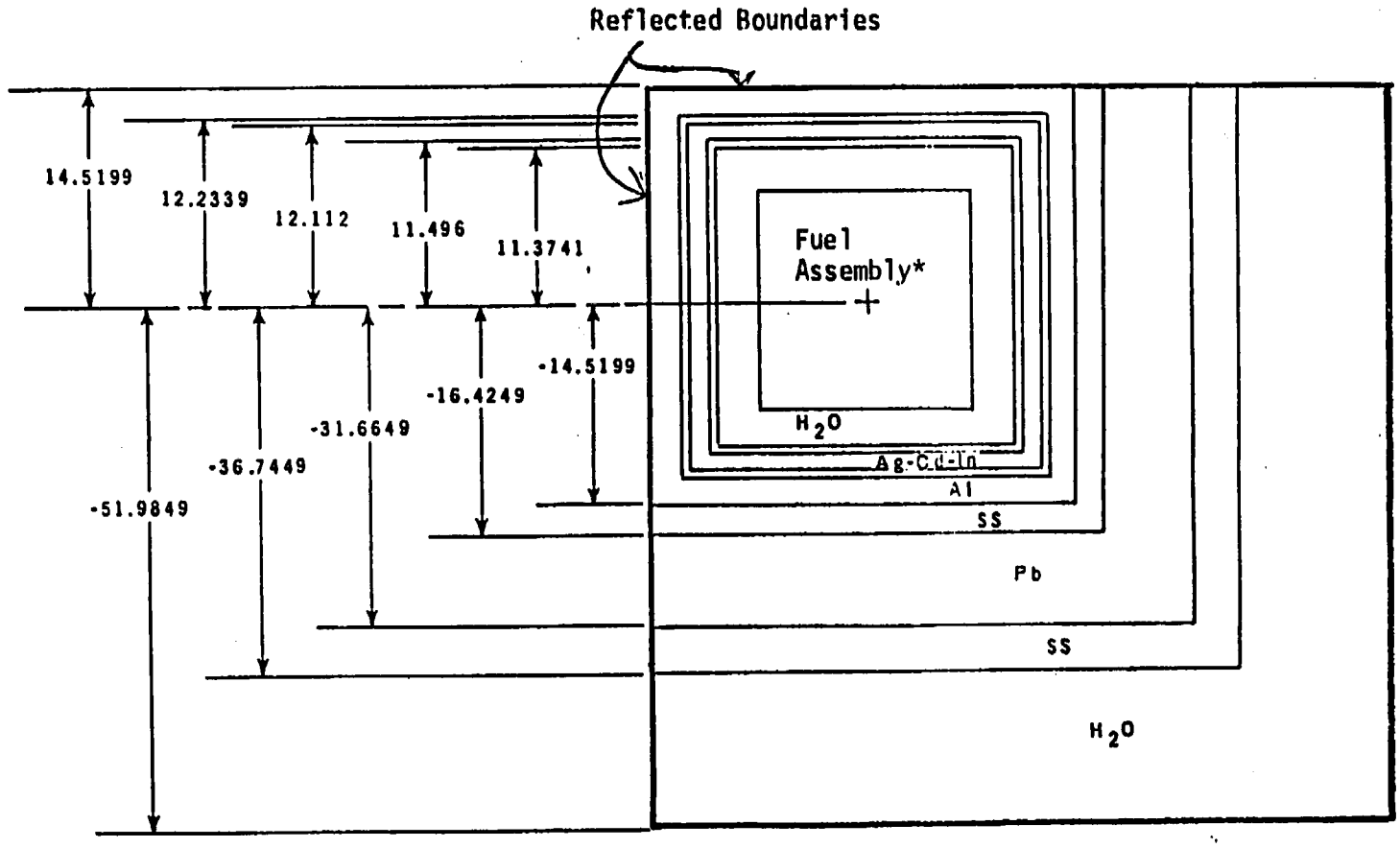
3.1.2 PWR Geometry

The geometry for the PWR 2x2 fuel assembly model is shown in Figure X-1. The cavity size and Ag-In-Cd poison have the same dimensions as in the full PWR basket. The aluminum, steel, lead and water are sized and placed to create a model with geometry similar to that of full PWR basket.
Only one fuel cavity is actually modeled. The reflective boundary condition on the two sides of the cavity give the effect of a full 2x2 fuel assembly model. The fuel itself is modeled discretely using the KENO "mixed box" geometry option. The detail for a single rod is shown in Figure X-2. To obtain the full fuel assembly model the "mixed box" array size is specified to be that of the actual fuel (17x17 for instance.) In the case where a

fuel assembly with holes is simulated the box type for the hole is water only. An example of the KENO geometry output for a 2x2 PWR case is found in Appendix A.

3.1.3 BWR Geometry

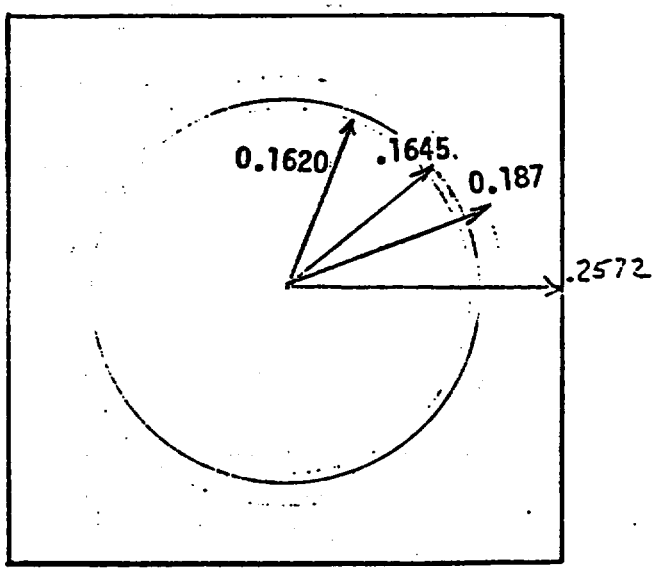
The geometry for the BWR 2x2 fuel assembly model is shown in Figure X-3. The cavity size for this model is the same as in the full BWR basket. The Ag-In-Cd, aluminum, steel, lead and water are sized and placed to create a model with geometry similar to that of the full BWR basket. As in the PWR model, only one cavity is actually modeled and the reflective boundary conditions generate the 2x2 fuel model. The individual BWR rods are modeled discretely as shown in Figure X-2. As in the PWR model the full fuel assembly is generated by specifying a 7x7 or 8x8 array of the rods in the " mixed box" geometry. In the case where the hole in the center region of the 8x8 is simulated the boxes are generated with water only. The KENO geometry output for a 2x2 BWR case is found in Appendix A.



* Note: Fuel assembly region is variable and can expand to fuel channel boundaries.

Figure X-1 KENO IV Geometry Model for 2x2 Fuel Assembly Calculations

Mixed Box Geometry for 17x17 Fuel Rod



All dimensions in inches

Mixed Box Geometry for 8x8 Fuel Rod

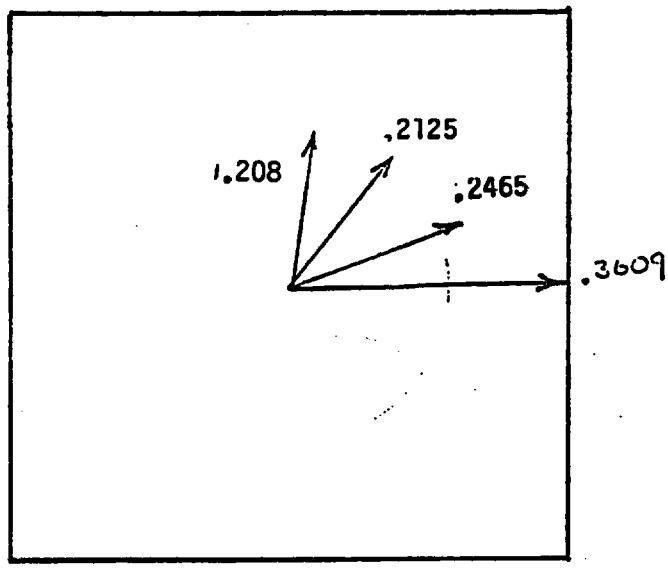
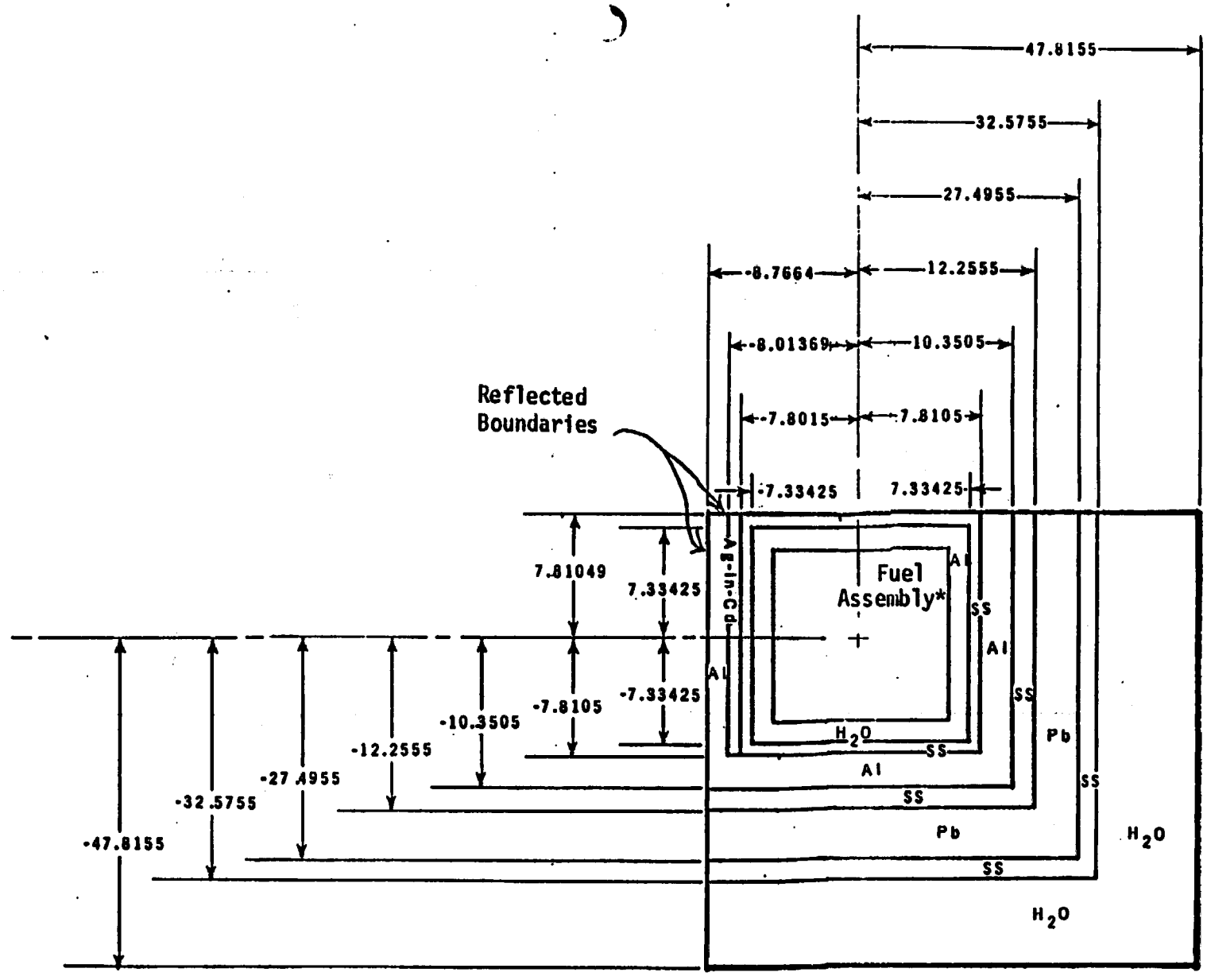


Figure X-2 Example of Box Types for PWR and BWR Fuel



* Note: Fuel assembly region is variable and can be expanded to fuel channel boundaries

Figure X-3 KENO IV Geometry Mo(for 2x2 Fuel Assembly Calculations

3.2 Fuels Considered

The PWR type reactor vendors have to date manufactured four basic types of fuel assemblies. Table X-1 gives fuel descriptions for several typical assemblies. This table only lists data for several representative fuels and is in no way complete. Within each array type the fuel geometry varies only slightly. Fuels of the same array type often vary slightly in their total loading of uranium. This is mainly due to differences in the density of UO_2. It would not be pratical to perform reactivity calculations for every type and modification of fuel assembly that has been manufactured. Instead, the following typical PWR rod sizes and UO_2 pellet sizes were chosen:

Array Type	Pellet O.D. inches	Rod O.D. inches
14x14	.379	.44
15x15	.370	.422
16x16	.325	.382
17x17	.324	.374

The BWR type reactor vendors have developed two basic fuel types. Table X-2 gives a fuel description for these fuels. As with the PWR fuels, BWR fuels have slight variations within each array type. The typical BWR rod size and UO_2 pellet size chosen for analysis are:

Array Type	Pellet O.D., inches	Rod O.D., inches
7x7	.478	.563
8x8	.416	.493

TABLE X-1 Typical PWR Fuel Properties

	WEST	WEST	B&W	B&W	Comb. Eng.	Comb. Eng.
Array	15x15	17x17	15x15	17x17	14x14	16x16
Active Fuel Length (in.)	144	144	141	141	136.7	150
Kg-U/Assy	465.6	468.4	475	475	395	438
ENRICH. (U-235,%)	3.5	3.5	3.23	3.49	3.0	3.5
Kg - U - 235/ASSY	16.30	16.39	15.34	16.577	11.85	15.33
Kg-U/inch rod length	3.233	3.253	3.369	3.369	2.827	2.92
PITCH (in.)	0.563	0.496	0.568	0.502	0.580	0.5063
ROD O.D. (in.)	0.422	0.374	0.430	0.379	0.440	0.382
CLAD. Thick (in.)	0.0243	0.0225	0.0265	0.0235	0.026	0.025

All the calculations were performed for zircalloy clad fuel. Stainless steel cladding of the fuel rods would make any given fuel assembly less reactive than one which was zircalloy clad because of stainless steel's significantly higher neutron absorption cross section.

3.3 Results of the 2x2 Fuel Assembly Model Calculations

The results of 12 BWR and 20 PWR calculations using the 2x2 fuel assembly models are shown in Tables X-3 and X-4 respectively. From these cases the conclusions are drawn about the most reactive fuel rod configuration, the effect of uranium loading, and the validity of the fuel homogenization techniques. The discussion which follows will take specific cases from Tables X-3 and X-4. The text will summarize the important aspects of the calculations. The more complete description of the calculations is found in the two tables. Portions of the AMPX output are displayed in Exhibits 1 & 2 of Appendix A for case No. 18 and 31 respectively.

3.3.1 Most Reactive Type of PWR Fuel

The 16x16 and 14x14 rod array fuel assemblies with uniform fuel loading in each rod were found to be most reactive when the fuel rods were expanded to fill the fuel cavity. This can be seen by examining cases 12-14 from Table X-3 for the 16x16 fuel and cases 16-18 for the 14x14 fuel. The 15x15 fuel was examined only at the fully expanded fuel condition and was assumed to follow the pattern of the fuel types which bracket it.

TABLE X-2 Typical BWR Fuel Properties (G.E.)

Array	7 x 7	8 x 8
Active Fuel Length (in.)	144	144
Kg-U/ASSY	197	197
ENRICH (U-235, %)	2.5	3.0
Kg-U-235/ASSY	4.925	6.304
Kg-U/inch rod length	1.368	1.368
PITCH (in.)	.738	.640
ROD O.D. (in.)	.563	.493
CLAD Thick (in.)	.037	.034
Pellet O.D.	0.478	0.416

TABLE X-3 Summary of 2x2 PWR Assembly Calculations

Case No.	Rod Array	Rod Pitch, in.	Uniform Spacing	Discrete Rod Geometry	Loading KgU/Assem	Pellet O.D. in.	Rod O.D. in.	Enrichment %U-235	H/U	K_{eff}	$\pm 1\sigma$	Comments
1	17x17	.502	yes	yes	513	.324	.374	3.5	1.72	.948	.006	As fabricated rod pitch
2	17x17	.5144	yes	yes	513	.324	.374	3.5	1.88	.981	.006	
3	17x17	.5268	yes	yes	513	.324	.374	3.5	2.03	.971	.005	Full uniform expansion rods in cavity
4	17x17	.5020	yes	yes	461	.324	.374	3.5	1.72	.933	.005	Reduced Loading of U
5	17x17	.5144	yes	yes	461	.324	.374	3.5	1.88	.949	.007	Reduced Loading of U
6	17x17	.5268	yes	yes	461	.324	.374	3.5	2.03	.958	.005	Reduced Loading of U
7	17x17	.5268	yes	yes	487	.324	.374	3.5	2.03	.975	.006	Reduced Loading of U
8	17x17	.5268	yes	yes	538	.324	.374	3.5	2.03	.986	.005	Increased Loading of U
9	17x17	.5268	yes	yes	436	.324	.374	3.5	2.03	.944	.005	Reduced Loading of U
10	17x17	.5144	no	yes	513	.324	.374	3.5	1.88	.981	.005	Simulate BBW fuel including empty rods (see note 1)
11	17x17	-	-	no	513	.324	.374	3.5	1.88	.982	.006	Homogenized fuel (see note 2)
12	16x16	.5063	yes	yes	513	.325	.382	3.5	1.71	.922	.005	As fabricated rod pitch
13	16x16	.5330	yes	yes	513	.325	.382	3.5	2.04	.956	.006	
14	16x16	.5597	yes	yes	513	.325	.382	3.5	2.39	.991	.006	Full uniform expansion of rods in cavity
15	15x15	.5971	yes	yes	513	.370	.422	3.5	2.01	.990	.005	Full uniform expansion of rods in cavity
16	14x14	.580	yes	yes	513	.379	.440	3.5	1.63	.909	.009	As fabricated rod pitch
17	14x14	.6099	yes	yes	513	.379	.440	3.5	1.94	.964	.007	
18	14x14	.6397	yes	yes	513	.379	.440	3.5	2.28	.995	.007	Full uniform expansion of rods in cavity
19	14x14	.6551	yes	yes	513	.379	.440	3.5	-	.997	.005	Rods spaced so outer row touch cavity liner
20	14x14	-	-	no	513	.379	.440	3.5	2.28	1.002	.006	Homogenized fuel (see note 3)

NOTES

1. All fuel parameters same as case 2 except for loading per rod.
2. All fuel parameters same as case 2.
3. All fuel parameters same as case 19.

TABLE X-4 Summary of 2x2 BWR Assembly Calculations

Case No.	Rod Array	Rod OD, in.	Pellet OD, in.	Rod Pitch in.	Assembly Loading KgU Assembly	Enrichment %U-235	H/U	Uniform Spacing	Discrete Rod Geometry	K_{eff}	$\pm 1\sigma$	Comments
21	7x7	.563	.478	.7380	197	3.0	1.65	yes	yes	.827	.009	As Fabricated
22	7x7	.563	.478	.7815	197	3.0	2.02	yes	yes	.856	.008	
23	7x7	.563	.478	.8250	197	3.0	2.41	yes	yes	.892	.007	Full Expansion of Rods
24	7x7	.563	.478	.8250	197	2.65	2.41	yes	yes	.851	.006	
25	7x7	.563	.478	.8250	197	2.75	2.41	yes	yes	.856	.009	
26	7x7	.563	.478	.8250	197	2.85	2.41	yes	yes	.884	.005	
27	7x7	.563	.478	.8250	197	3.0	2.41	yes	yes	.894	.006	
28	7x7	.563	.478	.8250	197	3.3	2.41	yes	yes	.914	.006	
29	8x8	.493	.416	.6400	197	3.0	1.61	yes	yes	.827	.008	As Fabricated
30	8x8	.493	.416	.6809	197	3.0	2.01	yes	yes	.884	.008	
31	8x8	.493	.416	.7219	197	3.0	2.43	yes	yes	.893	.009	Full Expansion of Rods
32	8x8	.493	.416	.7219	197	3.0	2.43	no	yes	.868	.009	w center hole

At full expansion of the 14x14, 15x15 and 16x16 fuel with equal loading and enrichment there is no significant difference in the calculated K_{eff} values.

Case No.	Array Type	$K_{eff} \pm 1\sigma$
14	16x16	0.991 ± .006
15	15x15	0.990 ± .005
18	14x14	0.995 ± .007

The K_{eff} of 14x14, 15x15 and 16x16 fuel increases significantly from the as fabricated geometry to one which fills the fuel channel. This is exemplified by the 14x14 array fuel where loading and enrichment are equal:

Case No.	Fuel Array	Pin Pitch	$K_{eff} \pm 1\sigma$
16	14x14	.58 (as fabricated)	.909 ± .009
17	14x14	.61	.964 ± .007
18	14x14	.64 (fully expanded)	.995 ± .009

The 17x17 rod array fuel does not show this marked increase in K_{eff} for changes in rod pitch. For a uranium loading of 513 KgU/assembly and 3.5% enrichment the values are:

Case No.	Fuel Array	Pin Pitch	$K_{eff} \pm 1\sigma$
1	17x17	.502 (as fabricated)	.948 ± .006
2	17x17	.5144	.981 ± .006
3	17x17	.5268 (fully expanded)	.971 ± .005

At a lower fuel loading (461 KgU/assembly) and otherwise under the same conditions as the previous cases the K_{eff} also changes slightly as the pitch is expanded, however, the highest K_{eff} is now at the fully expanded rod pitch:

Case No.	Fuel Array	Rod Pitch	$K_{eff} \pm 1\sigma$
4	17x17	.502	.933 ± .005
5	17x17	.5144	.949 ± .007
6	17x17	.5268	.958 ± .005

All four rod arrays from 14x14 to 17x17 examined at their most reactive rod pitch and at equivalent loading and enrichment, show that no statistical inferences concerning the most reactive type can be drawn. There is a suggestion that the 17x17 fuel in its most reactive configuration may be slightly less reactive than the other array types.

Case No.	Array Type	$K_{eff} \pm 1\sigma$
2	17x17	.981 ± .006
14	16x16	.991 ± .006
15	15x15	.990 ± .005
18	14x14	.995 ± .007

3.3.2 Effect of Non Uniform PWR Fuel Rod Distribution

All the PWR fuel assemblies currently manufactured are not uniformly fueled from rod to rod. The assemblies have a number of unfueled and empty rods which are used for control rods, burnable poison rods, instrumentation, or are left empty during irradiation. In the shipping configuration these rods are empty. This configuration represents an off optimum or possibly an equivalent reactivity situation for a given amount of uranium contained in

low enriched rods which are in a confined geometry. This statment is backed up by a number of experiments performed by Libby Johnson at ORNL. Unfortunately these experiments are to date unpublished. Two calculations for 17x17 fuel arrays, one with uniform loading of uranium and one with the configuration similar to B&W 17x17 fuel were performed to illustrate this:

Case No.	Array	Loading	$K_{eff} \pm 1\sigma$
2	17x17	Uniform in each rod	.981 ± .006
10	17x17	Per B&W	.981 ± .005

These cases indicate no statistical difference between uniform and non-uniform distribution of the fuel rods in the PWR fuel cavity.

Another case of non uniform distribution of fuel rods in a fuel cavity can occur if the outer row of rods is allowed to touch the fuel cavity wall. This allows a higher H/U ratio for the inner rods of the fuel assembly but lowers the H/U for the outer rods. To examine this condition the following two cases were run:

Case No.	Array	Rod Pitch	$K_{eff} \pm 1\sigma$
18	14x14	.64 (Uniform expansion of rods in cavity)	.995 ± .007
19	14x14	.655 (rods spaced so outer row touch cavity liner	.997 ± .005

These cases indicate no statistical difference in reactivity of the two rod pitches.

It is concluded that the uniform distribution of fuel rod in the fuel cavities is at least as reactive as any other feasible fuel rod distribution.

3.3.3 Effect of Total Uranium Loading on Reactivity

A series of calculations were made where the total uranium loading of the 17x17 type PWR fuel assembly was varied. The fuel assembly rods were expanded to fill the fuel channel for these calculations. The results are as follows:

Case No.	U Loading KgU/assembly	$K_{eff} \pm 1\sigma$
9	436	.944 ± .005
6	461	.958 ± .005
7	487	.975 ± .005
2	513	.971 ± .006
8	538	.986 ± .005

The calculations indicate that at the higher fuel loadings the reactivity changes very little with increase in total uranium. As the total uranium is lowered the reactivity begins to drop off. This is due mainly to the decrease in total U-235 in the assembly. The calculations show no indication of a peaking of the reactivity at a low uranium loading. It is assumed that the behaviour of the BWR fuel is the same as the PWR fuel because the rod size and pitch, relative rod U loading and H/U ratios are very similar.

3.3.4 Most Reactive Type of BWR Fuel Assembly

The most reactive geometry for the 7x7 and 8x8 type BWR fuel was found when the fuel rods are spaced so they uniformly fill the fuel channel

region. This can be clearly seen by examining cases 21 to 23 shown in Tables X-4 for the 7x7 type fuel and cases 30 to 32 for the 8x8 type fuel. No significant difference in reactivity was calculated between the 7x7 and 8x8 type fuels when they are in their most reactive geometry.

Case No.	Rod Array	$K_{eff} \pm 1\sigma$
23	7x7	.892 ± .007
31	8x8	.893 ± .009

3.3.5 Calculation for Actual 8x8 Fuel Geometry

The as manufactured 8x8 rod array BWR fuel has an instrument hole in the center of the assembly. A calculation was made to assure that this non uniform rod spacing is no more reactive than a uniform spacing case where all other parameters (loading, enrichment, etc.) are the same.

Case No.	Fuel Geometry	$K_{eff} \pm 1\sigma$
31	Uniform rod spacing	.893 ± .009
32	As Built with instrument hole	.878 ± .009

3.3.6 Validity of Fuel Homogenization

The calculations for the full cask are too complicated to give a discrete rod by rod description of the fuel. The fuel regions must be homogenized. The cross sections for the homogenized fuel region are generated by the XSDRNPM module of AMPX. To test the validity of this procedure, two homogenized cases were run with the 2x2 PWR fuel assembly model to directly compare with cases where the fuel rods were modeled discretely.

Case No.	Fuel Description	Rod Array	Rod Pitch	$K_{eff} \pm 1\sigma$
2	discrete rod	17x17	.5144	.981 ± .006
11	homogenized	17x17	.5144	.982 ± .006
18	discrete rod	14x14	.6397	.995 ± .007
20	homogenized	14x14	.6551	1.002 ± .006

These cases show the homogenized calculations with cross sections produced by XSDRNPM give essentially the same results as the calculations where the fuel rods are discretely modeled.

3.3.7 Conclusions from 2x2 Calculations

The following conclusions can be drawn from the 2x2 fuel assembly calculations:

(1) The most reactive configuration for the PWR and BWR assemblies can be assumed to be uniform distribution of the fuel rods which are at a rod pitch that fills the fuel cavity.

(2) The BWR fuel assemblies with 8x8 and 7x7 rod arrays having equal loading and enrichment are equivalent in reactivity when the assemblies are in their most reactive configuration.

(3) The PWR fuel assemblies with 14x14, 15x15, 16x16, and 17x17 rod arrays having equal loading and enrichment are equivalent in reactivity when the assemblies are in their most reactive configuration.

(4) The reactivity of the fuel assemblies increases as the total loading of uranium increases. No peak in reactivity is found as the total uranium content in the fuel rods is increased to the theoretical density of UO_2.

4.0 CASK ANALYSIS

The cask with both BWR and PWR baskets was analyzed using the KENO IV and AMPX codes along with the GAM-THERMOS cross section sets. Three PWR and two BWR calculations were made. Exhibits 3 and 4 of Appendix A show the AMPX/KENO IV input and relevant output for the final calculations.

4.1 Preliminary PWR Calculations

The cask and the PWR basket were modeled using the KENO "mixed box" geometry option. Figure X-4 shows the calculation model for the cask with a preliminary design for the PWR basket. Figure X-5 shows details of several typical box types for this model.

Two calculations were performed with this model to determine if there is any significant difference between the 17x17 and 14x14 rod array type fuels. The fuel region cross sections are homogenized using XSDRNPM module of AMPX. The fuel is zircalloy clad 3.5% U-235. The fuel rods are assumed to be uniformly spread. The results of the calculations are:

Fuel Type	$K_{eff} \pm 1\sigma$	Loading (KgU)
14x14	0.936 ± .006	475
17x17	0.943 ± .005	513

No statistical difference in reactivity can be inferred from these calculations.

4.2 Final PWR Calculations

The general aspects of the KENO model for the cask with the final PWR basket

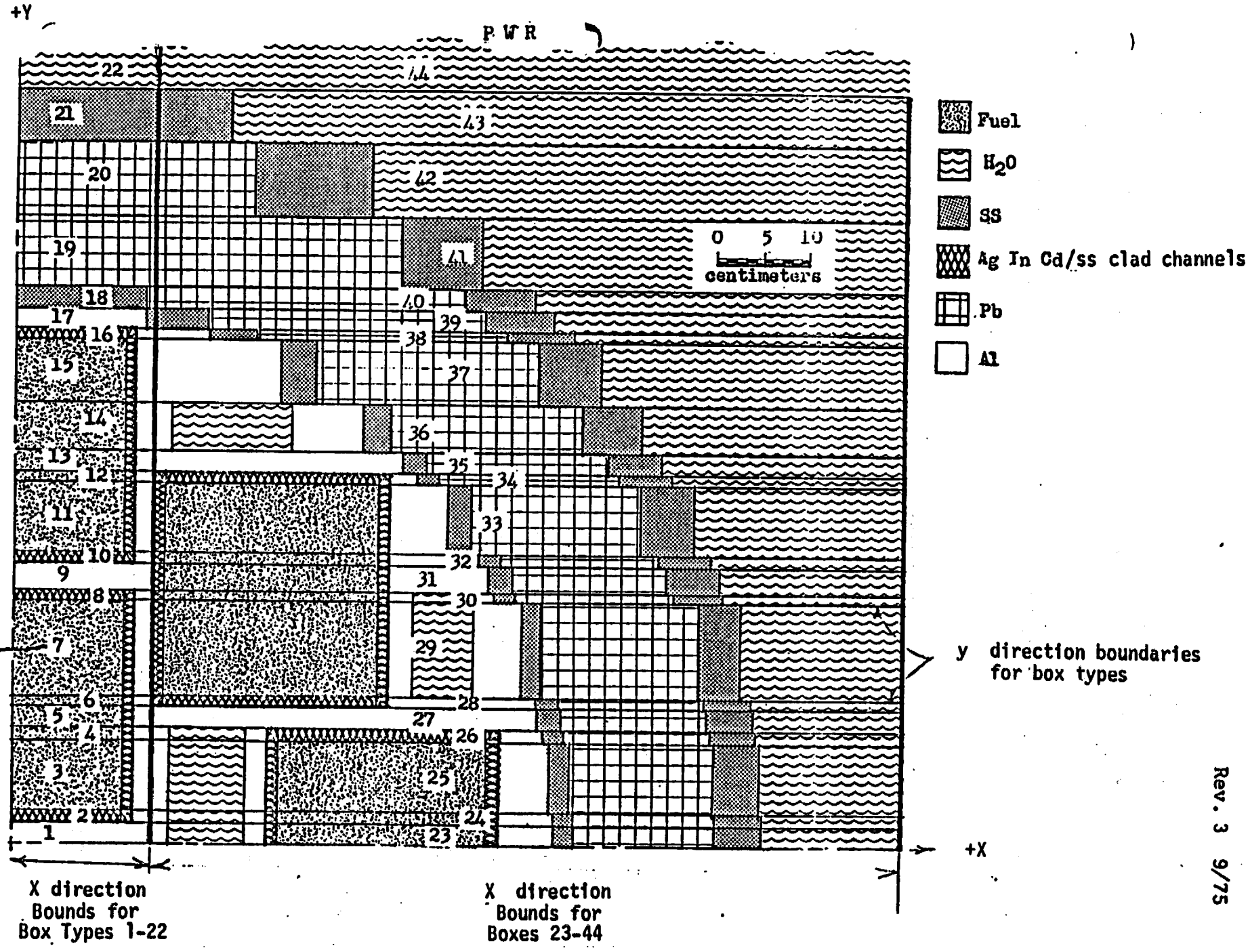


Figure X-4 KENO IV Geometry Model for Prelim y PWR Cask Calculations

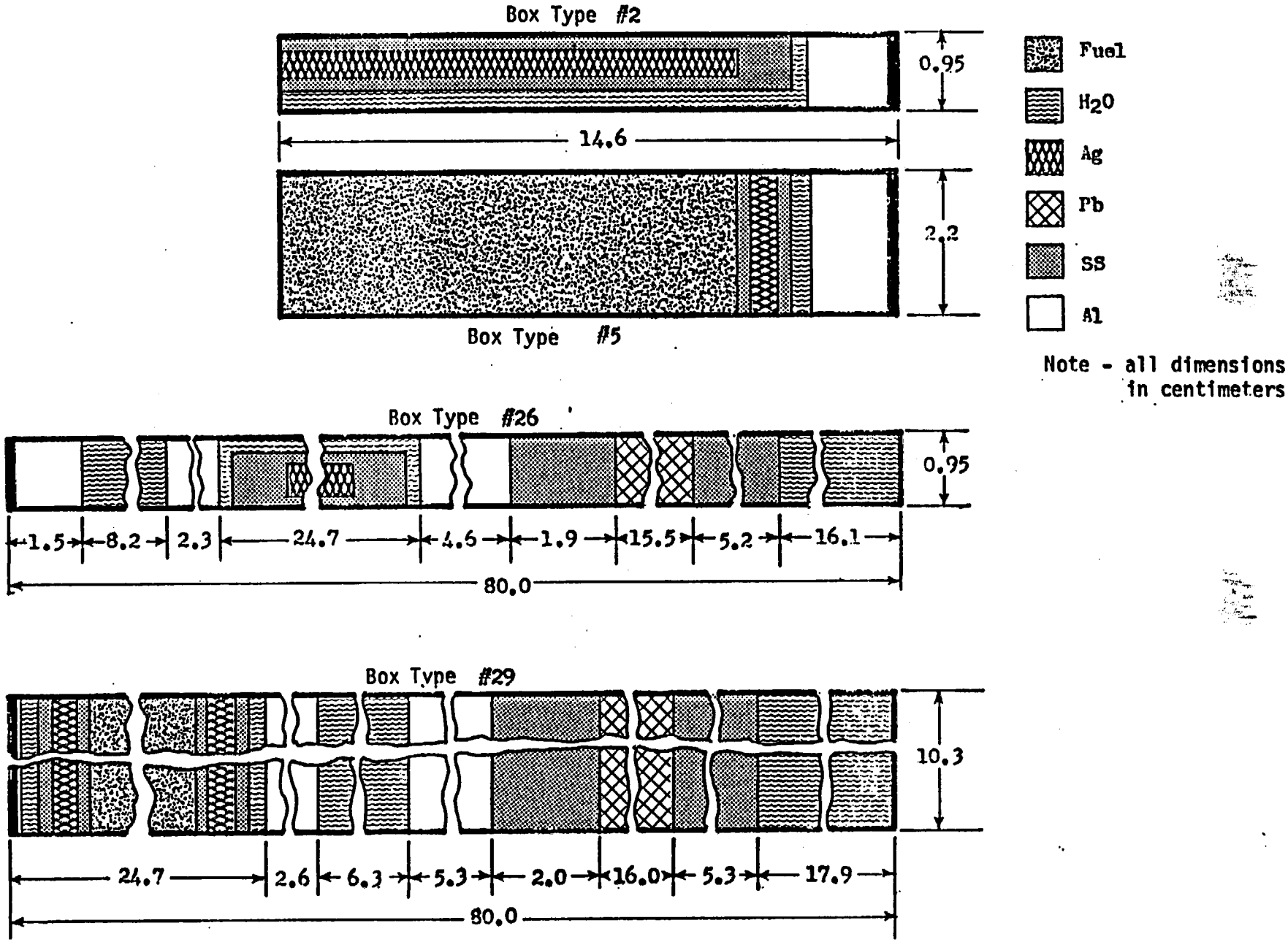


Figure X-5 Example of Selected Box Types for Preliminary PWR Cask Calculations

configuration is shown in Figure X-6. Figure X-7 shows details of several typical Box types for this model. Figure X-8 shows the details of the Ag-In-Cd poison sleeve. The final calculation for the cask with the PWR basket was made for 17x17 type fuel with an enrichment of 3.5% and a total uranium content of 513 KgU/assembly. Again the fuel rods are assumed to be spread to uniformly fill the fuel cavity. The complete details of the model are found in Exhibit 3 of Appendix A. Included in Exhibit 3 are the NITAWL resonance and self shielding calculations, the XSDRNPM cross section preparation for the homogenized fuel, and the complete details of the KENO IV calculation.

The calculated K_{eff} was 0.946 $\pm$ .005. Since the final PWR basket design incorporates only minor changes in basket geometry it was expected that little or no change would occur in K_{eff}.

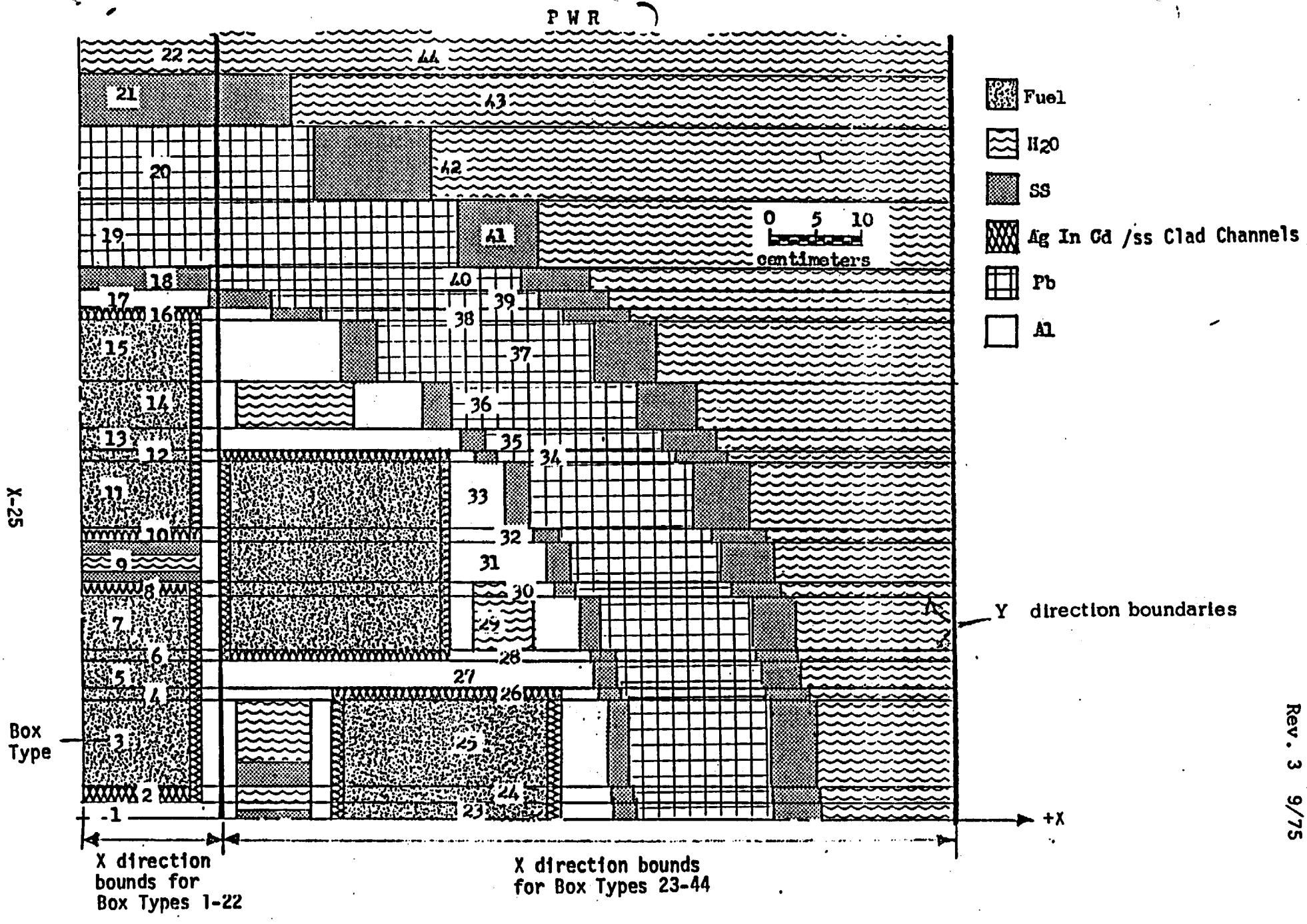


Figure X-6 KENO IV Geometry Model for Final PWR Cask Calculation

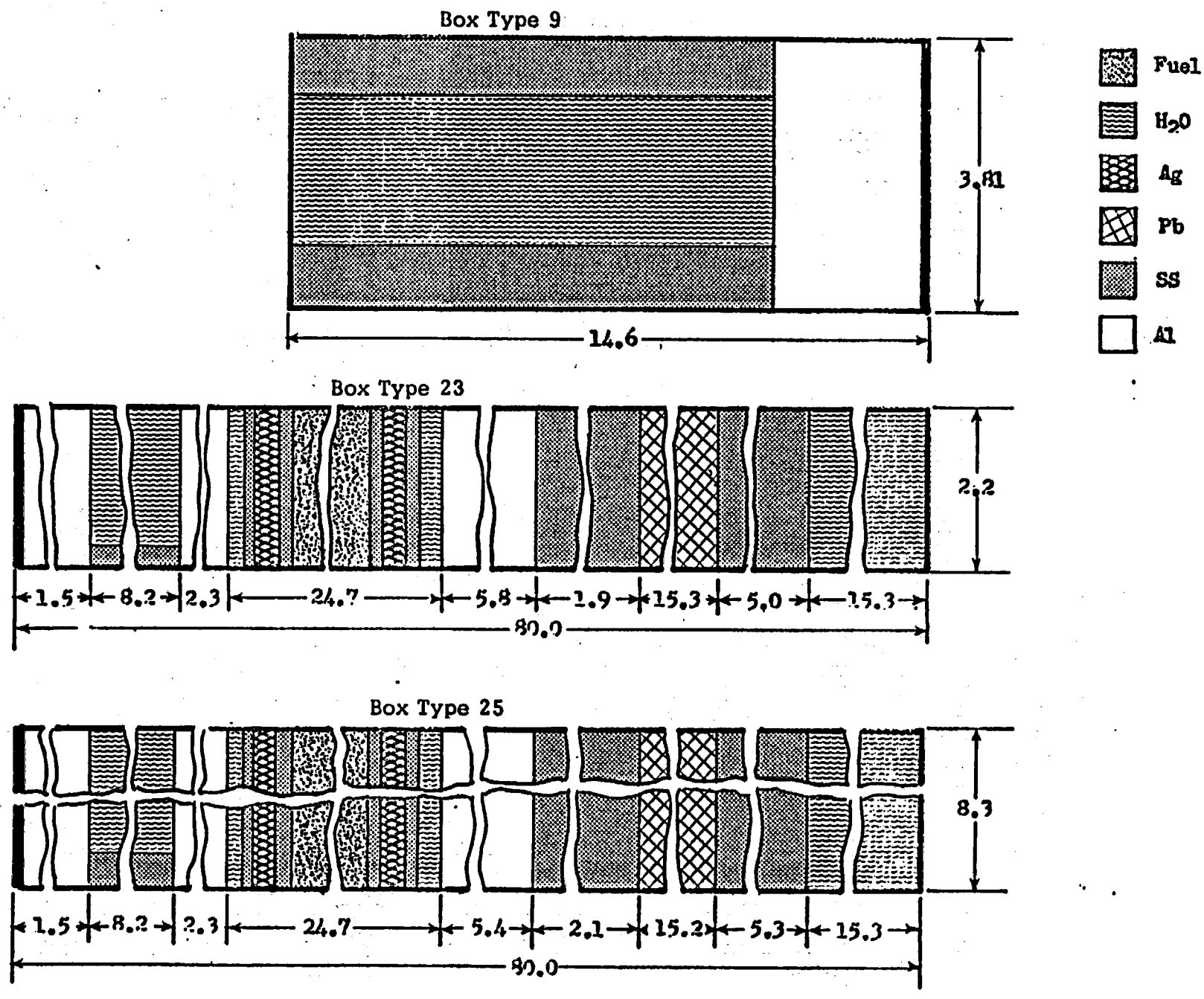
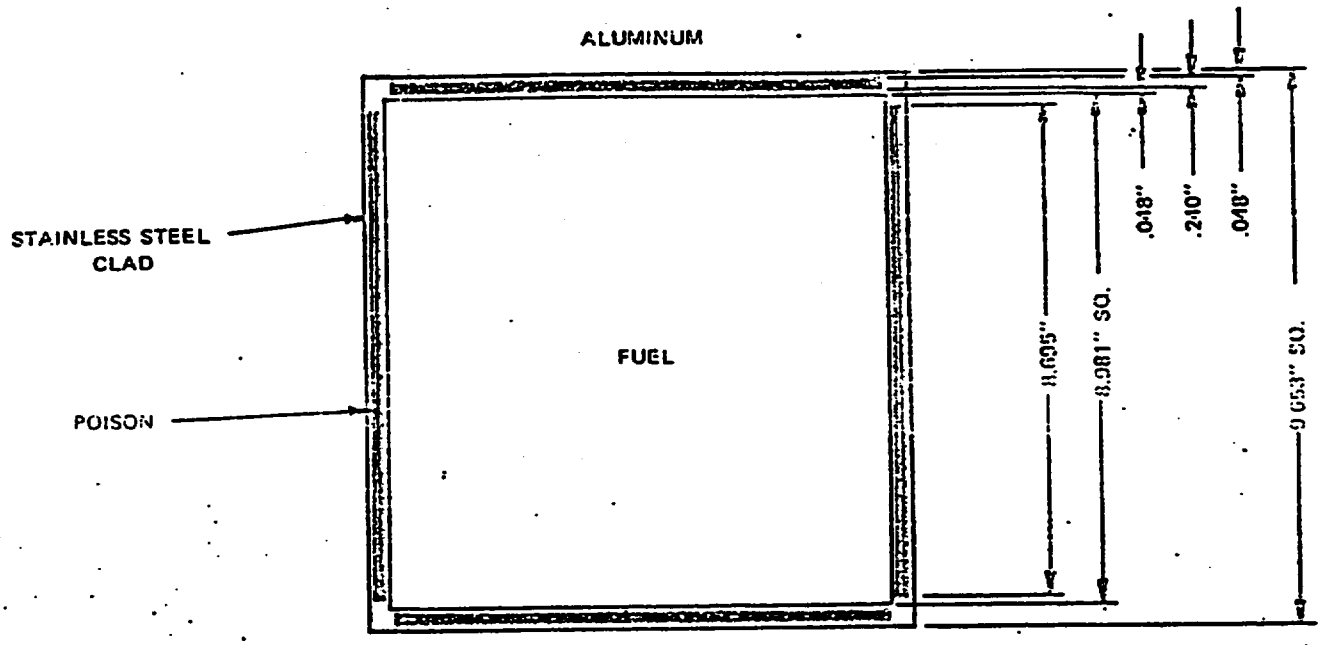


Figure X-7 Example of Selected Box Types fo[illegible]inal PWR Cask Calculations

Figure X-8 Fuel Assembly Ag-In-Cd Poison Channel



4.3 BWR Calculations

The cask with the BWR basket is modeled with the KENO generalized geometry option. Figure X-9 shows the calculation model. Figure X-10 gives a more detailed description of the stainless steel clad Ag-In-Cd poison fuel sleeves. The calculation was performed for the 8x8 rod array of fuel at 2.8% enrichment. The total uranium loading was 200 KgU/assembly. The fuel regions were homogenized and the cross sections were produced using the XSDRNPM module of AMPX. The results of the calculations (exhibit 4, Appendix A) are:

Enrichment %U-235	$K_{eff} \pm 1\sigma$
2.8	.953 ± .005

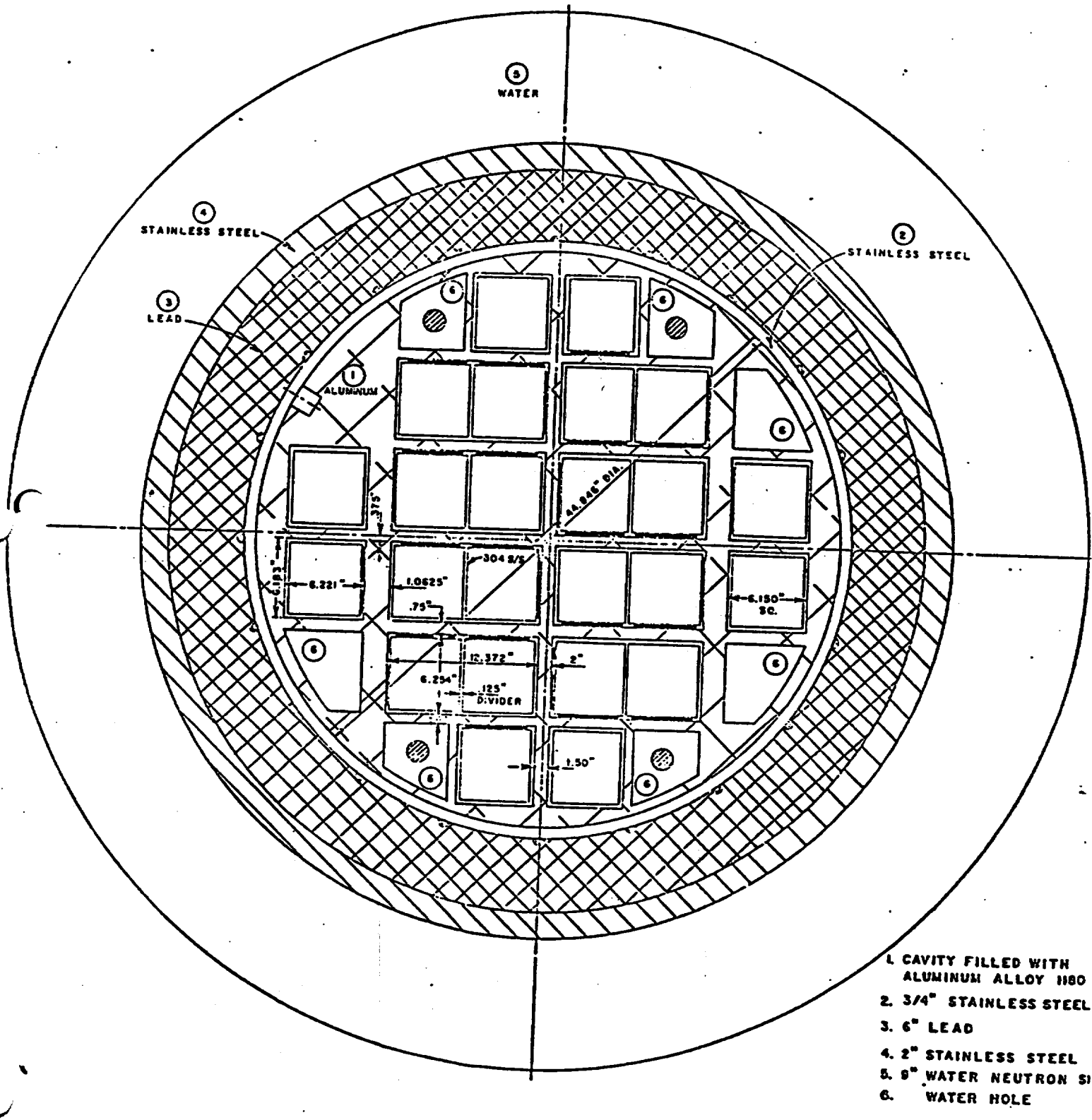
4.4 An Infinite Array of Undamaged Casks

To conservatively determine the effect on cask reactivity of placing two identical undamaged casks adjacent to one another, the change in cask reactivity resulting from a change in outer surface boundary conditions from no reflection to full reflection was determined. These calculations were carried out with the ANISN code in place of the KENO code, because KENO is not an efficient tool to determine small reactivity changes due to changes in reflector conditions.

Two ANISN[4] problems on the cask were run, the first with a zero reflection boundary condition at the outer surface of the water filled neutron shield and the second with a full reflection at the outer surface. The resulting change in reactivity is therefore, the maximum possible effect on reactivity

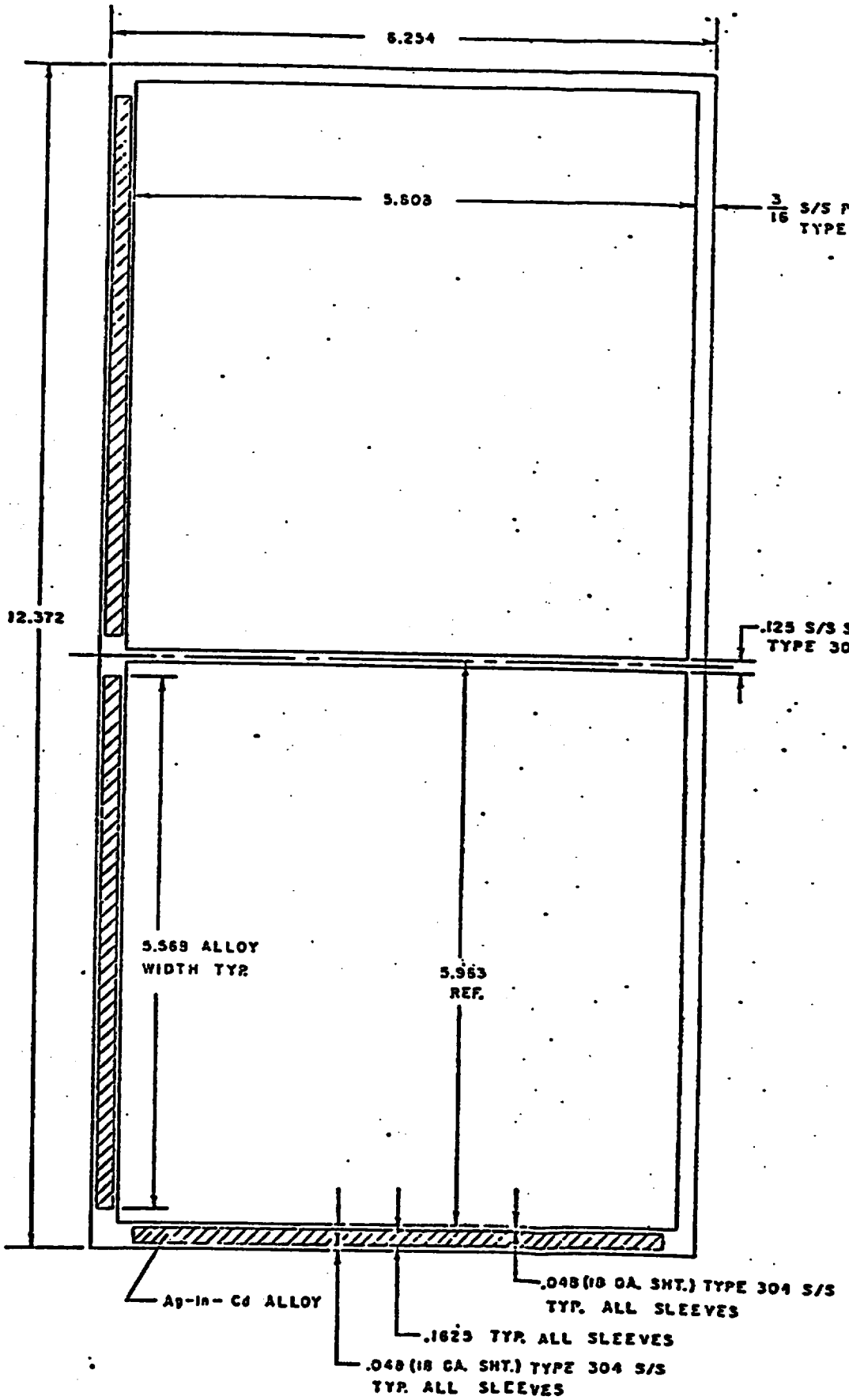
FIGURE X-9

24-ASSEMBLY BWR FUEL CASK



1. CAVITY FILLED WITH ALUMINUM ALLOY 1180
2. 3/4" STAINLESS STEEL
3. 6" LEAD
4. 2" STAINLESS STEEL
5. 9" WATER NEUTRON SI
6. WATER HOLE

Figure X-10
FUEL LINER DETAILS



in going from one cask to a large array of casks. Hanson and Roach [5] cross sections were used for these cases. Since ANISN is a one-dimensional code, it was necessary to first run a unit fuel assembly cell with all square material regions transformed into cylinders. The ANISN cell problem produced a set of flux weighted macroscopic cross sections for each material in the cell. This set of maxroscopic cross sections was then entered into the ANISN cask problem to represent a homogenized mixture of fuel, poison and aluminum in the cavity of the cask. Reflectors outside of this homogenized mixture were described explicitly.

The P1-S8 ANISN calculations yielded a K_{eff} of 0.932 for the PWR fuel cask with zero reflection and 0.932 for the PWR cask with full reflection. This indicates that the KENO K_{eff} for a single cask is also applicable to an infinite array of the undamaged casks.

4.5 Single Damaged Cask

The cask is designed so that the only effect of the hypothetical accident conditions as far as criticality is concerned is the potential loss of the external neutron shield water. The effect of varying the amount of water external to the cask shell has been examined with a series of ANISN calculations assuming the cavity is filled with water and zero neutron return at the outer surface of the several different thicknesses of water surrounding the cask. The results of the analyses are:

Thickness of Water Reflector, inch	ANISN K_{eff}
0	0.931
2	0.932
$9\frac{1}{2}$	0.932

4.6 The Dry Fuel

If there is no water in the inner cavity of the cask as in the case of normal transport conditions, the cask reactivity would decrease substantially. UO_2 containing less than 5 w/0 U-235 cannot become critical if no moderating material is present. Transport of the dry fuel will, therefore, pose no criticality problem.

5.0 VALIDITY OF CALCULATION METHODS

The KENO computer code has been shown to be a reliable computer program for performing criticality safety evaluations [6,7] of equal importance is the validity of the cross sections used. In this regard there is very little published data for low enriched fuel assemblies. ORNL has made a study of the 123 group ENDF/B and GAM-THERMOS cross section sets [8] Table X-5 gives a partial list of results from these studies. The average K_{eff} for all the experiments calculated with the GAM-THERMOS cross sections was 0.992, while for the ENDF/B cross sections the average K_{eff} was 0.975. Based on these results the GAM-THERMOS cross sections were used for this criticality safety evaluation.

TABLE X-5

Results of ORNL Benchmark Calculations

Case	K effective ENDF/B XSECS	K effective GAM XSECS
2 per cent Green Block $H/U^{235} = 195$	0.984 ± .005	1.009 ± .005
5 per cent UO_2F_2 Solution Sphere	0.979 ± .006	0.993 ± .005
1.95 per cent 5 x 5 x 1 Array 7.2 inch OD 2.6 inch ID Bullets	0.942 ± .005	1.008 ± .005
5 per cent rods 1.31 cm D 90 rods center to center spacing 3.94 cm	0.971 ± .006	0.985 ± .006
5 per cent rods 1.31 cm D 69 rods center to center spacing 2.99 cm	0.980 ± .007	0.991 ± .005
5 per cent rods 2.07 cm D 117 rods center to center spacing 5.20 cm	0.960 ± .007	0.978 ± .006
5 per cent rods 2.49 cm D 76 rods center to center spacing 5.62 cm	0.970 ± .005	0.968 ± .006
5 per cent rods 0.234 cm D 49 x 50 center to center spacing 0.514 cm	0.985 ± .006	0.995 ± .005
5 per cent rods 0.234 cm D 39 x 39 center to center spacing 0.845 cm	1.008 ± .006	0.998 ± .006

6.0 REFERENCES

1. AMPX-I, Modular Code for Generating Coupled Multigroup Neutron-Gamma Libraries from ENDF/B, ORNL-TM-3706, ORNL.

2. GAM-THERMOS, 123 Energy Group Cross Section Library, ORNL

3. KENO IV, An Improved Monte Carlo Criticality Program, L. M. Petrie & N. F. Cross, To Be Published By ORNL.

4. ANISN, A One Dimensional Discrete Ordinates Transport Code, K1693, ORNL, June 1973.

5. Six and Sixteen Group Cross Sections For Fast and Intermediate Critical Assemblies, LAMS-2543, G. E. Hansen and W. H. Roach, 1961

6. Y1858, Validation Checks of the ANISN and KENO Codes by Correlation with Experimental Data, G. R. Handley & C. M. Hopper.

7. The Reliability Safety Calculations Using the New Codes - CSC and KENO, Y-K6-96, E. C. Crume Jr., 1967

8. Private Communications, G.E. Whitesides, Sept. '75.

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SECTION X

APPENDIX A

Output from AMPX/KENO
Calculations

EXHIBIT 1

PWR 14x14, 2x2 Fuel Assembly Model

Fully Expanded Rod Pitch

```
THIS IS THE TOP OF AMPX

MODULE CONVERT  HAS BEEN CALLED

* CONVERT
1$$ 14 94 2$$ 47 1 T
4$$ 10CC1 80003 130000 240003 250005 260001 280003 400000 471090 481131
49115C 820000 922351 922381 T

MODULE CONVERT  IS FINISHED. USER CCCE 0000   SYSTEM CODE 000

MODULE NITAWL   HAS BEEN CALLED

* NITAWL
1$$ 0 14 5Z 1 2Z -1 0 T
2$$ 10001 8C0C3 130000 240003 250005 260001 280003 400000 471090 481131
49115C 820000 922351 922381
3** 922381 255 2 .482 .108 62.0 .0239 1 16 7.67 1 3Z 1 T

MODULE NITAWL   IS FINISHED. USER CCOE 0C00   SYSTEM CODE 000

MODULE KENO     HAS BEEN CALLED

KENO 123 GP 2X2 CELL PWR 14X14 .6357 IN PITCH
4 103 200 3 123 80 14 7 16 18 1 14 14 1 -14 1 0 2000 102  0 -1 -1 3Z
1 -922351 6.757-4  1 922381 2.3948-2 1 80003 4.9655-2
2 400000 4.2257-2  3 10CC1 6.6743-2 3 80C03 3.3371-2
4 240003 1.6733-2 4 250005 1.7614-3 4 260001 6.0416-2 4 280003 8.3667-2
5 130000 6.0252-2  6 471090 2.1707-2 6 481131 3.3172-4 6 491150 7.6069-3
6 80C03 1-15
7 820000 3.2553-2
CYLINDER  1 .48157 182.88 -182.88 123R.5
CYLINDER  0 .49276 182.88 -182.88 123R.5
CYLINDER  2 .5588  182.88 -182.88 123R.5
CUBOID  3 .81244 -.81244 .81244 -.81244 182.88 -182.88 123R.5
CORE BDY  0 11.3741 -11.3741 11.3741 -11.3741 182.88 -182.88 123R.5
CUBOID  3 11.3741 -11.3741 11.3741 -11.3741 182.88 -182.88 123R.5
CUBOID  4 11.496  -11.496  11.496  -11.496  182.88 -182.88 123R.5
CUBOID  6 12.112  -12.112  12.112  -12.112  182.88 -182.88 123R.5
CUBOID  4 12.2339 -12.2339 12.2339 -12.2339 182.88 -182.88 123R.5
CUBOID  5 14.5199 -14.5199 14.5199 -14.5199 182.88 -182.88 123R.5
CUBOID  4 16.4249 -14.5199 14.5199 -16.4249 182.88 -182.88 123R.5
CUBOID  7 31.6649 -14.5199 14.5199 -31.6649 182.88 -182.88 123R.5
CUBOID  4 36.7449 -14.5199 14.5199 -36.7449 182.88 -182.88 123R.5
CUBOID  3 39.7449 -14.5199 14.5199 -39.7449 182.88 -182.88
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56491-5 56439-5 56601-5 56735-5 56852-5 56619-5 56504-5 56659-5 56607-5 56859-5
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66452-5 64903-5 671-3 65187-5 65372-5 66593-5 68911-5 62219-5 67766-5 66333-5
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12652-3 12765-3 12879-3 13 13092-3 13166-3 13249-3 1335-2 13463-3 13597-3
13699-3 13755-3 13904-3
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67114-3 67662-3 68336-3
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22647-2 24155-2 25529-2 26642-2 26981-2 27108-2 27014-2 27361-2 28539-2 29443-2
29871-2 30214-2 30511-2 30736-2 30808-2 31018-2 3137-1 31994-2 32606-2 32959-2
33401-2 33814-2 34245-2 34713-2 35137-2 35446-2 35805-2 36221-2 3678-1 37346-2
37679-2 38252-2 3862-1

 MODULE KENO     IS FINISHED. USER CODE 0000   SYSTEM CODE 000
```

```
NITAWL

    1$ ARRAY     12 ENTRIES READ

    OT

  MSCM     NUMBER OF EXTRA CROSS SECTIONS                          0
  MMT      NUMBER OF NUCLIDES FROM MASTER LIBRARY                 14
  MWT      NUMBER OF NUCLIDES FROM X-SECT LIBRARY (LCG 2)          0
  MXT      NUMBER OF NUCLIDES FROM X-SECT LIBRARY (LCG 3)          0
  MCR      ANISN/DOT/MORSE OUTPUT TRIGGER                          0
  MXX      TOTAL CROSS SECTION POSITION                            0
  MS       WITHIN-GROUP SCATTERING CROSS SECTION POSITION          0
  IRES     NUMBER OF RESONANCE CALCULATIONS                        1
  IOM      TABLE LENGTH FOR CROSS SECTIONS                         0
  IPM      IS AN OLD ANISN LIBRARY MOUNTED ? (0/1:NO/YES)          0
  IPP      OUTPUT OPTION TRIGGER                                  -1
  IFG      PRINT CONTROL - ANISN OUTPUT                            0

THE STORAGE ALLOCATED FOR THIS CASE IS 193536 WORDS

    2$ ARRAY     14 ENTRIES READ

    3$ ARRAY     15 ENTRIES READ

    OT

GENERAL INFORMATION CONCERNING CROSS SECTION LIBRARY
  TAPE IDENTIFICATION NUMBER                    0
  NUMBER OF NUCLIDES ON TAPE                   14
  NUMBER OF NEUTRON ENERGY GROUPS             123
  FIRST THERMAL NEUTRON ENERGY GROUP           94
  NUMBER OF GAMMA ENERGY GROUPS                 0


XSDRN TAPE      0
                    SUPER-XSDRN LIBRARY--LAST DIGITS OF ID #'S ARE CODED AS FOLLOWS--      5-900K,6
                    -800K,7-850K,8-750K,9-1000K,ANYTHING ELSE IS PRECISELY THAT--IF THESE THERMAL TE
                    MPERATURES ARE DESIRED, CALL C.W. CRAVEN, JR. OR        N. M. GREENE----ALL THER
                    MAL DATA IS FO (IFTG=94).  ALSO J. WILSON DATA  AND 3 1/V NUCLIDES       JULY, 1
                    968                                    -THIS IS A CONVERTED TAPE

NUCLIDES FROM XSDRN TAPE
    1     URANIUM-235                          THERMAL TEMPERATURE = 294.6 K          922351
    2     URANIUM-238R                         THERMAL TEMPERATURE = 294.6 K          922381
    3     HYDROGEN--THERMOS ID=1803(X-640) THERMAL TEMPERATURE= 294.6 K                10001
    4     OXYGEN      NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 293.6 K              80003
    5     ALUMINUM    NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K            130000
    6    CHROMIUM        THERMAL TEMP=294.6                                           240003
    7     MANGANESE                              THERMAL TEMP =  900.0 K             250005
    8    IRON            THERMAL TEMP=294.6                                           260001
    9    NICKEL          THERMAL TEMP=294.6                                           260003
   10     ZIRCONIUM   NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K            400000
   11     SILVER-109                                                                  471090
   12     CADMIUM-113                          THERMAL TEMPERATURE= 294.6 K           481131
   13     INDIUM-115                                                                  491150
   14     LEAD        NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 293.6 K             820000

URANIUM-235                     THERMAL TEMPERATURE = 294.6 K          922351

URANIUM-238R                    THERMAL TEMPERATURE = 294.6 K          922381
```

```
RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A)          =   238.000          TEMPERATURE(KELVIN)       =   295.000
POTENTIAL SCATTER SIGMA=     9.500            LUMPED NUCLEAR DENSITY    = 0.2390000E-01

SPIN FACTOR (G)          =     1.000          LUMP DIMENSION (A-BAR)    = 0.4820000E 00

SIGMA-M(EFFECTIVE)       = 0.6200000E 02      CARCOFF CORRECTION (C)    = 0.1080000E 00

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-1      =    16.000          SIGMA(PER ABSORBER ATOM)= 0.7669999E 01

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 2-DIMENSIONAL OBJECT.

VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

IHC2091 IBCOM - PROGRAM INTERRUPT (1) - DIVIDE CHECK OLD PSW IS  FFE500400204EB04

TRACEBACK  ROUTINE  CALLED FROM ISN   REG.  14   REG.  15   REG.   0   REG.   1

           RSNAAC            0075     4204AE2E   00040890   0002AD08   000498EC

           HSTPFD            0162     4204856E   00049908   0000000E   00046E64

           TAPEFD            0219     52C3C578   00046C80   000659F4   00030200

           NETABL                     52030864   0003AD88   08002800   00030888

           ALCCAT            0066     520305F6   0003D7F0   00000000   00030294

             MAIN                     0001576C   010301E0   00000030   8003A260

ENTRY POINT=  01C301E0

STANDARD FIXUP TAKEN , EXECUTION CONTINUING

GROUP        RES ABS        RES FISS
 50       4.484381E-02      0.0
 51       5.625156E-02      0.0
 52       7.033260E-02      0.0
 53       8.762378E-02      0.0
 54       1.088757E-01      0.0
 55       1.346809E-01      0.0
 56       1.657212E-01      0.0
 57       2.028778E-01      0.0
 58       2.467002E-01      0.0
 59       2.579262E-01      0.0
 60       3.569502E-01      0.0
 61       4.237132E-01      0.0
 62       4.583135E-01      0.0
 63       5.601604E-01      0.0
 64       6.681403E-01      0.0
 65       7.101264E-01      0.0
 66       7.658687E-01      0.0
 67       7.614378E-01      0.0
 68       9.626374E-01      0.0
 69       1.155357E 00      0.0
 70       1.146654E 00      0.0
 71       1.128687E 00      0.0
 72       1.070655E 00      0.0
 73       1.066268E 00      0.0
 74       1.267557E 00      0.0
```

76	1.176762E 00	0.0
77	4.247354E 00	0.0
78	1.767355E 00	0.0
79	3.876251E 00	0.0
80	7.514759E-02	0.0
81	2.005703E 00	0.0
82	8.704724E 00	0.0
83	8.408353E-01	0.0
84	1.386880E 01	0.0
85	3.523550E-01	0.0
86	0.0	0.0
87	6.166079E-01	0.0
88	2.444824E 01	0.0
89	8.437069E 00	0.0
90	9.768339E-01	0.0
91	5.065718E-01	0.0
92	1.505453E-01	0.0

EXCESS RESONANCE INTEGRALS

	RESOLVED	UNRESOLVED	TOTAL
ABSORPTION	0.17455E 02	0.11283E 01	0.18624E 02
FISSION	0.0	0.0	0.0

ELAPSED TIME 0.26 MIN.

HYDROGEN--THERMOS ID=1803(X-640) THERMAL TEMPERATURE= 294.6 K 10001

OXYGEN NATURAL BROWN - ST. JOHN KERNEL TEMP. = 293.6 K 80003

ALUMINUM NATURAL BROWN - ST. JOHN KERNEL TEMP. = 627.13 K 130000

CHROMIUM THERMAL TEMP=294.6 240003

MANGANESE THERMAL TEMP = 900.0 K 250005

IRON THERMAL TEMP=294.6 260001

NICKEL THERMAL TEMP=294.6 280003

ZIRCONIUM NATURAL BROWN - ST. JOHN KERNEL TEMP. = 627.13 K 400000

SILVER-109 471090

GP 94 ELASTIC SUM OF 0.0 VERSUS AVERAGE VALUE 0.0

GP 95 ELASTIC SUM OF 0.0 VERSUS AVERAGE VALUE 0.0

GP 96 ELASTIC SUM OF 0.0 VERSUS AVERAGE VALUE 0.0

GP 97 ELASTIC SUM OF 0.0 VERSUS AVERAGE VALUE 0.0

GP 98 ELASTIC SUM OF 0.0 VERSUS AVERAGE VALUE 0.0

GP 99 ELASTIC SUM OF 0.0 VERSUS AVERAGE VALUE 0.0

GP 100 ELASTIC SUM OF 0.0 VERSUS AVERAGE VALUE 0.0

GP 101 ELASTIC SUM OF 0.0 VERSUS AVERAGE VALUE 0.0

GP 102 ELASTIC SUM OF 0.0 VERSUS AVERAGE VALUE 0.0

GP 103 ELASTIC SUM OF 0.0 VERSUS AVERAGE VALUE 0.0

```
THIS XSDRN WORKING TAPE WAS CREATED
THE TITLE OF THE PARENT CASE IS AS FOLLOWS
SUPER-XSDRN LIBRARY--LAST DIGITS OF ID #'S ARE CODED AS FOLLOWS--        5-900K,6
-800K,7-650K,8-750K,9-1000K,ANYTHING ELSE IS PRECISELY THAT--IF THESE THERMAL TE
MPERATURES ARE DESIRED, CALL C.W. CRAVEN, JR. OR        N. H. GREENE----ALL THER
    TAPE ID                          0          NUMBER OF NUCLIDES                14
    NUMBER OF NEUTRON GROUPS       123          NUMBER OF GAMMA GROUPS             0
    FIRST THERMAL GROUP             94
                                TABLE OF CONTENTS
    URANIUM-235                   THERMAL TEMPERATURE = 294.6 K          ID    922351
    URANIUM-238R                  THERMAL TEMPERATURE = 294.6 K          ID    922381
    HYDROGEN--THERMOS ID=1803(X-640) THERMAL TEMPERATURE= 294.6 K        ID     10001
    OXYGEN     NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 293.6 K       ID     80003
    ALUMINUM   NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K      ID    130000
   CHROMIUM       THERMAL TEMP=294.6                                     ID    240003
    MANGANESE                          THERMAL TEMP =  900.0 K          ID    250005
   IRON           THERMAL TEMP=294.6                                     ID    260001
   NICKEL         THERMAL TEMP=294.6                                     ID    280003
    ZIRCONIUM  NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K      ID    400000
    SILVER-109                                                           ID    471090
    CADMIUM-113                   THERMAL TEMPERATURE= 294.6 K           ID    481131
    INDIUM-115                                                           ID    491150
    LEAD       NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 293.6 K       ID    820000
```

```
KENO 123 GP 2X2 CELL PWR 14X14 .6397 IN PITCH

NUMBER OF GENERATIONS                    103
NUMBER PER GENERATION                    200
NUMBER OF GENERATIONS TO BE SKIPPED        3
NUMBER OF ENERGY GROUPS                  123
MAX. NUMBER OF ENERGY TRANSFERS           60
NUMBER OF INPUT NUCLIDES                  14
NUMBER OF MIXTURES                         7
NUMBER OF MIXING TABLE ENTRIES            16
NUMBER OF GEOMETRY CARDS                  18
NUMBER OF BOX TYPES                        1
NUMBER OF UNITS IN X DIRECTION            14
NUMBER OF UNITS IN Y DIRECTION            14
NUMBER OF UNITS IN Z DIRECTION             1
NUMBER OF NUCLIDES READ FROM TAPE        -14
ALBEDO TYPE                                1
SEARCH TYPE                                0

START TYPE                                 0
GENERATIONS BETWEEN CHECKPOINTS            0
LIST INPUT X-SECTIONS READ FROM TAPE      NO
LIST 1-D MIXTURE X SECTIONS               NO
LIST 2-D MIXTURE X-SECTIONS               NO
LIST FISS. AND ABS. BY REGION             NO
USE X-SECTIONS FROM PREVIOUS CASE         NO
USE GEOMETRY FROM PREVIOUS CASE           NO
USE VELOCITIES FROM PREVIOUS CASE         NO
COMPUTE MATRIX K-EFFECTIVE BY UNIT        NO
COMPUTE MATRIX K-EFFECTIVE BY BOX TYPE    NO
LIST FISS PROB MATRIX BY UNIT             NO
ADJOINT CALCULATION                       NO
USE EXPONENTIAL TRANSFORM                 NO
CALCULATE FLUX                            YES
CALCULATE FISSION DENSITIES               YES

THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION

THE ALBEDOS ARE +X = 0.0      -X = 1.00000E 00 +Y = 1.00000E 00 -Y = 0.0      +Z = 0.0      -Z = 0.0

MAXIMUM TIME =   4.0000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB =     188382
REMAINING AVAILABLE LOCATIONS=      7202
```

```
KENO 123 GP 2X2 CELL PWR 14X14 .6397 IN PITCH

     MIXTURE  NUCLIDE   DENSITY
         1   -922351   8.79700E-04
         1    922381   2.39480E-02
         1     80003   4.96550E-02
         2    400000   4.22570E-02
         3     10001   6.67430E-02
         3     80003   3.33710E-02
         4    240003   1.67330E-02
         4    250005   1.76140E-03
         4    260001   6.04160E-02
         4    280003   8.36670E-02
         5    130000   6.02520E-02
         6    471090   2.17070E-02
         6    481131   3.31720E-04
         6    491150   7.60650E-03
         6     80003   1.00000E-15
         7    820000   3.29930E-02


CROSS SECTIONS READ FROM TAPE

NUCLIDE =      922351    URANIUM-235                          THERMAL TEMPERATURE = 294.6 K
NUCLIDE =      922381    URANIUM-238R                         THERMAL TEMPERATURE = 294.6 K
NUCLIDE =       10001    HYDROGEN--THERMOS ID=1803(X-640) THERMAL TEMPERATURE= 294.6 K
NUCLIDE =       80003    OXYGEN      NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 293.6 K
NUCLIDE =      130000    ALUMINUM    NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K

IHC208I IBCOM - PROGRAM INTERRUPT (I) -  UNDERFLOW   OLD PSW IS  FFE5010022050FB4

TRACEBACK  ROUTINE  CALLED FROM ISN   REG.  14   REG.  15   REG.   0   REG.   1

            XSTAPE            0030    4204EE22   0004FD88   00000000   0004E9A0

             INPUT            0397    4203E358   0004E708   00000000   0003C428

              KENO                    52045A2C   0003B628   08002800   00045A50

           ALCCAT             0070    4203FCFA   00045988   00000000   0003F9EC

              MAIN                    0001576C   0103F928   00000030   8003A260

ENTRY POINT=  0103F928

STANDARD FIXUP TAKEN , EXECUTION CONTINUING
NUCLIDE =      240003   CHROMIUM       THERMAL TEMP=294.6
NUCLIDE =      250005    MANGANESE                                THERMAL TEMP =  900.0 K
NUCLIDE =      260001   IRON           THERMAL TEMP=294.6
NUCLIDE =      280003   NICKEL         THERMAL TEMP=294.6
NUCLIDE =      400000    ZIRCONIUM  NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K
NUCLIDE =      471090    SILVER-109
NUCLIDE =      481131    CADMIUM-113                          THERMAL TEMPERATURE= 294.6 K
NUCLIDE =      491150    INDIUM-115
NUCLIDE =      820000    LEAD       NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 293.6 K
```

KENO 123 GP 2X2 CELL PWR 14X14 .6397 IN PITCH

GEOMETRY DESCRIPTION

REGION

1	CYLINDER	1	RADIUS = 4.8197E-01	+Z = 1.8288E 02	-Z =-1.8288E 02			
2	CYLINDER	0	RADIUS = 4.9276E-01	+Z = 1.8288E 02	-Z =-1.8288E 02			
3	CYLINDER	2	RADIUS = 5.5880E-01	+Z = 1.8288E 02	-Z =-1.8288E 02			
4	CUBOID	3	+X = 8.1244E-01	-X =-8.1244E-01	+Y = 8.1244E-01	-Y =-8.1244E-01	+Z = 1.8288E 02	-Z =-1.8288E 02

REFLECTOR

REGION

1	CORE BDY	0	+X = 1.1374E 01	-X =-1.1374E 01	+Y = 1.1374E 01	-Y =-1.1374E 01	+Z = 1.8288E 02	-Z =-1.8288E 02
2	CUBOID	3	+X = 1.1374E 01	-X =-1.1374E 01	+Y = 1.1374E 01	-Y =-1.1374E 01	+Z = 1.8288E 02	-Z =-1.8288E 02
3	CUBOID	4	+X = 1.1496E 01	-X =-1.1496E 01	+Y = 1.1496E 01	-Y =-1.1496E 01	+Z = 1.8288E 02	-Z =-1.8288E 02
4	CUBOID	6	+X = 1.2112E 01	-X =-1.2112E 01	+Y = 1.2112E 01	-Y =-1.2112E 01	+Z = 1.8288E 02	-Z =-1.8288E 02
5	CUBOID	4	+X = 1.2234E 01	-X =-1.2234E 01	+Y = 1.2234E 01	-Y =-1.2234E 01	+Z = 1.8288E 02	-Z =-1.8288E 02
6	CUBOID	5	+X = 1.4520E 01	-X =-1.4520E 01	+Y = 1.4520E 01	-Y =-1.4520E 01	+Z = 1.8288E 02	-Z =-1.8288E 02
7	CUBOID	4	+X = 1.6425E 01	-X =-1.4520E 01	+Y = 1.4520E 01	-Y =-1.6425E 01	+Z = 1.8288E 02	-Z =-1.8288E 02
8	CUBOID	7	+X = 3.1665E 01	-X =-1.4520E 01	+Y = 1.4520E 01	-Y =-3.1665E 01	+Z = 1.8288E 02	-Z =-1.8288E 02
9	CUBOID	4	+X = 3.6745E 01	-X =-1.4520E 01	+Y = 1.4520E 01	-Y =-3.6745E 01	+Z = 1.8288E 02	-Z =-1.8288E 02
10	CUBOID	3	+X = 3.9745E 01	-X =-1.4520E 01	+Y = 1.4520E 01	-Y =-3.9745E 01	+Z = 1.8288E 02	-Z =-1.8288E 02
11	CUBOID	3	+X = 4.2745E 01	-X =-1.4520E 01	+Y = 1.4520E 01	-Y =-4.2745E 01	+Z = 1.8288E 02	-Z =-1.8288E 02
12	CUBOID	3	+X = 4.5745E 01	-X =-1.4520E 01	+Y = 1.4520E 01	-Y =-4.5745E 01	+Z = 1.8288E 02	-Z =-1.8288E 02
13	CUBOID	3	+X = 4.8745E 01	-X =-1.4520E 01	+Y = 1.4520E 01	-Y =-4.8745E 01	+Z = 1.8288E 02	-Z =-1.8288E 02
14	CUBOID	3	+X = 5.1985E 01	-X =-1.4520E 01	+Y = 1.4520E 01	-Y =-5.1985E 01	+Z = 1.8288E 02	-Z =-1.8288E 02

```
KENO 123 GP 2X2 CELL PWR 14X14 .6397 IN PITCH

VOLUMES

BOX TYPE      1
          REGION DEFINED BY GEOMETRY CARD      1   VOLUME =    2.66923E 02 CM**3        CUMULATIVE VOLUME =    2.66923E 02 CM**3
          REGION DEFINED BY GEOMETRY CARD      2   VOLUME =    1.20852E 01 CM**3        CUMULATIVE VOLUME =    2.79008E 02 CM**3
          REGION DEFINED BY GEOMETRY CARD      3   VOLUME =    7.97971E 01 CM**3        CUMULATIVE VOLUME =    3.58805E 02 CM**3
          REGION DEFINED BY GEOMETRY CARD      4   VOLUME =    6.06886E 02 CM**3        CUMULATIVE VOLUME =    9.65691E 02 CM**3

REFLECTOR VOLUMES -  GEOMETRY CARD      5 IS THE CORE BOUNDARY CARD
          REGION DEFINED BY GEOMETRY CARD      6   VOLUME =    0.0         CM**3        CUMULATIVE VOLUME =    1.89274E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD      7   VOLUME =    4.07656E 03 CM**3        CUMULATIVE VOLUME =    1.93352E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD      8   VOLUME =    2.12765E 04 CM**3        CUMULATIVE VOLUME =    2.14629E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD      9   VOLUME =    4.34175E 03 CM**3        CUMULATIVE VOLUME =    2.18970E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD     10   VOLUME =    8.94784E 04 CM**3        CUMULATIVE VOLUME =    3.08449E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD     11   VOLUME =    4.17956E 04 CM**3        CUMULATIVE VOLUME =    3.50244E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD     12   VOLUME =    4.29934E 05 CM**3        CUMULATIVE VOLUME =    7.80178E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD     13   VOLUME =    1.81067E 05 CM**3        CUMULATIVE VOLUME =    9.61245E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD     14   VOLUME =    1.15795E 05 CM**3        CUMULATIVE VOLUME =    1.07704E 06 CM**3
          REGION DEFINED BY GEOMETRY CARD     15   VOLUME =    1.22379E 05 CM**3        CUMULATIVE VOLUME =    1.19942E 06 CM**3
          REGION DEFINED BY GEOMETRY CARD     16   VOLUME =    1.28963E 05 CM**3        CUMULATIVE VOLUME =    1.32838E 06 CM**3
          REGION DEFINED BY GEOMETRY CARD     17   VOLUME =    1.35546E 05 CM**3        CUMULATIVE VOLUME =    1.46393E 06 CM**3
          REGION DEFINED BY GEOMETRY CARD     18   VOLUME =    1.53786E 05 CM**3        CUMULATIVE VOLUME =    1.61771E 06 CM**3

 TOTAL VOLUMES
    1       5.23168E 04
    2       2.36870E 03
    3       1.56462E 04
    4       1.18550E 05

VOLUME FRACTION OF THE CORE CONTAINING FISSILE MATERIAL= 0.27641E 00

START TYPE =    C

 THE NEUTRONS WERE STARTED IN THE ARRAY WITH A FLAT DISTRIBUTION.

  200 NEUTRONS WERE INITIALLY STARTED
0.00217 MINUTES WERE REQUIRED FOR STARTING.
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KENO 123 GP 2X2 CELL PWR 14X14 .6397 IN PITCH

GENERATION	K-EFFECTIVE	ELAPSED TIME(MIN)	AVG. K-EFF	DEVIATION	MATRIX K-EFF
			WARNING - ONLY 198 INDEPENDENT FISSION POINTS WERE GENERATED.		
1	8.86480E-01	9.96667E-02	1.00000E 00	0.0	0.0
2	1.02623E 00	1.86000E-01	1.00000E 00	0.0	0.0
3	9.41411E-01	2.61833E-01	9.41411E-01	0.0	0.0
4	1.01585E 00	3.70000E-01	9.78631E-01	3.72286E-02	0.0
5	9.66845E-01	4.57167E-01	9.75369E-01	2.17409E-02	0.0
6	1.03887E 00	5.41667E-01	9.91245E-01	2.20980E-02	0.0
7	1.01268E 00	6.30167E-01	9.95412E-01	1.76171E-02	0.0
8	9.47086E-01	7.21000E-01	9.87358E-01	1.64866E-02	0.0
9	1.03335E 00	8.04167E-01	9.93934E-01	1.54083E-02	0.0
10	1.05508E 00	8.91000E-01	1.00208E 00	1.56381E-02	0.0
11	1.02172E 00	9.75000E-01	1.00426E 00	1.39609E-02	0.0
12	1.00564E 00	1.07100E 00	1.00440E 00	1.24849E-02	0.0
13	9.23551E-01	1.16050E 00	9.97085E-01	1.34541E-02	0.0
14	1.04056E 00	1.25217E 00	1.00071E 00	1.28075E-02	0.0
15	9.76246E-01	1.34550E 00	9.98826E-01	1.19284E-02	0.0
16	1.00800E 00	1.43633E 00	9.99487E-01	1.10606E-02	0.0
17	9.38332E-01	1.52100E 00	9.95410E-01	1.10770E-02	0.0
18	1.06414E 00	1.60833E 00	9.99706E-01	1.12161E-02	0.0
19	9.46056E-01	1.69583E 00	9.96552E-01	1.10021E-02	0.0
			WARNING - ONLY 198 INDEPENDENT FISSION POINTS WERE GENERATED.		
20	8.37816E-01	1.78017E 00	9.87733E-01	1.36153E-02	0.0
21	1.01490E 00	1.86667E 00	9.89162E-01	1.29604E-02	0.0
22	1.05057E 00	1.95417E 00	9.92552E-01	1.27547E-02	0.0
23	9.64284E-01	2.04350E 00	9.92158E-01	1.21382E-02	0.0
24	1.00401E 00	2.13167E 00	9.92697E-01	1.15672E-02	0.0
25	1.00570E 00	2.22500E 00	9.93435E-01	1.10976E-02	0.0
26	9.97430E-01	2.31800E 00	9.93601E-01	1.06275E-02	0.0
27	9.68238E-01	2.41350E 00	9.92587E-01	1.02445E-02	0.0
28	1.07582E 00	2.50100E 00	9.95941E-01	1.04005E-02	0.0
29	9.42184E-01	2.59017E 00	9.93950E-01	1.02062E-02	0.0
30	9.84575E-01	2.67967E 00	9.93629E-01	9.84039E-03	0.0
31	1.00754E 00	2.76417E 00	9.94122E-01	9.50761E-03	0.0
32	1.01824E 00	2.84967E 00	9.94926E-01	9.22067E-03	0.0
33	1.02349E 00	2.93933E 00	9.95847E-01	8.96642E-03	0.0
34	9.61060E-01	3.02750E 00	9.94760E-01	8.74916E-03	0.0
35	9.85252E-01	3.11633E 00	9.94472E-01	8.48543E-03	0.0
36	1.01914E 00	3.20550E 00	9.95197E-01	8.26469E-03	0.0
37	1.04294E 00	3.29250E 00	9.96561E-01	8.14052E-03	0.0
38	1.02385E 00	3.38517E 00	9.97319E-01	7.94778E-03	0.0
39	9.91026E-01	3.47300E 00	9.97148E-01	7.73326E-03	0.0
40	9.72416E-01	3.56967E 00	9.96497E-01	7.55515E-03	0.0
41	9.77457E-01	3.66717E 00	9.96009E-01	7.37554E-03	0.0
42	9.86751E-01	3.75683E 00	9.95777E-01	7.19272E-03	0.0
43	9.51042E-01	3.84417E 00	9.94686E-01	7.10015E-03	0.0
44	9.96509E-01	3.93417E 00	9.94729E-01	6.92915E-03	0.0
45	9.69165E-01	4.02500E 00	9.94135E-01	6.79220E-03	0.0

THE MATRIX K-EFF IS THE LARGEST EIGENVALUE OF THE MATRIX OF FISSION PROBABILITIES BY UNIT.
THERE ARE NBXMAX * NBYMAX * NBZMAX UNITS IN AN ARRAY.

KENO 123 GP 2X2 CELL PWR 14X14 .6397 IN PITCH

LIFETIME = 2.65767E-05 + OR - 1.79893E-06 GENERATION TIME = 2.44332E-05 + OR - 2.69872E-07

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.99539	+ OR - 0.00682	0.98857 TO 1.00221	0.98174 TO 1.00904	0.97492 TO 1.01586	8400
4	0.99489	+ OR - 0.00697	0.98792 TO 1.00187	0.98094 TO 1.00884	0.97397 TO 1.01581	8200
5	0.99554	+ OR - 0.00712	0.98842 TO 1.00266	0.98130 TO 1.00978	0.97418 TO 1.01690	8000
6	0.99443	+ OR - 0.00722	0.98722 TO 1.00165	0.98000 TO 1.00886	0.97279 TO 1.01608	7800
7	0.99397	+ OR - 0.00739	0.98657 TO 1.00136	0.97918 TO 1.00875	0.97179 TO 1.01614	7600
8	0.99524	+ OR - 0.00748	0.98775 TO 1.00272	0.98027 TO 1.01020	0.97279 TO 1.01768	7400
9	0.99418	+ OR - 0.00762	0.98656 TO 1.00179	0.97894 TO 1.00941	0.97133 TO 1.01702	7200
10	0.99232	+ OR - 0.00760	0.98472 TO 0.99992	0.97712 TO 1.00752	0.96952 TO 1.01512	7000
11	0.99146	+ OR - 0.00778	0.98368 TO 0.99923	0.97590 TO 1.00701	0.96813 TO 1.01479	6800
12	0.99103	+ OR - 0.00800	0.98302 TO 0.99903	0.97502 TO 1.00704	0.96701 TO 1.01504	6600
17	0.99346	+ OR - 0.00870	0.98475 TO 1.00216	0.97605 TO 1.01086	0.96735 TO 1.01956	5600
22	0.99552	+ OR - 0.00647	0.98904 TO 1.00199	0.98257 TO 1.00846	0.97610 TO 1.01493	4600
27	0.99629	+ OR - 0.00809	0.98820 TO 1.00438	0.98011 TO 1.01248	0.97202 TO 1.02057	3600
32	0.99232	+ OR - 0.00767	0.98464 TO 0.99999	0.97697 TO 1.00766	0.96930 TO 1.01533	2600
37	0.98353	+ OR - 0.00766	0.97587 TO 0.99118	0.96821 TO 0.99884	0.96056 TO 1.00649	1600
42	0.97224	+ OR - 0.01321	0.95902 TO 0.98545	0.94581 TO 0.99867	0.93259 TO 1.01188	600

EXHIBIT 2

BWR 8x8, 2x2 Fuel Assembly Model

Fully Expanded Rod Pitch

```
THIS IS THE TOP OF AMPX
.. MODULE CONVERT  HAS BEEN CALLED
* CONVERT
188 14 94 288 47 1 T
488 10001 80003 130000 240003 250005 260001 280003 400000 471090 481131
491150 820000 922351 922381 T

MODULE CONVERT  IS FINISHED. USER CODE 0000   SYSTEM CODE 000

MODULE NITAWL   HAS BEEN CALLED

* NITAWL
188 0 14 52 1 22 -1 0 T
288 10001 80003 130000 240003 250005 260001 280003 400000 471090 481131
491150 820000 922351 922381
3** 922381 295 2 .528 .0832 55.0 .0236 1 16 7.63 1 32 1 T

MODULE NITAWL   IS FINISHED. USER CODE 0000   SYSTEM CODE 000

MODULE KENO     HAS BEEN CALLED

KENO 123 GP 2X2 CELL BWR 8X8 NO 1 .7219 IN PITCH
4 103 200 3 123 80 14 7 16 17 1 8 8 1 -14 1 0 2000 102  0 -1 -1 32
1 -922351 7.377-4  1 922381 2.3550-2 1 80003 4.8575-2
2 400000 4.2257-2  3 10001 6.6742-2 3 80003 3.3371-2
4 240003 1.6733-2 4 250005 1.7614-3 4 260001 6.0416-2 4 280003 8.3667-2
5 130000 6.0252-2  6 471090 2.1767-2 6 481131 3.3172-4 6 491150 7.6069-3
6 80003 1-15
7 820000 3.2993-2
CYLINDER  1 .52832 182.88 -182.88 123R.5
CYLINDER  0 .53975 182.88 -182.88 123R.5
CYLINDER  2 .62611 182.88 -182.88 123R.5
CUBOID  3 .91678  -.91678  .91678  -.91678  182.88 -182.88 123R.5
CORE BOX  0 7.33425 -7.33425 7.33425 -7.33425 182.88 -182.88 123R.5
CUBOID  3 7.33425 -7.33425 7.33425 -7.33425 182.88 -182.88 123R.5
CUBOID  4 7.8105  -7.8105  7.8105  -7.8105  182.88 -182.88 123R.5
CUBOID  6 7.8105  -8.0137  7.8105  -7.8105  182.88 -182.88 123R.5
CUBOID  5 10.3505 -8.9664  7.8105  -10.3505 182.88 -182.88 123R.5
CUBOID  4 12.2555 -8.9664  7.8105  -12.2555 182.88 -182.88 123R.5
CUBOID  7 27.4955 -8.9664  7.8105  -27.4955 182.88 -182.88 123R.5
CUBOID  4 32.5755 -8.9664  7.8105  -32.5755 182.88 -182.88 123R.5
REFLECTOR  3 15.24 32 15.24 32 500

MODULE KENO     IS FINISHED. USER CODE 0000   SYSTEM CODE 000
```

```
NITAWL

     1# ARRAY     12 ENTRIES READ

     OT

   NSCN      NUMBER OF EXTRA CROSS SECTIONS                          0
   NMT       NUMBER OF NUCLIDES FROM MASTER LIBRARY                 14
   NWT       NUMBER OF NUCLIDES FROM X-SECT LIBRARY (LCG 2)          0
   NXT       NUMBER OF NUCLIDES FROM X-SECT LIBRARY (LCG 3)          0
   NCR       ANISN/DOT/MORSE OUTPUT TRIGGER                          0
   NXX       TOTAL CROSS SECTION POSITION                            0
   NS        WITHIN-GROUP SCATTERING CROSS SECTION POSITION          0
   IRFS      NUMBER OF RESONANCE CALCULATIONS                        1
   IOM       TABLE LENGTH FOR CROSS SECTIONS                         0
   IPM       IS AN OLD ANISN LIBRARY MOUNTED ? (0/1:NO/YES)          0
   IPP       OUTPUT OPTION TRIGGER                                  -1
   IFG       PRINT CONTROL - ANISN OUTPUT                            0

THE STORAGE ALLOCATED FOR THIS CASE IS 156096 WORDS

     2# ARRAY     14 ENTRIES READ

     3# ARRAY     15 ENTRIES READ

     OT

GENERAL INFORMATION CONCERNING CROSS SECTION LIBRARY
   TAPE IDENTIFICATION NUMBER                    0
   NUMBER OF NUCLIDES ON TAPE                   14
   NUMBER OF NEUTRON ENERGY GROUPS             123
   FIRST THERMAL NEUTRON ENERGY GROUP           94
   NUMBER OF GAMMA ENERGY GROUPS                 0

XSDRN TAPE      0
                    SUPER-XSDRN LIBRARY--LAST DIGITS OF ID #'S ARE CODED AS FOLLOWS--      5-900K,6
                    -800K,7-850K,8-750K,9-1000K,ANYTHING ELSE IS PRECISELY THAT--IF THESE THERMAL TE
                    MPERATURES ARE DESIRED, CALL C.W. CRAVEN, JR. OR       N. M. GREENE----ALL THER
                    MAL DATA IS PO (IFTG=94).  ALSO J. WILSON DATA  AND 3 1/V NUCLIDES       JULY, 1
                    968                                    -THIS IS A CONVERTED TAPE

NUCLIDES FROM XSDRN TAPE
    1     URANIUM-235                          THERMAL TEMPERATURE = 294.6 K          922351
    2     URANIUM-238R                         THERMAL TEMPERATURE = 294.6 K          922381
    3     HYDROGEN--THERMOS ID=1E03(X-640) THERMAL TEMPERATURE= 294.6 K                10001
    4     OXYGEN      NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 293.6 K               80003
    5     ALUMINUM    NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K             130000
    6    CHROMIUM        THERMAL TEMP=294.6                                            240003
    7     MANGANESE                                THERMAL TEMP =  900.0 K             250005
    8    IRON            THERMAL TEMP=294.6                                            260001
    9    NICKEL          THERMAL TEMP=294.6                                            280003
   10     ZIRCONIUM   NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K             400000
   11     SILVER-109                                                                  471090
   12     CADMIUM-113                          THERMAL TEMPERATURE= 294.6 K           481131
   13     INDIUM-115                                                                  491150
   14     LEAD        NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 293.6 K             820000

URANIUM-235                      THERMAL TEMPERATURE = 294.6 K          922351

URANIUM-238R                     THERMAL TEMPERATURE = 294.6 K          922381
```

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RESONANCE DATA FOR THIS NUCLIDE

MASS NUMBER (A)          =   238.000          TEMPERATURE(KELVIN)      =   295.000
POTENTIAL SCATTER SIGMA=     9.500           LUMPED NUCLEAR DENSITY   = 0.2360000E-01

SPIN FACTOR (G)          =     1.000          LUMP DIMENSION (A-BAR)   = 0.5280000E 00

SIGMA-M(EFFECTIVE)       = 0.5500000E 02      DANCOFF CORRECTION (C)   = 0.8319998E-01

THE ABSORBER WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

MASS OF MODERATOR-1      =    16.000          SIGMA(PER ABSORBER ATOM)= 0.7629999E 01

MODERATOR-1 WILL BE TREATED BY THE NORDHEIM INTEGRAL METHOD.

THIS RESONANCE MATERIAL WILL BE TREATED AS A 2-DIMENSIONAL OBJECT.

VOLUME FRACTION OF LUMP IN CELL USED TO ACCOUNT FOR SPATIAL SELF-SHIELDING=1.00000

IHC209I IBCOM - PROGRAM INTERRUPT (I) - DIVIDE CHECK OLD PSW IS  FFE500400204EB04

TRACEBACK  ROUTINE  CALLED FROM ISN   REG.  14   REG.  15   REG.   0   REG.   1

           RSNANC            0075    4204AE2E   00C4C890   00028708   00049BEC

           MSTPRD            C162    4204856E   00C499D8   0000003E   00046E64

           TAPERD            0219    5203C978   00046C80   000659F4   00038200

           NITAWL                    52030864   0003AC88   08002800   0003D888

          ALOCAT             0066    5203D5F6   0003C7F0   00000000   0003D294

             MAIN                    0001576C   01C3C1E0   00000030   8003A260

ENTRY POINT=  C103D1E0

STANDARD FIXUP TAKEN , EXECUTION CONTINUING

GROUP        RES ABS        RES FISS
  50       4.475449E-02    0.0
  51       5.604173E-02    0.0
  52       7.003516E-02    0.0
  53       8.720594E-02    0.0
  54       1.081322E-01    0.0
  55       1.335715E-01    0.0
  56       1.641099E-01    0.0
  57       2.004161E-01    0.0
  58       2.431185E-01    0.0
  59       2.927816E-01    0.0
  60       3.496034E-01    0.0
  61       4.136910E-01    0.0
  62       4.847741E-01    0.0
  63       5.622468E-01    0.0
  64       6.448495E-01    0.0
  65       6.871125E-01    0.0
  66       7.557817E-01    0.0
  67       7.514263E-01    0.0
  68       9.491958E-01    0.0
  69       1.137410E 00    0.0
  70       1.128605E 00    0.0
  71       1.108606E 00    0.0
  72       1.053149E 00    0.0
  73       1.065414E 00    0.0
```

```
76        1.158657E C0     0.0
77        4.173873E C0     0.0
78        1.733198E C0     0.0
79        3.808515E C0     0.0
80        7.916933E-02     0.0
81        1.557177E C0     0.0
82        8.528132E C0     0.0
83        8.469710E-01     0.0
84        1.355581E C1     0.0
85        3.924609E-01     0.0
86        0.0              0.0
87        6.186013E-01     0.0
88        2.382822E C1     0.0
89        8.513224E C0     0.0
90        9.767179E-01     0.0
91        5.085681E-01     0.0
92        1.505542E-01     0.0

EXCESS RESONANCE INTEGRALS

                  RESOLVED       UNRESOLVED        TOTAL

ABSORPTION        0.17129E 02    0.11009E 01    0.18230E 02
FISSION           0.0            0.0            0.0

 ELAPSED TIME   0.26 MIN.

 HYDROGEN--THERMOS ID=1803(X-640) THERMAL TEMPERATURE= 294.6 K          10001

 OXYGEN     NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 293.6 K          80003

 ALUMINUM   NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K        130000

CHROMIUM        THERMAL TEMP=294.6                                      240003

 MANGANESE                              THERMAL TEMP =  900.0 K        250005

IRON            THERMAL TEMP=294.6                                      260001

NICKEL          THERMAL TEMP=294.6                                      280003

 ZIRCONIUM  NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K        400000

 SILVER-109                                                             471090

GP  94 ELASTIC SUM OF  0.0          VERSUS AVERAGE VALUE  0.0

GP  95 ELASTIC SUM OF  0.0          VERSUS AVERAGE VALUE  0.0

GP  96 ELASTIC SUM OF  0.0          VERSUS AVERAGE VALUE  0.0

GP  97 ELASTIC SUM OF  0.0          VERSUS AVERAGE VALUE  0.0

GP  98 ELASTIC SUM OF  0.0          VERSUS AVERAGE VALUE  0.0

GP  99 ELASTIC SUM OF  0.0          VERSUS AVERAGE VALUE  0.0

GP 100 ELASTIC SUM OF  0.0          VERSUS AVERAGE VALUE  0.0

GP 101 ELASTIC SUM OF  0.0          VERSUS AVERAGE VALUE  0.0

GP 102 ELASTIC SUM OF  0.0          VERSUS AVERAGE VALUE  0.0

GP 103 ELASTIC SUM OF  0.0          VERSUS AVERAGE VALUE  0.0
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THIS XSDRN WORKING TAPE WAS CREATED
THE TITLE OF THE PARENT CASE IS AS FOLLOWS
SUPER-XSDRN LIBRARY--LAST DIGITS OF ID #'S ARE CODED AS FOLLOWS--        5-500K,6
-800K,7-850K,8-750K,9-1000K,ANYTHING ELSE IS PRECISELY THAT--IF THESE THERMAL TE
MPERATURES ARE DESIRED, CALL C.W. CRAVEN, JR. OR        N. M. GREENE----ALL THER
    TAPE ID                                  0          NUMBER OF NUCLIDES                    14
    NUMBER OF NEUTRON GROUPS               123          NUMBER OF GAMMA GROUPS                 0
    FIRST THERMAL GROUP                     94
                                   TABLE OF CONTENTS
    URANIUM-235                      THERMAL TEMPERATURE = 294.6 K                ID    922351
    URANIUM-238R                     THERMAL TEMPERATURE = 294.6 K                ID    922381
    HYDROGEN--THERMOS ID=1803(X-640) THERMAL TEMPERATURE= 294.6 K                 ID     10001
    OXYGEN     NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 293.6 K                ID     80003
    ALUMINUM   NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K               ID    130000
   CHROMIUM        THERMAL TEMP=294.6                                             ID    240003
    MANGANESE                          THERMAL TEMP =  900.0 K                    ID    250005
   IRON            THERMAL TEMP=294.6                                             ID    260001
   NICKEL          THERMAL TEMP=294.6                                             ID    280003
    ZIRCONIUM  NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K               ID    400000
    SILVER-109                                                                    ID    471090
    CADMIUM-113                      THERMAL TEMPERATURE= 294.6 K                 ID    481131
    INDIUM-115                                                                    ID    491150
    LEAD       NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 293.6 K                ID    820000
```

KENO 123 GP 2X2 CELL BWR 8X8 NO 1 .7219 IN PITCH

NUMBER OF GENERATIONS	103	START TYPE	0
NUMBER PER GENERATION	200	GENERATIONS BETWEEN CHECKPOINTS	0
NUMBER OF GENERATIONS TO BE SKIPPED	3	LIST INPUT X-SECTIONS READ FROM TAPE	NO
NUMBER OF ENERGY GROUPS	123	LIST 1-D MIXTURE X SECTIONS	NO
MAX. NUMBER OF ENERGY TRANSFERS	80	LIST 2-D MIXTURE X-SECTIONS	NO
NUMBER OF INPUT NUCLIDES	14	LIST FISS. AND ABS. BY REGION	NO
NUMBER OF MIXTURES	7	USE X-SECTIONS FROM PREVIOUS CASE	NO
NUMBER OF MIXING TABLE ENTRIES	16	USE GEOMETRY FROM PREVIOUS CASE	NO
NUMBER OF GEOMETRY CARDS	17	USE VELOCITIES FROM PREVIOUS CASE	NO
NUMBER OF BOX TYPES	1	COMPUTE MATRIX K-EFFECTIVE BY UNIT	NO
NUMBER OF UNITS IN X DIRECTION	8	COMPUTE MATRIX K-EFFECTIVE BY BOX TYPE	NO
NUMBER OF UNITS IN Y DIRECTION	8	LIST FISS PROB MATRIX BY UNIT	NO
NUMBER OF UNITS IN Z DIRECTION	1	ADJOINT CALCULATION	NO
NUMBER OF NUCLIDES READ FROM TAPE	-14	USE EXPONENTIAL TRANSFORM	NO
ALBEDO TYPE	1	CALCULATE FLUX	YES
SEARCH TYPE	0	CALCULATE FISSION DENSITIES	YES

THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION

THE ALBEDOS ARE +X = 0.0 -X = 1.00000E 00 +Y = 1.00000E 00 -Y = 0.0. +Z = 0.0 -Z = 0.0

MAXIMUM TIME = 4.0000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 188382
REMAINING AVAILABLE LOCATIONS= 9762

```
KENO 123 GP 2X2 CELL BWR 8X8 NO 1 .7215 IN PITCH

MIXTURE  NUCLIDE   DENSITY
   1     -922351   7.3770CE-04
   1      922381   2.3550CE-02
   1       80003   4.8575CE-02
   2      400000   4.2257CE-02
   3       10001   6.6743CE-02
   3       80003   3.3371CE-02
   4      240003   1.6733CE-02
   4      250005   1.7614CE-03
   4      260001   6.0416CE-02
   4      280003   8.3667CE-02
   5      130000   6.0252CE-02
   6      471050   2.1707CE-02
   6      481131   3.3172CE-04
   6      491150   7.6069CE-03
   6       60003   1.0000CE-15
   7      820000   3.2993CE-02


CROSS SECTIONS READ FROM TAPE

NUCLIDE =     922351    URANIUM-235                          THERMAL TEMPERATURE = 294.6 K
NUCLIDE =     922381    URANIUM-238R                         THERMAL TEMPERATURE = 294.6 K
NUCLIDE =      10001    HYDROGEN--THERMOS ID=1803(X-640) THERMAL TEMPERATURE= 294.6 K
NUCLIDE =      80003    OXYGEN     NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 293.6 K
NUCLIDE =     130000    ALUMINUM   NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K

IHC208I IBCOM - PROGRAM INTERRUPT (1) -  UNDERFLOW   OLD PSW IS  FFE5010022050F84

TRACEBACK  ROUTINE  CALLED FROM ISN   REG.  14   REG.  15   REG.   0   REG.   1

           XSTAPE            0030   4204EE22   0004FC88   00000000   0004E5A0

           INPUT             0397   4203E398   00C4E708   00000000   0003C428

           KENO                     52045A2C   0003B624   08002800   00045850

           ALOCAT            0010   42C3FCFA   00045988   00000000   0003F5EC

           MAIN                     0001576C   01C3F928   00000030   8003A260

ENTRY POINT=  0103F528

STANDARD FIXUP TAKEN . EXECUTION CONTINUING
NUCLIDE =     240003   CHROMIUM      THERMAL TEMP=294.6 .
NUCLIDE =     250005    MANGANESE                                THERMAL TEMP =  900.0 K
NUCLIDE =     260001   IRON          THERMAL TEMP=294.6
NUCLIDE =     280003   NICKEL        THERMAL TEMP=294.6
NUCLIDE =     400000    ZIRCONIUM  NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 627.13 K
NUCLIDE =     471050    SILVER-109
NUCLIDE =     481131    CADMIUM-113                          THERMAL TEMPERATURE= 294.6 K
NUCLIDE =     491150    INDIUM-115
NUCLIDE =     820000    LEAD       NATURAL     BROWN - ST. JOHN KERNEL TEMP. = 293.6 K
```

```
KENO 123 GP 2X2 CELL BWR 8X8 NO 1 .7219 IN PITCH
GEOMETRY DESCRIPTION
REGION
1  CYLINDER  1  RADIUS = 5.2832E-01   +Z = 1.8288E 02   -Z =-1.8288E 02
2  CYLINDER  0  RADIUS = 5.3975E-01   +Z = 1.8288E 02   -Z =-1.8288E 02
3  CYLINDER  2  RADIUS = 6.2611E-01   +Z = 1.8288E 02   -Z =-1.8288E 02
4  CUBOID    3     +X = 9.1678E-01   -X =-9.1678E-01   +Y = 9.1678E-01   -Y =-9.1678E-01   +Z = 1.8288E 02   -Z =-1.8288E 02

REFLECTOR
REGION
1  CORE REG  0     +X = 7.3342E 00   -X =-7.3342E 00   +Y = 7.3342E 00   -Y =-7.3342E 00   +Z = 1.8288E 02   -Z =-1.8288E 02
2  CUBOID    3     +X = 7.3342E 00   -X =-7.3342E 00   +Y = 7.3342E 00   -Y =-7.3342E 00   +Z = 1.8288E 02   -Z =-1.8288E 02
3  CUBOID    4     +X = 7.8105E 00   -X =-7.8105E 00   +Y = 7.8105E 00   -Y =-7.8105E 00   +Z = 1.8288E 02   -Z =-1.8288E 02
4  CUBOID    6     +X = 7.8105E 00   -X =-8.0137E 00   +Y = 7.8105E 00   -Y =-7.8105E 00   +Z = 1.8288E 02   -Z =-1.8288E 02
5  CUBOID    5     +X = 1.0350E 01   -X =-8.9664E 00   +Y = 7.8105E 00   -Y =-1.0350E 01   +Z = 1.8288E 02   -Z =-1.8288E 02
6  CUBOID    4     +X = 1.2255E 01   -X =-8.9664E 00   +Y = 7.8105E 00   -Y =-1.2255E 01   +Z = 1.8288E 02   -Z =-1.8288E 02
7  CUBOID    7     +X = 2.7495E 01   -X =-8.9664E 00   +Y = 7.8105E 00   -Y =-2.7495E 01   +Z = 1.8288E 02   -Z =-1.8288E 02
8  CUBOID    4     +X = 3.2575E 01   -X =-8.9664E 00   +Y = 7.8105E 00   -Y =-3.2575E 01   +Z = 1.8288E 02   -Z =-1.8288E 02
REFLECTOR    3     +X = 1.5240E 01   -X = 0.0          +Y = 0.0          -Y = 1.5240E 01   +Z = 0.0          -Z = 0.0
                 WT. 10 = 50C
                 123 GROUP WEIGHTS FOR WATER      . HAVING 10 INTERVALS. EACH  3.0 CM THICK WERE USED.
9  CUBOID    3     +X = 3.5575E 01   -X =-8.9664E 00 +Y = 7.8105E 00   -Y =-3.5575E 01   +Z = 1.8288E 02   -Z =-1.8288E 02
10 CUBOID    3     +X = 3.8575E 01   -X =-8.9664E 00 +Y = 7.8105E 00   -Y =-3.8575E 01   +Z = 1.8288E 02   -Z =-1.8288E 02
11 CUBOID    3     +X = 4.1575E 01   -X =-8.9664E 00 +Y = 7.8105E 00   -Y =-4.1575E 01   +Z = 1.8288E 02   -Z =-1.8288E 02
12 CUBOID    3     +X = 4.4575E 01   -X =-8.9664E 00 +Y = 7.8105E 00   -Y =-4.4575E 01   +Z = 1.8288E 02   -Z =-1.8288E 02
13 CUBOID    3     +X = 4.7815E 01   -X =-8.9664E 00 +Y = 7.8105E 00   -Y =-4.7815E 01   +Z = 1.8288E 02   -Z =-1.8288E 02
```

KENO 123 GP 2X2 CELL BWR 8X8 NO 1 .7219 IN PITCH

WEIGHTING FUNCTION

BOX TYPE 1

	GRCUP	WTLOW	WT AVG	WT HI
REGION 1 DEFINED BY GEOMETRY CARD 1	1	0.167	0.500	1.500
	GRCUPS 2 TO 123 SAME AS ABOVE			
REGION 2 DEFINED BY GEOMETRY CARD 2	1	0.167	0.500	1.500
	GRCUPS 2 TO 123 SAME AS ABOVE			
REGION 3 DEFINED BY GEOMETRY CARD 3	1	0.167	0.500	1.500
	GRCUPS 2 TO 123 SAME AS ABOVE			
REGION 4 DEFINED BY GEOMETRY CARD 4	1	0.167	0.500	1.500
	GRCUPS 2 TO 123 SAME AS ABOVE			
REFLECTOR				
REGION 1 DEFINED BY GEOMETRY CARD 5	1	0.167	0.500	1.500
	GRCUPS 2 TO 123 SAME AS ABOVE			
REGION 2 DEFINED BY GEOMETRY CARD 6	1	0.167	0.500	1.500
	GROUPS 2 TO 123 SAME AS ABOVE			
REGION 3 DEFINED BY GEOMETRY CARD 7	1	0.167	0.500	1.500
	GRCUPS 2 TO 123 SAME AS ABOVE			
REGION 4 DEFINED BY GEOMETRY CARD 8	1	0.167	0.500	1.500
	GRCUPS 2 TO 123 SAME AS ABOVE			
REGION 5 DEFINED BY GEOMETRY CARD 9	1	0.167	0.500	1.500
	GRCUPS 2 TO 123 SAME AS ABOVE			
REGION 6 DEFINED BY GEOMETRY CARD 10	1	0.167	0.500	1.500
	GRCUPS 2 TO 123 SAME AS ABOVE			
REGION 7 DEFINED BY GEOMETRY CARD 11	1	0.167	0.500	1.500
	GRCUPS 2 TO 123 SAME AS ABOVE			
REGION 8 DEFINED BY GEOMETRY CARD 12	1	0.167	0.500	1.500
	GRCUPS 2 TO 123 SAME AS ABOVE			
REGION 9 DEFINED BY GEOMETRY CARD 13	1	0.198	0.594	1.782
	2	0.197	0.591	1.773
	3	0.197	0.591	1.773
	4	0.196	0.589	1.767
	5	0.196	0.589	1.768

7	0.196	0.589	1.766
8	0.195	0.584	1.752
9	0.191	0.572	1.716
10	0.189	0.567	1.700
11	0.188	0.565	1.695
12	0.188	0.564	1.693
13	0.189	0.566	1.698
14	0.189	0.567	1.702
15	0.190	0.569	1.706
16	0.189	0.566	1.699
17	0.188	0.565	1.695
18	0.189	0.567	1.700
19	0.189	0.566	1.698
20	0.190	0.569	1.706
21	0.190	0.570	1.709
22	0.189	0.568	1.705
23	0.189	0.567	1.702
24	0.189	0.566	1.697
25	0.189	0.566	1.698
26	0.188	0.565	1.695
27	0.189	0.566	1.698
28	0.188	0.564	1.692
29	0.187	0.560	1.680
30	0.186	0.559	1.676
31	0.186	0.558	1.675
32	0.186	0.558	1.674
33	0.186	0.558	1.674
34	0.186	0.559	1.678
35	0.187	0.561	1.684
36	0.188	0.563	1.690
37	0.188	0.563	1.690
38	0.188	0.564	1.691
39	0.188	0.564	1.693
40	0.189	0.566	1.698
41	0.189	0.567	1.702
42	0.190	0.569	1.707
43	0.190	0.571	1.712
44	0.191	0.573	1.718
45	0.191	0.574	1.723
46	0.192	0.576	1.728
47	0.193	0.578	1.733
48	0.193	0.579	1.737
49	0.194	0.581	1.742
50	0.194	0.583	1.750
51	0.196	0.588	1.763
52	0.197	0.591	1.774
53	0.198	0.594	1.783
54	0.200	0.599	1.797
55	0.201	0.602	1.807
56	0.202	0.605	1.816
57	0.203	0.610	1.830
58	0.205	0.615	1.845
59	0.206	0.619	1.856
60	0.207	0.621	1.864
61	0.209	0.626	1.879
62	0.210	0.631	1.893
63	0.212	0.635	1.905
64	0.213	0.638	1.913
65	0.213	0.640	1.921
66	0.214	0.642	1.925
67	0.214	0.642	1.927
68	0.213	0.639	1.918
69	0.214	0.642	1.926
70	0.217	0.652	1.957
71	0.220	0.660	1.980

73	0.219	0.656	1.968
74	0.219	0.658	1.973
75	0.217	0.650	1.950
76	0.216	0.648	1.945
77	0.217	0.651	1.952
78	0.219	0.657	1.971
79	0.220	0.659	1.977
80	0.221	0.664	1.993
81	0.222	0.665	1.994
82	0.216	0.649	1.947
83	0.224	0.671	2.013
84	0.217	0.652	1.956
85	0.218	0.654	1.961
86	0.222	0.666	1.998
87	0.230	0.689	2.067
88	0.207	0.622	1.867
89	0.226	0.678	2.033
90	0.221	0.663	1.990
91	0.237	0.710	2.131
92	0.241	0.723	2.170
93	0.246	0.737	2.211
94	0.248	0.745	2.235
95	0.249	0.748	2.245
96	0.249	0.748	2.244
97	0.248	0.744	2.231
98	0.249	0.746	2.237
99	0.254	0.762	2.287
100	0.258	0.774	2.322
101	0.259	0.778	2.334
102	0.260	0.780	2.341
103	0.260	0.781	2.344
104	0.260	0.780	2.341
105	0.259	0.776	2.327
106	0.258	0.773	2.319
107	0.258	0.774	2.322
108	0.260	0.779	2.338
109	0.262	0.785	2.354
110	0.263	0.788	2.364
111	0.264	0.792	2.375
112	0.265	0.795	2.386
113	0.266	0.799	2.397
114	0.268	0.803	2.409
115	0.269	0.806	2.418
116	0.269	0.808	2.425
117	0.270	0.811	2.433
118	0.272	0.815	2.444
119	0.273	0.819	2.456
120	0.275	0.824	2.471
121	0.276	0.827	2.482
122	0.277	0.831	2.492
123	0.278	0.835	2.505

REGION 10 DEFINED BY GEOMETRY CARD 14

1	0.279	0.838	2.514
2	0.275	0.826	2.477
3	0.276	0.827	2.482
4	0.274	0.823	2.469
5	0.275	0.825	2.475
6	0.277	0.832	2.497
7	0.275	0.826	2.479
8	0.270	0.811	2.432
9	0.257	0.771	2.314
10	0.252	0.756	2.269
11	0.252	0.756	2.267
12	0.253	0.758	2.273
13	0.256	0.767	2.300

14	0.258	0.775	2.326
15	0.262	0.785	2.354
16	0.261	0.782	2.347
17	0.261	0.782	2.345
18	0.264	0.791	2.374
19	0.265	0.795	2.384
20	0.270	0.810	2.429
21	0.273	0.819	2.458
22	0.274	0.822	2.465
23	0.275	0.825	2.475
24	0.275	0.826	2.478
25	0.279	0.837	2.511
26	0.281	0.842	2.525
27	0.285	0.856	2.565
28	0.285	0.856	2.567
29	0.282	0.845	2.534
30	0.283	0.848	2.543
31	0.285	0.856	2.568
32	0.288	0.864	2.592
33	0.292	0.875	2.624
34	0.296	0.889	2.668
35	0.305	0.914	2.741
36	0.313	0.939	2.817
37	0.313	0.940	2.820
38	0.315	0.946	2.838
39	0.319	0.956	2.868
40	0.323	0.970	2.909
41	0.328	0.983	2.949
42	0.332	0.997	2.991
43	0.337	1.012	3.036
44	0.342	1.027	3.081
45	0.347	1.041	3.124
46	0.352	1.056	3.168
47	0.356	1.069	3.208
48	0.361	1.083	3.249
49	0.365	1.096	3.289
50	0.373	1.118	3.355
51	0.384	1.151	3.453
52	0.394	1.181	3.543
53	0.403	1.208	3.623
54	0.413	1.238	3.714
55	0.421	1.264	3.793
56	0.430	1.289	3.866
57	0.439	1.318	3.954
58	0.449	1.348	4.043
59	0.458	1.373	4.119
60	0.465	1.395	4.185
61	0.475	1.424	4.273
62	0.484	1.453	4.358
63	0.493	1.478	4.435
64	0.500	1.499	4.498
65	0.507	1.520	4.561
66	0.513	1.538	4.613
67	0.517	1.552	4.657
68	0.518	1.555	4.665
69	0.526	1.579	4.738
70	0.543	1.630	4.890
71	0.557	1.671	5.012
72	0.556	1.668	5.003
73	0.561	1.683	5.049
74	0.568	1.705	5.114
75	0.563	1.690	5.071
76	0.567	1.702	5.105
77	0.577	1.731	5.192

80	0.614	1.843	5.528
81	0.621	1.864	5.593
82	0.608	1.825	5.474
83	0.647	1.940	5.821
84	0.628	1.885	5.655
85	0.640	1.921	5.763
86	0.668	2.005	6.015
87	0.713	2.138	6.414
88	0.624	1.872	5.617
89	0.720	2.161	6.482
90	0.710	2.129	6.388
91	0.799	2.398	7.193
92	0.832	2.496	7.489
93	0.866	2.599	7.796
94	0.891	2.672	8.015
95	0.899	2.697	8.091
96	0.900	2.701	8.102
97	0.894	2.682	8.046
98	0.901	2.703	8.110
99	0.936	2.808	8.425
100	0.961	2.884	8.652
101	0.971	2.913	8.740
102	0.977	2.932	8.797
103	0.981	2.943	8.829
104	0.982	2.945	8.834
105	0.975	2.925	8.774
106	0.973	2.920	8.761
107	0.979	2.936	8.807
108	0.992	2.975	8.924
109	1.004	3.013	9.040
110	1.013	3.038	9.115
111	1.021	3.064	9.191
112	1.030	3.089	9.268
113	1.038	3.115	9.345
114	1.047	3.142	9.426
115	1.054	3.161	9.484
116	1.059	3.177	9.532
117	1.065	3.196	9.587
118	1.073	3.218	9.653
119	1.081	3.243	9.728
120	1.090	3.271	9.814
121	1.098	3.293	9.878
122	1.103	3.310	9.931
123	1.111	3.334	10.001

REGION 11 DEFINED BY GEOMETRY CARD 15

1	0.373	1.118	3.354
2	0.366	1.098	3.295
3	0.369	1.106	3.318
4	0.368	1.103	3.310
5	0.371	1.113	3.338
6	0.378	1.134	3.402
7	0.377	1.130	3.389
8	0.369	1.107	3.321
9	0.348	1.043	3.130
10	0.343	1.029	3.087
11	0.347	1.041	3.123
12	0.352	1.056	3.169
13	0.362	1.087	3.261
14	0.37[illegible]	1.120	3.360
15	0.3[illegible]	1.157	3.470
16	0.38[illegible]	1.162	3.486
17	0.390	1.169	3.507

21	0.443	1.329	3.586
22	0.452	1.355	4.066
23	0.463	1.388	4.165
24	0.472	1.416	4.247
25	0.493	1.479	4.437
26	0.505	1.515	4.546
27	0.532	1.597	4.792
28	0.538	1.615	4.845
29	0.530	1.589	4.767
30	0.541	1.622	4.867
31	0.557	1.672	5.015
32	0.575	1.724	5.172
33	0.595	1.784	5.353
34	0.620	1.861	5.583
35	0.664	1.992	5.977
36	0.706	2.119	6.356
37	0.706	2.117	6.352
38	0.716	2.147	6.441
39	0.733	2.199	6.596
40	0.754	2.263	6.790
41	0.777	2.330	6.989
42	0.799	2.398	7.194
43	0.823	2.470	7.410
44	0.847	2.542	7.625
45	0.871	2.612	7.837
46	0.894	2.682	8.047
47	0.916	2.749	8.247
48	0.939	2.817	8.451
49	0.961	2.882	8.647
50	0.997	2.990	8.970
51	1.049	3.146	9.439
52	1.098	3.293	9.880
53	1.142	3.426	10.278
54	1.189	3.566	10.699
55	1.231	3.692	11.075
56	1.271	3.812	11.435
57	1.315	3.944	11.833
58	1.359	4.078	12.233
59	1.399	4.198	12.594
60	1.436	4.308	12.925
61	1.481	4.443	13.329
62	1.525	4.574	13.723
63	1.566	4.699	14.098
64	1.604	4.811	14.432
65	1.641	4.923	14.768
66	1.675	5.025	15.075
67	1.706	5.118	15.355
68	1.725	5.175	15.525
69	1.768	5.303	15.910
70	1.841	5.522	16.567
71	1.904	5.711	17.133
72	1.917	5.752	17.256
73	1.953	5.858	17.575
74	1.996	5.987	17.960
75	1.997	5.991	17.972
76	2.028	6.085	18.256
77	2.082	6.245	18.734
78	2.153	6.458	19.373
79	2.205	6.616	19.848
80	2.275	6.824	20.472
81	2.321	6.962	20.886
82	2.291	6.872	20.616
83	2.455	7.365	22.095
84	2.404	7.213	21.640
85	2.470	7.409	22.227
86	2.496	7.789	23.368

87	2.787	8.361	25.084
88	2.458	7.375	22.126
89	2.856	8.567	25.700
90	2.831	8.492	25.475
91	3.205	9.614	28.841
92	3.352	10.055	30.165
93	3.503	10.509	31.527
94	3.615	10.846	32.538
95	3.652	10.957	32.871
96	3.660	10.981	32.943
97	3.638	10.915	32.745
98	3.670	11.011	33.033
99	3.817	11.452	34.356
100	3.924	11.771	35.313
101	3.967	11.901	35.703
102	3.997	11.990	35.970
103	4.016	12.048	36.144
104	4.023	12.070	36.210
105	4.003	12.010	36.030
106	4.003	12.008	36.024
107	4.028	12.084	36.252
108	4.086	12.258	36.774
109	4.143	12.430	37.290
110	4.180	12.539	37.617
111	4.217	12.652	37.956
112	4.255	12.765	38.295
113	4.293	12.879	38.637
114	4.333	13.000	39.000
115	4.364	13.092	39.276
116	4.389	13.166	39.498
117	4.416	13.249	39.747
118	4.450	13.350	40.050
119	4.488	13.463	40.389
120	4.532	13.597	40.791
121	4.566	13.699	41.097
122	4.600	13.799	41.397
123	4.635	13.904	41.712

REGION 12 DEFINED BY GEOMETRY CARD 16

1	0.491	1.473	4.418
2	0.482	1.447	4.340
3	0.490	1.469	4.408
4	0.491	1.474	4.423
5	0.500	1.499	4.496
6	0.516	1.548	4.644
7	0.518	1.555	4.664
8	0.510	1.531	4.592
9	0.480	1.441	4.324
10	0.481	1.443	4.328
11	0.495	1.486	4.459
12	0.512	1.536	4.607
13	0.539	1.617	4.851
14	0.571	1.713	5.140
15	0.606	1.817	5.451
16	0.615	1.845	5.535
17	0.624	1.872	5.615
18	0.657	1.972	5.917
19	0.680	2.039	6.117
20	0.743	2.229	6.686
21	0.797	2.390	7.171
22	0.83[illegible]	2.499	7.498
23	0.8[illegible]	2.638	7.913
24	0.9[illegible]	2.763	8.288
25	1.005	3.016	9.048
[illegible]	1.054	[illegible]	[illegible]

28	1.201	3.604	10.811
29	1.177	3.531	10.593
30	1.230	3.689	11.068
31	1.302	3.907	11.722
32	1.382	4.146	12.437
33	1.473	4.418	13.253
34	1.588	4.763	14.290
35	1.789	5.368	16.104
36	1.975	5.924	17.771
37	1.967	5.902	17.706
38	2.012	6.035	18.106
39	2.091	6.274	18.823
40	2.189	6.568	19.705
41	2.292	6.876	20.629
42	2.398	7.194	21.582
43	2.509	7.528	22.583
44	2.621	7.863	23.590
45	2.732	8.196	24.587
46	2.842	8.527	25.580
47	2.949	8.847	26.540
48	3.057	9.171	27.512
49	3.161	9.483	28.449
50	3.331	9.994	29.983
51	3.580	10.739	32.217
52	3.814	11.442	34.329
53	4.028	12.085	36.255
54	4.249	12.746	38.238
55	4.449	13.348	40.044
56	4.642	13.927	41.781
57	4.850	14.550	43.650
58	5.059	15.176	45.528
59	5.252	15.757	47.271
60	5.433	16.300	48.900
61	5.646	16.937	50.811
62	5.856	17.568	52.704
63	6.059	18.177	54.531
64	6.245	18.736	56.208
65	6.435	19.304	57.912
66	6.612	19.837	59.511
67	6.779	20.337	61.011
68	6.898	20.695	62.085
69	7.114	21.343	64.029
70	7.456	22.367	67.101
71	7.757	23.272	69.816
72	7.863	23.588	70.764
73	8.055	24.164	72.492
74	8.281	24.844	74.532
75	8.338	25.014	75.042
76	8.519	25.556	76.668
77	8.792	26.377	79.131
78	9.142	27.426	82.278
79	9.421	28.262	84.786
80	9.769	29.307	87.921
81	10.021	30.064	90.192
82	9.945	29.834	89.502
83	10.717	32.150	96.450
84	10.550	31.650	94.950
85	10.892	32.677	98.031
86	11.512	34.537	103.611
87	12.424	37.271	111.813
88	11.014	33.043	99.129
89	12.853	38.560	115.680
90	12.810	38.429	115.287
91	14.572	43.716	131.148

94	16.691	50.074	150.222
95	16.882	50.647	151.941
96	16.938	50.815	152.445
97	16.856	50.568	151.704
98	17.033	51.098	153.294
99	17.739	53.216	159.648
100	18.266	54.798	164.394
101	18.497	55.491	166.473
102	18.669	56.008	168.024
103	18.804	56.413	169.239
104	18.888	56.665	169.995
105	18.861	56.582	169.746
106	18.928	56.784	170.352
107	19.096	57.287	171.861
108	19.423	58.270	174.810
109	19.746	59.239	177.717
110	19.953	59.858	179.574
111	20.166	60.498	181.494
112	20.383	61.150	183.450
113	20.608	61.825	185.475
114	20.852	62.556	187.668
115	21.059	63.176	189.528
116	21.218	63.654	190.962
117	21.400	64.201	192.603
118	21.622	64.867	194.601
119	21.868	65.604	196.812
120	22.125	66.374	199.122
121	22.371	67.114	201.342
122	22.554	67.662	202.986
123	22.779	68.336	205.008

REGION. 13 DEFINED BY GEOMETRY CARD 17

1	0.643	1.929	5.788
2	0.633	1.900	5.700
3	0.650	1.950	5.851
4	0.657	1.970	5.910
5	0.674	2.023	6.068
6	0.707	2.122	6.365
7	0.718	2.153	6.460
8	0.713	2.139	6.416
9	0.674	2.022	6.066
10	0.689	2.066	6.197
11	0.725	2.174	6.523
12	0.765	2.296	6.889
13	0.828	2.484	7.453
14	0.908	2.723	8.170
15	0.993	2.978	8.933
16	1.019	3.058	9.173
17	1.044	3.132	9.396
18	1.131	3.392	10.175
19	1.192	3.575	10.726
20	1.372	4.117	12.352
21	1.537	4.612	13.836
22	1.656	4.969	14.906
23	1.814	5.442	16.325
24	1.966	5.897	17.691
25	2.266	6.797	20.391
26	2.447	7.342	22.027
27	2.871	8.614	25.842
28	3.015	9.046	27.139
29	2.941	8.822	26.467
30	3.16[illegible]	9.481	28.443
31	3.4[illegible]	10.379	31.137
32	3.8[illegible]	11.399	34.197
33	4.195	12.585	37.755
34	4.708	14.125	42.375

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35	5.631	16.893	50.679
36	6.455	19.366	58.098
37	6.406	19.217	57.651
38	6.609	19.828	59.484
39	6.986	20.957	62.871
40	7.447	22.340	67.020
41	7.938	23.814	71.442
42	8.449	25.347	76.041
43	8.987	26.961	80.883
44	9.532	28.597	85.791
45	10.077	30.232	90.696
46	10.622	31.867	95.601
47	11.154	33.461	100.383
48	11.691	35.073	105.219
49	12.211	36.634	109.902
50	13.059	39.177	117.531
51	14.303	42.909	128.727
52	15.484	46.452	139.356
53	16.569	49.708	149.124
54	17.674	53.023	159.069
55	18.694	56.082	168.246
56	19.678	59.034	177.102
57	20.724	62.172	186.516
58	21.778	65.335	196.005
59	22.770	68.310	204.930
60	23.713	71.140	213.420
61	24.797	74.392	223.176
62	25.879	77.638	232.914
63	26.937	80.811	242.433
64	27.940	83.821	251.463
65	28.955	86.865	260.595
66	29.926	89.777	269.331
67	30.856	92.568	277.704
68	31.570	94.711	284.133
69	32.743	98.229	294.687
70	34.513	103.540	310.620
71	36.117	108.350	325.050
72	36.803	110.410	331.230
73	37.923	113.770	341.310
74	39.210	117.630	352.890
75	39.690	119.070	357.210
76	40.783	122.350	367.050
77	42.330	126.990	380.970
78	44.270	132.810	398.430
79	45.873	137.620	412.860
80	47.850	143.550	430.650
81	49.370	148.110	444.330
82	49.277	147.830	443.490
83	53.410	160.230	480.690
84	52.890	158.670	476.010
85	54.920	164.760	494.280
86	58.403	175.210	525.630
87	63.403	190.210	570.630
88	56.537	169.610	508.830
89	66.380	199.140	597.420
90	66.547	199.640	598.920
91	76.157	228.470	685.410
92	80.530	241.590	724.770
93	85.097	255.290	765.870
94	88.807	266.420	799.260
95	89.937	269.810	809.429
96	90.360	271.080	813.240
97	90.047	270.140	810.420
98	91.203	273.610	820.830
99	95.130	285.390	856.170
100	98.143	294.430	883.290

101	99.570	298.710	896.130
102	100.713	302.140	906.420
103	101.703	305.110	915.330
104	102.453	307.360	922.080
105	102.693	308.080	924.240
106	103.387	310.160	930.480
107	104.567	313.700	941.100
108	106.647	319.940	959.820
109	108.687	326.060	978.179
110	109.997	329.990	989.970
111	111.337	334.010	1002.029
112	112.713	338.140	1014.420
113	114.150	342.450	1027.350
114	115.710	347.130	1041.390
115	117.123	351.370	1054.110
116	118.160	354.480	1063.440
117	119.350	358.050	1074.149
118	120.737	362.210	1086.630
119	122.600	367.800	1103.399
120	124.553	373.660	1120.980
121	126.263	378.790	1136.369
122	127.507	382.520	1147.559
123	128.733,	386.200	1158.600

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KENO 123 GP 2X2 CELL BWR 8X8 NO 1 .7215 IN PITCH

VOLUMES

BOX TYPE      1
          REGION DEFINED BY GEOMETRY CARD      1   VOLUME =    3.20730E 02 CM**3        CUMULATIVE VOLUME =    3.20730E 02 CM**3
          REGION DEFINED BY GEOMETRY CARD      2   VOLUME =    1.40278E 01 CM**3        CUMULATIVE VOLUME =    3.34758E 02 CM**3
          REGION DEFINED BY GEOMETRY CARD      3   VOLUME =    1.15692E 02 CM**3        CUMULATIVE VOLUME =    4.50450E 02 CM**3
          REGION DEFINED BY GEOMETRY CARD      4   VOLUME =    7.79213E 02 CM**3        CUMULATIVE VOLUME =    1.22966E 03 CM**3

REFLECTOR VOLUMES -  GEOMETRY CARD      5 IS THE CORE BOUNDARY CARD
          REGION DEFINED BY GEOMETRY CARD      6   VOLUME =    0.0         CM**3        CUMULATIVE VOLUME =    7.86986E 04 CM**3
          REGION DEFINED BY GEOMETRY CARD      7   VOLUME =    1.05524E 04 CM**3        CUMULATIVE VOLUME =    8.92511E 04 CM**3
          REGION DEFINED BY GEOMETRY CARD      8   VOLUME =    1.16100E 03 CM**3        CUMULATIVE VOLUME =    9.04121E 04 CM**3
          REGION DEFINED BY GEOMETRY CARD      9   VOLUME =    3.79016E 04 CM**3        CUMULATIVE VOLUME =    1.28314E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD     10   VOLUME =    2.74405E 04 CM**3        CUMULATIVE VOLUME =    1.55755E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD     11   VOLUME =    3.15096E 05 CM**3        CUMULATIVE VOLUME =    4.70851E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD     12   VOLUME =    1.42788E 05 CM**3        CUMULATIVE VOLUME =    6.13638E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD     13   VOLUME =    9.31896E 04 CM**3        CUMULATIVE VOLUME =    7.06828E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD     14   VOLUME =    9.97732E 04 CM**3        CUMULATIVE VOLUME =    8.06601E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD     15   VOLUME =    1.06357E 05 CM**3        CUMULATIVE VOLUME =    9.12958E 05 CM**3
          REGION DEFINED BY GEOMETRY CARD     16   VOLUME =    1.12941E 05 CM**3        CUMULATIVE VOLUME =    1.02590E 06 CM**3
          REGION DEFINED BY GEOMETRY CARD     17   VOLUME =    1.29365E 05 CM**3        CUMULATIVE VOLUME =    1.15527E 06 CM**3

TOTAL VOLUMES
    1       2.05267E 04
    2       8.57781E 02
    3       7.40430E 03
    4       4.98696E 04

VOLUME FRACTION OF THE CORE CONTAINING FISSILE MATERIAL= 0.26083E 00

START TYPE =    0

THE NEUTRONS WERE STARTED IN THE ARRAY WITH A FLAT DISTRIBUTION.

  200 NEUTRONS WERE INITIALLY STARTED
0.00267 MINUTES WERE REQUIRED FOR STARTING.
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KENO 123 GP 2X2 CELL BWR 8X8 NO 1 .7219 IN PITCH

GENERATION	K-EFFECTIVE	ELAPSED TIME(MIN)	AVG. K-EFF	DEVIATION	MATRIX K-EFF
			WARNING - ONLY 198 INDEPENDENT FISSION POINTS WERE GENERATED.		
1	8.57876E-01	1.14167E-01	1.00000E 00	0.0	0.0
2	9.30913E-01	2.10000E-01	1.00000E 00	0.0	0.0
3	8.87977E-01	3.15500E-01	8.87977E-01	0.0	0.0
4	9.67827E-01	4.22667E-01	9.27902E-01	3.59250E-02	0.0
			WARNING - ONLY 199 INDEPENDENT FISSION POINTS WERE GENERATED.		
5	8.10954E-01	5.36667E-01	8.88919E-01	4.52873E-02	0.0
6	9.30009E-01	6.41333E-01	8.99192E-01	3.36315E-02	0.0
7	8.61151E-01	7.52500E-01	8.91563E-01	2.71394E-02	0.0
8	9.39411E-01	8.65000E-01	8.99555E-01	2.35496E-02	0.0
9	8.62421E-01	9.71000E-01	8.94250E-01	2.05980E-02	0.0
10	8.67605E-01	1.07600E 00	8.90919E-01	1.81468E-02	0.0
11	8.73147E-01	1.18083E 00	8.88944E-01	1.61262E-02	0.0
12	9.08348E-01	1.28267E 00	8.90885E-01	1.45536E-02	0.0
13	8.43344E-01	1.39333E 00	8.86563E-01	1.38557E-02	0.0
14	9.29922E-01	1.50083E 00	8.90176E-01	1.31546E-02	0.0
15	9.13383E-01	1.60917E 00	8.91961E-01	1.22312E-02	0.0
16	9.47732E-01	1.71850E 00	8.95945E-01	1.20046E-02	0.0
17	9.32895E-01	1.82883E 00	8.98408E-01	1.14441E-02	0.0
18	7.99178E-01	1.93350E 00	8.92206E-01	1.23718E-02	0.0
19	8.69615E-01	2.03583E 00	8.90877E-01	1.16973E-02	0.0
			WARNING - ONLY 197 INDEPENDENT FISSION POINTS WERE GENERATED.		
20	8.15662E-01	2.15050E 00	8.86699E-01	1.17933E-02	0.0
21	9.21700E-01	2.24583E 00	8.88540E-01	1.13088E-02	0.0
22	9.09664E-01	2.35550E 00	8.89566E-01	1.07826E-02	0.0
23	9.20293E-01	2.45250E 00	8.91057E-01	1.03594E-02	0.0
24	8.14492E-01	2.56850E 00	8.87577E-01	1.04734E-02	0.0
25	8.62245E-01	2.68467E 00	8.86475E-01	1.00671E-02	0.0
26	8.77926E-01	2.78267E 00	8.86119E-01	9.64694E-03	0.0
27	8.87577E-01	2.89750E 00	8.86177E-01	9.25282E-03	0.0
			WARNING - ONLY 190 INDEPENDENT FISSION POINTS WERE GENERATED.		
28	7.94027E-01	3.00417E 00	8.82632E-01	9.57081E-03	0.0
29	9.11781E-01	3.12217E 00	8.83712E-01	9.27228E-03	0.0
30	9.03954E-01	3.23050E 00	8.84434E-01	8.96464E-03	0.0
31	8.14042E-01	3.34933E 00	8.82007E-01	8.98405E-03	0.0
32	9.17216E-01	3.45667E 00	8.85514E-01	9.36126E-03	0.0
33	8.96086E-01	3.56767E 00	8.85854E-01	9.06175E-03	0.0
34	9.11121E-01	3.67850E 00	8.87894E-01	9.00805E-03	0.0
35	9.76778E-01	3.78083E 00	8.90405E-01	9.08563E-03	0.0
36	9.22354E-01	3.88550E 00	8.91344E-01	8.86416E-03	0.0
37	9.35469E-01	3.98917E 00	8.92605E-01	8.69965E-03	0.0
38	9.01129E-01	4.09050E 00	8.92841E-01	8.45798E-03	0.0

THE MATRIX K-EFF IS THE LARGEST EIGENVALUE OF THE MATRIX OF FISSION PROBABILITIES BY UNIT.
THERE ARE NBXMAX * NBYMAX * NBZMAX UNITS IN AN ARRAY.

KENO 123 GP 2X2 CELL BWR 8X8 NO 1 .7219 IN PITCH

LIFETIME = 4.99267E-05 + OR - 1.10012E-05 GENERATION TIME = 2.81072E-05 + OR - 3.18628E-07

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.89298	+ OR - 0.00870	0.88428 TO 0.90168	0.87559 TO 0.91037	0.86689 TO 0.91907	7000
4	0.89078	+ OR - 0.00866	0.88211 TO 0.89944	0.87345 TO 0.90811	0.86479 TO 0.91677	6800
5	0.89320	+ OR - 0.00858	0.88462 TO 0.90177	0.87605 TO 0.91035	0.86747 TO 0.91893	6600
6	0.89205	+ OR - 0.00877	0.88328 TO 0.90082	0.87451 TO 0.90959	0.86574 TO 0.91835	6400
7	0.89305	+ OR - 0.00900	0.88405 TO 0.90204	0.87505 TO 0.91104	0.86605 TO 0.92004	6200
8	0.89150	+ OR - 0.00916	0.88234 TO 0.90066	0.87317 TO 0.90983	0.86401 TO 0.91899	6000
9	0.89250	+ OR - 0.00943	0.88307 TO 0.90193	0.87365 TO 0.91136	0.86422 TO 0.92079	5800
10	0.89339	+ OR - 0.00973	0.88366 TO 0.90312	0.87394 TO 0.91285	0.86421 TO 0.92258	5600
11	0.89414	+ OR - 0.01007	0.88408 TO 0.90421	0.87401 TO 0.91427	0.86395 TO 0.92434	5400
12	0.89360	+ OR - 0.01044	0.88315 TO 0.90404	0.87271 TO 0.91449	0.86226 TO 0.92493	5200
17	0.88887	+ OR - 0.01212	0.87675 TO 0.90099	0.86462 TO 0.91312	0.85250 TO 0.92524	4200
22	0.89691	+ OR - 0.01376	0.88315 TO 0.91066	0.86939 TO 0.92442	0.85564 TO 0.93817	3200
27	0.90800	+ OR - 0.01786	0.89014 TO 0.92585	0.87228 TO 0.94371	0.85443 TO 0.96156	2200
32	0.92949	+ OR - 0.01180	0.91769 TO 0.94129	0.90588 TO 0.95310	0.89408 TO 0.96490	1200

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123     0.0          0.0

KENO 123 GP 2X2 CELL AWR 8X8 NO 1 .7215 IN PITCH

                                   FREQUENCY FOR GENERATIONS    4 TO   38
0.7940 TO 0.8223     ******
0.8223 TO 0.8506     *
0.8506 TO 0.8788     *******
0.8788 TO 0.9071     ****
0.9071 TO 0.9354     **********
0.9354 TO 0.9637     ****
0.9637 TO 0.9920     ***

                                   FREQUENCY FOR GENERATIONS   13 TO   38
0.7940 TO 0.8223     *****
0.8223 TO 0.8506     *
0.8506 TO 0.8788     ***
0.8788 TO 0.9071     ****
0.9071 TO 0.9354     ********
0.9354 TO 0.9637     ***
0.9637 TO 0.9920     **

                                   FREQUENCY FOR GENERATIONS   21 TO   38
0.7940 TO 0.8223     ***
0.8223 TO 0.8506
0.8506 TO 0.8788     **
0.8788 TO 0.9071     ****
0.9071 TO 0.9354     *****
0.9354 TO 0.9637     **
0.9637 TO 0.9920     **

                                   FREQUENCY FOR GENERATIONS   30 TO   38
0.7940 TO 0.8223     *
0.8223 TO 0.8506
0.8506 TO 0.8788
0.8788 TO 0.9071     ***
0.9071 TO 0.9354     *
0.9354 TO 0.9637     **
0.9637 TO 0.9920     **

********** END OF FILE ON UNIT ... 5 **********
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