5. SHIELDING EVALUATION

5.1 DISCUSSION AND RESULTS

The Model 2000 Transport Package is designed for transporting irradiated fuel, hardware, and waste. In view of the above, there is no single specific source term. Considering the varied use of the cask (e.g., hot cell waste, irradiated SNM, irradiated reactor hardware), it is extremely difficult to generate one appropriate source term. The purpose of the shielding is to maintain the loaded container within DOT transportation limits, and calculations have been made to demonstrate that the normal and accident condition dose rates with various, worst case radionuclide loads will not exceed the regulatory limits.

Several theoretical analyses of the Model 2000 Transport Package shielding capabilities were performed for various isotopic contents. One shielding model was set up for an irradiated uranium fuel load. The uranium mass and burnup used for the analyzed case were 1,750 grams of U-235 at 5% enrichment and 45 GWD/MTU. Following the irradiated fuel analysis, similar analyses were performed for unit activities of Cobalt-60, Cesium-137, Zirconium/Niobium-95, and Hafnium-181. The uranium burnup and mass limits were conservatively extrapolated from the calculated dose rates of the analyzed fuel case. The activation product isotope curie limits were calculated as the ratio of the respective regulatory limit to the calculated dose rate from the unit curie. The gamma dose rate calculations for fuel were made with two Radiation Shielding Information Center (RSIC) provided computer codes, RIBD and ISOSHLD. RIBD generates the fission product inventory from irradiated fuel, and ISOSHLD is a point kernel, general purpose shielding analysis code. The neutron dose rates from high burnup fuel were hand calculated and added to the gamma dose rates. ISOSHLD alone was used for the single isotope gamma dose rate calculations.

The gamma source used in the irradiated fuel analysis consisted of the fission product inventory from 1,750 grams of U-235, in 5% enriched uranium, irradiated for 1,879 days at 0.8381 MW and cooled for 120 days. The total beta and gamma decay heat from this source was 647 watts, slightly above the 600-watt package limit.

The neutron output for the high burnup fuel was taken from Figure 5.1.1. The "mean" (between low and high enrichment) curve was used for determining a neutron output. No credit was taken for neutron attenuation by the shipping container.

The 2000 Series Cask uses poured lead and stainless steel as the primary shielding media. The stainless steel structural shells of the overpack and distances to the outer surfaces of the overpack serve to further attenuate the radiation from the contents. An optional, lead-filled liner may be inserted in the cask cavity to provide additional shielding; the liner was included in this analysis.

The nominal thicknesses of shielding materials and distances, as determined from the fabrication drawings, were used in the shielding analysis. A cylindrical and a spherical source geometry were used in the normal and accident cases, respectively, taking credit for self-shielding by the source material.

For the irradiated fuel analysis, a simplifying assumption was made that the gamma dose rates do not change as the uranium mass and/or burnup are decreased to lower the calculated neutron dose rate. Burnup limits were established for the two 5% enriched fissile limits by establishing the maximum neutron emission rate which would comply with the dose rate limits. The limiting neutron output for the analyzed case is 4.67E7 neutrons per second. At a fissile limit of 1,750 grams U-235, the relative neutron emission is 1,330 neutrons per second per gram of uranium; and at 1,175 grams of U-235 it is 1,980 neutrons per second per gram of uranium. The corresponding burnup limits of 38 GWD/MTU and 42 GWD/MTU are found from Figure 5.1.1. Using the same logic, a U-235 mass limit of 935 grams (18,680 grams of uranium) is established for 45 GWD/MTU burnup fuel.

The summary of the maximum calculated dose rates from an irradiated fuel load is given in Table 5.1.1.

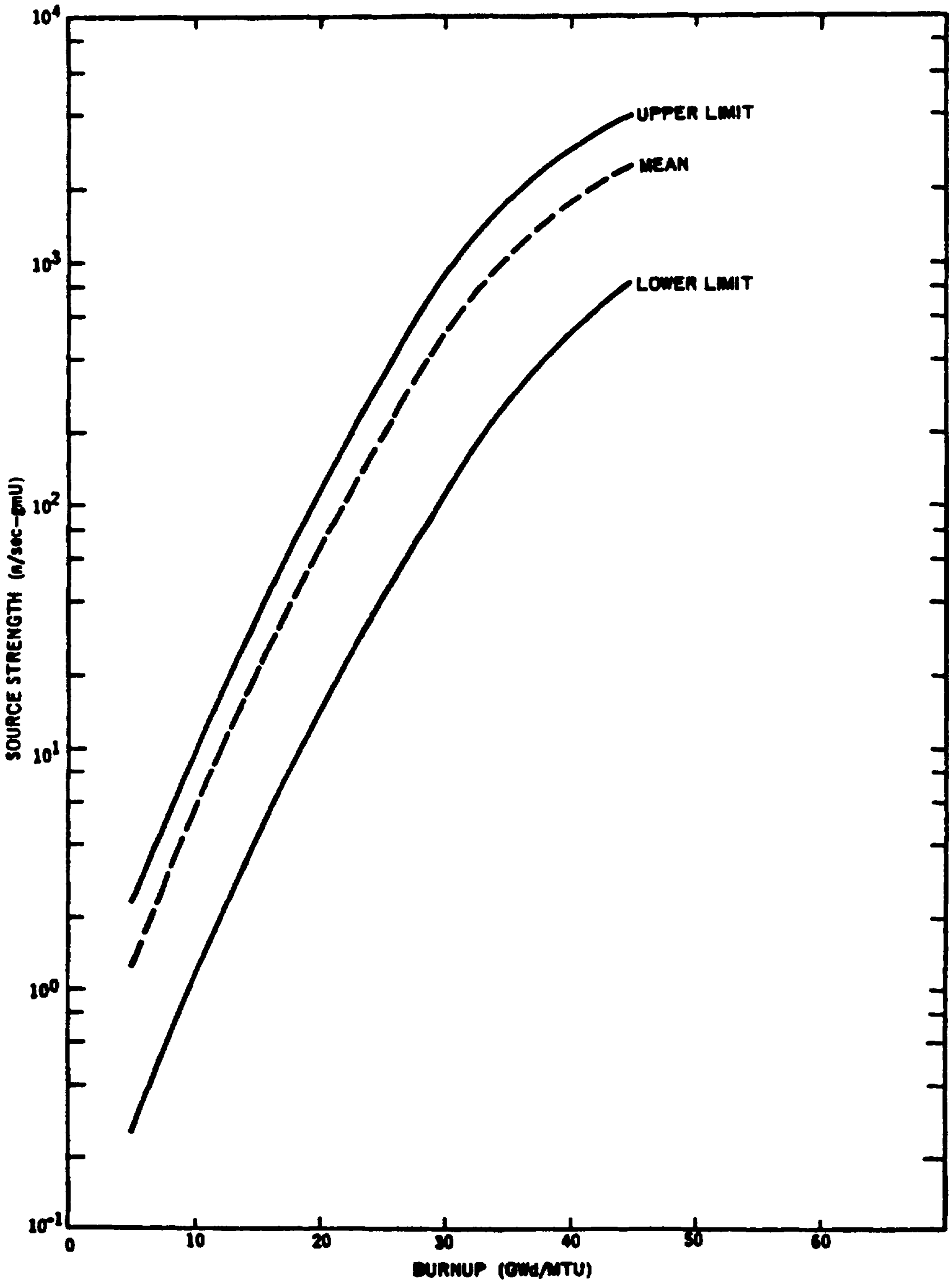

FIGURE 5.1.1. TOTAL SPONTANEOUS FISSION AND (A, N) NEUTRON EMISSION RATE VS. FUEL BURNUP; 120 DAYS COOLING

TABLE 5.1.1. SUMMARY OF MAXIMUM DOSE RATES (MR/HR), FROM A FUEL SOURCE

	Package Surface			1 Meter from Surface of Package			2 Meters from Side of Vehicle (Exclusive Use)	Cab of Vehicle
	Side	Top	Bottom	Side	Top	Bottom		
Normal Conditions								
Gamma	13.5	0.01	10.6	3.3	0.004	1.5	1.3	0.18
Neutron	186.0	15.6	47.8	21.8	6.0	10.8	7.7	0.98
Total	199.5	15.6	58.4	25.1	6.0	12.3	9.0	1.16
49 CFR Part 173.441 Limit	200	200	200	--	--	--	10	2
Hypothetical Accident Conditions								
Gamma	43.2	0.2	123.4	3.7	0.05	17.9	---	--
Neutron	265.6	28.7	121.2	22.7	8.9	17.5	---	--
Total	308.8	28.9	244.6	26.3	8.9	35.4	---	--
10 CFR Part 71 Limit	--	--	--	1000	1000	1000	---	--

5.2 SOURCE SPECIFICATIONS

The fuel source consists of the radiation emitted by the decay of some 450 fission product isotopes calculated by computer code RIBD. The gamma photons are segregated into 25 energy groups for dose rate calculations. It is recognized that high burnup fuel has a finite neutron emission rate from both spontaneous fissioning nuclides and alpha-neutron reactions with light elements (oxygen). The neutron dose rates from 45 and 35 GWD/MTU were hand calculated from the neutron output per gram of irradiated uranium as given in NEDO-10084-3[4].

The RIBD Code accounts for isotope decay and progeny buildup which results from the fission process during power production and the cooling following shutdown. The source is uniformly distributed throughout a 45-inch-long uranium and zirconium cylinder with a 3.73-inch diameter. The normal condition source is located at the wall of the liner cavity, and the hypothetical accident condition source is a 4.28-inch-diameter sphere located at the inner wall of the liner cavity. The evaluation in Chapter 2 demonstrates the lack of damage to or degradation of the cask shielding.

[4] IF-300 Shipping Cask Consolidated Safety Analysis Report; September, 1984; NEDO-10084-3.

5.2.1 Gamma Sources

The sum of the fission products used as the cylindrical and spherical source, after 120 days of decay, is 1.648 E5 curies. Of this total fission product activity, the gamma source activity is 2.183 E15 photons per second. The tabular list of the gamma photon source and the average energy of each group is shown below.

TABLE 5.2.1.1. 90-DAY DECAY, FISSION PRODUCT GAMMA SOURCE

Group	Total Group Production Rate (photons/sec)	Group Average Energy (MeV)
1	4.077E-10	1.500E-02
2	1.483E 12	2.500E-02
3	4.777E 11	3.500E-02
4	6.210E 12	4.500E-02
5	1.617E 10	5.500E-02
6	9.120E 08	6.500E-02
7	8.036E 05	7.500E-02
8	2.003E 13	8.500E-02
9	9.592E 10	9.500E-02
10	1.606E 14	1.500E-01
11	9.590E 12	2.500E-01
12	8.194E 11	3.500E-01
13	2.651E 14	4.750E-01
14	6.571E 14	6.500E-01
15	1.030E 15	8.250E-01
16	1.029E 13	1.000E 00
17	5.039E 12	1.225E 00
18	8.363E 12	1.475E 00
19	6.630E 10	1.700E 00
20	2.127E 10	1.900E 00
21	6.485E 12	2.100E 00
22	5.430E 11	2.300E 00
23	7.741E 10	2.500E 00
24	2.055E 00	2.700E 00
25	2.838E 09	3.000E 00
TOTAL	2.183E 15	

The RIBD Code uses an isotope library which contains the major decay modes, fission yields, and abundances in the calculation of a particular fission product source. The total photon data base resulting from the RIBD calculations is sorted into the 25 energy groups by a computer routine. Details of these processes can be found in the code descriptions (References 1 and 2).

5.2.2 Neutron Source

Neutron emissions from irradiated fuel are dependent on the fuel composition and burnup. The neutron dose rates were hand calculated by integrating a line source for the normal case and using a point source for the accident case. The neutron source strength at 45 GWD/MTU is 2,500 neutrons per second per gram of uranium. At a total uranium content of 35,000 grams, the neutron output from the fuel is 8.75E07 neutrons per second. The neutron emission rate at 38 GWD/MTU is 1,330 neutrons per second per gram of uranium for a total neutron source strength of 4.67E7 neutrons per second.

The neutron energy spectrum was assumed to be the same as the fission spectrum from Californium-252, and no credit was taken for neutron attenuation by the shipping container. The unshielded dose rates were taken from the Cf-252 Shielding Guide[5]. The basis for using a fission spectrum is twofold; the neutron dose rates in air are well documented, and the spontaneous fission source is shown in ORNL/TM-9591/V1&R1[6] to be the major fraction of the neutron output from high burnup fuel.

5.3 MODEL SPECIFICATION

5.3.1 Description of the Radial and Axial Shielding Configuration

A cutaway sketch of the package showing the normal condition source and dose rate points is presented in Figure 5.1.

[5] D. H. Stoddard and H. E. Hootman, Cf-252 Shielding Guide; March, 1971; DP-1246.

[6] Roddy, J. W. et. al., Physical and Decay Characteristics of Commercial LWR Spent Fuel; January, 1986; ORNL/TM-9591/V1&R1.

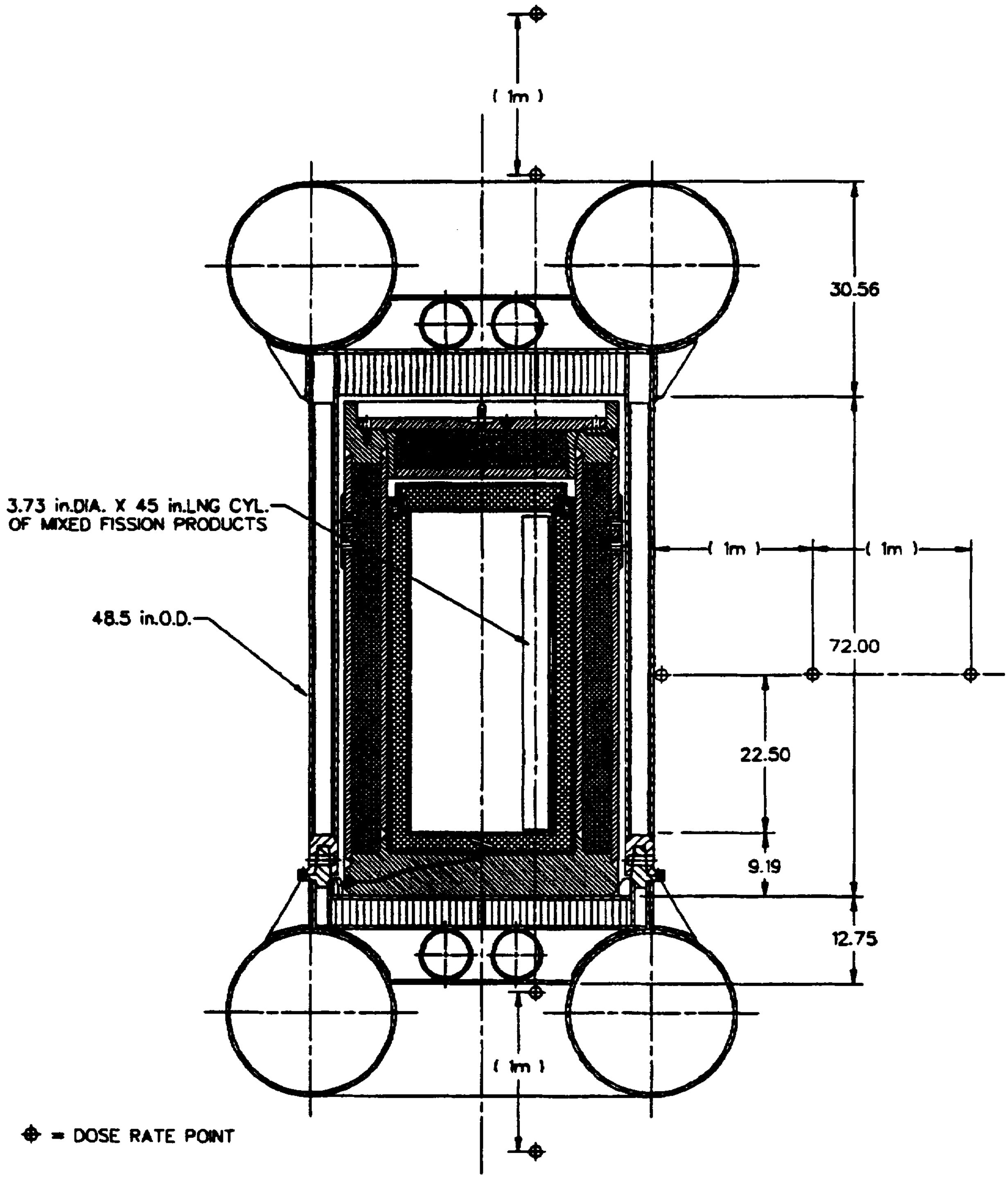

FIGURE 5.1. NORMAL CONDITION SHIELD ANALYSIS GEOMETRY

The simplified geometry used for the computer analysis (i.e., a cylindrical and spherical source shielded by an iron slab and a lead slab) is shown in Figures 5.2 and 5.3. Iron is used in place of the stainless steel shells because it is one of the standard materials available in the ISOSHLD library, and there is no significant difference in attenuation properties.

No reductions in the nominal shield thickness were made for localized penetrations or variations, such as drain lines or bolt holes. The justification for this decision is that an actual radioactive load in the container would be distributed over more volume than a single cylinder or sphere and, therefore, only a small fraction of the source radiation would penetrate directly through shield depletions. Practically, any maximum dose rate from streaming or localized source concentration will be detected during the mandatory radiation surveys on loaded containers before shipment. The dose rates must comply with the appropriate transport limits.

The difference between the normal condition evaluation and the accident condition evaluation was the shape and location of the source. In the normal case evaluation, the distance from the centerline of the 3.73-in.-diameter cylindrical source to the side dose points was equivalent to placing the source at the side of the liner cavity. In the accident condition, the distance was equivalent to locating the 4.28-in.-diameter spherical source at the top and bottom of the inner wall of the liner cavity. No shield thickness changes were made for any of the evaluations.

5.3.2 Shield Regional Densities

The material densities used for the shielding analyses were:

Zirconium in the fuel volume	0.034 g/cc
Uranium in the fuel volume	4.344 g/cc
Iron in the irradiated hardware volume	6.91 g/cc
Air inside the liner cavity	1.293×10^{-3} g/cc
Lead in the liner and cask	11.34 g/cc
Iron in the liner, cask and overpack	7.8 g/cc

NOTE: Top and bottom variables brackets [ ].

	Dimension, inches		
Variable	Side	Top	Bottom
T(1)	1.865	45	45
T(2)	0.004	0.004	0.004
T(3)	3.75	5.062	8.25
T(4)	6.25	8.63	2.25
SLTH	45	1.865	1.865
Y	22.5	NA	NA
X (Contact)	15.99	93.37	66.94
X (2 meters)	94.73	172.11	145.68

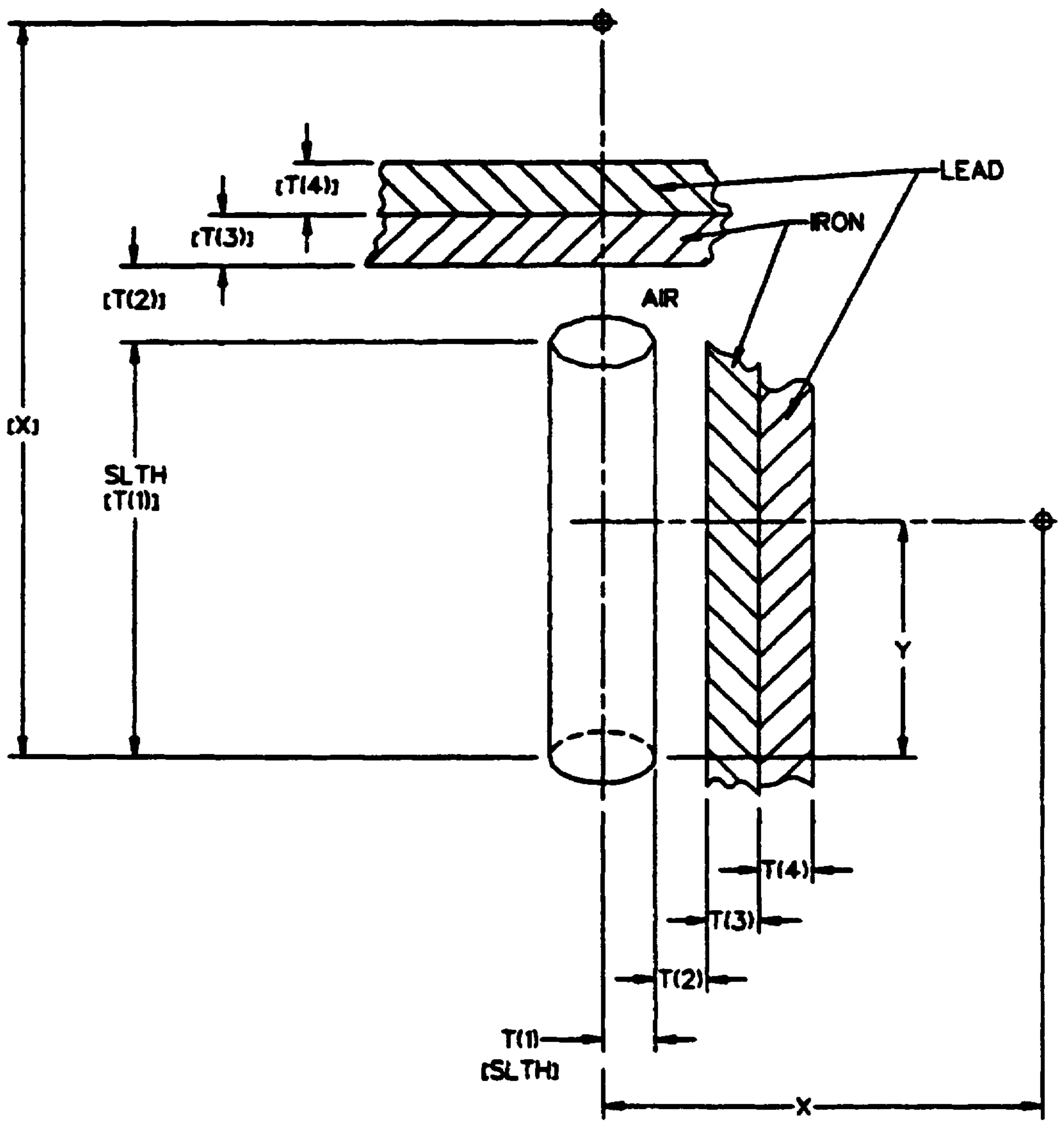

FIGURE 5.2. SOURCE AND SHIELD MODELS FOR ISOSHLD CODE INPUT (NORMAL CASE)

NOTE: Top and bottom variables brackets [ ].

Variable	Dimension, inches		
	Side	Top	Bottom
T(1)	2.14	2.14	2.14
T(2)	0.004	0.004	0.004
T(3)	3.75	5.062	8.25
T(4)	6.25	8.63	2.25
X (1 meter)	95.01	128.25	102.82

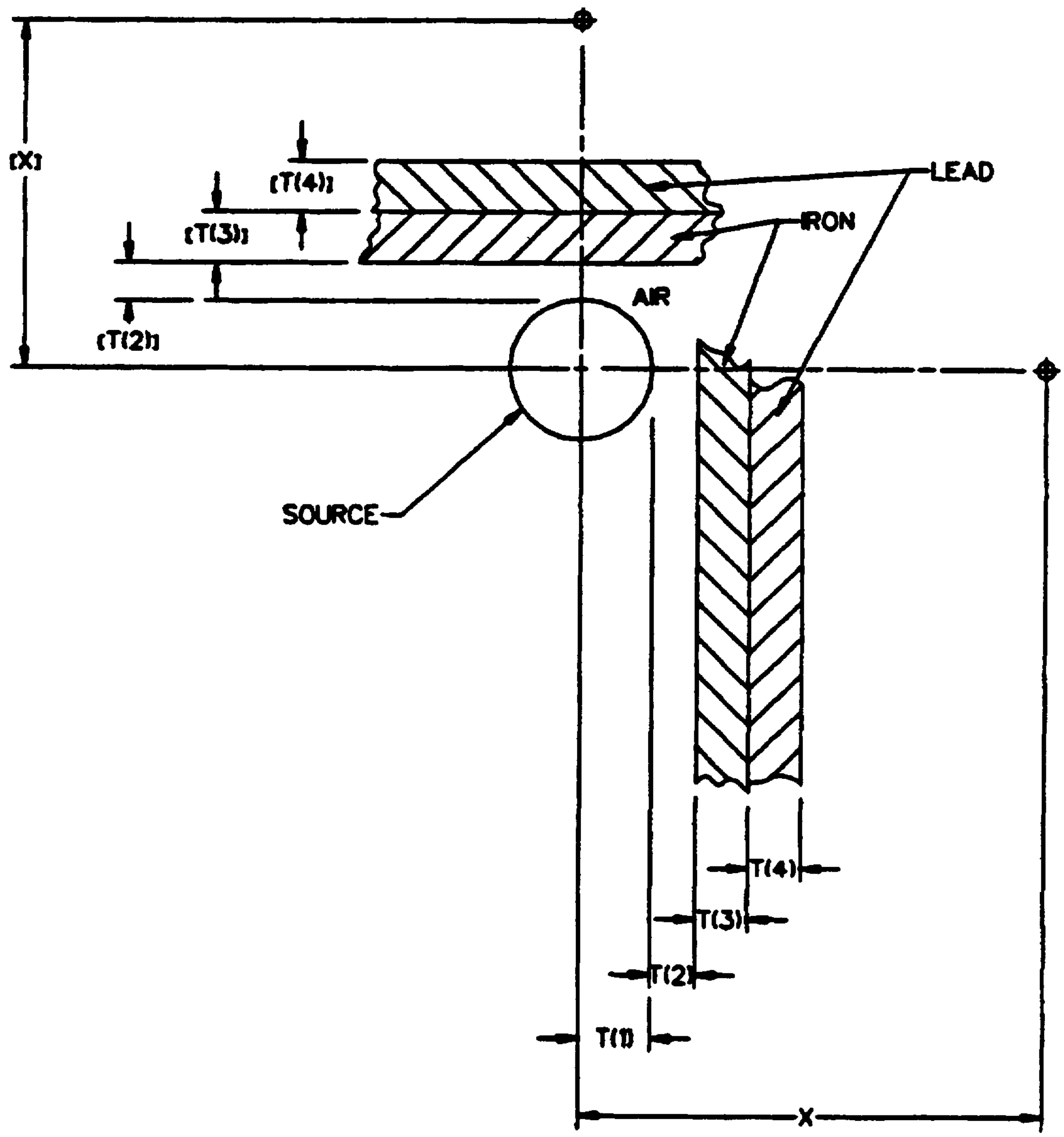

FIGURE 5.3. SOURCE AND SHIELD MODELS FOR ISOSHLD CODE INPUT

5.4 SHIELDING EVALUATION

5.4.1 Fuel Source

The basic method of determining the estimated dose rates at the surface, one meter, two meters, and 21 feet (cab of vehicle) from the surface of the Model 2000 transport container is outlined as follows.

1. The isotopic source was selected to be a mixture of the fission products which result from the long-term (1,879 days) irradiation of U-235 fuel followed by 120 days of cooling (decay). The operating power of the fuel was chosen to give a total burnup of approximately 45 GWD/MTU.

2. The selected fuel operating and decay conditions were used as the input to the RIBD computer code portion of the combined RIBD and ISOSHLD codes. All of the fission products calculated by RIBD were used as source input to the ISOSHLD portion of the combined codes. The specific RIBD input parameters used are:

   Fuel operating power - 0.8381 MW
   Operating time - 1,879 days
   Decay time after shutdown - 120 days
   Average thermal neutron flux - 1.0×10^{13} n/cm^2-s
   U-235 absorption cross section - 683 barns
   U-235 fission cross section - 577 barns
   U-238 absorption cross section - 2.71 barns
   U-235 weight - 1,750 grams
   Total U weight - 35,000 grams
   U-239 production rate - 0.09328 g U-239/MWd

3. The normal condition geometry consisted of a 45-in.-long x 3.73-in.-diameter cylindrical source at the side wall of the cask liner shielded by a 6.25-in. slab of lead plus a 3.75-in. slab of iron at the side, a 8.63-in. slab of lead plus a 5.06-in. slab of iron at the top, and a 2.25-in. slab of lead plus a 8.25-in. slab of iron at the bottom. The input to ISOSHLD to express the relative geometry of a cylindrical source, slab shields, and the dose point requires two angles and a differential thickness to define the point source elements, the thickness of the shields,

the distance from the dose point to the center or end of the cylinder, and the dimensions of the cylinder.

The input values for the normal conditions are:

	All Cases	Top Case	Bottom Case	Side Case
Source radius =	4.737 cm			
Source length =	114.3 cm			
Air thickness =	0.01 cm			
Iron thickness =	----	12.857 cm	20.955 cm	9.525 cm
Lead thickness =	----	12.92 cm	5.715 cm	15.875 cm
Buildup shield =	Lead			
Number of source division angles =	----	30	30	30 x 30
Source length or radius divisions =	----	1.9 cm	1.9 cm	0.158 cm
Distance to surface =	----	237.16 cm	170.028 cm	40.615 cm
Distance to one meter =	----	337.16 cm	270.028 cm	140.615 cm
Distance to two meters =	----	437.16 cm	370.028 cm	240.615 cm

The RIBD-ISOSHLD computer program was selected for the shielding analysis because it is a public domain code (i.e., it is distributed by the RSIC for unrestricted use), and reasonable accuracy is possible with the standard isotope, attenuation, and buildup libraries included in the code. The results from the ISOSHLD evaluation could be reasonably duplicated by standard hand calculations, barring human error.

The gamma flux-to-dose rate conversion factors as a function of energy are given below.

Group Average Energy (MeV)	Flux-To-Dose Rate Conversion Factor (R/hr per MeV/cm^2-sec)
1.500E-02	8.230E-05
2.500E-02	1.730E-05
3.500E-02	6.349E-06
4.500E-02	3.280E-06
5.500E-02	2.289E-06
6.500E-02	1.891E-06
7.500E-02	1.714E-06
8.500E-02	1.618E-06
9.500E-02	1.603E-06
1.500E-01	1.728E-06
2.500E-01	1.960E-06
3.500E-01	2.060E-06
4.750E-01	2.039E-06
6.500E-01	2.080E-06
8.250E-01	2.000E-06
1.000E 00	1.930E-06
1.225E 00	1.841E-06
1.475E 00	1.761E-06
1.700E 00	1.710E-06
1.900E 00	1.660E-06
2.100E 00	1.600E-06
2.300E 00	1.540E-06
2.500E 00	1.520E-06
2.700E 00	1.480E-06
3.000E 00	1.430E-06

4. The neutron dose rates were calculated by dividing the cylindrical source into 20 axial segments, determining the distance from the center of the segment to the point of interest, calculating the dose rate from each segment for an equivalent neutron emission from Cf-252, and summing the 20 results.

5. The summed gamma and neutron dose rates were compared with the regulatory dose rate limits, i.e., 200 mRem/hr at the surface,

2 mRem/hr in the vehicle cab, and 10 mRem/hr at two meters for the normal case and 1,000 mRem/hr at one meter for the accident case. The neutron dose rate from the case having the most restrictive dose rate (as compared to the regulatory limit) was reduced to a value at which the gamma plus the new neutron dose rate was within the limit. This limiting neutron dose rate was used to determine uranium mass and burnup limits from Figure 5.1.1.

5.4.2 Activation Product Sources

Dose rate calculations using the same general approach as was used for the fuel source, were made for four radionuclides which were uniformly distributed in slightly different source materials and sizes.

The activation product source is a volume of iron which contains a uniform dispersion of the isotope of interest. Activated hardware can have many shapes and sizes. For the normal condition shielding analysis of activation products it was assumed that the source isotope is contained in a cylinder with a volume which is capable of containing 84 tubes of 0.188 in. diameter by 48 in. length plus a cruciform control rod blade of 5.5 in. width by 48 in. length by 1.0 in. thickness. The resulting dimensions of the cylindrical volume are 6.1 in. diameter by 45 in. long.

The material of the activation hardware is 149,000 grams of iron, which is the approximate weight of steel which would fit in the 84 holes and the cruciform shape of the poison rod carrier rack (Figure 1.2.8). The resulting calculated density of iron in the source volume is 6.91 grams per cubic centimeter.

The accident case geometry for irradiated hardware is a 13.6-in.-diameter sphere of the iron located at the inside bottom, side, and top corner of the liner. This sphere represents the consolidation of the hardware due to the forces of some accident.

The dose rate calculations for irradiated hardware/waste were made for a unit activity of the isotope of interest and the limiting activity determined from the most restrictive ratio of the dose rate limits to the calculated dose rate for the unit activity.

The isotopes for which limits were calculated are: Cobalt-60, Cesium-137, Zirconium-95/Niobium-95, and Hafnium-181.

5.4.3 Bounding Limits

The maximum cask loadings which resulted from the above discussed dose rate calculations are summarized in Table 5.4.1. These loading limits are for the geometry and material cases analyzed only and are the curie or mass limits which comply with the regulatory dose rate limits only. The heat loading limits can and do place more restrictive limits on the activity limits.

TABLE 5.4.1. MASS AND CURIE LIMITS FOR MODEL 2000 (DOSE RATE BASIS)

Source Type	Isotope or Material	Uranium Limit, Grams	Activity Limit, Curies	600-Watt Equivalent, Curies
Irradiated Fuel	Uranium at 38 GWD/MTU	35,000	~1.65E5	~1.53E5
Irradiated Fuel	Uranium at 42 GWD/MTU	23,500	~1.65E5	~1.53E5
Irradiated Fuel	Uranium at 45 GWD/MTU	18,680	~1.65E5	~1.53E5
Activation Products	Co-60	N/A	1.08E5	3.89E4
"	Cs-137	"	1.95E9	1.38E5
"	Zr/Nb-95	"	9.75E6	6.10E4
"	Hf-181	"	6.87E11	1.57E5

5.5 APPENDIX

This Appendix contains:

- Copies of the RSIC Code package descriptions of RIBD and ISOSHLD.
- Samples of the RIBD and ISOSHLD input/output for the reported analysis.
- Samples of the neutron dose rate calculations at the top and side surfaces of the Model 2000 package.

5.5.1 RSIC Code Package CCC-137

RSIC CODE PACKAGE CCC-137

1. NAME AND TITLE OF CODE

RIBD: Radioisotope Buildup and Decay Code and Data Library.

An abbreviated version of RIBD is built into the CCC-79D/ISOSHLD Code.

2. CONTRIBUTOR

Battelle Memorial Institute, Pacific Northwest Laboratory, Richland, Washington.

3. CODING LANGUAGE AND COMPUTER

FORTRAN IV; UNIVAC 1108.

4. NATURE OF PROBLEM SOLVED

RIBD is a radioisotope buildup and decay code designed to analyze the fission product content of irradiated reactor fuel in terms of potential biological hazards and heating effects accompanying radioactive decay.

5. METHOD OF SOLUTION

RIBD is a grid processor which calculates isotopic concentrations resulting from two fission sources with normal down-chain decay by beta emission and isomeric transfer and inter-chain coupling resulting from any reactions. The calculations follow the irradiation history through an unlimited number of step changes of unrestricted duration and variability including shutdown periods, restarts at different power levels and/or any other level changes.

A nuclear data library has been generated for use with RIBD to calculate fission product inventories and decay heat rates associated with fuels irradiated in fast reactor environments.

6. RESTRICTIONS OR LIMITATIONS

None noted.

7. TYPICAL RUNNING TIME

No study of typical running time has been made by RSIC.

8. COMPUTER HARDWARE REQUIREMENTS

RIBD was designed to run on the UNIVAC 1108 computer with standard input-output devices.

9. COMPUTER SOFTWARE REQUIREMENTS

The packaged code version was compiled and executed on the UNIVAC 1108 FORTRAN compiler.

10. REFERENCES

R. O. Gumprecht, "Mathematical Basis of Computer Code RIBD," DUN-4136 (June 1968).

L. D. O'Dell and W. L. Bunch, "Revised Fast Reactor Library for Use with RIBD," BNWL-962 (April 1969).

J. L. Rash, "Use of Computer Code RIBD for Fission Product Analysis," RL-NRD-610 (November 1965).

11. CONTENTS OF CODE PACKAGE

The Package contains the following items:

a. the referenced documents, and

b. a reel of magnetic tape on which is written in 3 separate files: the source card decks, system routines, and library of data.

12. HOW TO OBTAIN PACKAGE

Inquiries or requests for the code package may be mailed to

CODES COORDINATOR
Radiation Shielding Information Center
Oak Ridge National Laboratory
Post Office Box X
Oak Ridge, Tennessee 37830

or telephoned to

Area Code 615; 483-8611, extension 3-6944, or to
FTS xx-615-483-6944.

Persons requesting the package should send a reel of magnetic tape to the above address.

13. DATE OF ABSTRACT

February 1972.

	RSIC #	CCC-137
	Code Name	RIBD
Master Tape #	Computer	UNIVAC 1108
Duplicate Tape	Date	6/70

CONTENTS

File	Description	Mode	Records
1	RIBD Source	BCD	909
2	Systems Routines	BCD	212
3	RIBD Library	BCD	451
			1572

RSIC CODE PACKAGE CCC-79

1. NAME AND TITLE OF CODE

ISOSHLD: Kernel Integration Code—General Purpose Isotope Shielding Analysis.

Two versions are packaged: ISOSHLD I and II. RIBD is used in both versions as a subroutine to calculate fission product inventories. The CCC-31/BREMRAD code package can be used to calculate the bremsstrahlung spectrum mesh, but must be requested separately.

2. CONTRIBUTOR

Battelle Memorial Institute, Pacific Northwest Laboratories, Richland, Washington.

3. CODING LANGUAGE AND COMPUTER

(A) ISOSHLD III: FORTRAN IV; UNIVAC 1108 (Update 12/73)

(B) ISOSHLD II: FORTRAN IV; IBM 360

(C) ISOSHLD II: FORTRAN IV; UNIVAC 1108

4. NATURE OF PROBLEM SOLVED

ISOSHLD calculates the decay gamma-ray and bremsstrahlung dose at the exterior of a shielded radiation source. The source may be one of a number of common geometric shapes. If the radiation source originated as one or a group of fission products produced under known irradiation conditions, then the strength of the source is also calculated. The code calculates shield region mass attenuation coefficients, buildup factors, and other basic data necessary to solve the specific problem.

5. METHOD OF SOLUTION

ISOSHLD performs kernel integration for common geometric shapes. The "standard" point attenuation kernel (buildup factor x exponential attenuation + geometry factor) is numerically integrated over the source volume for 25 source energy groups. Buildup is considered characteristic of the last shield region (or a different specified region) but dependent on the total number of mean free paths from source to dose point and is obtained by interpolation on effective atomic number from a table of point isotopic buildup factor data. Mixed mass attenuation coefficients are obtained from a library of basic data using code input material density specifications. The source strength may be specified 1) as the emissions from a selection of fission products irradiated under specific conditions, 2) the curies of particular fission and/or activation products, or 3) a number of photons per second of energy E specified by input. An exponential source distribution may be specified for those source geometries which are applicable. If the source originates in a combination of fission products and their daughters, these are calculated by a fission product inventory procedure which runs through transmutation (decay chain) calculations for each fission product and daughter. The latest modification (ISOSHLD - ISOSHLD II) adds the capability for calculating shielded dose rates from bremsstrahlung sources. This addition consists of routines for calculating the bremsstrahlung source spectra from the beta decay properties of the isotope(s) of interest. Bremsstrahlung photons per group for 25 energy groups (9 groups below 0.1 MeV have been added) are obtained by interpolation from tables of resolved spectra. This spectral mesh, for internal and external bremsstrahlung, is tabulated as a function of the following parameters: beta-emitting and stopping nuclides with atomic numbers of 10, 30, 50, 70, and 90; ratios of photon energy to beta end point energy for 25 intervals from 0-003T5 to 1.0; beta and point energies at the intervals 0.1, 0.2, 0.5, 1, 2, and 4 MeV. Buildup factors for photon energies less than 0.1 MeV are interpolated from a table which contains data for 5 values of initial photon energy in the range 0.01 to 0.2 MeV, seven values of shield thickness in the range 1 to 20 mfp, and 6 atomic numbers in the range 13 to 92.

The entire shielding problem is solved for most types of isotope shielding applications without reference to shielding handbooks for basic data.

6. RESTRICTIONS OR LIMITATIONS

These limits apply: 5 source cooling times,, 500 radioactive isotopes., 5 shield regions including source region, 25 energy groups, 20 materials in each shield region, choice of 3.1 source geometries.

7. TYPICAL RUNNING TIME

Dose from cylindrical volume source 20 integration increments in each direction, fission product inventory calculations with 5 decay times,. 25 energy groups, 4 shield layers, 5 materials homogenized into each shield layer and the-source volume --- 6 minutes UNIVAC 1107. '(most other source geometries require less computation time.)

8. COMPUTER HARDWARE REQUIREMENTS

The codes were originally designed for the 65K UNIVAC 1107. They have been modified by RSIC to run on the IBM 7090 (I) and the 360 (II).

9. COMPUTER SOFTWARE REQUIREMENTS

The codes were originally designed for the UNIVAC 1107 EXEC II Monitor System.

ISOSHLD I is available as an overlay job an the IBM FORTRAN IV IBJOB Monitor within the IBSYS Operating System. The ALTIO package is used.

ISOSHLD II is available for the IBM 360 computer and has been run on the Model 50 on the Level H compiler.

A library of data is packaged for each version.

10. REFERENCES

R. L. Engle, J. Greenborg, and M. M. Hendrickson, "ISOSHLD - A Computer Code for General Purpose Isotope Shielding Analysis," BNWL-236 (June 10).

R. O. Gumprecht, "RIBD-Radioisotope Buildup and Decay," Unpublished data.

H. H. Van Tuyl, "BREMRAD - A Computer Code for External and Internal Bremsstrahlung Calculations, HW-83784 (September 1964) (Packaged in CCC-31 only).

G. L. Simmons, J. J. Regimbal, J. Greenborg, E. L. Kelly, Jr., and H. H. Van Tuyl, "ISOSHLD-II: Code Revision to Include Calculations of Dose Rate from Shielded Bremsstrahlung Sources," BNWL-236SUP1 (March 1967).

11. CONTENTS OF CODE PACKAGE

The package contains the following items:

a. the referenced documents, with exception noted, and

b. for each code version a reel of magnetic tape has been written which containing the BCD source card decks, the binary card decks, a BCD library of data, BCD input for a sample problem, and a BCD output listing for the problem.

12. HOW TO OBTAIN PACKAGE

Inquiries or requests for the code package may be mailed to

CODES COORDINATOR
Radiation Shielding Information Center
Oak Ridge National Laboratory
Post Office Box X
Oak Ridge, Tennessee 37830

or telephoned to

Area Code 615; 483-8611, extension 3-6944, or to
FTS xx-615-483-6944.

Persons requesting the package should send a reel of magnetic tape to the above address.

13. DATE OF ABSTRACT

January 1968.

5.5.2 RIBD/ISOSHLD Input

RIBD/ISOSHLD INPUT FOR 45 GWD/MTU FUEL

```
$$ ASIS,ROUT(1U),TAB(:,8,16,79),KEYWORD(BMM)
$:IDENT:V151,BMM,VVV18,X4455
$:OPTION:FORTRAN
$:SELECT:ISHLD01
$:LIMITS:100,44K,,30f
$:REMOTE:06,1U
$:DATA:I*
   MODE = 4
450 RIBD LIBRARY CURRENT THRU JAN 74 (E.J. MORGAN JAN 74)
  2000 MFP INV., 45 GWD/T, 1750 GMS     9.32BE-02          00
 8.381E-01 1.879E 03 1.109E 00 6.83 E 02 0.000E 00 0 0
 7.776E6 8.640E6 9.504E6 1.037E7 1.123E7 1.210E7 1.296E7 1.382E7 1.469E7
999999
TOP OF 2000, NORMAL FUEL CYL AT SIDE OF LINER, SURFACE.
 $INPUT NEXT = 1, IGEOM = 9, SLTH = 4.737, NTHETA = 30., T(4) = 21.92.
 T(1) = 114.3, T(3) = 12.857, NSHLD = 4, GROUP(5) = 1.0, DELR = 1.9,
 T(2) = 0.01, JBUF = 4,  ISPEC = 1, X = 237.16 $
 AIR     3           1.293E-03
 ZIRC   11 3.400E-02
 URAN   15 4.344E 00
 LEAD   14                              1.134E 01
 IRON    9                    7.800E 00
TOP OF 2000, NORMAL FUEL CYL AT SIDE OF LINER, 1 METER.
 $INPUT NEXT = 4, X = 337.16 $
TOP OF 2000, NORMAL FUEL CYL AT SIDE OF LINER, 2 METERS.
 $INPUT NEXT = 4, X = 437.16 $
BOTTOM OF 2000 CASK, NORMAL FUEL CYL AT SIDE OF LINER, SURFACE.
 $INPUT NEXT = 4, T(3) = 20.955, T(4) = 5.715, X = 170.028 $
BOTTOM OF 2000 CASK, NORMAL FUEL CYL AT SIDE OF LINER, 1 METER.
 $INPUT NEXT = 4, X = 270.028 $
BOTTOM OF 2000 CASK, NORMAL FUEL CYL AT SIDE OF LINER, 2 METERS.
 $INPUT NEXT = 4, X = 370.028 $
SIDE OF 2000, NORMAL FUEL CYL AT SIDE OF LINER, SURFACE.
 $INPUT NEXT = 4, IGEOM = 7, T(1) = 4.737, T(3) = 9.525,
 T(4) = 15.875, SLTH = 114.3, X = 40.615, Y = 57.15, NTHETA = 30,
 NPSI = 30, DELR = 0.158 $
SIDE OF 2000, NORMAL FUEL CYL AT SIDE OF LINER, 1 METER.
 $INPUT NEXT = 4, X = 140.615 $
SIDE OF 2000, NORMAL FUEL CYL AT SIDE OF LINER, 2 METERS.
 $INPUT NEXT = 4, X = 240.615 $
SIDE OF 2000, ACCIDENT FUEL SPHERE AT SIDE OF LINER SURFACE.
```

```
 $INPUT NEXT = 4, IGEOM = 3, T(1) = 5.436, T(2) = 0.01, T(3) = 9.525,
 T(4) = 15.875, X = 41.314 $
SIDE OF 2000, ACCIDENT FUEL SPHERE AT SIDE OF CAVITY, 1 METER.
 $INPUT NEXT = 4, X = 141.314 $
SIDE OF 2000, ACCIDENT FUEL SPHERE AT SIDE OF CAVITY, 2 METERS.
 $INPUT NEXT = 4, X = 241.314 $
TOP OF 2000, ACCIDENT FUEL SPHERE AT UPPER CORNER OF LINER, SURFACE.
 $INPUT NEXT = 4, IGEOM = 4, T(1) = 5.436, T(2) = 0.01, T(3) = 12.857,
 T(4) = 21.92, X = 125.755 $
TOP OF 2000, ACCIDENT FUEL SPHERE AT UPPER CORNER OF LINER, 1 METER.
 $INPUT NEXT = 4, X = 225.755 $
TOP OF 2000, ACCIDENT FUEL SPHERE AT UPPER CORNER OF LINER, 2 METERS.
 $INPUT NEXT = 4, X = 325.755 $
BOTTOM OF 2000, ACCIDENT FUEL SPHERE AT LOWER CORNER OF LINER, SURFACE.
 *INPUT NEXT = 4, T(3) = 20.955, T(4) = 5.715, X = 61.163 $
BOTTOM OF 2000, ACCIDENT FUEL SPHERE AT LOWER CORNER OF LINER, 1 METER.
 $INPUT NEXT = 4, X = 161.163 $
BOTTOM OF 2000, ACCIDENT FUEL SPHERE AT LOWER CORNER OF LINER, 2 METERS.
 $INPUT NEXT = 4, X = 261.163 $
DUMMY TITLE CARD
 $INPUT NEXT = 6 $
$:ENDJOB
```

```
**********  **********  **********  **********  **      **  **          *******            **************
**********  **********  **********  **********  **      **  **          ********           **************
    **      **      **  **      **  **      **  **      **  **          **     **            **  **  **
    **      **      **  **      **  **      **  **      **  **          **      **           **  **  **
    **      **          **      **  **          **      **  **          **      **           **  **  **
    **      **          **      **  **          **      **  **          **      **           **  **  **
    **      **          **      **  **          **      **  **          **      **           **  **  **
    **      **          **      **  **          **      **  **          **      **           **  **  **
    **      **********  **      **  **********  **********  **          **      **  *****    **  **  **
    **      **********  **      **  **********  **********  **          **      **  *****    **  **  **
    **              **  **      **          **  **      **  **          **      **           **  **  **
    **              **  **      **          **  **      **  **          **      **           **  **  **
    **              **  **      **          **  **      **  **          **      **           **  **  **
    **              **  **      **          **  **      **  **          **      **           **  **  **
    **      **      **  **      **  **      **  **      **  **      **  **      **           **  **  **
    **      **      **  **      **  **      **  **      **  **      **  **     **            **  **  **
**********  **********  **********  **********  **      **  **********  ********           **************
**********  **********  **********  **********  **      **  **********  *******            **************
EXP UNDERFLO  AT LOCATION     106727
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*  USERS ARE REMINDED THAT THE STANDARD 450-ISOTOPE LIBRARY IS AVAILABLE BY PUNCHING ZERO IN COLUMN 3 OF THE TITLE CARD  *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

CASE I.D. GE2000 MFP INV., 45 GWD/T, 1750 GMS WRITTEN BY SUBROUTINE FROG. PETE'S VERSION OF RIBD

CONVERSION RATIO G(U-239)/MWD	0.093
SCRAM REACTIVITY, MILLI-K	0.
PROMPT NEUTRON LIFE, MSEC	0.
NUMBER OF EXTRA DECAY CARDS	0
OUTPUT OPTION REQUESTED	0
FUEL POWER, MEGAWATTS	8.3810E-01
TIME AT THIS POWER, DAYS	1.8790E 03
EXPOSURE (FLUX*SIGMA25*TIME)	1.1090E 00
U-235 ABSORPTION CROSS-SECT.	6.8300E 02
PU239 FISSIONS/U235 FISSIONS	0.
NUMBER OF EXTRA IRRAD. CARDS	0

```
EXP UNDERFLO  AT LOCATION    055633
EXP UNDERFLO  AT LOCATION    056743
EXP UNDERFLO  AT LOCATION    056561
EXP UNDERFLO  AT LOCATION    057147
EXP UNDERFLO  AT LOCATION    057316
EXP UNDERFLO  AT LOCATION    057316
EXP UNDERFLO  AT LOCATION    057316
EXP UNDERFLO  AT LOCATION    057316
EXP UNDERFLO  AT LOCATION    057316
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EXP UNDERFLO  AT LOCATION    057316
EXP UNDERFLO  AT LOCATION    057316
EXP UNDERFLO  AT LOCATION    057316
EXP UNDERFLO  AT LOCATION    056743
EXP UNDERFLO  AT LOCATION    056743
EXP UNDERFLO  AT LOCATION    056743
EXP UNDERFLO  AT LOCATION    056417
EXP UNDERFLO  AT LOCATION    056417
** THIS IS THE LAST TIME THE ABOVE MESSAGE WILL APPEAR*
```

GE2000 MFP INV., 45 GWD/T, 1750 GMS ACTIVITY AFTER SHUTDOWN - CURIES 1574.8 MWD IN 1879.0 DAYS. SUMMARY

ELEMENT	SHUTDOWN	90.0 DAYS	100.0 DAYS	110.0 DAYS	120.0 DAYS	130.0 DAYS	140.0 DAYS	150.0 DAYS	160.0 DAYS	170.0 DAYS
30 ZN	8.340E-01	6.346E-15	1.775E-16	4.965E-18	1.377E-19	3.917E-21	1.069E-22	3.039E-24	8.644E-26	2.358E-27
31 GA	4.920E 00	9.107E-15	2.547E-16	7.125E-18	1.977E-19	5.621E-21	1.534E-22	4.362E-24	1.240E-25	3.384E-27
32 GE	7.055E 01	0.	0.	0.	0.	0.	0.	0.	0.	0.
33 AS	2.519E 03	5.670E-16	7.964E-18	1.119E-19	1.556E-21	2.228E-23	3.038E-25	4.353E-27	6.235E-29	8.502E-31
34 SE	2.138E 04	8.712E-03	8.712E-03	8.712E-03	8.712E-03	8.712E-03	8.712E-03	8.712E-03	8.712E-03	8.712E-03
35 BR	5.496E 04	1.058E-18	9.505E-21	8.542E-23	7.593E-25	6.974E-27	6.065E-29	5.571E-31	5.117E-33	0.
36 KR	1.510E 05	4.893E 02	4.884E 02	4.875E 02	4.867E 02	4.858E 02	4.850E 02	4.841E 02	4.833E 02	4.824E 02
37 RB	2.255E 05	3.714E-01	2.564E-01	1.770E-01	1.220E-01	8.439E-02	5.810E-02	4.018E-02	2.778E-02	1.913E-02
38 SR	2.170E 05	9.638E 03	8.897E 03	8.248E 03	7.679E 03	7.184E 03	6.745E 03	6.365E 03	6.033E 03	5.738E 03
39 Y	2.382E 05	1.273E 04	1.173E 04	1.084E 04	1.005E 04	9.346E 03	8.715E 03	8.160E 03	7.666E 03	7.222E 03
40 ZR	1.062E 05	1.628E 04	1.463E 04	1.315E 04	1.182E 04	1.063E 04	9.546E 03	8.584E 03	7.720E 03	6.934E 03
41 NB	2.551E 05	2.730E 04	2.519E 04	2.318E 04	2.128E 04	1.949E 04	1.781E 04	1.626E 04	1.482E 04	1.348E 04
42 MO	1.670E 05	6.072E-06	4.883E-07	3.927E-08	3.140E-09	2.555E-10	2.019E-11	1.642E-12	1.336E-13	1.056E-14
43 TCP	1.889E 05	7.200E-01	7.200E-01	7.200E-01	7.200E-01	7.200E-01	7.200E-01	7.200E-01	7.200E-01	7.200E-01
44 RU	8.298E 04	2.262E 04	2.120E 04	1.997E 04	1.889E 04	1.795E 04	1.711E 04	1.637E 04	1.571E 04	1.512E 04
45 RH	1.017E 05	2.260E 04	2.118E 04	1.995E 04	1.887E 04	1.793E 04	1.709E 04	1.636E 04	1.570E 04	1.511E 04
46 PD	1.549E 04	8.732E-05	8.732E-05	8.732E-05	8.732E-05	8.732E-05	8.732E-05	8.732E-05	8.732E-05	8.732E-05
47 AG	1.059E 04	1.092E 01	1.047E 01	1.013E 01	9.841E 00	9.574E 00	9.316E 00	9.070E 00	8.832E 00	8.598E 00
48 CD	2.054E 02	7.003E-01	5.963E-01	5.078E-01	4.323E-01	3.685E-01	3.135E-01	2.673E-01	2.279E-01	1.940E-01
49 IN	2.986E 02	3.216E-06	2.800E-06	2.438E-06	2.121E-06	1.848E-06	1.607E-06	1.400E-06	1.220E-06	1.061E-06
50 SN	1.997E 04	8.500E 00	8.029E 00	7.697E 00	7.436E 00	7.214E 00	7.012E 00	6.827E 00	6.653E 00	6.485E 00
51 SB	1.424E 05	2.225E 02	2.209E 02	2.194E 02	2.178E 02	2.163E 02	2.148E 02	2.132E 02	2.118E 02	2.103E 02
52 TE	1.806E 05	1.390E 03	1.208E 03	1.056E 03	9.276E 02	8.206E 02	7.291E 02	6.523E 02	5.868E 02	5.300E 02
53 I	2.909E 05	1.114E 01	4.712E 00	1.993E 00	8.415E-01	3.580E-01	1.513E-01	6.512E-02	2.852E-02	1.288E-02
54 XE	2.725E 05	3.519E 00	1.876E 00	1.030E 00	5.723E-01	3.214E-01	1.797E-01	1.013E-01	5.706E-02	3.194E-02
55 CS	2.561E 05	6.060E 03	6.045E 03	6.031E 03	6.017E 03	6.005E 03	5.992E 03	5.980E 03	5.968E 03	5.956E 03
56 BA	2.326E 05	4.931E 03	4.799E 03	4.721E 03	4.675E 03	4.646E 03	4.629E 03	4.617E 03	4.609E 03	4.603E 03
57 LA	1.886E 05	3.544E 02	2.062E 02	1.200E 02	6.973E 01	4.068E 01	2.358E 01	1.376E 01	8.024E 00	4.651E 00
58 CE	1.748E 05	3.288E 04	3.108E 04	2.951E 04	2.813E 04	2.693E 04	2.564E 04	2.487E 04	2.400E 04	2.318E 04
59 PR	1.396E 05	2.730E 04	2.647E 04	2.573E 04	2.505E 04	2.441E 04	2.380E 04	2.321E 04	2.265E 04	2.210E 04
60 ND	3.086E 04	6.008E 01	3.217E 01	1.723E 01	9.215E 00	4.949E 00	2.639E 00	1.418E 00	7.613E-01	4.060E-01
61 PM	3.205E 04	1.065E 04	1.055E 04	1.046E 04	1.037E 04	1.029E 04	1.020E 04	1.012E 04	1.004E 04	9.963E 03
62 SM	6.141E 03	1.045E 01	1.045E 01	1.045E 01	1.045E 01	1.044E 01	1.044E 01	1.044E 01	1.044E 01	1.043E 01
63 EU	2.917E 03	2.248E 02	2.111E 02	2.020E 02	1.958E 02	1.913E 02	1.880E 02	1.854E 02	1.833E 02	1.814E 02
64 GD	1.480E 02	5.729E 00	5.621E 00	5.515E 00	5.411E 00	5.310E 00	5.210E 00	5.112E 00	5.016E 00	4.921E 00
65 TB	5.018E 01	7.470E 00	7.202E 00	6.953E 00	6.718E 00	6.499E 00	6.290E 00	6.095E 00	5.911E 00	5.734E 00
66 DY	4.237E 00	2.402E-09	3.002E-10	3.752E-11	4.666E-12	5.888E-13	7.253E-14	9.153E-15	1.155E-15	1.423E-16
67 HO	4.285E-01	3.639E-09	4.548E-10	5.684E-11	7.069E-12	8.921E-13	1.099E-13	1.387E-14	1.750E-15	2.155E-16
68 ER	4.320E-05	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	3.809E 06	1.956E 05	1.842E 05	1.739E 05	1.648E 05	1.566E 05	1.492E 05	1.425E 05	1.364E 05	1.308E 05

GE2000 MFP INV., 45 GWD/T, 1750 GMS BETA POWER AFTER SHUTDOWN - MW 1574.8 MWD IN 1879.0 DAYS. SUMMARY

ELEMENT	SHUTDOWN	90.0 DAYS	100.0 DAYS	110.0 DAYS	120.0 DAYS	130.0 DAYS	140.0 DAYS	150.0 DAYS	160.0 DAYS	170.0 DAYS
30 ZN	1.928E-08	6.669E-25	1.865E-26	5.218E-28	1.447E-29	4.116E-31	1.123E-32	3.194E-34	9.084E-36	2.478E-37
31 GA	1.293E-06	3.429E-24	9.592E-26	2.683E-27	7.443E-29	2.117E-30	5.776E-32	1.642E-33	4.671E-35	1.274E-36
32 GE	6.303E-07	0.	0.	0.	0.	0.	0.	0.	0.	0.
33 AS	3.384E-05	1.607E-24	2.210E-26	3.040E-28	4.139E-30	5.806E-32	7.750E-34	1.087E-35	1.525E-37	2.036E-39
34 SE	2.357E-04	1.610E-11	1.610E-11	1.610E-11	1.610E-11	1.610E-11	1.610E-11	1.610E-11	1.610E-11	1.610E-11
35 BR	7.645E-04	8.305E-27	7.559E-29	6.881E-31	6.195E-33	5.763E-35	5.077E-37	4.723E-39	0.	0.
36 KR	6.765E-04	6.076E-07	6.066E-07	6.055E-07	6.044E-07	6.034E-07	6.023E-07	6.012E-07	6.002E-07	5.991E-07
37 RB	2.078E-03	1.332E-09	9.194E-10	6.347E-10	4.377E-10	3.027E-10	2.084E-10	1.441E-10	9.964E-11	6.860E-11
38 SR	1.567E-03	2.390E-05	2.138E-05	1.918E-05	1.726E-05	1.560E-05	1.413E-05	1.286E-05	1.176E-05	1.079E-05
39 Y	2.227E-03	5.348E-05	4.975E-05	4.643E-05	4.347E-05	4.085E-05	3.850E-05	3.643E-05	3.459E-05	3.293E-05
40 ZR	9.367E-04	1.069E-05	9.609E-06	8.637E-06	7.762E-06	6.980E-06	6.270E-06	5.638E-06	5.070E-06	4.554E-06
41 NS	1.893E-03	6.367E-06	5.875E-06	5.406E-06	4.961E-06	4.545E-06	4.152E-06	3.790E-06	3.455E-06	3.142E-06
42 MO	8.349E-04	1.449E-14	1.165E-15	9.370E-17	7.492E-18	6.095E-19	4.817E-20	3.919E-21	3.189E-22	2.520E-23
43 TC	1.724E-03	1.206E-09	1.206E-09	1.206E-09	1.206E-09	1.206E-09	1.206E-09	1.206E-09	1.206E-09	1.206E-09
44 RU	2.794E-04	3.472E-06	3.041E-06	2.677E-06	2.368E-06	2.108E-06	1.886E-06	1.699E-06	1.539E-06	1.402E-06
45 RH	4.248E-04	1.248E-04	1.224E-04	1.202E-04	1.179E-04	1.157E-04	1.135E-04	1.114E-04	1.093E-04	1.073E-04
46 PD	2.788E-05	4.368E-13	4.368E-13	4.368E-13	4.368E-13	4.368E-13	4.368E-13	4.368E-13	4.368E-13	4.368E-13
47 AG	2.175E-05	5.661E-09	5.143E-09	4.861E-09	4.674E-09	4.529E-09	4.400E-09	4.281E-09	4.167E-09	4.056E-09
48 CD	6.241E-06	1.168E-08	9.940E-09	8.461E-09	7.199E-09	6.132E-09	5.213E-09	4.441E-09	3.783E-09	3.216E-09
49 IN	2.076E-05	1.403E-20	1.272E-21	7.028E-22	6.775E-22	6.764E-22	6.764E-22	6.765E-22	6.765E-22	6.765E-22
50 SN	7.013E-04	6.938E-08	6.441E-08	6.038E-08	5.690E-08	5.379E-08	5.088E-08	4.820E-08	4.567E-08	4.326E-08
51 SB	1.080E-03	3.901E-07	3.606E-07	3.345E-07	3.112E-07	2.905E-07	2.718E-07	2.553E-07	2.405E-07	2.271E-07
52 TE	7.273E-04	2.265E-06	1.885E-06	1.574E-06	1.317E-06	1.107E-06	9.314E-07	7.882E-07	6.696E-07	5.702E-07
53 I	1.519E-03	1.166E-08	4.930E-09	2.084E-09	8.796E-10	3.736E-10	1.572E-10	6.700E-11	2.869E-11	1.232E-11
54 XE	1.222E-03	2.426E-10	6.512E-11	1.748E-11	4.677E-12	1.263E-12	3.359E-13	9.071E-14	2.450E-14	6.515E-15
55 CS	1.975E-03	6.881E-06	6.866E-06	6.853E-06	6.840E-06	6.827E-06	6.815E-06	6.803E-06	6.791E-06	6.779E-06
56 BA	1.043E-03	5.433E-07	3.161E-07	1.839E-07	1.069E-07	6.235E-08	3.615E-08	2.108E-08	1.230E-06	7.130E-09
57 LA	1.303E-03	1.000E-06	5.819E-07	3.386E-07	1.968E-07	1.148E-07	6.654E-08	3.881E-08	2.264E-08	1.312E-08
58 CE	4.536E-04	1.733E-05	1.600E-05	1.488E-05	1.392E-05	1.311E-05	1.240E-05	1.179E-05	1.126E-05	1.078E-05
59 PR	6.961E-04	1.840E-04	1.787E-04	1.739E-04	1.694E-04	1.652E-04	1.611E-04	1.571E-04	1.533E-04	1.496E-04
60 ND	6.336E-05	6.972E-08	3.734E-08	2.000E-08	1.069E-08	5.744E-09	3.063E-09	1.645E-09	8.835E-10	4.711E-10
61 PM	6.134E-05	3.407E-06	3.342E-06	3.284E-06	3.231E-06	3.183E-06	3.139E-06	3.098E-06	3.061E-06	3.026E-06
62 SM	9.526E-06	1.078E-09	1.078E-09	1.077E-09	1.077E-09	1.077E-09	1.077E-09	1.076E-09	1.076E-09	1.076E-09
63 EU	5.791E-06	3.789E-07	3.597E-07	3.465E-07	3.371E-07	3.302E-07	3.248E-07	3.205E-07	3.167E-07	3.133E-07
64 GD	2.542E-07	0.	0.	0.	0.	0.	0.	0.	0.	0.
65 TB	1.749E-07	2.933E-09	2.662E-09	2.418E-09	2.195E-09	1.994E-09	1.810E-09	1.645E-09	1.494E-09	1.356E-09
66 DY	4.125E-09	1.782E-19	2.266E-20	2.934E-21	3.808E-22	5.026E-23	6.487E-24	8.575E-25	1.134E-25	1.464E-26
67 HO	3.920E-10	2.014E-13	2.014E-13	2.014E-13	2.014E-13	2.014E-13	2.014E-13	2.014E-13	2.014E-13	2.014E-13
68 ER	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
92 U 239	1.466E-04	0.	0.	0.	0.	0.	0.	0.	0.	0.
93 NP239	3.346E-05	1.003E-16	5.256E-18	2.754E-19	1.433E-20	7.613E-22	3.908E-23	2.076E-24	1.103E-25	5.661E-27
TOTAL	2.500E-02	4.397E-04	4.213E-04	4.049E-04	3.901E-04	3.767E-04	3.642E-04	3.527E-04	3.421E-04	3.320E-04
SUBTOTALS										
NOBLES	1.899E-03	6.079E-07	6.066E-07	6.055E-07	6.044E-07	6.034E-07	6.023E-07	6.012E-07	6.002E-07	5.991E-07
HALOGENS	2.284E-03	1.166E-08	4.930E-09	2.084E-09	8.796E-10	3.736E-10	1.572E-10	6.700E-11	2.869E-11	1.232E-11
VOLATILES	6.965E-03	9.537E-06	9.113E-06	8.762E-06	8.469E-06	8.225E-06	8.018E-06	7.846E-06	7.701E-06	7.576E-06
OTHERS	1.385E-02	4.295E-04	4.116E-04	3.955E-04	3.810E-04	3.678E-04	3.556E-04	3.443E-04	3.338E-04	3.239E-04
TOTAL LESS NOBLES	2.310E-02	4.391E-04	4.207E-04	4.043E-04	3.895E-04	3.761E-04	3.636E-04	3.521E-04	3.415E-04	3.314E-04

GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.0 MWD IN 1879.0 DAYS SUMMARY

GAMMA POWER AFTER SHUTDOWN - MW

ELEMENT	SHUTDOWN	90.0 DAYS	100.0 DAYS	110.0 DAYS	120.0 DAYS	130.0 DAYS	140.0 DAYS	150.0 DAYS	160.0 DAYS	170.0 DAYS
30 ZN	6.548E-10	6.864E-24	1.920E-25	5.370E-27	1.490E-28	4.236E-30	1.156E-31	3.287E-33	9.348E-35	2.551E-36
31 GA	6.004E-07	2.288E-23	6.400E-25	1.790E-26	4.966E-28	1.412E-29	3.853E-31	1.096E-32	3.116E-34	8.503E-36
32 GE	5.215E-07	0.	0.	0.	0.	0.	0.	0.	0.	0.
33 AS	5.710E-05	1.607E-25	2.210E-27	3.040E-29	4.139E-31	5.806E-33	7.750E-35	1.087E-36	1.525E-38	0.
34 SE	1.129E-05	1.987E-26	2.733E-28	3.759E-30	5.118E-32	7.179E-34	9.583E-36	1.344E-37	1.886E-39	0.
35 BR	2.921E-04	1.571E-25	1.430E-27	1.301E-29	1.172E-31	1.090E-33	9.603E-36	8.933E-38	0.	0.
36 KR	8.877E-04	9.722E-09	9.705E-09	9.688E-09	9.671E-09	8.654E-09	9.636E-09	9.620E-09	9.603E-09	9.586E-09
37 RB	1.444E-03	1.958E-10	1.351E-10	9.328E-11	6.433E-11	4.448E-11	3.063E-11	2.118E-11	1.464E-11	1.008E-11
38 SR	1.252E-03	6.780E-09	5.912E-09	5.155E-09	4.494E-09	3.921E-09	3.416E-09	2.980E-09	2.600E-09	2.265E-09
39 Y	1.738E-03	2.295E-07	2.047E-07	1.827E-07	1.630E-07	1.457E-07	1.301E-07	1.164E-07	1.043E-07	9.330E-08
40 ZR	5.277E-04	6.486E-05	5.830E-05	5.240E-05	4.709E-05	4.235E-05	3.804E-05	3.420E-05	3.076E-05	2.763E-05
41 NB	1.793E-03	1.130E-04	1.042E-04	8.591E-05	8.801E-05	8.063E-05	7.365E-05	6.723E-05	6.128E-05	5.572E-05
42 MO	1.295E-03	4.382E-15	3.524E-16	2.834E-17	2.266E-18	1.843E-19	1.457E-20	1.185E-21	9.644E-23	7.621E-24
43 TC	1.439E-03	4.876E-15	3.987E-16	3.862E-17	9.653E-18	7.341E-18	7.152E-18	7.137E-18	7.136E-18	7.136E-18
44 RU	2.948E-04	6.455E-05	6.051E-05	5.700E-05	5.393E-05	5.125E-05	4.887E-05	4.678E-05	4.493E-05	4.324E-05
45 RH	1.407E-04	2.139E-05	2.077E-05	2.019E-05	1.965E-05	1.915E-05	1.867E-05	1.823E-05	1.781E-05	1.741E-05
46 PD	1.098E-05	5.824E-39	0.	0.	0.	0.	0.	0.	0.	0.
47 AG	1.105E-05	1.480E-07	1.441E-07	1.403E-07	1.366E-07	1.330E-07	1.295E-07	1.261E-07	1.228E-07	1.195E-07
48 CD	5.580E-06	6.892E-10	5.866E-10	4.992E-10	4.248E-10	3.618E-10	3.076E-10	2.620E-10	2.232E-10	1.897E-10
49 IN	9.898E-06	2.822E-19	1.259E-20	5.617E-22	2.488E-23	1.126E-24	4.918E-26	2.226E-27	1.008E-28	4.399E-30
50 SN	4.314E-04	2.396E-08	2.259E-08	2.135E-08	2.021E-08	1.916E-08	1.816E-08	1.722E-08	1.633E-08	1.548E-08
51 SB	5.346E-04	1.856E-06	1.711E-06	1.582E-06	1.467E-06	1.364E-06	1.272E-06	1.190E-06	1.117E-06	1.050E-06
52 TE	4.794E-04	4.340E-07	3.770E-07	3.295E-07	2.897E-07	2.567E-07	2.286E-07	2.051E-07	1.853E-07	1.682E-07
53 I	2.480E-03	2.585E-08	1.093E-08	4.620E-09	1.949E-09	0.275E-10	3.479E-10	1.479E-10	6.296E-11	2.667E-11
54 XE	5.578E-04	2.449E-09	1.328E-09	7.341E-10	4.085E-10	2.290E-10	1.277E-10	7.167E-11	4.022E-11	2.241E-11
55 CS	9.415E-04	9.833E-06	9.707E-06	9.598E-06	9.499E-06	9.407E-06	9.317E-06	9.231E-06	9.147E-06	9.063E-06
56 BA	3.946E-04	1.865E-05	1.847E-05	1.836E-05	1.829E-05	1.824E-05	1.821E-05	1.819E-05	1.817E-05	1.816E-05
57 LA	1.253E-03	5.142E-06	2.992E-06	1.741E-06	1.012E-06	5.902E-07	3.421E-07	1.996E-07	1.164E-07	6.748E-08
58 CE	2.910E-04	8.112E-06	7.303E-06	6.631E-06	6.070E-06	5.603E-06	5.204E-06	4.870E-06	4.584E-06	4.334E-06
59 PR	2.377E-04	4.619E-06	4.508E-06	4.399E-06	4.293E-06	4.190E-06	4.088E-06	3.990E-06	3.894E-06	3.800E-06
60 ND	6.015E-05	5.941E-08	3.182E-08	1.704E-08	9.113E-09	4.895E-09	2.610E-09	1.402E-09	7.529E-10	4.015E-10
61 PM	1.006E-04	7.207E-06	7.032E-06	6.877E-06	6.739E-06	6.616E-06	6.505E-06	6.404E-06	6.313E-06	6.228E-06
62 SM	3.708E-06	2.269E-11	2.269E-11	2.268E-11	2.268E-11	2.267E-11	2.267E-11	2.266E-11	2.266E-11	2.265E-11
63 EU	6.274E-06	9.254E-07	9.009E-07	8.836E-07	8.709E-07	8.612E-07	8.533E-07	8.466E-07	8.408E-07	8.353E-07
64 GD	1.454E-07	0.	0.	0.	0.	0.	0.	0.	0.	0.
65 TB	5.814E-08	1.748E-08	1.588E-06	1.442E-08	1.309E-06	1.190E-08	1.080E-08	9.811E-09	8.914E-09	8.091E-09
66 DY	1.224E-09	1.250E-19	1.633E-20	2.137E-21	2.785E-22	2.785E-22	4.755E-24	6.287E-25	8.313E-26	1.074E-26
67 HO	3.290E-11	2.685E-13	2.685E-13	2.685E-13	2.685E-13	2.685E-13	2.685E-13	2.685E-13	2.685E-13	2.685E-13
68 ER	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0.
92 U239	2.688E-05	0.	0.	0.	0.	0.	0.	0.	0.	0.0.
93 NP239	1.469E-04	4.402E-16	2.307E-17	1.209E-18	6.290E-20	3.341E-21	1.715E-22	9.111E-24	4.839E-25	2.484E-26
TOTAL	1.916E-02	3.211E-04	2.973E-04	2.763E-04	2.576E-04	2.408E-04	2.256E-04	2.119E-04	1.994E-04	1.879E-04

SUBTOTALS --

NOBLES	1.445E-03	1.217E-08	1.103E-08	1.042E-08	1.008E-08	9.883E-09	9.764E-09	9.691E-09	9.643E-09	9.608E-09
HALOGENS	2.772E-03	2.585E-08	1.093E-06	4.620E-09	1.949E-09	8.275E-10	3.479E-10	1.479E-10	6.296E-11	2.667E-11
VOLATILES	4.763E-03	1.212E-05	1.180E-05	1.151E-05	1.126E-05	1.103E-05	1.082E-05	1.063E-05	1.045E-05	1.028E-05
OTHERS	1.018E-02	3.089E-04	2.854E-04	2.648E-04	2.463E-04	2.298E-04	2.147E-04	2.012E-04	1.889E-04	1.777E-04
TOTAL LESS NOBLES	1.771E-02	3.211E-04	2.972E-04	2.763E-04	2.575E-04	2.408E-04	2.255E-04	2.118E-04	1.994E-04	1.879E-04

ISOTOPE SELECTION DATA

ISOTOPES CONSIDERED ARE ALL 1.000E 00 VALUES REPRESENT A WEIGHTING FACTOR

SHIELD COMPOSITION GR/CC	1	2	3	4	5
AIR	0.	1.293E-03	0.	0.	0.
ZR	3.400E-02	0.	0.	0.	0.
URANIUM	4.344E 00	0.	0.	0.	0.
LEAD	0.	0.	0.	1.134E 01	0.
IRON	0.	0.	7.800E 00	0.	0.

MASS ABSORPTION COEFFICIENTS (LAST REGION IS AIR)

4.180E 02	4.425E-03	3.445E 02	8.201E 02	4.424E-03	0.
2.243E 02	6.543E-04	9.576E 01	5.415E 02	6.542E-04	0.
1.007E 02	3.504E-04	4.434E 01	1.928E 02	3.504E-04	0.
4.825E 01	2.715E-04	2.055E 01	9.202E 01	2.715E-04	0.
2.735E 01	2.405E-04	1.135E 01	5.262E 01	2.405E-04	0.
1.793E 01	2.247E-04	7.574E 00	3.489E 01	2.247E-04	0.
1.245E 01	2.137E-04	5.405E 00	2.419E 01	2.137E-04	0.
8.687E 00	2.049E-04	3.918E 00	2.507E 01	2.049E-04	0.
6.568E 00	1.985E-04	3.111E 00	2.853E 01	1.985E-04	0.
9.205E 00	1.725E-04	1.591E 00	1.564E 01	1.725E-04	0.
3.123E 00	1.474E-04	1.069E 00	6.339E 00	1.474E-04	0.
1.690E 00	1.312E-04	7.784E-01	3.476E 00	1.312E-04	0.
9.913E-01	1.183E-04	6.825E-01	2.013E 00	1.183E-04	0.
5.977E-01	1.118E-04	5.616E-01	1.452E 00	1.118E-04	0.
4.344E-01	8.986E-05	4.969E-01	9.923E-01	8.986E-05	0.
3.560E-01	8.211E-05	4.586E-01	8.233E-01	8.210E-05	0.
2.929E-01	7.409E-05	4.001E-01	7.008E-01	7.408E-05	0.
2.449E-01	6.659E-05	3.666E-01	6.056E-01	6.658E-05	0.
2.252E-01	6.181E-05	3.479E-01	5.534E-01	6.180E-05	0.
2.113E-01	5.818E-05	3.237E-01	5.250E-01	5.818E-05	0.
2.021E-01	5.495E-05	3.136E-01	5.024E-01	5.495E-05	0.
1.968E-01	5.263E-05	2.972E-01	4.854E-01	5.262E-05	0.
1.929E-01	5.004E-05	2.948E-01	4.751E-01	5.004E-05	0.
1.907E-01	4.784E-05	2.855E-01	4.683E-01	4.784E-05	0.
1.889E-01	4.383E-05	2.769E-01	4.661E-01	4.383E-05	0.

GAMMA ATTENUATION CALCULATION TOP OF GE2000, NORMAL FUEL CYL AT SIDE OF LINER, SURFACE.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 2.372E 02 CM. VOL.=8.058E 03 CC

LENGTH = 1.143E 02 CM RADIUS = 4.737E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	1.510E-34	2.612E-39
3	4.777E 11	3.500E-02	7.097E-35	0.
4	6.210E 12	4.500E-02	1.235E-33	4.050E-39
5	1.617E 10	5.500E-02	4.055E-36	0.
6	9.120E 08	6.500E-02	2.767E-37	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	8.317E-33	1.345E-38
9	9.592E 10	9.500E-02	4.551E-35	0.
10	1.606E 14	1.500E-01	6.214E-27	1.074E-32
11	9.590E 12	2.500E-01	2.636E-30	5.167E-36
12	8.194E 11	3.500E-01	6.770E-32	1.395E-37
13	2.651E 14	4.750E-01	4.464E-16	9.106E-22
14	6.571E 14	6.500E-01	1.896E-09	3.944E-15
15	1.030E 15	8.250E-01	3.966E-04	7.932E-10
16	1.029E 13	1.000E 00	3.786E-04	7.307E-10
17	5.039E 12	1.225E 00	8.219E-03	1.512E-08
18	8.363E 12	1.475E 00	2.368E-01	4.168E-07
19	6.630E 10	1.700E 00	9.390E-03	1.606E-08
20	2.127E 10	1.900E 00	9.915E-03	1.646E-08
21	6.485E 12	2.100E 00	6.596E 00	1.055E-05
22	5.430E 11	2.300E 00	1.119E 00	1.723E-06
23	7.741E 10	2.500E 00	2.082E-01	3.165E-07
24	2.055E 00	2.700E 00	8.148E-12	1.206E-17
25	2.838E 09	3.000E 00	1.556E-02	2.226E-08
TOTAL	2.183E 15		8.204E 00	1.308E-05

GAMMA ATTENUATION CALCULATION TOP OF GE2000, NORMAL FUEL CYL AT SIDE OF LINER, 1 METER.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 3.372E 02 CM. VOL.=8.058E 03 CC

LENGTH = 1.143E 02 CM RADIUS = 4.737E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	5.887E-35	0.
3	4.777E 11	3.500E-02	2.767E-35	0.
4	6.210E 12	4.500E-02	4.815E-34	1.579E-39
5	1.617E 10	5.500E-02	1.581E-36	0.
6	9.120E 08	6.500E-02	1.079E-37	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	3.243E-33	5.244E-39
9	9.592E 10	9.500E-02	1.775E-35	0.
10	1.606E 14	1.500E-01	2.953E-27	5.103E-33
11	9.590E 12	2.500E-01	1.207E-30	2.367E-36
12	8.194E 11	3.500E-01	2.986E-32	6.151E-38
13	2.651E 14	4.750E-01	1.362E-16	2.778E-22
14	6.571E 14	6.500E-01	5.786E-10	1.203E-15
15	1.030E 15	8.250E-01	1.215E-04	2.430E-10
16	1.029E 13	1.000E 00	1.164E-04	2.247E-10
17	5.039E 12	1.225E 00	2.541E-03	4.676E-09
18	8.363E 12	1.475E 00	7.365E-02	1.296E-07
19	6.630E 10	1.700E 00	2.930E-03	5.010E-09
20	2.127E 10	1.900E 00	3.103E-03	5.150E-09
21	6.485E 12	2.100E 00	2.068E 00	3.309E-06
22	5.430E 11	2.300E 00	3.514E-01	5.411E-07
23	7.741E 10	2.500E 00	6.545E-02	9.949E-08
24	2.055E 00	2.700E 00	2.563E-12	3.793E-18
25	2.838E 09	3.000E 00	4.902E-03	7.009E-09
TOTAL	2.183E 15		2.573E 00	4.102E-06

GAMMA ATTENUATION CALCULATION TOP OF GE2000, NORMAL FUEL CYL AT SIDE OF LINER, 2 METERS.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 4.372E 02 CM. VOL.=8.058E 03 CC

LENGTH = 1.143E 02 CM RADIUS = 4.737E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	3.143E-35	0.
3	4.777E 11	3.500E-02	1.478E-35	0.
4	6.210E 12	4.500E-02	2.571E-34	0.
5	1.617E 10	5.500E-02	8.443E-37	0.
6	9.120E 08	6.500E-02	5.761E-38	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	1.732E-33	2.800E-39
9	9.592E 10	9.500E-02	9.475E-36	0.
10	1.606E 14	1.500E-01	1.759E-27	3.039E-33
11	9.590E 12	2.500E-01	6.997E-31	1.371E-36
12	8.194E 11	3.500E-01	1.697E-32	3.497E-38
13	2.651E 14	4.750E-01	6.442E-17	1.314E-22
14	6.571E 14	6.500E-01	2.737E-10	5.693E-16
15	1.030E 15	8.250E-01	5.765E-05	1.153E-10
16	1.029E 13	1.000E 00	5.533E-05	1.068E-10
17	5.039E 12	1.225E 00	1.210E-03	2.227E-09
18	8.363E 12	1.475E 00	3.517E-02	6.189E-08
18	6.630E 10	1.700E 00	1.401E-03	2.396E-09
20	2.127E 10	1.900E 00	1.486E-03	2.466E-09
21	6.485E 12	2.100E 00	9.914E-01	1.586E-06
22	5.430E 11	2.300E 00	1.685E-01	2.595E-07
23	7.741E 10	2.500E 00	3.141E-02	4.775E-08
24	2.055E 00	2.700E 00	1.231E-12	1.821E-18
25	2.838E 09	3.000E 00	2.355E-03	3.368E-09
TOTAL	2.183E 15		1.233E 00	1.966E-06

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000 CASK, NORMAL FUEL CYL AT SIDE OF LINER, SURFACE.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 1.700E 02 CM. VOL.=8.058E 03 CC

LENGTH = 1.143E 02 CM RADIUS = 4.737E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	4.565E-34	7.898E-39
3	4.777E 11	3.500E-02	2.146E-34	0.
4	6.210E 12	4.500E-02	3.733E-33	1.225E-36
5	1.617E 10	5.500E-02	1.226E-35	0.
6	9.120E 06	6.500E-02	8.367E-37	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	2.515E-32	4.067E-38
9	9.592E 10	9.500E-02	1.376E-34	0.
10	1.606E 14	1.500E-01	1.136E-27	1.963E-33
11	9.590E 12	2.500E-01	2.808E-20	5.504E-26
12	8.194E 11	3.500E-01	2.134E-11	4.395E-17
13	2.651E 14	4.750E-01	5.391E-04	1.100E-09
14	6.571E 14	6.500E-01	8.611E-01	1.791E-06
15	1.030E 15	8.250E-01	1.903E 02	3.805E-04
16	1.029E 13	1.000E 00	1.724E 01	3.327E-05
17	5.039E 12	1.225E 00	7.909E 01	1.455E-04
18	8.363E 12	1.475E 00	6.407E 02	1.128E-03
19	6.630E 10	1.700E 00	1.263E 01	2.160E-05
20	2.127E 10	1.900E 00	9.713E 00	1.612E-05
21	6.485E 12	2.100E 00	4.781E 03	7.649E-03
22	5.430E 11	2.300E 00	6.856E 02	1.056E-03
23	7.741E 10	2.500E 00	1.111E 02	1.689E-04
24	2.055E 00	2.700E 00	4.091E-09	6.055E-15
25	2.838E 09	3.000E 00	7.669E 00	1.097E-05
TOTAL	2.183E 15		6.536E 03	1.061E-02

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000 CASK, NORMAL FUEL CYL AT SIDE OF LINER, 1 METER.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 2.700E 02 CM. VOL.=8.058E 03 CC

LENGTH = 1.143E 02 CM RADIUS = 4.737E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	1.048E-34	1.814E-39
3	4.777E 11	3.500E-02	4.929E-35	0.
4	6.210E 12	4.500E-02	8.574E-34	2.812E-39
5	1.617E 10	5.500E-02	2.816E-36	0.
6	9.120E 08	6.500E-02	1.922E-37	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	5.776E-33	9.340E-39
9	9.592E 10	9.500E-02	3.160E-35	0.
10	1.606E 14	1.500E-01	4.258E-28	7.358E-34
11	9.590E 12	2.500E-01	4.044E-21	7.926E-27
12	8.194E 11	3.500E-01	2.930E-12	6.036E-18
13	2.651E 14	4.750E-01	7.269E-05	1.483E-10
14	6.571E 14	6.500E-01	1.170E-01	2.433E-07
15	1.030E 15	8.250E-01	2.618E 01	5.237E-05
16	1.029E 13	1.000E 00	2.398E 00	4.628E-06
17	5.039E 12	1.225E 00	1.114E 01	2.050E-05
18	8.363E 12	1.475E 00	9.150E 01	1.610E-04
19	6.630E 10	1.700E 00	1.816E 00	3.106E-06
20	2.127E 10	1.900E 00	1.405E 00	2.333E-06
21	6.485E 12	2.100E 00	6.950E 02	1.112E-03
22	5.430E 11	2.300E 00	9.993E 01	1.539E-04
23	7.741E 10	2.500E 00	1.623E 01	2.467E-05
24	2.055E 00	2.700E 00	5.985E-10	8.857E-16
25	2.838E 09	3.000E 00	1.124E 00	1.607E-06
TOTAL	2.183E 15		9.468E 02	1.536E-03

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000 CASK, NORMAL FUEL CYL AT SIDE OF LINER, 2 METERS.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 3.700E 02 CM. VOL.=8.058E 03 CC

LENGTH = 1.143E 02 CM RADIUS = 4.737E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0
2	1.483E 12	2.500E-02	4.678E-35	0
3	4.777E 11	3.500E-02	2.199E-35	0
4	6.210E 12	4.500E-02	3.826E-34	0
5	1.617E 10	5.500E-02	1.257E-36	0.
6	9.120E 08	6.500E-02	8.574E-38	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	2.577E-33	4.168E-39
9	9.592E 10	9.500E-02	1.410E-35	0.
10	1.606E 14	1.500E-01	2.218E-28	3.833E-34
11	9.590E 12	2.500E-01	1.477E-21	2.895E-27
12	8.194E 11	3.500E-01	1.073E-12	2.210E-18
13	2.651E 14	4.750E-01	2.673E-05	5.453E-11
14	6.571E 14	6.500E-01	4.316E-02	8.977E-08
15	1.030E 15	8.250E-01	9.712E 00	1.942E-05
16	1.029E 13	1.000E 00	8.924E-01	1.722E-06
17	5.039E 12	1.225E 00	4.165E 00	7.664E-06
18	8.363E 12	1.475E 00	3.437E 01	6.049E-05
19	6.630E 10	1.700E 00	6.841E-01	1.170E-06
20	2.127E 10	1.900E 00	5.306E-01	8.808E-07
21	6.485E 12	2.100E 00	2.628E 02	4.205E-04
22	5.430E 11	2.300E 00	3.783E 01	5.826E-05
23	7.741E 10	2.500E 00	6.149E 00	9.346E-06
24	2.055E 00	2.700E 00	2.269E-10	3.358E-16
25	2.838E 09	3.000E 00	4.266E-01	6.100E-07
TOTAL	2.183E 15		3.576E 02	5.801E-04

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL FUEL CYL AT SIDE OF LINER, SURFACE.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 4.061E 01 CM. LENGTH 1.143E 02 CM. VOL.=8.058E 03 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.1580E 00

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 4.737E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	1.860E-33	3.219E-38
3	4.777E 11	3.500E-02	8.746E-34	5.554E-39
4	6.210E 12	4.500E-02	1.521E-32	4.990E-38
5	1.617E 10	5.500E-02	4.997E-35	0.
6	9.120E 08	6.500E-02	3.410E-36	0.
7	8.036E 05	7.500E-02	3.548E-39	0.
8	2.003E 13	8.500E-02	1.025E-31	1.657E-37
9	9.592E 10	9.500E-02	5.608E-34	0.
10	1.606E 14	1.500E-01	5.530E-29	9.555E-35
11	9.590E 12	2.500E-01	1.407E-30	2.759E-36
12	8.194E 11	3.500E-01	1.842E-22	3.794E-28
13	2.651E 14	4.750E-01	6.415E-09	1.309E-14
14	6.571E 14	6.500E-01	8.834E-04	1.837E-09
15	1.030E 15	8.250E-01	1.148E 01	2.296E-05
16	1.029E 13	1.000E 00	3.912E 00	7.551E-06
17	5.039E 12	1.225E 00	3.502E 01	6.444E-05
18	8.363E 12	1.475E 00	5.273E 02	9.280E-04
19	6.630E 10	1.700E 00	1.458E 01	2.493E-05
20	2.127E 10	1.900E 00	1.186E 01	1.968E-05
21	6.485E 12	2.100E 00	6.637E 03	1.062E-02
22	5.430E 11	2.300E 00	9.682E 02	1.491E-03
23	7.741E 10	2.500E 00	1.690E 02	2.568E-04
24	2.055E 00	2.700E 00	6.128E-09	9.070E-15
25	2.838E 09	3.000E 00	1.098E 01	1.570E-05
TOTAL	2.183E 15		8.390E 03	1.345E-02

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL FUEL CYL AT SIDE OF LINER, 1 METER.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 1.406E 02 CM. LENGTH 1.143E 02 CM. VOL.=8.058E 03 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.1580E 00

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 4.737E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	2.170E-34	3.753E-39
3	4.777E 11	3.500E-02	1.020E-34	0.
4	6.210E 12	4.500E-02	1.774E-33	5.820E-39
5	1.617E 10	5.500E-02	5.827E-36	0.
6	9.120E 08	6.500E-02	3.976E-37	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	6.500E-02	1.195E-32	1.933E-38
9	9.592E 10	9.500E-02	6.540E-35	0.
10	1.606E 14	1.500E-01	3.082E-30	5.325E-36
11	9.590E 12	2.500E-01	1.098E-31	2.153E-37
12	8.194E 11	3.500E-01	5.357E-23	1.104E-26
13	2.651E 14	4.750E-01	1.842E-09	3.758E-15
14	6.571E 14	6.500E-01	2.490E-04	5.179E-10
15	1.030E 15	8.250E-01	3.130E 00	6.259E-06
16	1.029E 13	1.000E 00	1.042E 00	2.011E-06
17	5.039E 12	1.225E 00	9.071E 00	1.669E-05
18	8.363E 12	1.475E 00	1.329E 62	2.340E-04
19	6.630E 10	1.700E 00	3.610E 00	6.174E-06
20	2.127E 10	1.900E 00	2.891E 00	4.798E-06
21	6.485E 12	2.100E 00	1.601E 03	2.562E-03
22	5.430E 11	2.300E 00	2.310E 02	3.558E-04
23	7.741E 10	2.500E 00	4.015E 01	6.103E-05
24	2.055E 00	2.700E 00	1.448E-09	2.143E-15
25	2.838E 09	3.000E 00	2.580E 00	3.690E-06
TOTAL	2.183E 15		2.027E 03	3.252E-03

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL FUEL CYL AT SIDE OF LINER, 2 meters.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 2.406E 02 CM. LENGTH 1.143E 02 CM. VOL.=8.058E 03 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.1580E 00

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 4.737E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	7.684E-35	0.
3	4.777E 11	3.500E-02	3.612E-35	0.
4	6.210E 12	4.500E-02	6.284E-34	2.061E-39
5	1.617E 10	5.500E-02	2.064E-36	0.
6	9.120E 08	6.500E-02	1.408E-37	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	4.233E-33	6.845E-39
9	9.592E 10	9.500E-02	2.316E-35	0.
10	1.606E 14	1.500E-01	1.039E-30	1.795E-36
11	9.590E 12	2.500E-01	3.775E-32	7.399E-38
12	8.194E 11	3.500E-01	2.931E-23	6.038E-29
13	2.651E 14	4.750E-01	9.345E-10	1.906E-15
14	6.571E 14	6.500E-01	1.196E-04	2.487E-10
15	1.030E 15	8.250E-01	1.416E 00	2.832E-06
16	1.029E 13	1.000E 00	4.589E-01	8.858E-07
17	5.039E 12	1.225E 00	3.891E 00	7.160E-06
18	8.363E 12	1.475E 00	5.589E 01	9.837E-05
19	6.630E 10	1.700E 00	1.500E 00	2.566E-06
20	2.127E 10	1.900E 00	1.190E 00	1.976E-06
21	6.485E 12	2.100E 00	6.555E 02	1.049E-03
22	5.430E 11	2.300E 00	9.408E 01	1.449E-04
23	7.741E 10	2.500E 00	1.632E 01	2.480E-05
24	2.055E 00	2.700E 00	5.866E-10	8.682E-16
25	2.838E 09	3.000E 00	1.043E 00	1.492E-06
TOTAL	2.183E 15		8.313E 02	1.334E-03

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT FUEL SPHERE AT SIDE OF LINER, SURFACE.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 4.131E 01 CM. VOL.=6.729E 02 CC

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 5.436E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	0.	0.
3	4.777E 11	3.500E-02	0.	0.
4	6.210E 12	4.500E-02	0.	0.
5	1.617E 10	5.500E-02	0.	0.
6	9.120E 08	6.500E-02	0.	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	0.	0.
9	9.592E 10	9.500E-02	0.	0.
10	1.606E 14	1.500E-01	0.	0.
11	9.590E 12	2.500E-01	0.	0.
12	8.194E 11	3.500E-01	9.376E-22	1.931E-27
13	2.651E 14	4.750E-01	2.911E-08	5.939E-14
14	6.571E 14	6.500E-01	3.756E-03	7.812E-09
15	1.030E 15	8.250E-01	4.438E 01	8.877E-05
16	1.029E 13	1.000E 00	1.443E 01	2.786E-05
17	5.039E 12	1.225E 00	1.239E 02	2.279E-04
18	8.363E 12	1.475E 00	1.790E 03	3.150E-03
19	6.630E 10	1.700E 00	4.821E 01	8.244E-05
20	2.127E 10	1.900E 00	3.849E 01	6.390E-05
21	6.485E 12	2.100E 00	2.124E 04	3.399E-02
22	5.430E 11	2.300E 00	3.061E 03	4.715E-03
23	7.741E 10	2.500E 00	5.309E 02	8.070E-04
24	2.055E 00	2.700E 00	1.914E-08	2.832E-14
25	2.838E 09	3.000E 00	3.411E 01	4.878E-05
TOTAL	2.183E 15		2.693E 04	4.320E-02

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT FUEL SPHERE AT SIDE OF CAVITY, 1 METER.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 1.413E 02 CM. VOL.=6.729E 02 CC

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 5.436E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	0.	0.
3	4.777E 11	3.500E-02	0.	0.
4	6.210E 12	4.500E-02	0.	0.
5	1.617E 10	5.500E-02	0.	0.
6	9.120E 08	6.500E-02	0.	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	0.	0.
9	9.592E 10	9.500E-02	0.	0.
10	1.606E 14	1.500E-01	0.	0.
11	9.590E 12	2.500E-01	0.	0.
12	8.194E 11	3.500E-01	7.896E-23	1.627E-28
13	2.651E 14	4.750E-01	2.454E-09	5.006E-15
14	6.571E 14	6.500E-01	3.168E-04	6.588E-10
15	1.030E 15	8.250E-01	3.751E 00	7.502E-06
16	1.029E 13	1.000E 00	1.221E 00	2.356E-06
17	5.039E 12	1.225E 00	1.048E 01	1.929E-05
18	8.363E 12	1.475E 00	1.516E 02	2.668E-04
19	6.630E 10	1.700E 00	4.085E 00	6.985E-06
20	2.127E 10	1.900E 00	3.263E 00	5.417E-06
21	6.485E 12	2.100E 00	1.801E 03	2.882E-03
22	5.430E 11	2.300E 00	2.597E 02	3.999E-04
23	7.741E 10	2.500E 00	4.504E 01	6.846E-05
24	2.055E 00	2.700E 00	1.624E-09	2.403E-15
25	2.838E 09	3.000E 00	2.896E 00	4.141E-06
TOTAL	2.183E 15		2.283E 03	3.663E-03

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT FUEL SPHERE AT SIDE OF CAVITY, 2 METERS.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 2.413E 02 CM. VOL.=6.729E 02 CC

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 5.436E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	0.	0.
3	4.777E 11	3.500E-02	0.	0.
4	6.210E 12	4.500E-02	0.	0.
5	1.617E 10	5.500E-02	0.	0.
6	9.120E 08	6.500E-02	0.	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	0.	0.
9	9.592E 10	9.500E-02	0.	0.
10	1.606E 14	1.500E-01	0.	0.
11	9.590E 12	2.500E-01	0.	0.
12	8.194E 11	3.500E-01	2.673E-23	5.506E-29
13	2.651E 14	4.750E-01	8.319E-10	1.697E-15
14	6.571E 14	6.500E-01	1.074E-04	2.235E-10
15	1.030E 15	8.250E-01	1.275E 00	2.550E-06
16	1.029E 13	1.000E 00	4.152E 01	8.014E-07
17	5.039E 12	1.225E 00	3.569E 00	6.567E-06
18	8.363E 12	1.475E 00	5.165E 01	9.091E-05
19	6.630E 10	1.700E 00	1.393E 00	2.381E-06
20	2.127E 10	1.900E 00	1.113E 00	1.847E-06
21	6.485E 12	2.100E 00	6.145E 02	9.832E-04
22	5.430E 11	2.300E 00	8.861E 01	1.365E-04
23	7.741E 10	2.500E 00	1.537E 01	2.337E-05
24	2.055E 00	2.700E 00	5.543E-10	8.204E-16
25	2.838E 09	3.000E 00	9.889E-01	1.414E-06
TOTAL	2.183E 15		7.789E 02	1.250E-03

GAMMA ATTENUATION CALCULATION TOP OF GE2000, ACCIDENT FUEL SPHERE AT UPPER CORNER OF LINER, SURFACE.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 1.258E 02 CM. VOL.=6.729E 02 CC

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 5.436E 00 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	0.	0.
3	4.777E 11	3.500E-02	0.	0.
4	6.210E 12	4.500E-02	0.	0.
5	1.617E 10	5.500E-02	0.	0.
6	9.120E 08	6.500E-02	0.	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	6.500E-02	0.	0.
9	9.592E 10	9.500E-02	0.	0.
10	1.606E 14	1.500E-01	0.	0.
11	9.590E 12	2.500E-01	0.	0.
12	8.194E 11	3.500E-01	0.	0.
13	2.651E 14	4.750E-01	6.742E-15	1.375E-20
14	6.571E 14	6.500E-01	2.887E-08	6.005E-14
15	1.030E 15	8.250E-01	5.846E-03	1.169E-08
16	1.029E 13	1.000E 00	5.395E-03	1.041E-08
17	5.039E 12	1.225E 00	1.117E-01	2.055E-07
18	8.363E 12	1.475E 00	3.047E 00	5.363E-06
19	6.630E 10	1.700E 00	1.172E-01	2.005E-07
20	2.127E 10	1.900E 00	1.205E-01	2.000E-07
21	6.485E 12	2.100E 00	7.862E 01	1.258E-04
22	5.430E 11	2.300E 00	1.317E 01	2.028E-05
23	7.741E 10	2.500E 00	2.430E 00	3.694E-06
24	2.055E 00	2.700E 00	9.442E-11	1.397E-16
25	2.838E 09	3.000E 00	1.789E-01	2.558E-07
TOTAL	2.183E 15		9.780E 01	1.560E-04

GAMMA ATTENUATION CALCULATION TOP OF GE2000, ACCIDENT FUEL SPHERE AT UPPER CORNER OF LINER, 1 METER.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 2.258E 02 CM. VOL.=6.729E 02 CC

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 5.436E 00 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	0.	0.
3	4.777E 11	3.500E-02	0.	0.
4	6.210E 12	4.500E-02	0.	0.
5	1.617E 10	5.500E-02	0.	0.
6	9.120E 08	6.500E-02	0.	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	0.	0.
9	9.592E 10	9.500E-02	0.	0.
10	1.606E 14	1.500E-01	0.	0.
11	9.590E 12	2.500E-01	0.	0.
12	8.194E 11	3.500E-01	0.	0.
13	2.651E 14	4.750E-01	2.101E-15	4.286E-21
14	6.571E 14	6.500E-01	8.962E-09	1.864E-14
15	1.030E 15	8.250E-01	1.813E-03	3.625E-09
16	1.029E 13	1.000E 00	1.672E-03	3.226E-09
17	5.039E 12	1.225E 00	3.460E-02	6.366E-08
18	8.363E 12	1.475E 00	9.439E-01	1.661E-06
19	6.630E 10	1.700E 00	3.632E-02	6.210E-08
20	2.127E 10	1.900E 00	3.733E-02	6.196E-08
21	6.485E 12	2.100E 00	2.436E 01	3.898E-05
22	5.430E 11	2.300E 00	4.080E 00	6.294E-06
23	7.741E 10	2.500E 00	7.531E-01	1.145E-06
24	2.055E 00	2.700E 00	2.927E-11	4.332E-17
25	2.838E 09	3.000E 00	5.547E-02	7.933E-08
TOTAL	2.183E 15		3.031E 01	4.834E-05

GAMMA ATTENUATION CALCULATION TOP OF GE2000, ACCIDENT FUEL SPHERE AT UPPER CORNER OF LINER, 2 METERS.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 3.258E 02 CM. VOL.=6.729E 02 CC

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 5.436E 00 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	0.	0.
3	4.777E 11	3.500E-02	0.	0.
4	6.210E 12	4.500E-02	0.	0.
5	1.617E 10	5.500E-02	0.	0.
6	9.120E 08	6.500E-02	0.	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	6.500E-02	0.	0.
9	9.592E 10	9.500E-02	0.	0.
10	1.606E 14	1.500E-01	0.	0.
11	9.590E 12	2.500E-01	0.	0.
12	0.194E 11	3.500E-01	0.	0.
13	2.651E 14	4.750E-01	1.001E-15	2.043E-21
14	6.571E 14	6.500E-01	4.269E-09	8.880E-15
15	1.030E 15	8.250E-01	8.646E-04	1.729E-09
16	1.029E 13	1.000E 00	7.978E-04	1.540E-09
17	5.039E 12	1.225E 00	1.652E-02	3.040E-08
18	8.363E 12	1.475E 00	4.510E-01	7.937E-07
19	6.630E 10	1.700E 00	1.736E-02	2.968E-08
20	2.127E 10	1.900E 00	1.785E-02	2.963E-08
21	6.485E 12	2.100E 00	1.165E 01	1.864E-05
22	5.430E 11	2.300E 00	1.952E 00	3.006E-06
23	7.741E 10	2.500E 00	3.604E-01	5.477E-07
24	2.055E 00	2.700E 00	1.401E-11	2.073E-17
25	2.838E 09	3.000E 00	2.656E-02	3.798E-08
TOTAL	2.183E 15		1.449E 01	2.312E-05

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000, ACCIDENT FUEL SPHERE AT LOWER CORNER OF LINER, SURFACE.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 6.116E 01 CM. VOL.=6.729E 02 CC

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 5.436E 00 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	0.	0.
3	4.777E 11	3.500E-02	0.	0.
4	6.210E 12	4.500E-02	0.	0.
5	1.617E 10	5.500E-02	0.	0.
6	9.120E 08	6.500E-02	0.	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	0.	0.
9	9.592E 10	9.500E-02	0.	0.
10	1.606E 14	1.500E-01	0.	0.
11	9.590E 12	2.500E-01	2.047E-19	4.012E-25
12	8.194E 11	3.500E-01	2.452E-10	5.052E-16
13	2.651E 14	4.750E-01	7.244E-03	1.478E-08
14	6.571E 14	6.500E-01	1.185E 01	2.465E-05
15	1.030E 15	8.250E-01	2.573E 03	5.146E-03
16	1.029E 13	1.000E 00	2.276E 02	4.394E-04
17	5.039E 12	1.225E 00	1.008E 03	1.854E-03
18	8.363E 12	1.475E 00	7.819E 03	1.376E-02
19	6.630E 10	1.700E 00	1.504E 02	2.572E-04
20	2.127E 10	1.900E 00	1.131E 02	1.878E-04
21	6.485E 12	2.100E 00	5.481E 04	8.770E-02
22	5.430E 11	2.300E 00	7.776E 03	1.198E-02
23	7.741E 10	2.500E 00	1.252E 03	1.903E-03
24	2.055E 00	2.700E 00	4.583E-08	6.782E-14
25	2.838E 09	3.000E 00	8.536E 01	1.221E-04
TOTAL	2.183E 15		7.583E 04	1.234E-01

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000, ACCIDENT FUEL SPHERE AT LOWER CORNER OF LINER, 1 METER.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 1.612E 02 CM. VOL.=6.729E 02 CC

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 5.436E 00 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	0.	0.
3	4.777E 11	3.500E-02	0.	0.
4	6.210E 12	4.500E-02	0.	0.
5	1.617E 10	5.500E-02	0.	0.
6	9.120E 08	6.500E-02	0.	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	0.	0.
9	9.592E 10	9.500E-02	0.	0.
10	1.606E 14	1.500E-01	0.	0.
11	9.590E 12	2.500E-01	3.192E-20	6.257E-26
12	8.194E 11	3.500E-01	3.693E-11	7.608E-17
13	2.651E 14	4.750E-01	1.074E-03	2.190E-09
14	6.571E 14	6.500E-01	1.740E 00	3.619E-06
15	1.030E 15	8.250E-01	3.759E 02	7.518E-04
16	1.029E 13	1.000E 00	3.318E 01	6.404E-05
17	5.039E 12	1.225E 00	1.465E 02	2.696E-04
18	8.363E 12	1.475E 00	1.135E 03	1.998E-03
19	6.630E 10	1.700E 00	2.182E 01	3.731E-05
20	2.127E 10	1.900E 00	1.640E 01	2.722E-05
21	6.485E 12	2.100E 00	7.944E 03	1.271E-02
22	5.430E 11	2.300E 00	1.127E 03	1.735E-03
23	7.741E 10	2.500E 00	1.813E 02	2.757E-04
24	2.055E 00	2.700E 00	6.638E-09	9.824E-15
25	2.838E 09	3.000E 00	1.237E 01	1.768E-05
TOTAL	2.183E 15		1.100E 04	1.789E-02

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000, ACCIDENT FUEL SPHERE AT LOWER CORNER OF LINER, 2 METERS.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 2.612E 02 CM. VOL.=6.729E 02 CC

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 5.436E 00 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	0.	0.
3	4.777E 11	3.500E-02	0.	0.
4	6.210E 12	4.500E-02	0.	0.
5	1.617E 10	5.500E-02	0.	0.
6	9.120E 08	6.500E-02	0.	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	0.	0.
9	9.592E 10	9.500E-02	0.	0.
10	1.606E 14	1.500E-01	0.	0.
11	9.590E 12	2.500E-01	1.210E-20	2.372E-26
12	8.194E 11	3.500E-01	1.397E-11	2.877E-17
13	2.651E 14	4.750E-01	4.058E-04	8.279E-10
14	6.571E 14	6.500E-01	6.574E-01	1.367E-06
15	1.030E 15	8.250E-01	1.423E 02	2.845E-04
16	1.029E 13	1.000E 00	1.256E 01	2.425E-05
17	5.039E 12	1.225E 00	5.551E 01	1.021E-04
18	8.363E 12	1.475E 00	4.302E 02	7.572E-04
19	6.630E 10	1.700E 00	8.273E 00	1.415E-05
20	2.127E 10	1.900E 00	6.220E 00	1.033E-05
21	6.485E 12	2.100E 00	3.014E 03	4.822E-03
22	5.430E 11	2.300E 00	4.274E 02	6.583E-04
23	7.741E 10	2.500E 00	6.882E 01	1.046E-04
24	2.055E 00	2.700E 00	2.520E-09	3.729E-15
25	2.838E 09	3.000E 00	4.695E 00	6.714E-06
TOTAL	2.183E 15		4.170E 03	6.786E-03

GAMMA ATTENUATION CALCULATION SIDE OF 2000, NORMAL FUEL CYL AT SIDE OF LINER, 21 FEET (CAB).

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 6.801E 02 CM. LENGTH 1.143E 02 CM. VOL.=8.058E 03 CC

INTEGRATION SPECS NTHETA = 11 NPSI = 31 DELR =0.1580E 00

REACTOR DATA GE2000 MFP INV., 45 GWD/T, 1750 GMS 1574.8 MWD IN 1879.0 DAYS 120.0 DAYS AFTER SHUTDOWN

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 4.737E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	4.077E-10	1.500E-02	0.	0.
2	1.483E 12	2.500E-02	9.653E-36	0.
3	4.777E 11	3.500E-02	4.539E-36	0.
4	6.210E 12	4.500E-02	7.896E-35	0.
5	1.617E 10	5.500E-02	2.593E-37	0.
6	9.120E 06	6.500E-02	1.770E-38	0.
7	8.036E 05	7.500E-02	0.	0.
8	2.003E 13	8.500E-02	5.319E-34	0.
9	9.592E 10	9.500E-02	2.910E-36	0.
10	1.606E 14	1.500E-01	1.276E-31	2.205E-37
11	9.590E 12	2.500E-01	4.679E-33	9.171E-39
12	8.194E 11	3.500E-01	5.205E-24	1.072E-29
13	2.651E 14	4.750E-01	1.469E-10	2.997E-16
14	6.571E 14	6.500E-01	1.774E-05	3.690E-11
15	1.030E 15	8.250E-01	2.010E-01	4.021E-07
16	1.029E 13	1.000E 00	6.396E-02	1.235E-07
17	5.039E 12	1.225E 00	5.341E-01	9.828E-07
18	8.363E 12	1.475E 00	7.588E 00	1.336E-05
19	6.630E 10	1.700E 00	2.025E-01	3.462E-07
20	2.127E 10	1.900E 00	1.599E-01	2.655E-07
21	6.485E 12	2.100E 00	8.784E 01	1.405E-04
22	5.430E 11	2.300E 00	1.257E 01	1.936E-05
23	7.741E 10	2.500E 00	2.180E 00	3.313E-06
24	2.055E 00	2.700E 00	7.828E-11	1.158E-16
25	2.838E 09	3.000E 00	1.392E-01	1.991E-07
TOTAL	2.182E 15		1.115E 02	1.789E-04

ISOTOPE SELECTION DATA

ISOTOPES CONSIDERED ARE VALUES SPECIFY CURIES

C02 60
0.100E 01

SHIELD COMPOSITION GR/CC	1	2	3	4	
AIR	0.	1.293E-03	0.	0.	0.
LEAD	0.	0.	0.	1.134E 01	0.
IRON	6.910E 00	0.	7.800E 00	0.	0.

MASS ABSORPTION COEFFICIENTS (LAST REGION IS AIR)

3.052E 02	4.425E-03	3.445E 02	8.201E 02	4.424E-03	0.
8.493E 01	6.543E-04	9.576E 01	5.415E 02	6.542E-04	0.
3.928E 01	3.504E-04	4.434E 01	1.928E 02	3.504E-04	0.
1.821E 01	2.715E-04	2.055E 01	9.202E 01	2.715E-04	0.
1.005E 01	2.405E-04	1.135E 01	5.262E 01	2.405E-04	0.
6.710E 00	2.247E-04	7.574E 00	3.489E 01	2.247E-04	0.
4.789E 00	2.137E-04	5.405E 00	2.419E 01	2.137E-04	0.
3.471E 00	2.049E-04	3.918E 00	2.507E 01	2.049E-04	0.
2.756E 00	1.985E-04	3.111E 00	2.853E 01	1.985E-04	0.
1.410E 00	1.725E-04	1.591E 00	1.564E 01	1.725E-04	0.
9.467E-01	1.474E-04	1.069E 00	6.339E 00	1.474E-04	0.
6.896E-01	1.312E-04	7.784E-01	3.476E 00	1.312E-04	0.
6.046E-01	1.183E-04	6.685E-01	2.013E 00	1.183E-04	0.
4.975E-01	1.118E-04	5.616E-01	1.452E 00	1.118E-04	0.
4.402E-01	8.986E-05	4.969E-01	9.923E-01	8.986E-05	0.
4.063E-01	8.211E-05	4.586E-01	8.233E-01	8.210E-05	0.
3.545E-01	7.409E-05	4.001E-01	7.008E-01	7.408E-05	0.
3.248E-01	6.659E-05	3.666E-01	6.056E-01	6.658E-05	0.
3.082E-01	6.181E-05	3.479E-01	5.534E-01	6.180E-05	0.
2.868E-01	5.818E-05	3.237E-01	5.250E-01	5.818E-05	0.
2.778E-01	5.495E-05	3.136E-01	5.024E-01	5.495E-05	0.
2.633E-01	5.263E-05	2.972E-01	4.854E-01	5.262E-05	0.
2.612E-01	5.004E-05	2.948E-01	4.751E-01	5.004E-05	0.
2.529E-01	4.784E-05	2.855E-01	4.683E-01	4.784E-05	0.
2.453E-01	4.303E-05	2.769E-01	4.661E-01	4.383E-05	0.

GAMMA ATTENUATION CALCULATION TOP OF GE2000, NORMAL, 1 CURIE CO60 CYL AT SIDE OF LINER, SURFACE.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 2.372E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	9.925E-05	1.826E-10
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		9.925E-05	1.826E-10

GAMMA ATTENUATION CALCULATION TOP OF GE2000, NORMAL, 1 CURIE CO60 CYL AT SIDE OF LINER, 1 METER.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 3.372E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	3.081E-05	5.669E-11
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		3.081E-05	5.669E-11

GAMMA ATTENUATION CALCULATION   TOP OF GE2000, NORMAL, 1 CURIE CO60 CYL AT SIDE OF LINER, 2 METERS.

END OF CYL. SOURCE   SLAB SHIELDS   DIST TO DETECTOR 4.372E 02 CM.   VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM   RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31   NPSI = 0   DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS   1.143E 02   1.000E-02   1.286E 01   2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	1.468E-05	2.701E-11
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		1.468E-05	2.701E-11

GAMMA ATTENUATION CALCULATION   BOTTOM OF GE2000, NORMAL, 1 CURIE CO60 CYL AT SIDE OF LINER, SURFACE.

END OF CYL. SOURCE   SLAB SHIELDS   DIST TO DETECTOR 1.700E 02 CM.   VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM   RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31   NPSI =   0   DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS   1.143E 02   1.000E-02   2.095E 01   5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	9.420E-01	1.733E-06
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		9.420E-01	1.733E-06

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000, NORMAL, 1 CURIE CO60 CYL AT SIDE OF LINER, 1 METER.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 2.700E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	1.353E-01	2.489E-07
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		1.353E-01	2.489E-07

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000, NORMAL, 1 CURIE CO60 CYL AT SIDE OF LINER, 2 METERS.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 3.700E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	5.055E-02	9.302E-08
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		5.055E-02	9.302E-08

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL, 1 CURIE CO60 CYL AT SIDE OF LINER, SURFACE.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 3.569E 01 CM. LENGTH 1.143E 02 CM. VOL.=2.155E 04 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.2490E 00

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 7.747E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	2.879E-01	5.297E-07
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		2.879E-01	5.297E-07

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL, 1 CURIE CO60 CYL AT SIDE OF LINER, 1 METER.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 1.357E 02 CM. LENGTH 1.143E 02 CM. VOL.=2.155E 04 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.2490E 00

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 7.747E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	6.935E-02	1.276E-07
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		6.935E-02	1.276E-07

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL, 1 CURIE CO60 CYL AT SIDE OF LINER, 2 METERS.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 2.357E 02 CM. LENGTH 1.143E 02 CM. VOL.=2.155E 04 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.2490E 00

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 7.747E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	2.948E-02	5.425E-08
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		2.948E-02	5.425E-08

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT, 1 CURIE CO60 SPHERE AT SIDE OF LINER, SURFACE.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 5.315E 01 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	1.773E-01	3.263E-07
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		1.773E-01	3.263E-07

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT, 1 CURIE CO60 SPHERE AT SIDE OF LINER, 1 METER.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 1.531E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	2.096E-02	3.857E-08
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		2.096E-02	3.857E-08

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT, 1 CURIE CO60 SPHERE AT SIDE OF LINER, 2 METERS.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 2.531E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	7.610E-03	1.400E-08
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		7.610E-03	1.400E-08

GAMMA ATTENUATION CALCULATION TOP OF GE2000, ACCIDENT, 1 CI CO60 SPHERE AT TOP CORNER LINER, SURFACE.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 1.376E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	3.998E-04	7.356E-10
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		3.998E-04	7.356E-10

GAMMA ATTENUATION CALCULATION TOP OF GE2000, ACCIDENT, 1 CI CO60 SPHERE AT TOP CORNER LINER, 1 METER.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 2.376E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	1.396E-04	2.568E-10
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		1.396E-04	2.568E-10

GAMMA ATTENUATION CALCULATION TOP OF GE2000, ACCIDENT, 1 CI CO60 SPHERE AT TOP CORNER LINER, 2 METERS.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 3.376E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	6.949E-05	1.279E-10
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		6.949E-05	1.279E-10

GAMMA ATTENUATION CALCULATION BOTTOM, ACCIDENT, 1 CI CO60 SPHERE AT BOTTOM CORNER LINER, SURFACE.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 7.300E 01 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	2.846E 00	5.236E-06
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		2.846E 00	5.236E-06

GAMMA ATTENUATION CALCULATION BOTTOM, ACCIDENT, 1 CI CO60 SPHERE AT BOTTOM CORNER LINER, 1 METER.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 1.730E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	5.682E-01	1.045E-06
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		5.682E-01	1.045E-06

GAMMA ATTENUATION CALCULATION BOTTOM, ACCIDENT, 1 CI CO60 SPHERE AT BOTTOM CORNER LINER, 2 METERS.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 2.730E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	6.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	0.	6.500E-01	0.	0.
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	7.400E 10	1.225E 00	2.302E-01	4.235E-07
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	7.400E 10		2.302E-01	4.235E-07

ISOTOPE SELECTION DATA

ISOTOPES CONSIDERED ARE

VALUES SPECIFY CURIES

CS2 137
0.100E 01

SHIELD COMPOSITION GR/CC	1	2	3	4	5	
AIR	0.	1.293E-03	0.	0.	0.	
LEAD	0.	0.	0.	1.134E 01	0.	
IRON	6.910E 00	0.	7.800E 00	0.	0.	
MASS ABSORPTION COEFFICIENTS (LAST REGION IS AIR)						
	3.052E 02	4.425E-03	3.445E 02	8.201E 02	4.424E-03	0.
	8.483E 01	6.543E-04	9.576E 01	5.415E 02	6.542E-04	0.
	3.928E 01	3.504E-04	4.434E 01	1.926E 02	3.504E-04	0.
	1.821E 01	2.715E-04	2.055E 01	9.202E 01	2.715E-04	0.
	1.005E 01	2.405E-04	1.135E 01	5.262E 01	2.405E-04	0.
	6.710E 00	2.247E-04	7.574E 00	3.489E 01	2.247E-04	0.
	4.789E 00	2.137E-04	5.405E 00	2.419E 01	2.137E-04	0.
	3.471E 00	2.049E-04	3.918E 00	2.507E 01	2.049E-04	0.
	2.756E 00	1.905E-04	3.111E 00	2.853E 01	1.985E-04	0.
	1.410E 00	1.725E-04	1.591E 00	1.564E 01	1.725E-04	0.
	9.467E-01	1.474E-04	1.069E 00	6.339E 00	1.474E-04	0.
	6.896E-01	1.312E-04	7.784E-01	3.476E 00	1.312E-04	0.
	6.046E-01	1.183E-04	6.825E-01	2.013E 00	1.183E-04	0.
	4.975E-01	1.118E-04	5.616E-01	1.452E 00	1.118E-04	0.
	4.402E-01	8.986E-05	4.969E-01	9.923E-01	8.986E-05	0.
	4.063E-01	8.211E-05	4.586E-01	8.233E-01	8.210E-05	0.
	3.545E-01	7.409E-05	4.001E-01	7.008E-01	7.408E-05	0.
	3.248E-01	6.659E-05	3.666E-01	6.056E-01	6.658E-05	0.
	3.082E-01	6.181E-05	3.479E-01	5.534E-01	6.180E-05	0.
	2.868E-01	5.818E-05	3.237E-01	5.250E-01	5.818E-05	0.
	2.778E-01	5.495E-05	3.136E-01	5.024E-01	5.495E-05	0.
	2.633E-01	5.263E-05	2.972E-01	4.854E-01	5.262E-05	0.
	2.612E-01	5.004E-05	2.948E-01	4.751E-01	5.004E-05	0.
	2.529E-01	4.784E-05	2.855E-01	4.683E-01	4.784E-05	0.
	2.453E-01	4.303E-05	2.769E-01	4.661E-01	4.383E-05	0.

GAMMA ATTENUATION CALCULATION TOP OF GE2000, NORMAL, 1 CURIE CS137 CYL AT SIDE OF LINER, SURFACE.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 2.372E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	1.058E-13	2.201E-19
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		1.058E-13	2.201E-19

GAMMA ATTENUATION CALCULATION   TOP OF GE2000, NORMAL, 1 CURIE CS137 CYL AT SIDE OF LINER, 1 METER.

END OF CYL. SOURCE   SLAB SHIELDS   DIST TO DETECTOR 3.372E 02 CM.   VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM   RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA =   31   NPSI =   0   DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS   1.143E 02   1.000E-02   1.286E 01   2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	3.288E-14	6.840E-20
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		3.288E-14	6.840E-20

GAMMA ATTENUATION CALCULATION TOP OF GE2000, NORMAL, 1 CURIE CS137 CYL AT SIDE OF LINER, 2 METERS.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 4.372E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	1.562E-14	3.250E-20
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		1.562E-14	3.250E-20

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000, NORMAL, 1 CURIE CS137 CYL AT SIDE OF LINER, SURFACE.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 1.700E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.175E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	4.602E-05	9.572E-11
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		4.602E-05	9.572E-11

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000, NORMAL, 1 CURIE CS137 CYL AT SIDE OF LINER, 1 METER.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 2.700E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.175E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	6.633E-06	1.380E-11
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		6.633E-06	1.380E-11

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000, NORMAL, 1 CURIE CS137 CYL AT SIDE OF LINER, 2 METERS.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 3.700E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.175E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	2.464E-06	5.125E-12
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		2.464E-06	5.125E-12

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL, 1 CURIE CS137 CYL AT SIDE OF LINER, SURFACE.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 3.569E 01 CM. LENGTH 1.143E 02 CM. VOL.=2.155E 04 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.2490E 00

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 7.747E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	2.984E-08	6.206E-14
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		2.984E-08	6.206E-14

GAMMA ATTENUATION CALCULATION   SIDE OF GE2000, NORMAL, 1 CURIE CS137 CYL AT SIDE OF LINER, 1 METER.

CYLINDRICAL SOURCE   CYLINDRICAL SHIELDS   DIST TO DETECTOR 1.357E 02 CM.   LENGTH 1.143E 02 CM.   VOL.=2.155E 04 CC

INTEGRATION SPECS   NTHETA = 31   NPSI = 31   DELR =0.2490E 00

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS   7.747E 00   1.000E-02   9.525E 00   1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	7.717E-09	1.605E-14
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		7.717E-09	1.605E-14

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL, 1 CURIE CS137 CYL AT SIDE OF LINER, 2 METERS.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 2.357E 02 CM. LENGTH 1.143E 02 CM. VOL.=2.155E 04 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.2490E 00

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 7.747E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	3.691E-09	7.677E-15
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		3.691E-09	7.677E-15

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT, 1 CURIE CS137 SPHERE AT SIDE OF LINER, SURFACE.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 5.315E 01 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	1.852E-08	3.853E-14
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		1.852E-08	3.853E-14

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT, 1 CURIE CS137 SPHERE AT SIDE OF LINER, 1 METER.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 1.531E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	2.189E-09	4.553E-15
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		2.189E-09	4.553E-15

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT, 1 CURIE CS137 SPHERE AT SIDE OF LINER, 2 METERS.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 2.531E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	7.920E-10	1.647E-15
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		7.920E-10	1.647E-15

GAMMA ATTENUATION CALCULATION TOP OF GE2000, ACCIDENT, 1 CI CS137 SPHERE AT TOP CORNER LINER, SURFACE.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 1.376E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	4.021E-13	8.363E-19
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		4.021E-13	8.363E-19

GAMMA ATTENUATION CALCULATION TOP OF GE2000, ACCIDENT, 1 CI CS137 SPHERE AT TOP CORNER LINER, 1 METER.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 2.376E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	1.465E-13	3.047E-19
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		1.465E-13	3.047E-19

GAMMA ATTENUATION CALCULATION TOP OF GE2000, ACCIDENT, 1 CI CS137 SPHERE AT TOP CORNER LINER, 2 METERS.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 3.376E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	7.353E-14	1.529E-19
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		7.353E-14	1.529E-19

GAMMA ATTENUATION CALCULATION   BOTTOM, ACCIDENT, 1 CI CS137 SPHERE AT BOTTOM CORNER LINER, SURFACE.

SPHERICAL SOURCE   SLAB SHIELDS   DIST TO DETECTOR 7.300E 01 CM.   VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS   1.727E 01   1.000E-02   2.095E 01   5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	1.266E-04	2.632E-10
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		1.266E-04	2.632E-10

GAMMA ATTENUATION CALCULATION BOTTOM, ACCIDENT, 1 CI CS137 SPHERE AT BOTTOM CORNER LINER, 1 METER.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 1.730E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	2.740E-05	5.699E-11
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		2.740E-05	5.699E-11

GAMMA ATTENUATION CALCULATION BOTTOM, ACCIDENT, 1 CI CS137 SPHERE AT BOTTOM CORNER LINER, 2 METERS.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 2.730E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	0.	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	3.145E 10	6.500E-01	1.118E-05	2.326E-11
15	0.	8.250E-01	0.	0.
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	3.145E 10		1.118E-05	2.326E-11

ISOTOPE SELECTION DATA

ISOTOPES CONSIDERED ARE

VALUES SPECIFY CURIES

ZR2 95	NB1 95	NB2 95
0.100E 01	0.100E 01	0.100E 01

SHIELD COMPOSITION GR/CC	1	2	3	4	5
AIR	0.	1.293E-03	0.	0.	0.
LEAD	0.	0.	0.	1.134E 01	0.
IRON	6.910E 00	0.	7.800E 00	0.	0.

MASS ABSORPTION COEFFICIENTS (LAST REGION IS AIR)

3.052E 02	4.425E-03	3.445E 02	8.201E 02	4.424E-03	0.
8.483E 01	6.543E-04	9.576E 01	5.415E 02	6.542E-04	0.
3.928E 01	3.504E-04	4.434E 01	1.928E 02	3.504E-04	0.
1.821E 01	2.715E-04	2.055E 01	9.202E 01	2.715E-04	0.
1.005E 01	2.405E-04	1.135E 01	5.262E 01	2.405E-04	0.
6.710E 00	2.247E-04	7.574E 00	3.489E 01	2.247E-04	0.
4.789E 00	2.137E-04	5.405E 00	2.419E 01	2.137E-04	0.
3.471E 00	2.049E-04	3.918E 00	2.507E 01	2.049E-04	0.
2.756E 00	1.905E-04	3.111E 00	2.853E 01	1.985E-04	0.
1.410E 00	1.725E-04	1.591E 00	1.564E 01	1.725E-04	0.
9.467E-01	1.474E-04	1.069E 00	6.339E 00	1.474E-04	0.
6.896E-01	1.312E-04	7.784E-01	3.476E 00	1.312E-04	0.
6.046E-01	1.183E-04	6.825E-01	2.013E 00	1.183E-04	0.
4.975E-01	1.118E-04	5.616E-01	1.452E 00	1.118E-04	0.
4.402E-01	8.986E-05	4.969E-01	9.923E-01	8.986E-05	0.
4.063E-01	8.211E-05	4.586E-01	8.233E-01	8.210E-05	0.
3.545E-01	7.409E-05	4.001E-01	7.008E-01	7.408E-05	0.
3.248E-01	6.659E-05	3.666E-01	6.056E-01	6.658E-05	0.
3.082E-01	6.181E-05	3.479E-01	5.534E-01	6.180E-05	0.
2.868E-01	5.818E-05	3.237E-01	5.250E-01	5.818E-05	0.
2.778E-01	5.495E-05	3.136E-01	5.024E-01	5.495E-05	0.
2.633E-01	5.263E-05	2.972E-01	4.854E-01	5.262E-05	0.
2.612E-01	5.004E-05	2.948E-01	4.751E-01	5.004E-05	0.
2.529E-01	4.784E-05	2.855E-01	4.683E-01	4.784E-05	0.
2.453E-01	4.383E-05	2.769E-01	4.661E-01	4.383E-05	0.

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**THIS IS THE LAST TIME THE ABOVE MESSAGE WILL APPEAR*
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GAMMA ATTENUATION CALCULATION TOP OF GE2000, NORMAL, 1 CURIE ZR95 CYL AT SIDE OF LINER, SURFACE.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 2.372E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	8.888E-34	1.742E-39
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	6.099E-14	1.269E-19
15	5.513E 10	8.250E-01	2.060E-08	4.120E-14
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		2.060E-08	4.120E-14

GAMMA ATTENUATION CALCULATION TOP OF GE2000, NORMAL, 1 CURIE ZR95 CYL AT SIDE OF LINER, 1 METER.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 3.372E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	3.689E-34	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	1.896E-14	3.943E-20
15	5.513E 10	8.250E-01	6.386E-09	1.277E-14
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		6.386E-09	1.277E-14

GAMMA ATTENUATION CALCULATION TOP OF GE2000, NORMAL, 1 CURIE ZR95 CYL AT SIDE OF LINER, 2 METERS.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 4.372E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	2.031E-34	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	9.006E-15	1.873E-20
15	5.513E 10	8.250E-01	3.037E-09	6.075E-15
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		3.038E-09	6.075E-15

GAMMA ATTENUATION CALCULATION   BOTTOM OF GE2000, NORMAL, 1 CURIE ZR95 CYL AT SIDE OF LINER, SURFACE.

END OF CYL. SOURCE   SLAB SHIELDS   DIST TO DETECTOR 1.700E 02 CM.   VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM   RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31   NPSI = 0   DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	1.640E-22	3.215E-28
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	2.653E-05	5.518E-11
15	5.513E 10	8.250E-01	9.588E-03	1.918E-08
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		9.615E-03	1.923E-08

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000, NORMAL, 1 CURIE ZR95 CYL AT SIDE OF LINER, 1 METER.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 2.700E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	2.643E-23	5.181E-29
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	3.824E-06	7.953E-12
15	5.513E 10	8.250E-01	1.374E-03	2.749E-09
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		1.378E-03	2.757E-09

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000, NORMAL, 1 CURIE ZR95 CYL AT SIDE OF LINER, 2 METERS.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 3.700E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	9.869E-24	1.934E-29
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	1.421E-06	2.955E-12
15	5.513E 10	8.250E-01	5.118E-04	1.024E-09
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		5.132E-04	1.026E-09

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL, 1 CURIE ZR95 CYL AT SIDE OF LINER, SURFACE.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 3.569E 01 CM. LENGTH 1.143E 02 CM. VOL.=2.155E 04 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.2490E 00

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 7.747E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	6.654E-33	1.304E-38
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	1.720E-08	3.578E-14
15	5.513E 10	8.250E-01	3.745E-04	7.491E-10
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		3.746E-04	7.491E-10

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL, 1 CURIE ZR95 CYL AT SIDE OF LINER, 1 METER.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 1.357E 02 CM. LENGTH 1.143E 02 CM. VOL.=2.155E 04 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.2490E 00

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 7.747E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	4.176E-34	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	4.449E-09	9.253E-15
15	5.513E 10	8.250E-01	9.424E-05	1.885E-10
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		9.424E-05	1.885E-10

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL, 1 CURIE ZR95 CYL AT SIDE OF LINER, 2 METERS.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 2.357E 02 CM. LENGTH 1.143E 02 CM. VOL.=2.155E 04 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.2490E 00

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 7.747E 00 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	1.386E-34	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	2.128E-09	4.425E-15
15	5.513E 10	8.250E-01	4.238E-05	8.476E-11
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		4.238E-05	8.476E-11

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT, 1 CURIE ZR95 SPHERE AT SIDE OF LINER, SURFACE.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 5.315E 01 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	1.068E-08	2.221E-14
15	5.513E 10	8.250E-01	2.305E-04	4.610E-10
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		2.305E-04	4.610E-10

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT, 1 CURIE ZR95 SPHERE AT SIDE OF LINER, 1 METER.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 1.531E 02 CM. VOL.=2.155E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	1.262E-09	2.625E-15
15	5.513E 10	8.250E-01	2.725E-05	5.451E-11
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		2.726E-05	5.451E-11

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT, 1 CURIE ZR95 SPHERE AT SIDE OF LINER, 2 METERS.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 2.531E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	4.566E-10	9.497E-16
15	5.513E 10	8.250E-01	9.881E-06	1.976E-11
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		9.882E-06	1.976E-11

GAMMA ATTENUATION CALCULATION TOP OF GE2000, ACCIDENT, 1 CI ZR95 SPHERE AT TOP CORNER LINER, SURFACE.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 1.376E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	2.318E-13	4.821E-19
15	5.513E 10	8.250E-01	8.095E-08	1.619E-13
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		8.095E-08	1.619E-13

GAMMA ATTENUATION CALCULATION   TOP OF GE2000, ACCIDENT, 1 CI ZR95 SPHERE AT TOP CORNER LINER, 1 METER.

SPHERICAL SOURCE   SLAB SHIELDS   DIST TO DETECTOR 2.376E 02 CM.   VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS   1.727E 01   1.000E-02   1.286E 01   2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	8.444E-14	1.756E-19
15	5.513E 10	8.250E-01	2.877E-08	5.753E-14
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		2.877E-08	5.753E-14

GAMMA ATTENUATION CALCULATION TOP OF GE2000, ACCIDENT, 1 CI ZR95 SPHERE AT TOP CORNER LINER, 2 METERS.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 3.376E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	0.	0.
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	4.239E-14	8.817E-20
15	5.513E 10	8.250E-01	1.437E-08	2.874E-14
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		1.437E-08	2.874E-14

GAMMA ATTENUATION CALCULATION BOTTOM, ACCIDENT, 1 CI ZR95 SPHERE AT BOTTOM CORNER LINER, SURFACE.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 7.300E 01 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	3.176E-22	6.225E-28
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	7.296E-05	1.518E-10
15	5.513E 10	8.250E-01	2.758E-02	5.516E-08
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		2.765E-02	5.532E-08

GAMMA ATTENUATION CALCULATION BOTTOM, ACCIDENT, 1 CI ZR95 SPHERE AT BOTTOM CORNER LINER, 1 METER.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 1.730E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	9.815E-23	1.924E-28
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	1.580E-05	3.285E-11
15	5.513E 10	8.250E-01	5.729E-03	1.146E-08
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		5.745E-03	1.149E-08

GAMMA ATTENUATION CALCULATION BOTTOM, ACCIDENT, 1 CI ZR95 SPHERE AT BOTTOM CORNER LINER, 2 METERS.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 2.730E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	0.	1.500E-02	0.	0.
2	0.	2.500E-02	0.	0.
3	0.	3.500E-02	0.	0.
4	0.	4.500E-02	0.	0.
5	0.	5.500E-02	0.	0.
6	0.	6.500E-02	0.	0.
7	0.	7.500E-02	0.	0.
8	0.	8.500E-02	0.	0.
9	0.	9.500E-02	0.	0.
10	0.	1.500E-01	0.	0.
11	3.700E 10	2.500E-01	4.217E-23	8.265E-29
12	0.	3.500E-01	0.	0.
13	0.	4.750E-01	0.	0.
14	1.813E 10	6.500E-01	6.448E-06	1.341E-11
15	5.513E 10	8.250E-01	2.330E-03	4.660E-09
16	0.	1.000E 00	0.	0.
17	0.	1.225E 00	0.	0.
18	0.	1.475E 00	0.	0.
19	0.	1.700E 00	0.	0.
20	0.	1.900E 00	0.	0.
21	0.	2.100E 00	0.	0.
22	0.	2.300E 00	0.	0.
23	0.	2.500E 00	0.	0.
24	0.	2.700E 00	0.	0.
25	0.	3.000E 00	0.	0.
TOTAL	1.103E 11		2.336E-03	4.673E-09

SHIELD COMPOSITION GR/CC	1	2	3	4	5	
AIR	0.	1.293E-03	0.	0.	0.	
LEAD	0.	0.	0.	1.134E 01	0.	
IRON	6.910E 00	0.	7.800E 00	0.	0.	
MASS ABSORPTION COEFFICIENTS (LAST REGION IS AIR)						
	1.752E 00	1.791E-04	1.978E 00	1.892E 01	1.652E-04	0.
	6.999E-01	1.319E-04	7.900E-01	3.590E 00	1.217E-04	0.
	6.016E-01	1.181E-04	6.790E-01	1.997E 00	1.090E-04	0.
	5.183E-01	1.131E-04	5.851E-01	1.561E 00	1.043E-04	0.
	0.	0.	0.	0.	0.	0.
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**THIS IS THE LAST TIME THE ABOVE MESSAGE WILL APPEAR*
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GAMMA ATTENUATION CALCULATION TOP OF GE2000, NORMAL, 1 CURIE HF181 CYL AT SIDE OF LINER, SURFACE.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 2.372E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	1.287E-33	2.182E-39
2	6.364E 09	3.460E-01	1.320E-34	0.
3	3.079E 10	4.800E-01	1.188E-19	2.425E-25
4	5.291E 07	6.160E-01	1.161E-17	2.405E-23
TOTAL	5.484E 10		1.173E-17	2.430E-23

GAMMA ATTENUATION CALCULATION TOP OF GE2000, NORMAL, 1 CURIE HF181 CYL AT SIDE OF LINER, 1 METER.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 3.372E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	5.383E-34	0.
2	6.364E 09	3.460E-01	5.469E-35	0.
3	3.079E 10	4.800E-01	3.716E-20	7.585E-26
4	5.291E 07	6.160E-01	3.615E-18	7.491E-24
TOTAL	5.484E 10		3.652E-18	7.566E-24

GAMMA ATTENUATION CALCULATION   TOP OF GE2000, NORMAL, 1 CURIE HF181 CYL AT SIDE OF LINER, 2 METERS.

END OF CYL. SOURCE   SLAB SHIELDS   DIST TO DETECTOR 4.372E 02 CM.   VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM   RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31   NPSI =   0   DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	2.977E-34	0.
2	6.364E 09	3.460E-01	3.009E-35	0.
3	3.079E 10	4.800E-01	1.768E-20	3.610E-26
4	5.291E 07	6.160E-01	1.719E-16	3.562E-24
TOTAL	5.484E 10		1.737E-16	3.598E-24

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000, NORMAL, 1 CURIE HF181 CYL AT SIDE OF LINER, SURFACE.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 1.700E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.175E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	2.283E-34	0.
2	6.364E 09	3.460E-01	1.192E-13	2.451E-19
3	3.079E 10	4.800E-01	1.082E-07	2.208E-13
4	5.291E 07	6.160E-01	2.330E-08	4.629E-14
TOTAL	5.484E 10		1.315E-07	2.691E-13

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000, NORMAL, 1 CURIE HF181 CYL AT SIDE OF LINER, 1 METER.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 2.700E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.175E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	6.174E-35	0.
2	6.364E 09	3.460E-01	1.798E-14	3.697E-20
3	3.079E 10	4.800E-01	1.577E-08	3.219E-14
4	5.291E 07	6.160E-01	3.368E-09	6.979E-15
TOTAL	5.484E 10		1.914E-08	3.917E-14

GAMMA ATTENUATION CALCULATION BOTTOM OF GE2000, NORMAL, 1 CURIE HF181 CYL AT SIDE OF LINER, 2 METERS.

END OF CYL. SOURCE SLAB SHIELDS DIST TO DETECTOR 3.700E 02 CM. VOL.=2.155E 04 CC

LENGTH = 1.143E 02 CM RADIUS = 7.747E 00 CM

INTEGRATION SPECS NTHETA = 31 NPSI = 0 DELR =0.1900E 01

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.143E 02 1.000E-02 2.095E 01 5.175E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	2.906E-35	0.
2	6.364E 09	3.460E-01	6.694E-15	1.376E-20
3	3.079E 10	4.800E-01	5.862E-09	1.197E-14
4	5.291E 07	6.160E-01	1.252E-09	2.595E-15
TOTAL	5.484E 10		7.114E-09	1.456E-14

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL, 1 CURIE HF181 CYL AT SIDE OF LINER, SURFACE.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 3.569E 01 CM. LENGTH 1.143E 02 CM. VOL.=2.155E 03 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.2490E 00

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 7.747E 02 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	9.690E-33	1.644E-38
2	6.364E 09	3.460E-01	2.705E-25	5.562E-31
3	3.079E 10	4.800E-01	9.431E-13	1.925E-18
4	5.291E 07	6.160E-01	6.349E-12	1.316E-17
TOTAL	5.484E 10		7.292E-12	1.508E-17

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL, 1 CURIE HF181 CYL AT SIDE OF LINER, 1 METER.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 1.357E 02 CM. LENGTH 1.143E 02 CM. VOL.=2.155E 04 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.2490E 00

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 7.747E 02 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	3.483E-34	0.
2	6.364E 09	3.460E-01	7.194E-26	1.479E-31
3	3.079E 10	4.800E-01	2.478E-13	5.059E-19
4	5.291E 07	6.160E-01	1.650E-12	3.420E-18
TOTAL	5.484E 10		1.898E-12	3.926E-16

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, NORMAL, 1 CURIE HF181 CYL AT SIDE OF LINER, 2 METERS.

CYLINDRICAL SOURCE CYLINDRICAL SHIELDS DIST TO DETECTOR 2.357E 02 CM. LENGTH 1.143E 02 CM. VOL.=2.155E 04 CC

INTEGRATION SPECS NTHETA = 31 NPSI = 31 DELR =0.2490E 00

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 7.747E 02 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	1.126E-34	0.
2	6.364E 09	3.460E-01	3.928E-26	8.075E-32
3	3.079E 10	4.800E-01	1.252E-13	2.556E-19
4	5.291E 07	6.160E-01	7.999E-13	1.658E-16
TOTAL	5.484E 10		9.251E-13	1.913E-16

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT, 1 CURIE HF181 SPHERE AT SIDE OF LINER, SURFACE.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 5.315E 01 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	0.	0.
2	6.364E 09	3.460E-01	1.706E-25	3.508E-31
3	3.079E 10	4.800E-01	5.875E-13	1.199E-18
4	5.291E 07	6.160E-01	3.944E-12	8.173E-18
TOTAL	5.484E 10		4.532E-12	9.372E-18

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT, 1 CURIE HF181 SPHERE AT SIDE OF LINER, 1 METER.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 1.531E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	0.	0.
2	6.364E 09	3.460E-01	2.022E-26	4.157E-32
3	3.079E 10	4.800E-01	6.957E-14	1.420E-19
4	5.291E 07	6.160E-01	4.667E-13	9.670E-19
TOTAL	5.484E 10		5.362E-13	1.109E-16

GAMMA ATTENUATION CALCULATION SIDE OF GE2000, ACCIDENT, 1 CURIE HF181 SPHERE AT SIDE OF LINER, 2 METERS.

SPHERICAL SOURCE SPHERICAL SHIELDS DIST TO DETECTOR 2.531E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 9.525E 00 1.588E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	0.	0.
2	6.364E 09	3.460E-01	7.310E-27	1.503E-32
3	3.079E 10	4.800E-01	2.518E-14	5.139E-20
4	5.291E 07	6.160E-01	1.690E-13	3.501E-19
TOTAL	5.484E 10		1.941E-13	4.015E-19

GAMMA ATTENUATION CALCULATION TOP OF GE2000, ACCIDENT, 1 CI HF181 SPHERE AT TOP CORNER LINER, SURFACE.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 1.376E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	0.	0.
2	6.364E 09	3.460E-01	0.	0.
3	3.079E 10	4.800E-01	4.332E-19	8.842E-25
4	5.291E 07	6.160E-01	4.375E-17	9.067E-23
TOTAL	5.484E 10		4.419E-17	9.155E-23

GAMMA ATTENUATION CALCULATION   TOP OF GE2000, ACCIDENT, 1 CI HF181 SPHERE AT TOP CORNER LINER, 1 METER.

SPHERICAL SOURCE   SLAB SHIELDS   DIST TO DETECTOR 2.376E 02 CM.   VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS   1.727E 01   1.000E-02   1.286E 01   2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	0.	0.
2	6.364E 09	3.460E-01	0.	0.
3	3.079E 10	4.800E-01	1.630E-19	3.327E-25
4	5.291E 07	6.160E-01	1.605E-17	3.327E-23
TOTAL	5.484E 10		1.622E-17	3.360E-23

GAMMA ATTENUATION CALCULATION TOP OF GE2000, ACCIDENT, 1 CI HF181 SPHERE AT TOP CORNER LINER, 2 METERS.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 3.376E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 1.286E 01 2.192E 01

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	0.	0.
2	6.364E 09	3.460E-01	0.	0.
3	3.079E 10	4.800E-01	8.253E-20	1.685E-25
4	5.291E 07	6.160E-01	8.078E-18	1.674E-23
TOTAL	5.484E 10		8.161E-18	1.691E-23

GAMMA ATTENUATION CALCULATION BOTTOM, ACCIDENT, 1 CI HF181 SPHERE AT BOTTOM CORNER LINER, SURFACE.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 7.300E 01 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	0.	0.
2	6.364E 09	3.460E-01	2.781E-13	5.717E-19
3	3.079E 10	4.800E-01	2.803E-07	5.722E-13
4	5.291E 07	6.160E-01	6.331E-08	1.312E-13
TOTAL	5.484E 10		3.437E-07	7.034E-13

GAMMA ATTENUATION CALCULATION   BOTTOM, ACCIDENT, 1 CI HF181 SPHERE AT BOTTOM CORNER LINER, 1 METER.

SPHERICAL SOURCE   SLAB SHIELDS   DIST TO DETECTOR 1.730E 02 CM.   VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS   1.727E 01   1.000E-02   2.095E 01   5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	0.	0.
2	6.364E 09	3.460E-01	7.128E-14	1.465E-19
3	3.079E 10	4.800E-01	6.425E-08	1.312E-13
4	5.291E 07	6.160E-01	1.388E-08	2.875E-14
TOTAL	5.484E 10		7.813E-08	1.599E-13

GAMMA ATTENUATION CALCULATION BOTTOM, ACCIDENT, 1 CI HF181 SPHERE AT BOTTOM CORNER LINER, 2 METERS.

SPHERICAL SOURCE SLAB SHIELDS DIST TO DETECTOR 2.730E 02 CM. VOL.=2.158E 04 CC

TAYLOR BUILDUP DATA FOR SHIELD 4 WITH EFFECTIVE ATOMIC NUMBER OF 82.0 USED

SHIELD THICKNESS 1.727E 01 1.000E-02 2.095E 01 5.715E 00

GROUP	GROUP PRODUCTION RATE PHOTONS	GROUP AVERAGE ENERGY MEV	ENERGY FLUX AT DOSE POINT MEV/CMS/SEC	DOSE RATE AT DOSE POINT ROENTGENS/HOUR
1	1.763E 10	1.360E-01	0.	0.
2	6.364E 09	3.460E-01	2.978E-14	6.124E-20
3	3.079E 10	4.800E-01	2.644E-08	5.398E-14
4	5.291E 07	6.160E-01	5.677E-09	1.176E-14
TOTAL	5.484E 10		3.212E-08	6.574E-14

5.5.3 Sample of the Neutron Dose Rate Calculations at the Top and Side Surfaces of the Model 2000 Package

TABLE 5.5.3.1. UNSHIELDED NEUTRON DOSE RATE CALCULATIONS

THE FOLLOWING CALCULATIONS ARE TO INTEGRATE THE NEUTRON DOSE RATE IN AIR FROM A GIVEN GEOMETRICAL SHAPE CONTAINING SOME SOURCE STRENGTH OF FISSION SPECTRUM NEUTRONS.

EQUATION: DOSE RATE = (1.22E-1)/(4)/(PI)/(r^2) mrem/hr/n/s

WHERE: r = DISTANCE FROM POINT SOURCE, cm

SOURCE STRENGTH = 4.67E+07 n/sec

SOURCE GEOMETRY: LINE

LENGTH = 45 inches = 114.3 cm.

INTEGRATION DIVISIONS = 20

DETECTOR LOCATIONS:

1. AXIS AT "A" INCHES FROM THE FAR END OF THE SOURCE.
2. MIDDLE AT "B" INCHES FROM THE CENTERLINE OF THE SOURCE.

CALCULATION:

	(TOP SURFACE) "A" = 93.37 INCHES		(SIDE SURFACE) "B" = 15.99 INCHES	
SOURCE DIVISION NUMBER	r, cm.	ELEMENT DOSE RATE, mRem/hr	r, cm.	ELEMENT DOSE RATE, mRem/hr
1	234.3023	4.13E-01	67.8028118	4.93E+00
2	228.5873	4.34E-01	63.3191853	5.65E+00
3	222.8723	4.56E-01	59.0486209	6.50E+00
4	217.1573	4.81E-01	55.0407348	7.48E+00
5	211.4423	5.07E-01	51.3570617	8.59E+00
6	205.7273	5.36E-01	48.0721909	9.81E+00
7	200.0123	5.67E-01	45.2730133	1.11E+01
8	194.2973	6.00E-01	43.0543655	1.22E+01
9	188.5823	6.37E-01	41.5094385	1.32E+01
10	182.8673	6.78E-01	40.7149977	1.37E+01
11	177.1523	7.22E-01	40.7149977	1.37E+01
12	171.4373	7.71E-01	41.5094385	1.32E+01
13	165.7223	8.25E-01	43.0543655	1.22E+01
14	160.0073	8.85E-01	45.2730133	1.11E+01
15	154.2923	9.52E-01	48.0721909	9.81E+00
16	148.5773	1.03E+00	51.3570617	8.59E+00
17	142.8623	1.11E+00	55.0407348	7.48E+00
18	137.1473	1.21E+00	59.0486209	6.50E+00
19	131.4323	1.31E+00	63.3191853	5.65E+00
20	125.7173	1.43E+00	67.8028118	4.93E+00
TOTAL DOSE RATE, mRem/hr =		1.56E+01		1.86E+02

5.5.4 Horizontal Shipment

5.5.4.1 Scope

The Model 2000 Transportation Package needs to be shipped in a horizontal position under certain conditions (see Figure 5.5.4.1). As a result of tilting the package to a horizontal position, the original bottom of the package becomes the back and the original top of the cask becomes the front of the package. The dose rates from all the previous calculations for the Package presented in Chapter 5 of Reference 1 are bounding with the exception of the back (original bottom) and the cab dose rates, now measured from the front (original top) of the package. Neutron dose rate analysis is done for the back surfaces of the package. The neutron dose rate from the front to the cab is conservatively assumed to be the 1m accident dose from the top. This would envelop the actual dose rate. The three analyses are presented below.

5.5.4.2 Assumptions

All assumptions presented in Chapter 5 of Reference 1 are valid. The worst case scenario from a standpoint of dose rates was produced by the 93.2% enriched MTR source. This MTR source also bounds the TRIGA sources (See Section 5.5 of the report).

Credit has been explicitly taken for a 1.27 cm (0.5 inch) steel plate just above the toroidal region of the back overpack and the two plates enclosing the bottom honeycomb have been reduced to 0.5" each. (Credit was not taken for this stainless steel plate in the original vertical shipment analyses. However, the jacket bottom plates, each 0.5" thick, enclosing the bottom honeycomb, were taken to be 0.75" thick, thus effectively including 0.5 inch stainless steel- the plate above the honeycomb was 0.125" stainless steel. followed by 0.5" tungsten, followed by another 0.125" of stainless steel; the plate below the honey comb was 0.75" stainless steel). Overall, the bottom overpack has 0.5" tungsten and 1" of stainless steel.

The closest approachable surface at the back is 89.5 inches from the back overpack. No credit is taken for any of the structures between the back overpack and the outside surface. The distance to the cab of the truck from

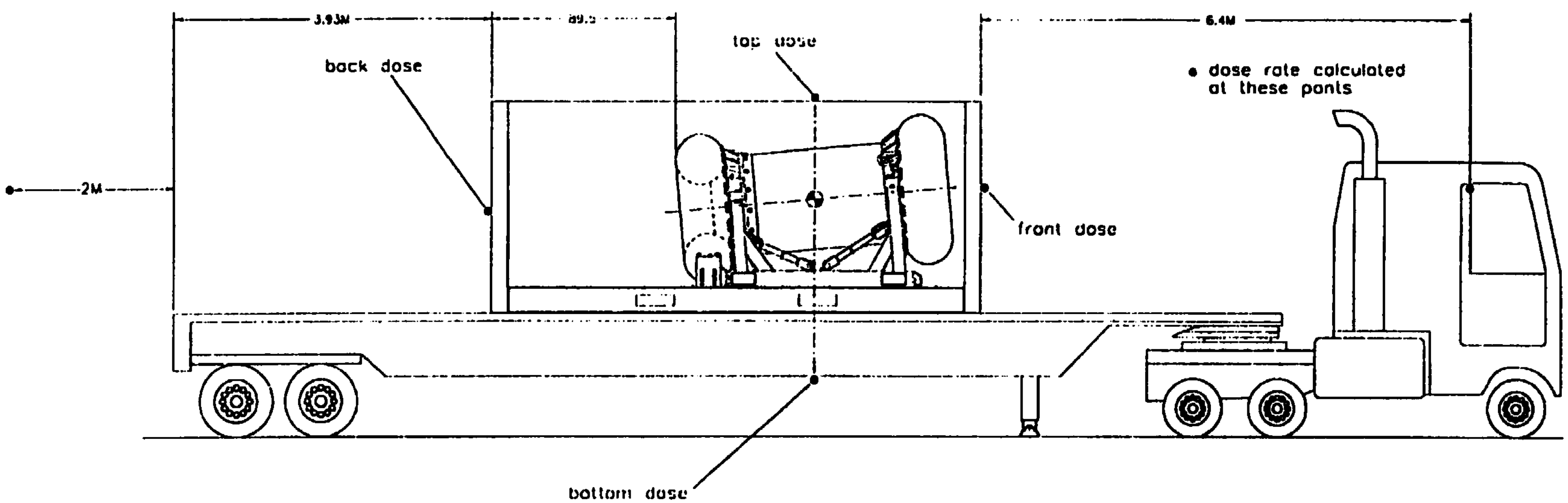


FIGURE 5.5.4.1. HORIZONTAL SHIPMENT NORMAL DOSE RATE LOCATIONS (DIMENSIONS IN METERS AND INCHES)

the front over pack is 254.23 inches (6.45 m). The 2m dose rate for exclusive use is measured from the back end of the truck and is thus 5.93m from the closest approachable surface a the back. Figure 5.5.4.1 shows the distance from the front of the package (the cradle) to the cab to be 6.4m. In the cab dose rate analysis, the distance from the front overpack to the cab was taken to be 6.4m, thus making this calculation conservative (credit was not taken for an additional 13.75").

For the neutron analysis, the 20% enriched case is the limiting case and the analysis is done for the neutron source term derived from a 20% enriched fuel (see Table in Section 5). Also, the lead in the cask and the lumped fission product in the fuel have been removed. Both these assumptions are mildly conservative.

5.5.4.2.1 Gamma Source Term

The gamma source terms are shown in Table 5.5.4.1 while the neutron source terms are shown in Table 5.5.4.2.

The Source terms were generated using RIBD for the gammas and these verified sources are in Sections 5 Reference 1. The source term has been calculated using RIBD based on a maximum allowed burnup of 533,000 MWd/t, for 93.2% enriched fuel with 880 days of cooling, time.

5.5.4.2.2 Neutron Source Term

The neutron source term was generated using ORIGEN as described in Section 5.2. The 20% enriched case has the highest neutron source strength and would envelop the other enrichments. The TRIGA fuels will be enveloped by these calculations.

5.5.4.3 Description of Source Inputs in MCNP

The gamma and neutron sources are described in Section 5 of this report.

TABLE 5.5.4.1. SOURCE TERM

Group	Group Average Energy (MeV)	Total Group Production Rate (photons/see) 93.2% ENRICHED CASE
1	1.500E-02	6.704E+13
2	2.500E-02	4.726E+13
3	3.500E-02	2.976E+13
4	4.500E-02	1.847E+13
5	5.500E-02	1.393E+13
6	6.500E-02	1.029E+13
7	7.500E-02	8.398E+12
8	8.500E-02	6.784E+13
9	9.500E-02	5.333E+12
10	1.500E-01	3.242E+14
11	2.500E-01	1.119E+12
12	3.500E-01	3.516E+11
13	4.750E-01	3.040E+14
14	6.500E-01	1.941E+15
15	8.250E-01	1.024E+14
16	1.000E 00	2.107E+13
17	1.225E 00	1.021E+13
18	1.475E 00	1.416E+13
19	1.700E 00	2.070E+11
20	1.900E 00	2.748E-04
21	2.100E 00	2.004E+13
22	2.300E 00	1.185E+12
23	2.500E 00	3.566E-06
24	2.700E 00	0.000E+00
25	3.000E 00	1.308E-07
TOTALS		3.008E+15

TABLE 5.5.4.2. NEUTRON SOURCE TERMS

Enrichment Percent	Spontaneous Fission neutrons/sec	(α,n) neutrons/sec
20	2.206e+06	3.772e+05

5.5.4.4 Geometry Description of Cask, Overpack, and Fuel Basket

The geometry description of cask, overpack, and fuel basket is described in Section 5 of the report. The only additional modeling is as follows:

The back of the package is modified to include the stainless steel plates:

The inner plate of the jacket made of tungsten (above the honeycomb) is 1.27 cm (0.5 inch) thick (surf 6022-surf 201); there is a 10.16 cm (4 inch) gap representing the honeycomb (surf 602-surf 6022); the bottom plate of the honeycomb is stainless steel 1.27 cm (0.5 inch) thick (surf 601-surf 602); this is followed by a 18.45056 cm (7.264 inch) gap (surf 1004-surf 601); the last stainless steel plate is 1.27 cm (0.5 inch) thick (surf 1005-surf 1004); finally, the rest of the toroidal region is represented as a void of thickness 41.23944 cm (16.236 inch) (surf 1113-surf 1005). Figure 5.5.4.2 shows details of this region.

5.5.4.5 Tallies in MCNP

5.5.4.5.1 Gamma Tallies

The Gamma tallies in MCNP are all point detector tallies (type *F5) which give MeV/cm^2-source neutron, which is multiplied by the dose conversion factors accompanying the code ISOSHLD.

The Back Gamma dose rate is calculated at the bottom of the truck bed: (bottom of cask, surf 601, add 24" for the additional overpack region, and 89.5 in for the closest approachable surface. This gives a point of -391.16 cm in the z-direction from the origin of the problem. The 2m exclusive use dose rate at the back is measured from the back end of the truck. This distance is 5.93 in from the closest approachable surface (3.93 m to the end of the truck plus 2 m). Thus, this point is at -984.16 cm from the origin of the problem.

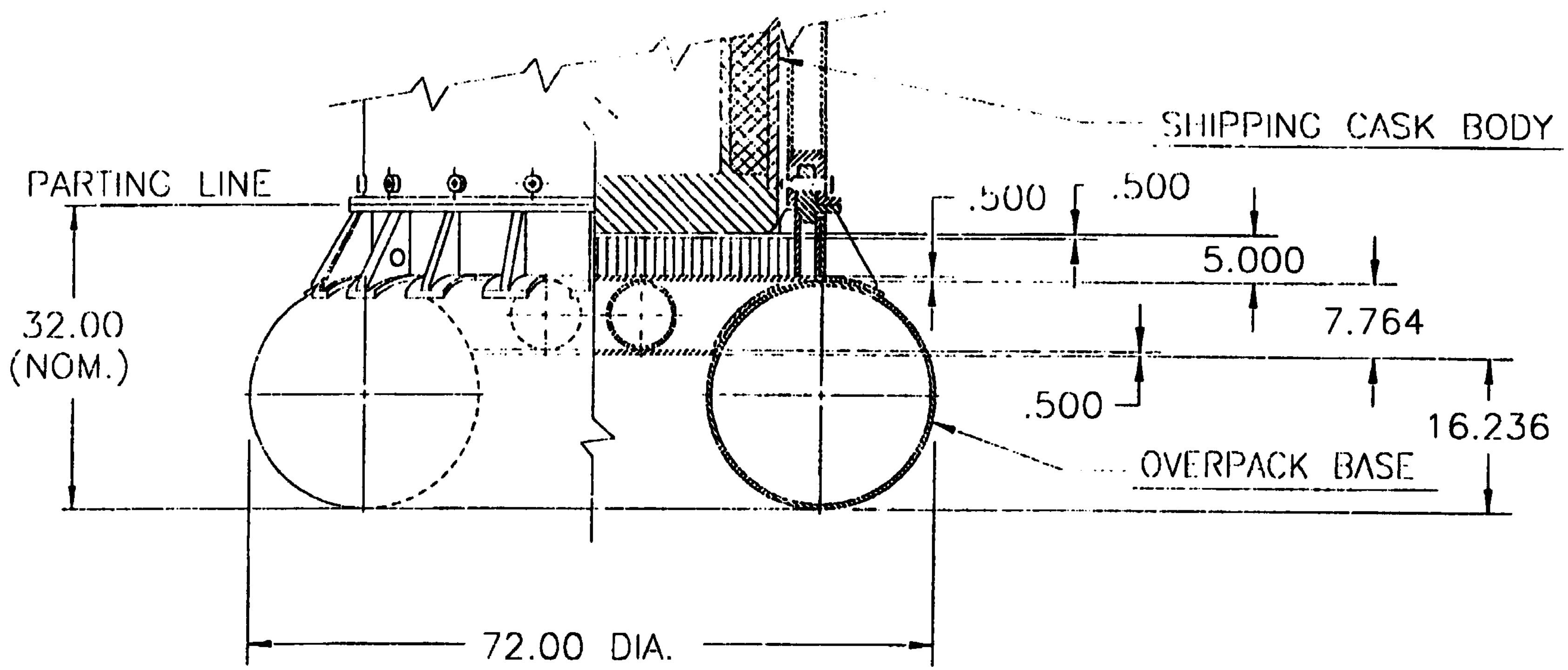


FIGURE 5.5.4.2. DETAILS OF THE BACK OF PACKAGE

The final dose rate presented has been multiplied by the source strength. The results presented, as in Section 5 of Reference 1, include the 2-sigma uncertainty. No bias is added as MCNP neutron and gamma transport biases for these problems are negligible (References 3 and 4).

The gamma flux-to-dose conversion factors are presented below. These are taken from the ISOSHLD code (ISOSHLD, Kernel Integration Code- general Purpose Isotope Shielding Analysis, CCC-79).

Flux-to-Dose Rate Average Energy (MeV)	Conversion Factor (R/hr per MeV/cm^2-sec)
1.500E-02	8.230E-05
2.500E-02	1.730E-05
3.500E-02	6.349E-06
4.500E-02	3.280E-06
5.500E-02	2.289E-06
6.500E-02	1.891E-06
7.500E-02	1.714E-06
8.500E-02	1.618E-06
9.500E-02	1.603E-06
1.500E-01	1.728E-06
2.500E-01	1.960E-06
3.500E-01	2.060E-06
4.750E-01	2.039E-06
6.500E-01	2.080E-06
8.250E-01	2.000E-06
1.000E 00	1.930E-06
1.225E 00	1.841E-06
1.475E 00	1.761E-06
1.700E 00	1.710E-06
1.900E 00	1.660E-06
2.100E 00	1.600E-06
2.300E 00	1.540E-06
2.500E 00	1.520E-06
2.700E 00	1.480E-06
3.000E 00	1.430E-06

5.5.4.5.2 Neutron Tallies

The neutron tallies were also performed at the same locations as the first gamma tally, i.e. at -391.16 and -984.16 cm. from the origin of the problem.

The neutron flux-to-dose conversion factors are from NCRP-38, ANSI/ANS 6.1.1-1977 (also found in Appendix H of reference 2).

Neutron Energy (Mev)	Conversion Factor (rem/hr)/ (neutron/cm^2-sec)
2.5e-08	3.67e-06
1.0e-07	3.67e-06
1.0e-06	4.46e-06
1.0e-05	4.54e-06
1.0e-04	4.18e-06
1.0e-03	3.76e-06
1.0e-02	3.56e-06
1.0e-01	2.17e-05
5.0e-01	9.26e-05
1.00	1.32e-04
2.50	1.25e-04
5.00	1.56e-04
7.00	1.47e-04
10.00	1.47e-04
14.00	2.08e-04
20.00	2.27e-04

5.5.4.6 Material Types

There were no differences between materials used here and those in Section 5 of the report.

5.5.4.7 Results

The analysis assumes a good deal of conservatism in the specific burnups used for these calculations. They represent an upper bound for each enrichment and thus the dose rates have that conservatism built into them. Table 5.5.4.3 that follows presents these results. The other normal condition dose rates and all accident condition dose rates presented in Section 5, are bounding for the horizontally placed transport package. Thus, all the dose

TABLE 5.5.4.3. SUMMARY OF MAXIMUM DOSE RATES (MREM/HR), FROM A MTR-TYPE FUEL SOURCE

For Gammas: 93.2% enriched fuel: 533,000 MWd/T, (28 MW for 300 days), cooled for 880 days, 1265.1 Watts decay heat.

For Neutrons 20% enriched fuel: 100,000 MWd/T (22.5 MW for 156 days), cooled for 880 days, 582.4 Watts decay heat

All results shown are presented as calculated dose rate + 2σ

Normal Conditions	Back Surface of Package	2 Meters from the Back Surface of Truck	Cab of Vehicle from Front
Gamma	39.53	4.90	0.22
Neutron	0.02	0.003	0.06*
Total	39.55	4.903	0.28
49 CFR Part 173.441 Limit	200	10	2

* Neutron Dose rate is the 1m accident dose rate from the original 20% enriched case (Ref. 1), an extremely conservative number.

Rates are within prescribed limits for both the vertical and horizontal shipments under normal or accident conditions.

No bias is assumed for the MCNP calculations. This is a reasonable assumption given the extensive qualification and benchmarking work performed with the code by LANL. The details are presented in References 3 and 4.

5.5.4.8 Appendix References

1. Model 2000 Radioactive Material Transport Package: MTR-Type Fuel Divider and Tower Shielding Reactor Fuel Basket Safety Analysis Report, NEDO-32408.

2. J.F. Briesmeister, Editor, "MCNP - Monte Carlo N-Particle Transport Code", Version 4A, LA-12625, Los Alamos National Laboratory, March 1994.

3. Whalen, D.J. et. al., "MCNP: Photon Benchmark Problems", LA-12196, Los Alamos National Laboratory, 1991.

4. Whalen, D.J. et. al., "MCNP: Neutron Benchmark Problems", LA-12212, Los Alamos National Laboratory, 1991.

5. Research, Training, Test and Production Reactor Directory: USA, 3rd Edition, American Nuclear Society, 1988, pp 85-92.

6. RIBD, Radioisotope Buildup and Decay Code and Library, CCC-137.

7. A.G. Croff, "ORIGEN2, A User's Manual", ORNL-TM7175, July 1980.

5.4 REFERENCES

1. RIBD, Radioisotope Buildup and Decay Code and Library, CCC-137.

2. ISOSHLD, Kernel Integration Code - General Purpose Isotope Shielding Analysis, CCC-79.

6. CRITICALITY EVALUATION

A criticality evaluation of the Model 2000 transport package is given below. The cask has a cavity that is 26.5 inches inside diameter by 54 inches long for holding material including special nuclear material. The cask is of steel-encased, lead-shielded construction. The purpose of this chapter is to identify, describe, discuss and analyze the principle criticality engineering-physics design of the packaging and components important to safety and necessary to comply with the requirements of 10 CFR Part 71.

6.1 DISCUSSION AND RESULTS

The Model 2000 cask was shown to be critically safe for the transport of fissile materials for three different loadings. Criticality control in the Model 2000 cask is achieved through the use of fissile content control for two of the loadings and fissile plus geometry for one of the loadings. One loading involves a 500-gram U-235 equivalent mass (500 grams U-235 or 300 grams Pu) in any geometry configuration. Two other loading types involve segmented irradiated UO_2 fuel rods in which the enrichment is ≤ 5 w/o U-235 in uranium. For a fuel loading having pellets ≥ 0.35 inches OD, 1,750 grams fissile are permitted when the fuel rods are contained within closed 5-inch Schedule 40 pipes with maximum useable lengths of 39-5/8 inches and no more than 437.5 grams fissile per 5-inch Schedule 40 pipe. The pipes, however, can be in any array. For a fuel loading having pellets ≥ 0.3 inches outside diameter, 1,175 grams fissile are permitted in any configuration.

Therefore, for pellets < 0.3 inches OD, the permitted loading is 500 grams U-235, any enrichment. For pellets of 0.3 inches OD to less than 0.35 inches OD, the maximum permitted loading is 1,175 grams fissile with an enrichment ≤ 5 w/o U-235 in uranium. For pellets of ≥ 0.35 inches OD, the maximum permitted loading is 1,750 grams fissile with an enrichment ≤ 5 w/o U-235 in uranium when contained in a minimum of four 5-inch Schedule 40 pipes. Loadings for enrichments > 5 w/o U-235 are limited to 500 grams fissile.

The contents of the cask during shipment are normally dry. Even after the accident described in 10CFR71.73, the seal to the cask remains intact and the contents of the cask remain dry. However, for loading and unloading activities for which hot cells are not available, the loading and unloading may be accomplished under water. After an underwater loading is completed, for example, the lid is placed on the cask and the cask is removed from the water; then the water is drained from the cask.

For the purposes of the criticality safety demonstration, water is considered to be present in the fuel assembly inside the cask to achieve optimum water moderation for the physical forms and geometries possible. The cask is also analyzed with the presence of a lead liner.

In summary, the maximum cask k-effective values, including biases, are contained in Table 6.1.

TABLE 6.1. RESULTS - WORST CASE

GEOMETRY	MAX. K-EFFECTIVE
500 gm U-235 equiv. mass, Double Cask	0.919
1,750 gm fuel rods, Single Cask (≥ 0.35 inch OD pellet)	0.941
1,175 gm fuel rods, Double Cask (≥ 0.30 inch OD pellet)	0.938

6.2 PACKAGE FUEL LOADING

The type, form, and maximum quantity of special nuclear material per package are:

1. Plutonium in excess of twenty (20) curies per package must be in the form of metal, metal alloy or reactor fuel elements, and special nuclear material must be in solid form. The loading shall not exceed 500 grams U-235 equivalent mass.

2. Irradiated UO_2 fuel rods that may be segmented and contain ≤ 1,175 grams fissile provided the enrichment is ≤ 5 w/o U-235 in uranium and the minimum pellet diameter is ≥ 0.3 inches outside diameter.

3. Irradiated UO_2 fuel rods that may be segmented and contain ≤ 1,750 grams fissile provided the enrichment is ≤ 5 w/o U-235 in uranium and the minimum pellet diameter is ≥ 0.35 inches outside diameter. The fuel shall be contained within closed (but not leak-tight) 5-inch Schedule 40 pipes with a maximum useable pipe length of 39-5/8 inches with no more than 437.5 grams fissile per pipe.

The loading above qualifies as Fissile Class III under the provisions of 10CFR71.61, and the maximum number of packages per shipment is one (1). The U-235 equivalent mass is determined by the U-235 mass plus 1.66 times the Pu mass.

6.3 MODEL SPECIFICATION

The model for normal conditions is two casks side by side and touching. The units of fissile material inside each cask are near the lead and near each other. The hydrogen-to-fissile ratio within each fissile material unit in each cask is varied to find the peak k-effective value for the fuel form considered. The inside of each cask is flooded. The two-cask array is surrounded by 12 inches of water reflection on all sides.

The model for the accident condition is one cask that is flooded. The fissile material unit inside the cask is placed near the lead. The hydrogen-to-fissile ratio within the fissile material unit is varied to find the peak k-effective for each fuel form considered. The outside of the cask is surrounded by a 12-in.-thick water reflector.

The model considered the presence of a lead liner for both normal and accident conditions. The analysis with lead liner is contained in Subsection 6.6.

More details of the fissile material modeling and the cask modeling are described below.

6.3.1 Description of Calculational Models

In the discussion below, the fuel modeling is presented first followed by the cask modeling. Each of these models is prepared as input to the SCALE System (Reference 1) using the 27 GROUPNDF4 cross-section set and the KENO-IV criticality code to perform the k-effective calculations. The worst case model as determined by the SCALE System was also analyzed with the GE MERIT criticality code to account for a dimensional change in the cask stainless steel liner thickness.

The models identified for this criticality evaluation include:

Model 1: a homogeneous uranium-water sphere containing 500 grams U-235 of uranium enriched to 100 w/o;

Model 2: a homogeneous plutonium-water sphere containing 300 grams Pu-239;

Model 3: a heterogeneous UO_2 pellet-water sphere containing pellets having outside diameters ≥ 0.30 inches and containing 1,175 grams U-235 for uranium enriched to 5 w/o; and,

Model 4: a heterogeneous UO_2 pellet-water mixture having pellets that are ≥ 0.35 inches OD and containing 1,750 grams U-235 for uranium enriched to 5 w/o in four cylinders fabricated from 5-inch Schedule 40 pipe (≤ 437.5 grams U-235 per pipe).

Models for normal conditions will follow the numeric designation by an A, and models for the accident condition will follow the numeric designation by a B. For example, a model for fully enriched uranium at normal conditions is Model 1A and a model for plutonium under accident conditions is Model 2B.

The Model 2000 cask is modeled in three dimensions. The cask has a cavity of 26.5 inches in diameter and 54 inches in height. The cask outside diameter is 38.5 inches. The total cask radial wall and bottom plate thickness is 6.0 inches. Initially, the radial wall and bottom consisted of 0.5 inch of 304 stainless steel, then 5 inches of lead, and then 0.5 inch of 304 stainless steel was analyzed. The final Model 2000 cask consists of a layered radial wall design composed of 1.0 inch of 304 stainless steel, 4.0 inches of lead, and then another 1.0 inch of 304 stainless steel. The final 2000 cask bottom consists of 6 inches of 304 stainless steel. The top of the cask was modeled as having a 1.5-in.-thick 304 stainless steel plate inside the cask at the top, then 4.5 inches of lead, and then a 1.75-in.-thick 304 stainless steel plate on the top of the cask.

Some of the fissile material units in this analysis are centered within the lead cask, and other fissile material units are near the steel-lead wall. For the fissile material units located near the cylindrical steel-lead wall, the technique used to perform the k-effective calculations involves preparing a model of the fissile material units centered as input to the SCALE System, but running only a few neutron histories, and capturing the cross section information as output from the SCALE System on a tape. Then, models of the fissile material units that are off-centered in the cask and located near the cylindrical steel-lead walls are prepared as input to the free-standing KENO-IV Code (Reference 2) on the SCALE System, using the generalized geometry option available in KENO-IV, and the cross section information is fed into the KENO-IV models from the tape captured in the SCALE runs with the fissile material units centered in the cask. Some examples of input prepared in this manner for all of the models used in this criticality analysis, but only for those hydrogen-to-fissile ratios which produced a peak k-effective for each model, are given below.

Models 1 through 4 prepared as input for the SCALE System may be seen in Tables 6.3.1-1 through 6.3.1-4, respectively. Note that Model 1 and Model 2 are prepared for an infinite homogeneous medium and that Tape 4 is staged to capture the cross section information. Also, the only difference between Model 1 in Table 6.3.1-1 and Model 2 in Table 6.3.1-2 is the three number density cards for each fissile material mixture, which is mixture 1 in these models. This is because the size of the fissile material-water mixture sphere giving the peak k-effective result is the same for the uranium and for the plutonium models.

In Model 3 and Model 4, homogenized fuel pellet-water cross sections are used. Input to obtain the homogenized fuel cross sections on tape is shown in Table 6.3.1-3 for Model 3 and in Table 6.3.1-4 for Model 4. Fuel homogenization is accomplished by two actions: the use of the LATTICECELL card and the

TRIANGPITCH card to specify the pitch between the fuel pellets and the fuel pellet diameter for each model considered, coupled with the use of Material 500 to describe the fuel-water mixture inside the sphere in Model 3 and inside the cylinder in Model 4. When the SCALE System encounters this input, the XSDRNPM Code is then used to flux and volume weight the cross sections for either the 0.762-cm pellet outside diameter (POD) at the 2.07-cm pitch specified for Model 3, or for the 0.889-cm POD specified for the 1.83-cm pitch in Model 4 into homogeneous fuel materials represented by Material 500 in each of these models. In each of these models, Tape 3 is staged to capture the cross sections of the homogenized fissile material-water mixtures for use in later calculations for each of the models.

In Table 6.3.1-4 for Model 4, the 5-inch Schedule 40 pipe is represented by an outside radius of 7.065 cm (5.563 inches OD) and by an inside radius of 6.477 cm (5.1 inches ID). This gives a pipe wall thickness of 0.588 cm (0.2315 inches), which is about 10% smaller than the standard wall thickness to allow for manufacturing tolerances. The 0.588-cm thick wall is also used on the bottom of the cylinder. The material used for the cylinder in this evaluation is water.

Models for normal conditions prepared as input for the KENO-IV Code may be seen in Tables 6.3.1-5 through 6.3.1-8 for Models 1A through 4A. Tape 4 is staged with the proper tape number to provide the proper cross section input for each of these models as specified by the number densities in these tables. It is also noted that in Table 6.3.1-5 from the BOX TYPE 1 card onto the end, the input is identical to that required for Table 6.3.1-6. This is due to the same size spheres occurring for the fissile material-water mixtures for the uranium and plutonium models, as noted earlier. Therefore, this input is not presented in Table 6.3.1-6.

The input shown in Tables 6.3.1-5 through 6.3.1-8 contains generalized geometry information, and this information may be displayed pictorially with the Picture code (Reference 3). Some examples of output from the Picture code are given below.

Figure 6.3.1-1 shows a plan view and a vertical view for Model 3A shown in Table 6.3.1-7. Figure 6.3.1-2 shows a plan view and a vertical view for Model 4A shown in Table 6.3.1-8. Picture code output for Model 1A in Table 6.3.1-5 and for Model 2A in Table 6.3.1-6 is similar to the output for Model 3A shown in Figure 6.3.1-1 except that the sphere diameter is smaller for Models 1A and 2A. The Picture code results for Models 1A and 2A are not presented here.

Models 1B through 4B prepared as input for KENO-IV may be seen in Tables 6.3.1-9 through 6.3.1-12, respectively. The Picture code result for Model 3B in Table 6.3.1-11 is shown in Figure 6.3.1-3. Picture code results for Models 1B and 2B in Tables 6.3.1-9 and 6.3.1-10, respectively, are not presented due to their similarity with the results shown in Figure 6.3.1-3; only the sphere diameter is smaller for Models 1B and 2B. Picture code results for Model 4B in Table 6.3.1-12 are shown in Figure 6.3.1-4.

Models for the fissile material units described thus far but located outside of a cask and surrounded by water are simpler and are described in Section 6.4 along with the k-effective results they produce. These results permit a comparison with the k-effective results of the fissile material units in a cask and near the lead to show the effect of the cask lead-steel structure on k-effective.

6.3.2 Package Regional Densities

The number densities for the materials used in the models in this evaluation may be seen in Tables 6.3.1-1 through 6.3.1-12. The names for the cross sections corresponding to the coded material numbers presented in these tables that are provided by the SCALE System for the 27 GROUPNDF4 cross section set are shown in Tables 6.4.2-1 through 6.4.2-13. Equivalent atom densities were used for the GE MERIT criticality code.

In formulating these number densities, values for some constants were used. These constants and their values are given below.

Item	Value
Molecular Weight for Oxygen	15.9994 grams/gram-mole
Molecular Weight for U-235	235.043933 grams/gram-mole
Molecular Weight for U-238	238.05076 grams/gram-mole
Molecular Weight for Pu-239	239.0522 grams/gram-mole
Number Density for Oxygen in Water	0.0333773 atoms/barn-cm
Avogadro's Number	6.025E+23 gram-atoms/gram-mole
Density of UO_2	10.96 grams UO_2/cc UO_2
Barn	1.E-24 cm^2

6.4 CRITICALITY CALCULATIONS

The calculational methods used to determine the nuclear reactivity for the fuel loadings chosen for this package are described below. This is followed by a presentation of the k-effective results obtained using these methods and a discussion of these results.

6.4.1 Calculational Methods

The computational tools used in this evaluation are the KENO-IV (SCALE System) code and the GE MERIT code. A brief description of these computational tools is given below.

a. SCALE System

The SCALE System was run on a Control Data Corporation 7600 Computer. This computer system contained:

1. Stand-alone computer codes referred to here as functional modules for neutronic analysis that included criticality analysis and shielding analysis.

2. Computer codes noted here as control modules which read simplified sets of input data and invoked one or more of the functional modules in a pre-established sequence to perform a specific type of criticality or shielding analysis.

3. A driver package which interfaced with the CDC System to provide the software and operating environment in which various control modules may be executed.

4. Data libraries containing nuclear cross section data and material property data.

The control modules read a simplified set of input describing a given problem, perform a number of auxiliary calculations formerly required by the program user, and call the necessary functional modules sometimes in an iterative fashion to achieve a desired solution.

The Criticality Safety Analysis Sequence 2 (CSAS2) in the SCALE System is used to calculate the effective neutron multiplication factor (k-eff) for multidimensional systems which can be described in the KENO-IV geometry. An optional one-dimensional calculation in CSAS2 allows the user to 1) describe a unit cell in the fuel assembly, 2) perform a one-dimensional eigenvalue calculation of the unit cell to determine the spatially dependent flux spectrum, 3) cell-weight the microscopic cross section data with this spatially dependent spectrum, 4) homogenize the nuclide number densities in the unit cell [fuel assembly], and then 5) use these homogenized cell-weighted cross sections in a subsequent multidimensional KENO-IV calculation. This analysis sequence includes two cross section processing codes, NITAWL and BONAMI; a one-dimensional transport code for cell-weighting cross section data called XSDRNPM; and a three-dimensional Monte Carlo code called KENO-IV for calculating the effective neutron multiplication factor (k-eff) for the entire system.

In the calculational sequence defined by CSAS2, the master cross section library selected first will be processed by BONAMI, which will perform a resonance self-shielding calculation for those nuclides which have Bondarenko data in lieu of resonance parameters. Dancoff factors are determined in DANCOF for lumped absorbers for the resonance self-shielding calculation. The self-shielding data for these nuclides, along with the original data for all the other nuclides, then will be stored on-line in the same format as the original master library. Data for nonresonance nuclides and data for nuclides with resonance parameters will be copied onto this library essentially unchanged from the original library. The NITAWL code then will read the second master library, perform a resonance self-shielding calculation for those nuclides having resonance parameters, and collect results into a working library which may be used by the XSDRNPM and/or KENO-IV codes. This working library has the same number of energy groups and the same group structure as the original master library selected by the user. Unlike the original master library, it contains the self-shielded, group-averaged cross section data for the given physical situation. XSDRNPM is a one-dimensional discrete-ordinates transport code used by CSAS2 to obtain cell-weighted microscopic cross sections. To obtain the spatially dependent flux spectrum, XSDRNPM will perform a one-dimensional eigenvalue calculation for the unit cell. To ensure good resolution, the control module automatically will determine the amount of spatial mesh intervals to be used in each material zone. The cell-weighted working library produced by XSDRNPM then will have the same number of groups and the same group structure as the original master library selected by the user. Cross sections for the user-defined mixtures not found in the fuel assembly are effectively copied from the NITAWL working library to the XSDRNPM working library without change.

KENO-IV is a multigroup Monte Carlo code used by CSAS2 to determine the effective neutron multiplication factor of the multidimensional system specified by the user. KENO geometry is a three-dimensional geometry and allows for the simultaneous use of cuboids, spheres, hemispheres, cylinders, hemicylinders, and embedded arrays of such bodies.

Three cross section libraries had been assembled for use in the SCALE System on General Electric's CDC 7600 Computer at the time this analysis was performed. These included a 16-group cross section set based on earlier Hansen-Roach data, a 27-group cross section set collapsed from a 218-group cross section set based on ENDF/B-IV data, and a 123-group cross section set based on earlier GAM-THERMOS (Reference 4) data. The 27-group cross section set was selected for this evaluation.

b. GE MERIT

The GE MERIT program is a Monte Carlo program for solving the linear neutron transport equation as a fixed source or an eigenvalue problem in three space dimensions. The cross sections in MERIT are processed from the ENDF/B library in the multigroup and resonance parameter formats. Thermal scattering in water is represented by the Haywood Kernal obtained from the ENDF/B library. The MERIT program utilizes 190 full spectrum cross section energy groups. The types of reactions considered in MERIT are fission, elastic, inelastic and (n,2n) reactions. Absorptions are implicitly treated by applying the non-absorption probability to neutron weights on each collision. This code is available on the GE Honeywell 6000 computer system.

6.4.2 Criticality Results

K-effective is plotted as a function of hydrogen-to-fissile ratio in Figures 6.4.2-1 through 6.4.2-8 for all of the models considered in this evaluation in order to find the peak k-effective value for each model. K-effective results are presented for each peak k-effective value for each model in Tables 6.4.2-1 through 6.4.2-8. Additional k-effective information is plotted in Figure 6.4.2-9. Additional k-effective information is also presented in Tables 6.4.2-9 through 6.4.2-15. More detail about information contained in these figures and tables is presented below.

In Figures 6.4.2-1 through 6.4.2-9, k-effective results are presented. Each k-effective result is presented for a mean value and an upper limit and a lower limit at 2 sigma. Each of the k-effective values presented contains a bias. The bias is different for each of the fissile materials considered and is discussed in Section 6.5. The bias applied in each figure is stated in the title for each figure.

K-effective results are also presented in Tables 6.4.2-1 through 6.4.2-13 for peak k-effective values. These tables contain the number densities for the materials used in each model; names identifying each of these materials that are provided by the SCALE System for the 27 GROUPNDF4 cross section set; some fissile material unit array information if an array was used in the model; the k-effective result calculated showing the mean value, the one sigma value, and the number of neutron histories achieved for each calculation; and a histogram of the k-effective values calculated for each model. The k-effective results in these tables do not contain a bias. K-effective results are discussed for each of the models separately below.

A comparison of k-effective results in Figures 6.4.2-1 and 6.4.2-2 shows there to be little difference between the two-cask model and the single cask model. A comparison of k-effective results between Tables 6.4.2-1 and 6.4.2-2 shows the peak k-effective to occur with the two-cask model (1A) and to have a k-effective value of 0.919 with biases applied, which is about 0.005 higher than the peak k-effective for the one-cask model (1B). A comparison of k-effective values between Tables 6.4.2-2 and 6.4.2-9 shows the peak k-effective to occur when the fissile material unit is centered in the lead cask and to have a peak k-effective value of 0.918 with biases applied, which is about 0.004 higher in k-effective than Model 1B.

A comparison of k-effective results in Figures 6.4.2-3 and 6.4.2-4 shows there to be little difference between the one-cask and two-cask models for the plutonium spheres. A comparison of k-effective results between Tables 6.4.2-3 and 6.4.2-4 shows the peak k-effective to be 0.918 at 2 sigma for the single cask model (2B) and to be about 0.006 higher than for the two-cask model (2A). A comparison between Tables 6.4.2-4 and 6.4.2-10 shows the peak k-effective of 0.918 to be about 0.010 higher in k-effective than when the plutonium sphere is centered in the cask.

A comparison of k-effective results between Figures 6.4.2-5 and 6.4.2-6 shows little difference between the one-cask model and the two-cask model. A comparison of k-effective results in Tables 6.4.2-5 and 6.4.2-6 shows the peak k-effective to be 0.941 at 2 sigma with biases applied for the two-cask model (3A), which is about 0.003 higher than the one-cask model (3B). A comparison of k-effective values between Tables 6.4.2-6 and 6.4.2-11 shows the peak k-effective to be 0.938 at 2 sigma with biases applied for Model 3B, which is about 0.009 higher than for the UO_2 sphere centered in the cask.

A comparison of the values in Figures 6.4.2-7 and 6.4.2-8 shows the k-effective to be higher for the single cask model (4B). A comparison of the results between Tables 6.4.2-7 and 6.4.2-8 shows a peak k-effective of 0.941 to occur at 2 sigma with biases applied, which is about 0.025 higher than the two-cask model (4A). A comparison of the results between Tables 6.4.2-8 and 6.4.2-12 shows the peak k-effective to be 0.941 for Model 4B, which is 0.044 higher in k-effective than when these cylinders are centered in the cask. K-effective values for four cylinders in Model 4 that are flooded but located outside of a cask and fully reflected by water are also shown in Figure 6.4.2-8. Peak results for the case with the four cylinders outside of a cask are presented in Table 6.4.2-13 and are lower in k-effective by 0.039 than for Model 4B.

There is concern whether UO_2 pellet-water mixtures are more reactive or less reactive for other pellet OD's than they are for 0.3-inch pellet OD's or 0.35-inch pellet OD's for 5 w/o UO_2 pellets. Examination of data in DP-1014, Appendix B for 5 w/o UO_2 pellets shows the following:

Pellet OD, inches	Minimum Critical Mass, grams U-235
0.	1,850
0.05	1,600
0.10	1,560
0.20	1,660
0.30	1,880
0.40	2,140

These results show that peak k-effective occurs at a 0.1-inch pellet OD for 5 w/o UO_2 pellet-water mixtures.

There is concern whether a model in which the 5-inch Schedule 40 pipes are touching gives the highest k-effective values. Therefore, additional calculations were made in which the four pipes, flooded and located outside of a cask, were separated by 0.5 inches, 1 inch, and 2 inches. In these calculations the four cylindrical fuel assemblies were modeled with an OD of 5.1 inches, and the space around the fuel assemblies was filled with water. Twelve inches of water surrounded the four-pipe arrangement on all six sides. The results of these calculations are shown in Figure 6.4.2-9. These results show the peak k-effective to occur when the pipes are touching and that no higher k-effective values occur as the pipes are separated. These calculations were performed at a hydrogen-to-fissile ratio of 276.

MERIT calculations were performed on Model 3B using the old cask wall thickness composition for comparison to the SCALE system. Table 6.4.2-14 shows the result of the comparison. The results after correction for biases show the same k-effective value to within the statistical uncertainty of the calculations. Therefore, the two independent codes provide the same result for the same geometry model.

The MERIT result for Model 3A using the final cask dimensions resulted in a maximum k-effective of 0.938, including biases and a 2 sigma uncertainty. Table 6.4.2-15 contains these results. Since the results for the single and double cask analyses described earlier in this chapter yielded almost identical results, it was already demonstrated that the casks are almost neutronically decoupled. Therefore, as these results show, increasing the higher cross section stainless steel material thickness does not increase the k-effective of the system for the worst possible situation involving the Model 2000 shipping cask.

6.5 CRITICAL BENCHMARK EXPERIMENTS

In the discussion below, the benchmark experiments are presented first. This is followed by tables showing models of these experiments prepared as input to the SCALE System. Then the k-effective results using these models are presented, followed by the determination of biases required for each of the types of fissile material.

6.5.1 Benchmark Experiments and Applicability

Uranium with enrichments varying from 5 w/o to fully enriched and plutonium are the fissile materials that need to be considered in the validation of the computational tools for this evaluation. The forms include fully enriched homogeneous uranium-water mixtures, low-enriched heterogeneous uranium dioxide-water mixtures, and homogeneous plutonium-water mixtures.

In Table 6.5.1-1, critical experiments suitable for validation of computational tools as based on the various combinations of fissile materials that may appear in cask loadings in this evaluation are identified.

6.5.2 Details of the Benchmark Calculations

Models of TRX-1 and TRX-2 prepared as input to the SCALE system are shown in Tables 6.5.2-1 and 6.5.2-2, respectively. Models of ORNL-1, ORNL-2, PNL-1, and PNL-2 are shown in Table 6.5.2-3. Models of the B&W UO_2 rod and MO_2 rod are shown in Table 6.5.2-4.

6.5.3 K-Effective Results of the Benchmark Calculations

K-effective results for the SCALE system are presented for the ORNL, PNL, TRX, and B&W critical experiments in Table 6.5.3-1. Based on these critical experiments, the k-effective values calculated by the SCALE System, using the 27-group cross section set, will be corrected as follows: a positive bias correction of 2.3 percent for low-enriched, clumped uranium rods in water; and no bias correction for plutonium solutions. The bias corrections were conservatively selected from the Benchmark Experiments on Table 6.5.3-1, and represent the maximum underprediction of the critical eigenvalue, for uranium and plutonium systems, respectively. The uncertainty on the bias correction for low-enriched, clumped uranium rods in water is 0.3 percent on the sigma deviation, and is applied as a bias when determining the maximum k-effective of each geometry calculation.

K-effective results for the GE MERIT system are presented for the ORNL, PNL, TRX, and B&W critical experiments in Table 6.5.3-2. The uncertainties quoted in the table are one standard deviation. In the TRX cases, MERIT was used to compute K-infinity and the leakage corrections from Reference 5 were applied to obtain k-effective. For all other calculations, the MERIT model used full three-dimensional geometric representations. For the Gross Section Evaluation Working Group (CSEWG, Reference 6) problems, MERIT is generally in agreement within statistics with the other calculations agreeing especially well with the detailed BAPL (Bettis Atomic Power Laboratories) Monte Carlo calculations. For the two B&W critical experiments, MERIT underpredicts the eigenvalue by 0.5 percent. In the BWR critical experiments with boron curtains and gadolinia rods, MERIT underpredicts the eigenvalue by approximately 0.3 to 0.5 percent. The previous CSWEG evaluations of the ENDF/B-IV files (Reference 6) concluded that the experimental k-effective is generally overpredicted by 1-2% for plutonium nitrate systems and underpredicted by approximately 0.5 percent for high moderator-to-fuel ratios to approximately 1.5 percent for low moderator-to-fuel ratios in water-moderated uranium lattices. The MERIT results in Table 6.5.3-2 confirm these biases, thus supporting the CSWEG conclusions.

The MERIT critical benchmark bias for low enriched uranium lattice systems was determined to be 0.51 percent from the experiments contained in Table 6.5.3-2 and additional experiments contained in Reference 7. The uncertainty on the bias correction is 0.26 percent on the one sigma deviation.

6.6 APPENDIX

6.6.1 Criticality Evaluation of Package with Lead Liner

The 2000 cask was analyzed with lead liner present for the most limiting package fuel loading. The criticality analysis for both normal and accident conditions for the limiting package fuel was demonstrated to be less than k-effective equal to 0.95. No credit was taken for the structural integrity of the lead liner under accident conditions.

The most limiting payload analyzed was package fuel load 2 described in Section 6.2. The model for normal conditions is two casks side by side and touching. The units of fissile material inside each cask are at the bottom near the wall and near each other. Figure 6.6.1 illustrates the location of the fissile material in the normal condition without a lead liner and Figure 6.6.2 with a lead liner. The case with lead liner resulted in a small increase in the maximum k-effective of 0.07% Δk. The maximum calculated k-effective with lead liner is 0.9351. Since the fissile units are well isolated from each other and the geometric relation between the fissile unit and the lead in the cask wall is similar with and without a liner, the results support the insensitivity to the presence of the lead liner.

The maximum k-effective is lower for the no-liner case when compared to Table 6.1 because the neutron histories for this comparison were increased from 50,000 to 150,000. This reduced the calculation uncertainty contribution to the maximum k-effective.

The model for the accident condition is one cask that is flooded. For the accident condition the cask is assumed to be upside down with the fissile material unit placed at the top lid and wall near the lead. The liner lid which contains more lead than the liner wall is assumed to collapse onto the top of the fissile material. The resulting accident condition results in a 0.12% Δk increase compared to the normal condition without a liner. The maximum calculated k-effective with the lead liner in the accident condition is 0.9356.

000AD 2000 CASK DESIGN 3A 1175 GM U235 H/F=386.21 05 MAR 1989 10:53:06 PAGE 8

GEOMETRY PLOT. LTP 1, NPX 125, NPY 63, X1-7.03750E+01, X2 7.03750E+01, Y1-7.03750E+01, Y2 4.00001E+01, Z1-5.17800E+01.

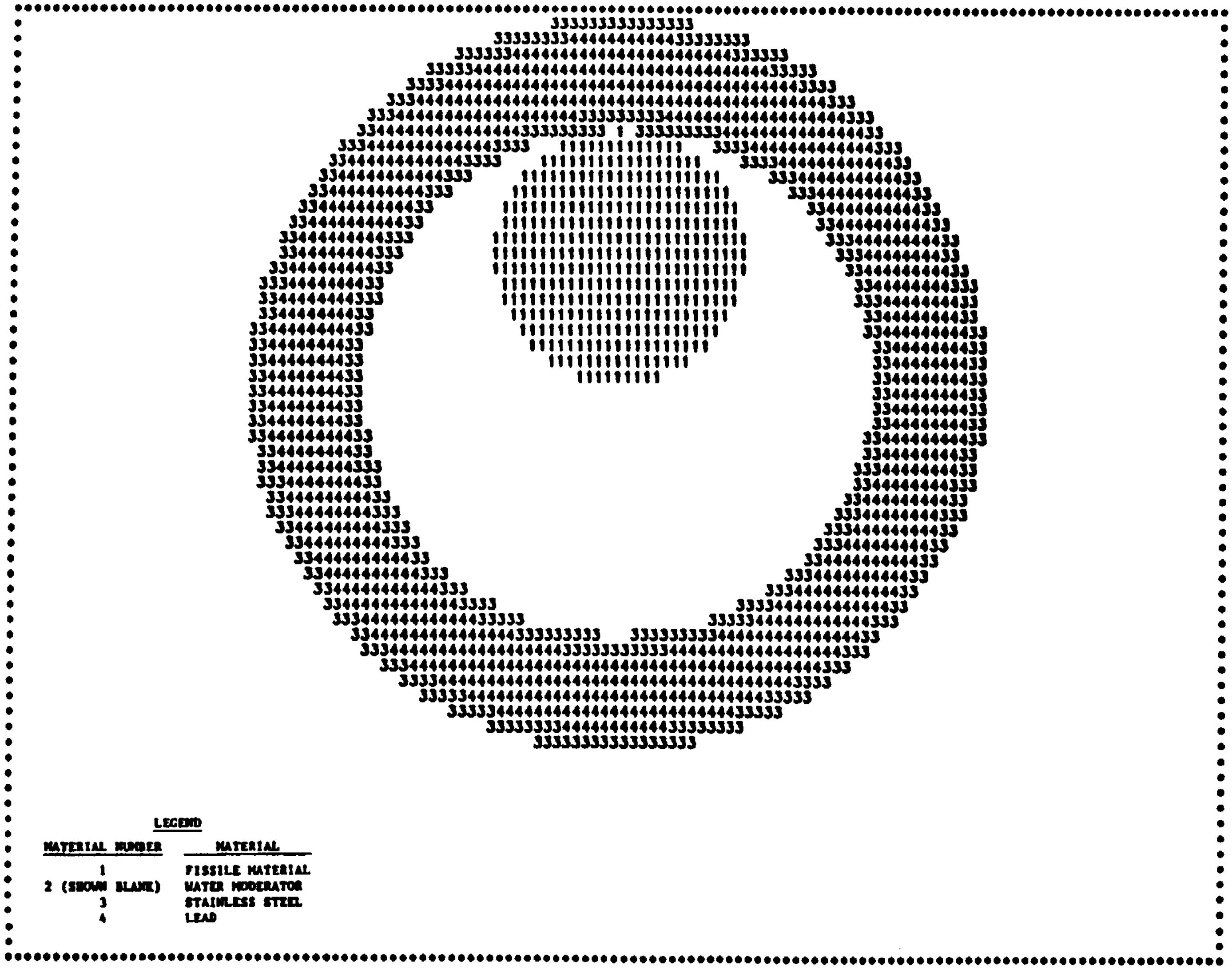
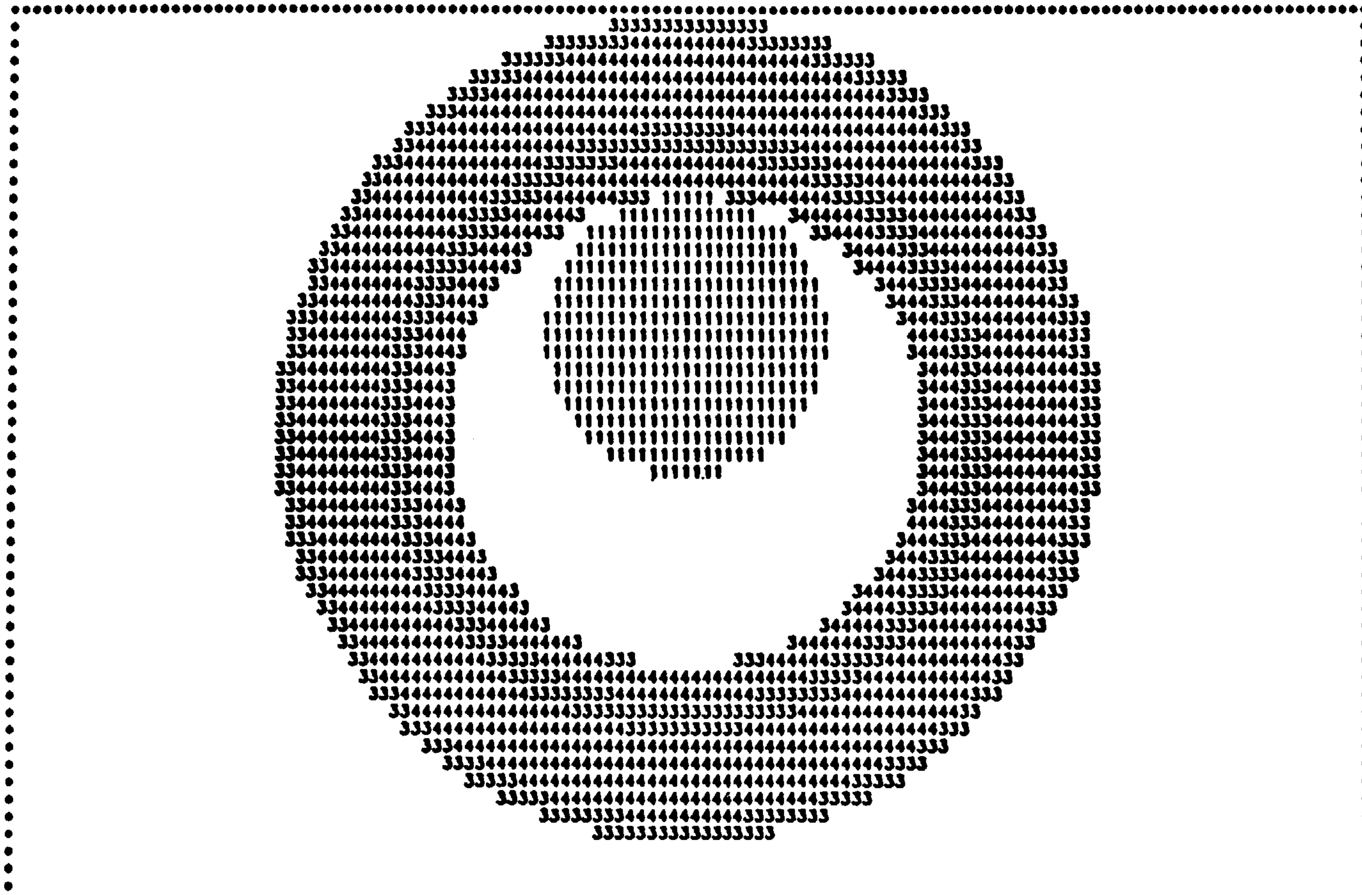


FIGURE 6.6.1. CASK MODEL WITHOUT LINER

001C2 2000 CASK DESIGN 3A 1175 GM U235 H/F=388.21 W/LEAD LINER 07 MAR 1989 13:40:57 PAGE 9

GEOMETRY PLOT. LTP 1, NPX 125, NPY 63, X1-7.03750E+01, X2 7.03750E+01, Y1-7.03750E+01, Y2 4.80001E+01, Z1-4.35250E+01.



LEGEND

MATERIAL NUMBER	MATERIAL
1	FISSILE MATERIAL
2 (SHOWN BLANK)	WATER MODERATOR
3	STAINLESS STEEL
4	LEAD

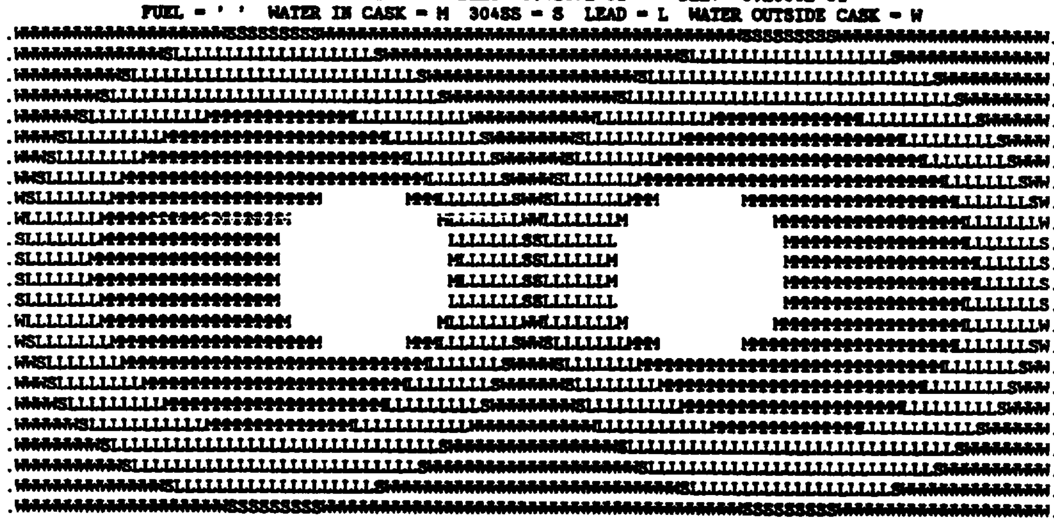
FIGURE 6.6.2. CASK MODEL WITH LINER

PLAN VIEW MODEL 3A

X	-0.1000E 03	0.1000E 03
Y	0.5000E 02	-0.5000E 02
Z	0.1680E 02	0.1680E 02

NU= 24 NV= 100 DELU= 0.4167E 01 DELV= 0.2000E 01

FUEL = ' ' WATER IN CASK = M 304SS = S LEAD = L WATER OUTSIDE CASK = W



VERTICAL VIEW MODEL 3A

X	-0.1000E 03	0.1000E 03
Y	0.	0. E 00
Z	0.1612E 03	-0.1800E 02

NU= 43 NV= 100 DELU=-0.4167E 01 DELV= 0.2000E 01

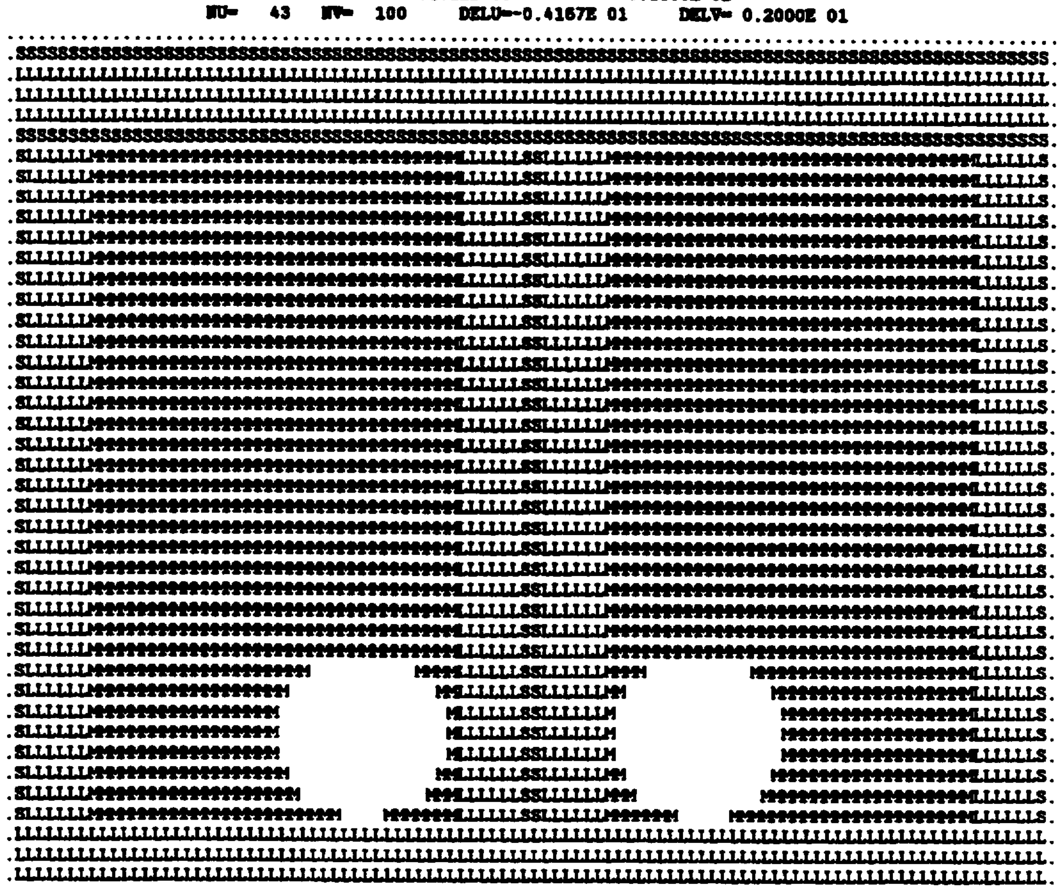
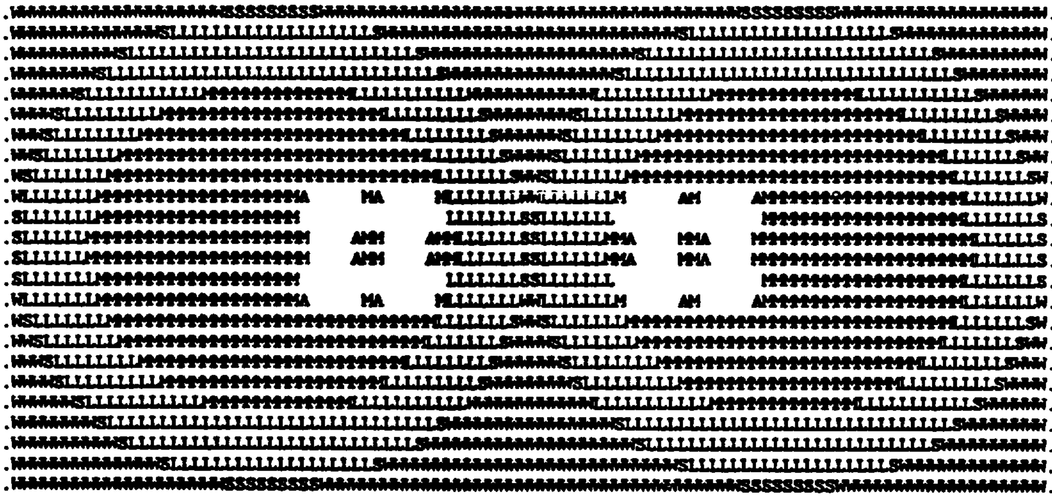


FIGURE 6.3.1-1. PLAN VIEW MODEL 3A

PLAN VIEW MODEL 4A

X -0.1000E 03 0.1000E 03
Y 0.5000E 02 -0.5000E 02
Z 0.1600E 02 0.1600E 02
NU= 24 NV= 100 DELU= 0.4167E 01 DELV= 0.2000E 01

FUEL = ' ' WATER IN CASK = M WATER PIPE WALL = A 304SS = S LEAD = L WATER OUTSIDE CASK = W



VERTICAL VIEW MODEL 4A

X -0.1000E 03 0.1000E 03
Y 0.7065E 01 0.7065E 01
Z 0.1612E 03 -0.1800E 02
NU= 43 NV= 100 DELU= 0.4167E 01 DELV= 0.2000E 01

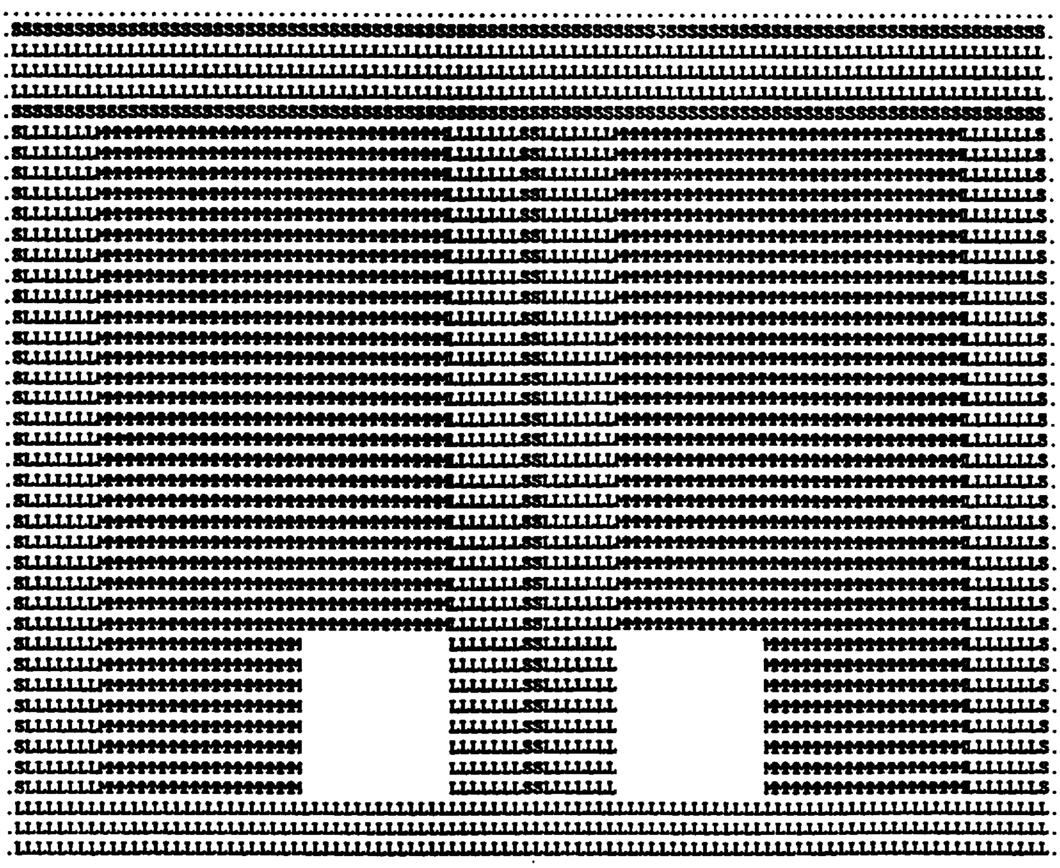
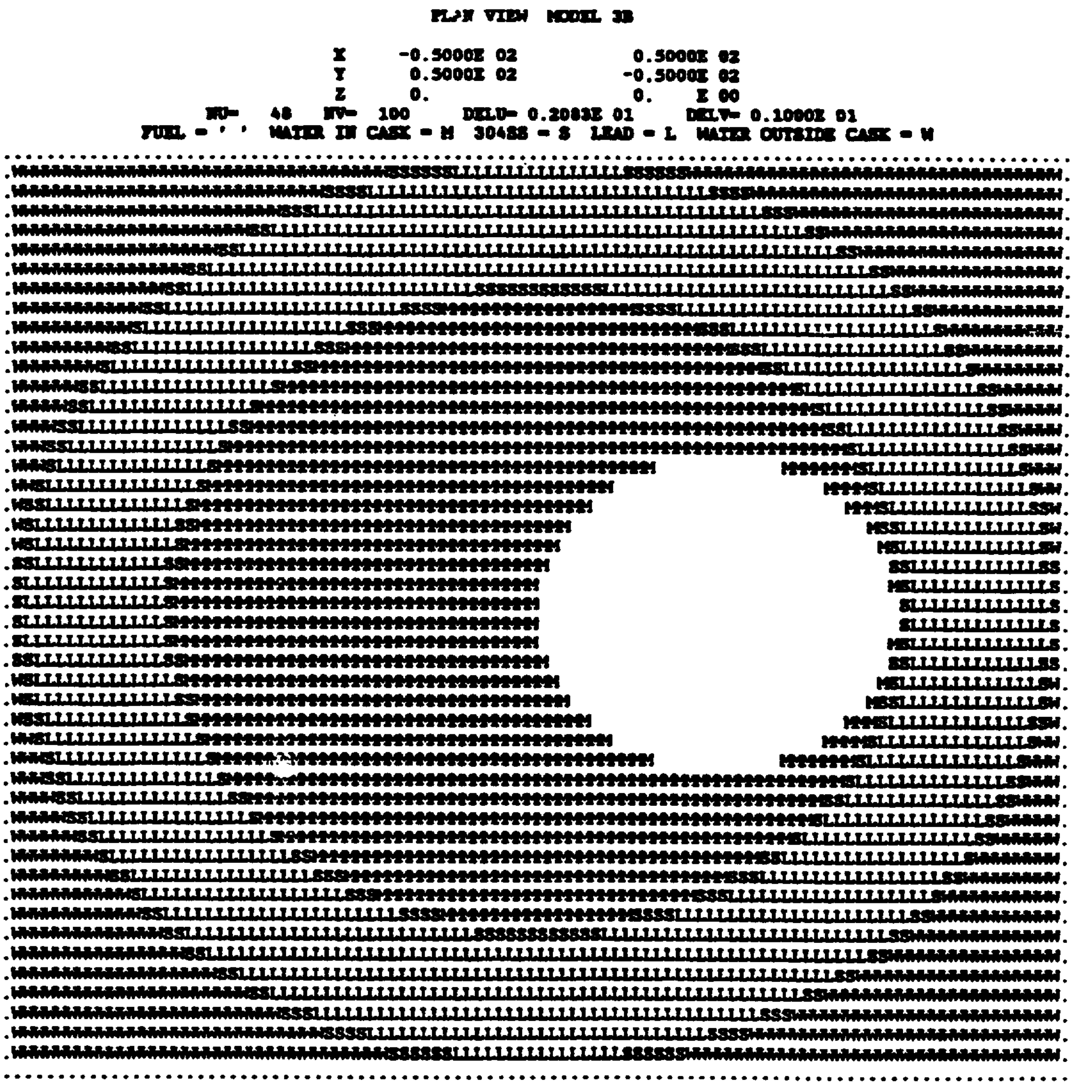


FIGURE 6.3.1-2. PLAN VIEW MODEL 4A



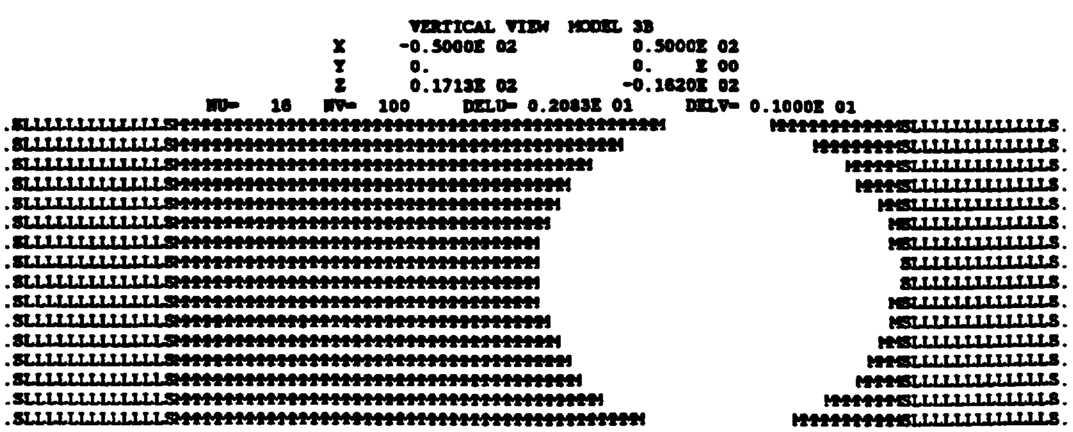
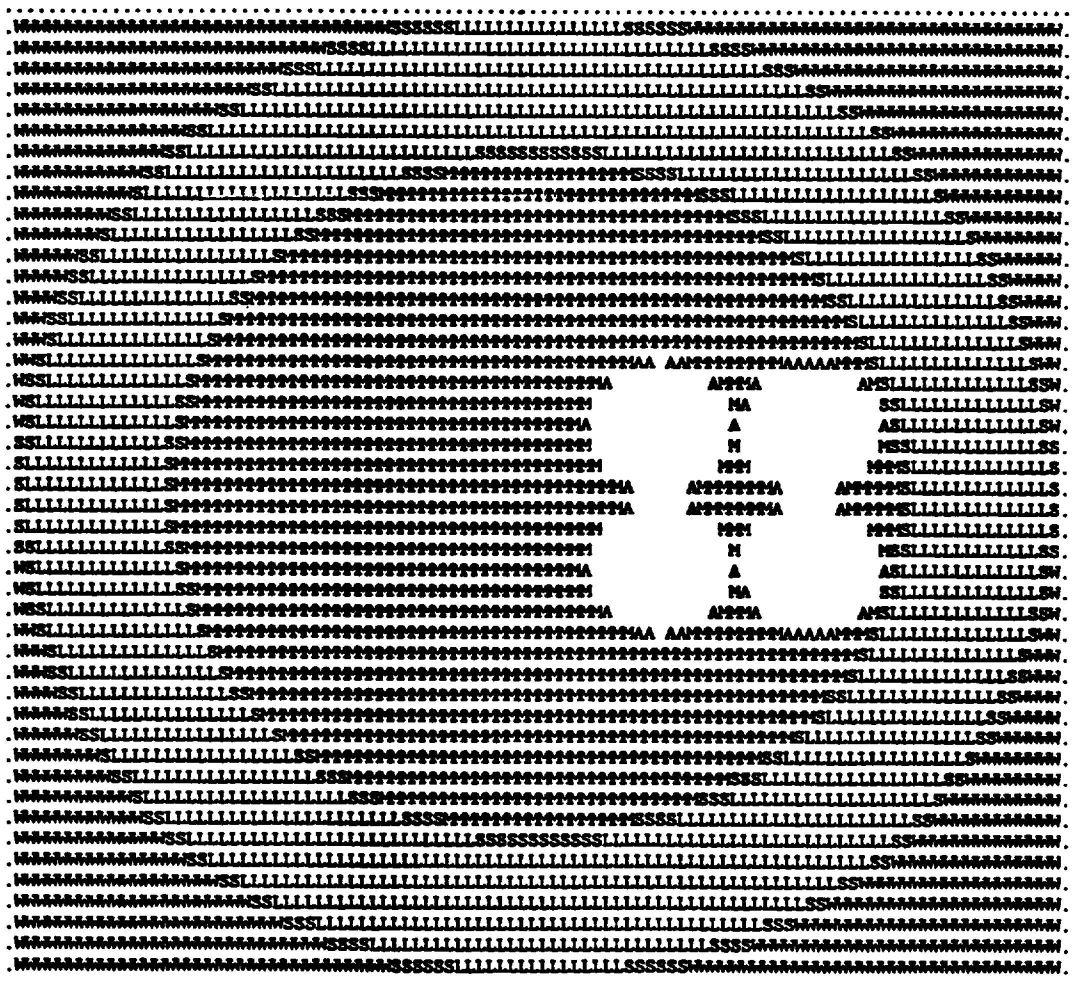


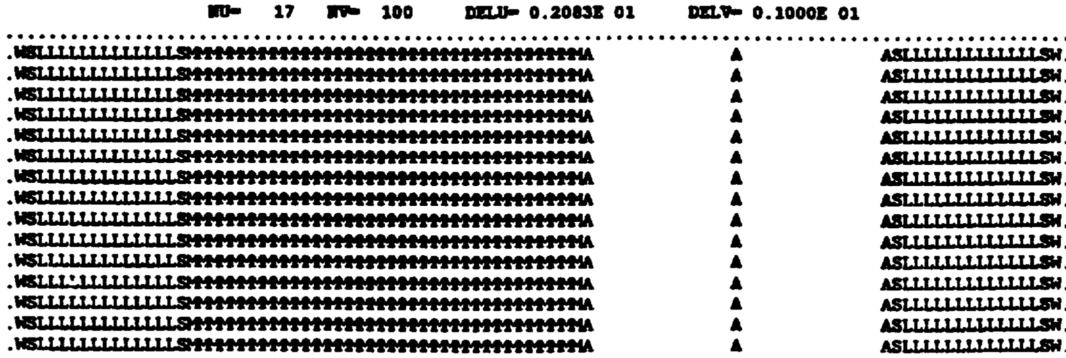
FIGURE 6.3.1-3. PLAN VIEW MODEL 3B

PLAN VIEW MODEL 4B

X -0.5000E 02 0.5000E 02
Y 0.5000E 02 -0.5000E 02
Z 0. 0. E 00
NU= 48 NV= 100 DELU= 0.4167E 01 DELV= 0.1000E 01
FUEL = ' ' WATER IN CASK = M WATER PIPE WALL = A 304SS = S LEAD = L WATER OUTSIDE CASK = W



VERTICAL VIEW MODEL 4B
X -0.5000E 02 0.5000E 02
Y -0.7065E 01 0.7065E 01
Z 0.1842E 02 -0.1700E 02
NU= 17 NV= 100 DELU= 0.2083E 01 DELV= 0.1000E 01



PLAN VIEW MODEL 3B

FIGURE 6.3.1-4. PLAN VIEW MODEL 4B

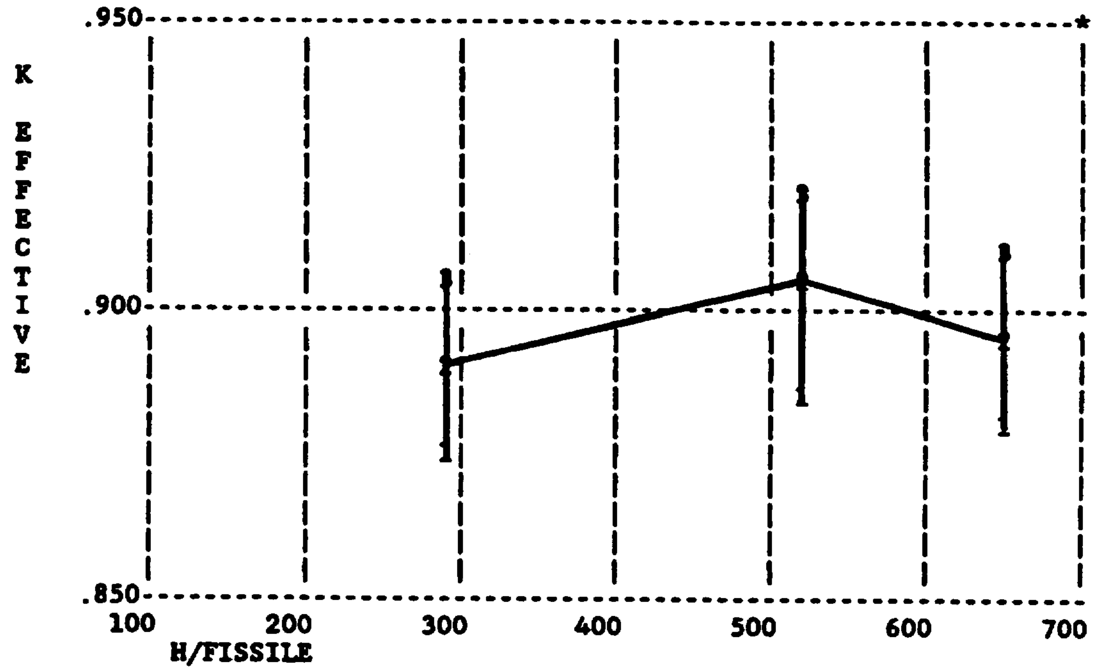


FIGURE 6.4.2-1. K-EFFECTIVE (±2 SIGMA) VS. H/FISSILE FOR MODEL 1A. TWO 500 GRAM U-235 UNITS OF U(100)-H2O ARE EACH IN SPHERICAL HOMOGENEOUS MIXTURES IN SEPARATE FLOODED CASKS SIDE-BY-SIDE NEAR THE LEAD AND NEAR EACH OTHER. THERE IS 12" OF WATER REFLECTION AROUND THE ARRAY. K-EFFECTIVE VALUES CONTAIN A BIAS OF 0.3 PERCENT IN THE 1 SIGMA VALUE.

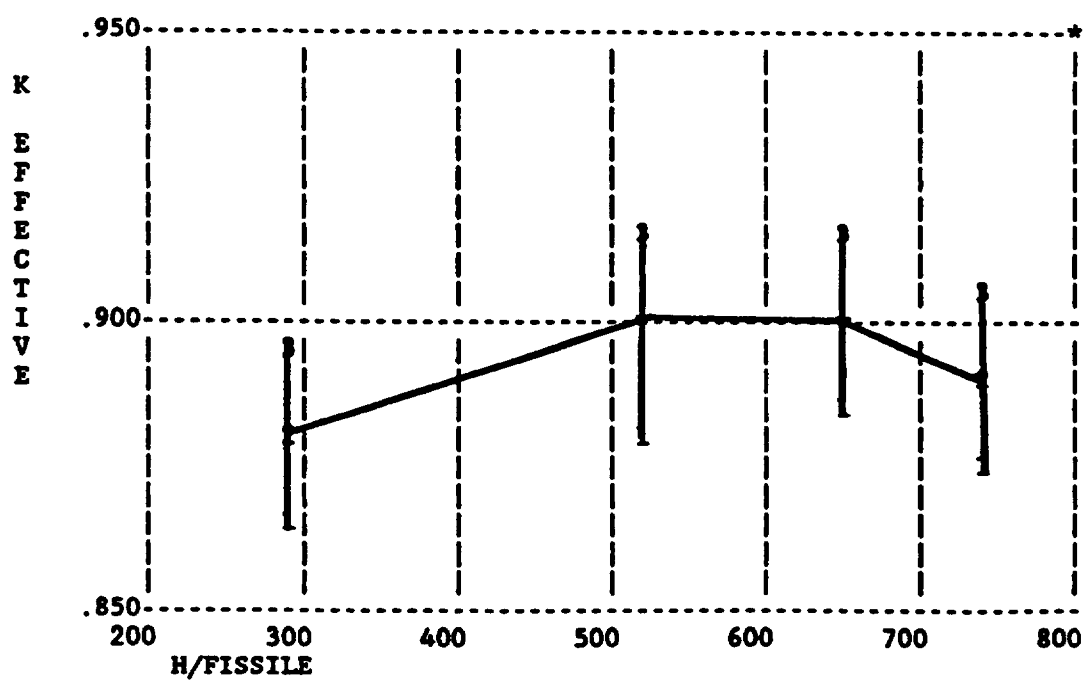


FIGURE 6.4.2-2. K-EFFECTIVE (±2 SIGMA) VS. H/FISSILE FOR MODEL 1B. A 500 GRAM U-235 UNIT OF U(100)-H2O IS IN A SPHERICAL HOMOGENEOUS MIXTURE NEAR THE LEAD INSIDE A FLOODED CASK. THERE IS 12" OF WATER REFLECTION AROUND THE ARRAY. K-EFFECTIVE VALUES CONTAIN A BIAS OF 0.3 PERCENT IN THE 1 SIGMA VALUE.

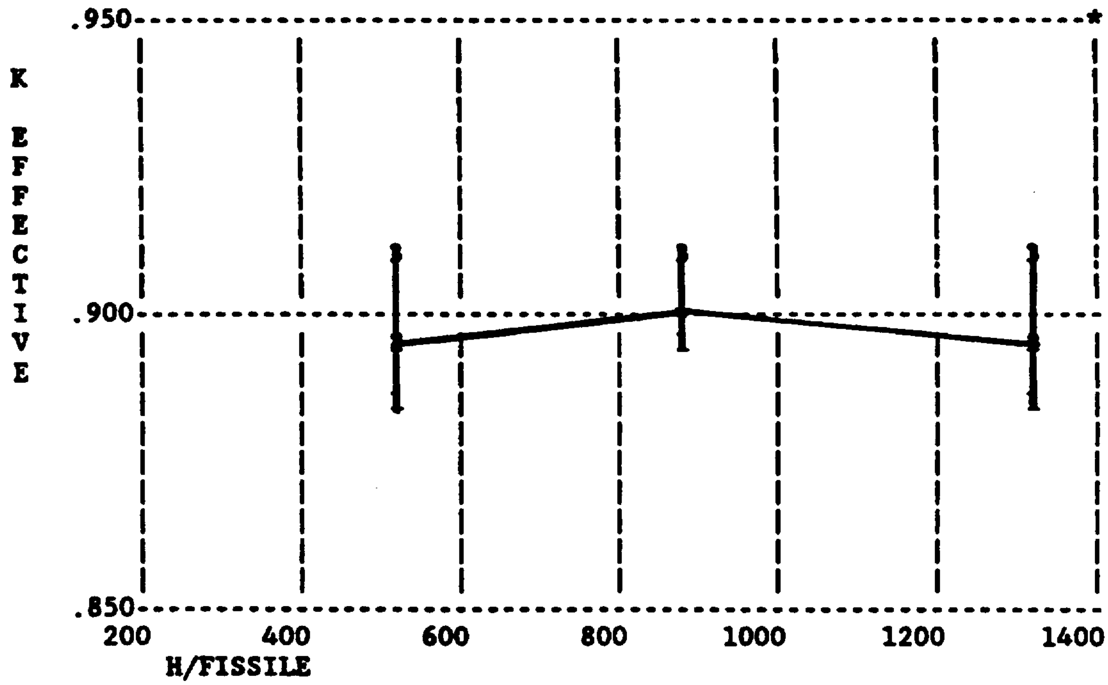


FIGURE 6.4.2-3. K-EFFECTIVE (±2 SIGMA) VS. H/FISSILE FOR MODEL 2A. TWO 300 GRAM PU-239 UNITS OF PU(0PU240)-H2O ARE EACH IN SPHERICAL HOMOGENEOUS MIXTURES IN SEPARATE FLOODED CASKS SIDE-BY-SIDE NEAR THE LEAD AND NEAR EACH OTHER. THERE IS 12" OF WATER REFLECTION AROUND THE ARRAY.

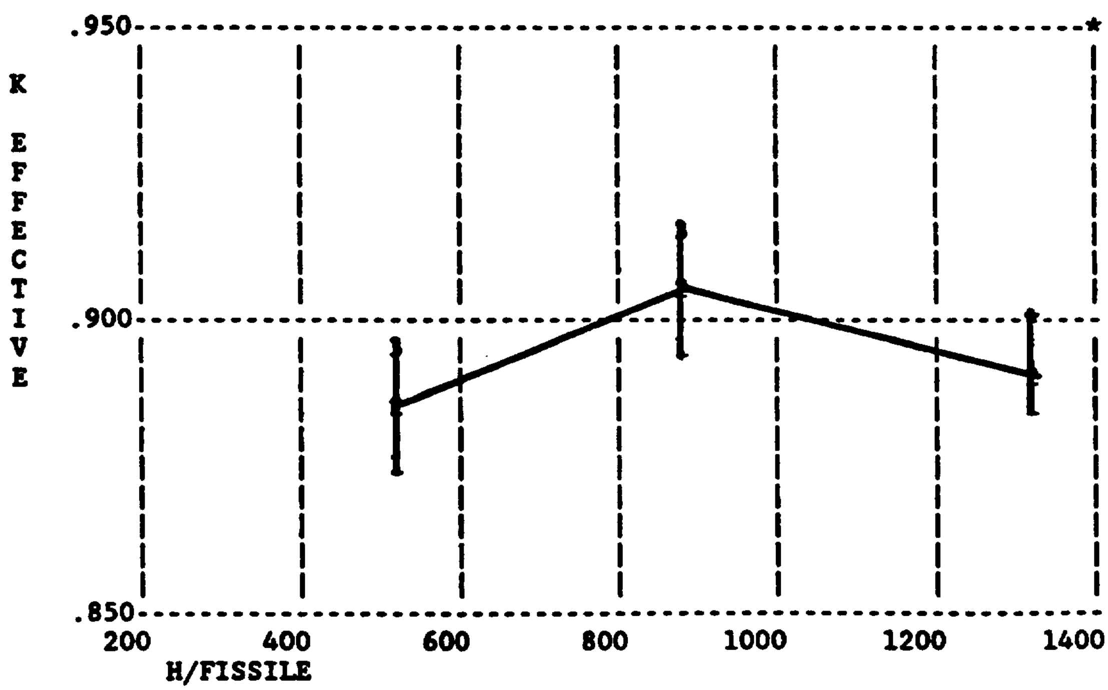


FIGURE 6.4.2-4. K-EFFECTIVE (±2 SIGMA) VS. H/FISSILE FOR MODEL 2B. A 300 GRAM PU-239 UNIT OF PU(0PU240)-H2O IS IN A SPHERICAL HOMOGENEOUS MIXTURE NEAR THE LEAD INSIDE A FLOODED CASK. THERE IS 12" OF WATER REFLECTION AROUND THE ARRAY.

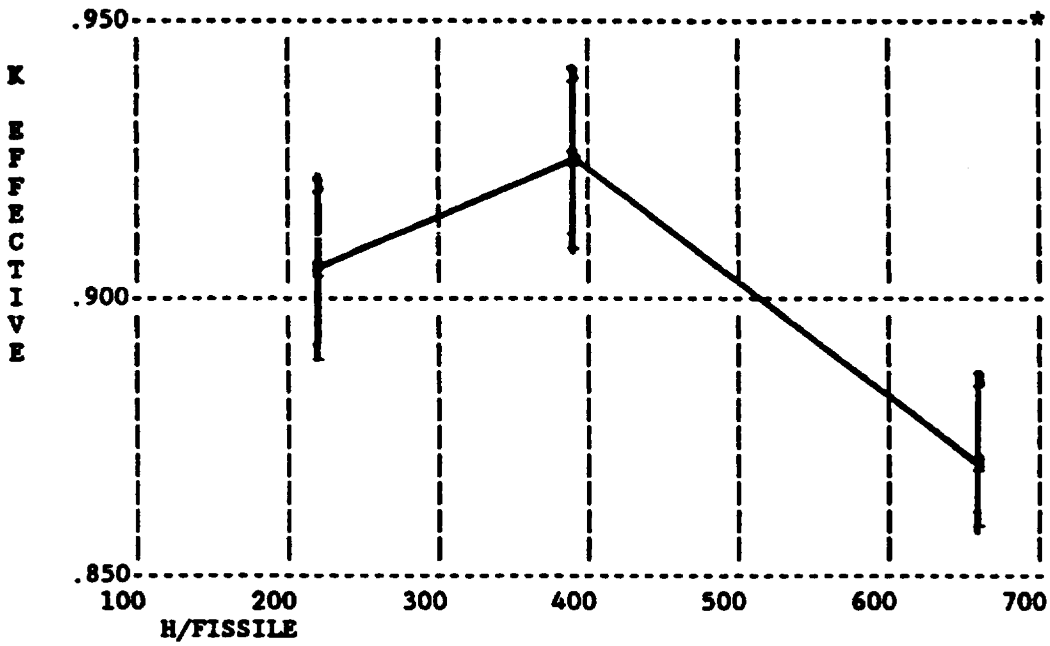


FIGURE 6.4.2-5. K-EFFECTIVE (±2 SIGMA) VS. H/FISSILE FOR MODEL 3A. TWO 1175 GRAM U-235 UNITS OF U(5)O2-H2O ARE EACH IN SPHERICAL HOMOGENEOUS MIXTURES IN SEPARATE FLOODED CASKS SIDE-BY-SIDE NEAR THE LEAD AND NEAR EACH OTHER. EACH SPHERE CONTAINS ≥0.30" OD UO2 PELLETS. THERE IS 12" OF WATER REFLECTION AROUND THE ARRAY. K-EFFECTIVE VALUES CONTAIN A BIAS OF 2.3 PERCENT IN THE MEAN VALUE AND 0.3 PERCENT IN THE 1 SIGMA VALUE.

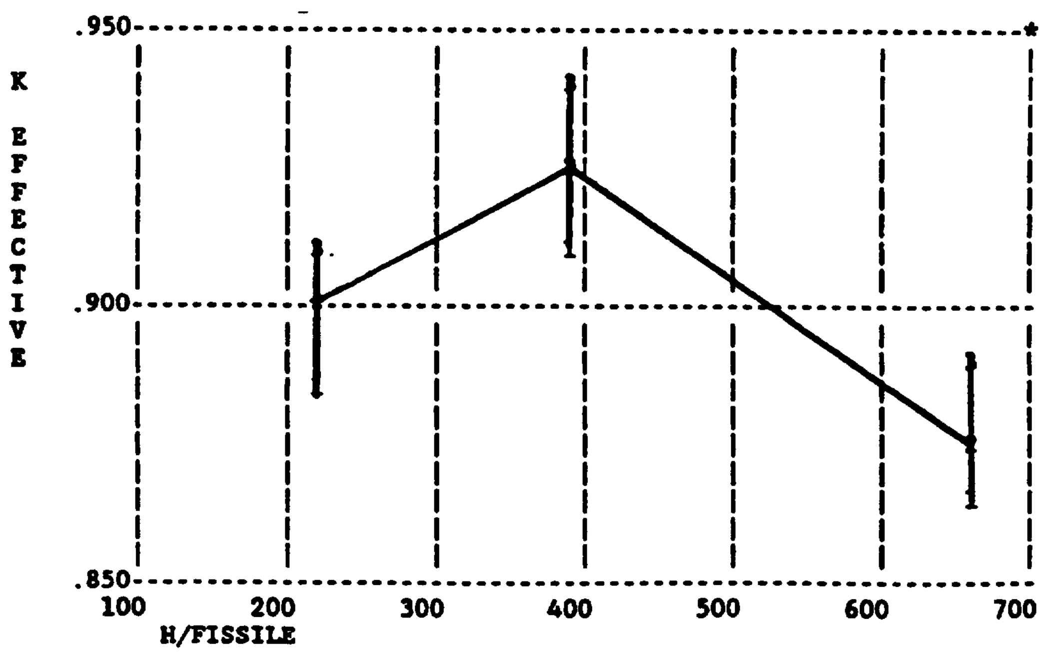


FIGURE 6.4.2-6. K-EFFECTIVE (±2 SIGMA) VS. H/FISSILE FOR MODEL 3B. A 1175 GRAM U-235 UNIT OF U(5)O2-H2O IS IN A SPHERICAL HOMOGENEOUS MIXTURE NEAR THE LEAD INSIDE A FLOODED CASK. THE SPHERE CONTAINS ≥0.30" OD UO2 PELLETS. THERE IS 12" OF WATER REFLECTION AROUND THE ARRAY. K-EFFECTIVE VALUES CONTAIN A BIAS OF 2.3 PERCENT IN THE MEAN VALUE AND 0.3 PERCENT IN THE 1 SIGMA VALUE.

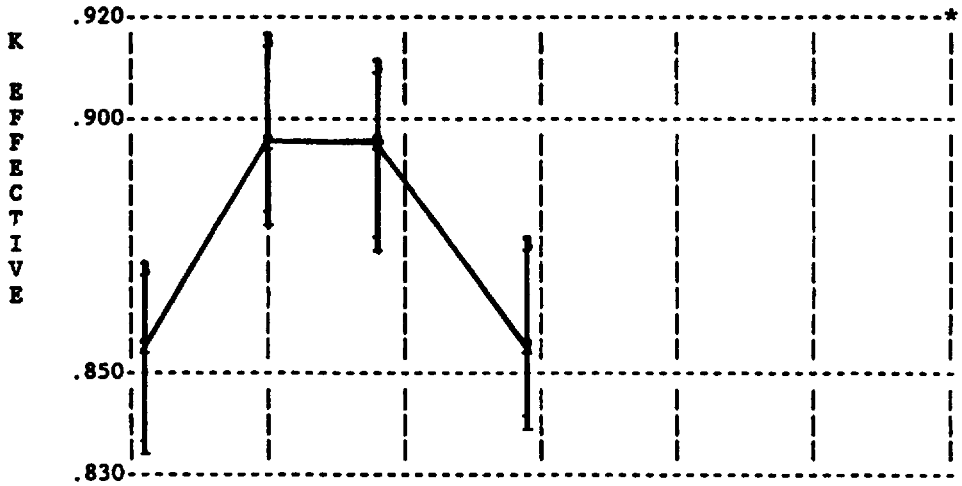


FIGURE 6.4.2-7. K-EFFECTIVE (±2 SIGMA) VS. H/FISSILE FOR MODEL 4A. TWO 1750 GRAM U-235 UNITS OF U(5)O2-H2O ARE EACH IN A 4 CYLINDER FUEL UNIT (≤437.5 GRAMS U-235/CYLINDER) IN SEPARATE FLOODED CASKS SIDE-BY-SIDE NEAR THE LEAD AND NEAR EACH OTHER. THE CYLINDERS ARE 5" SCHEDULE 40 PIPES AND TOUCHING, CONTAINING ≥0.35" OD UO_2 PELLETS. THERE IS 12" OF WATER REFLECTION AROUND THE ARRAY. K-EFFECTIVE VALUES CONTAIN A BIAS OF 2.3 PERCENT IN THE MEAN VALUE AND 0.3 PERCENT IN THE 1 SIGMA VALUE.

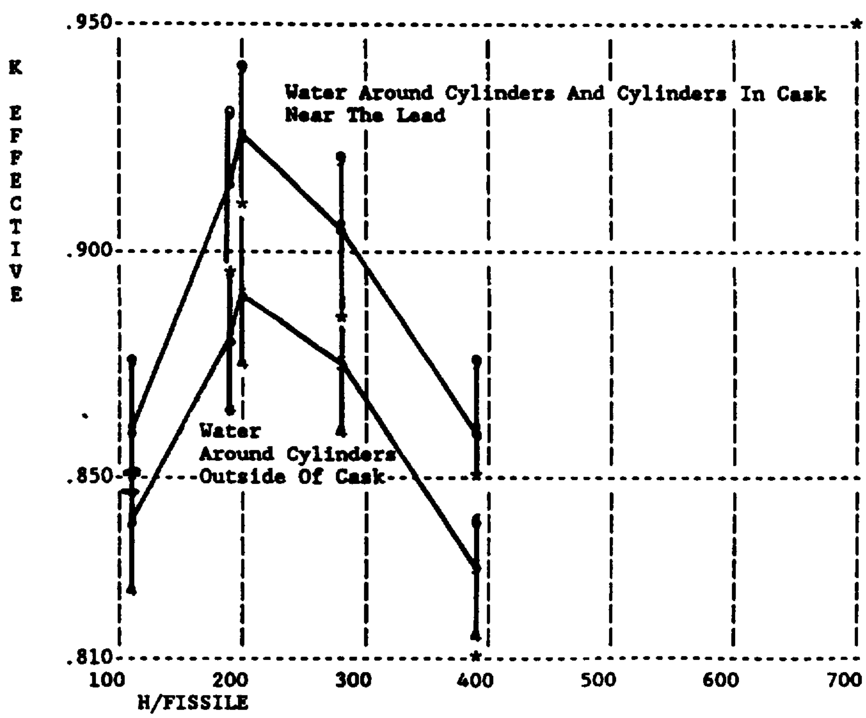


FIGURE 6 4.2-8. K-EFFECTIVE (±2 SIGMA) VS. H/FISSILE FOR MODEL 4B. 1750 GRAMS U-235 OF U(5)O2-H2O ARE IN A 4 CYLINDER FUEL UNIT (≤437.5 GRAMS U-235/CYLINDER) NEAR THE LEAD INSIDE A FLOODED CASK. THE CYLINDERS ARE 5" SCHEDULE 40 PIPES AND TOUCHING, CONTAINING ≥0.35" OD UO_2 PELLETS. THERE IS 12" OF WATER REFLECTION AROUND THE ARRAY. K-EFFECTIVE VALUES CONTAIN A BIAS OF 2.3 PERCENT IN THE MEAN VALUE AND 0.3 PERCENT IN THE 1 SIGMA VALUE.

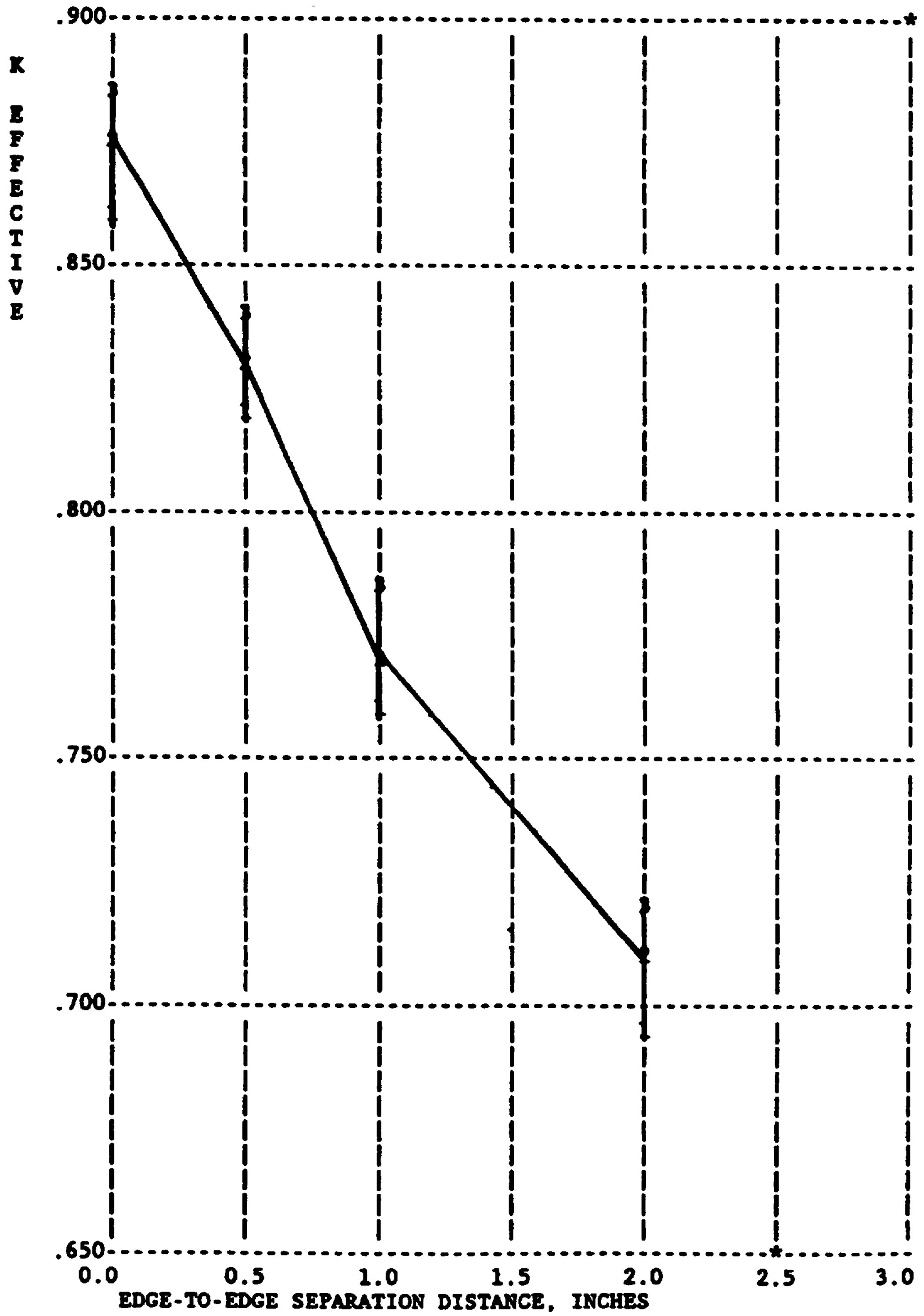


FIGURE 6.4.2-9. K-EFFECTIVE (±2 SIGMA) VS. EDGE-TO-EDGE SEPARATION DISTANCE BETWEEN CYLINDERS FOR MODEL 4. 1750 GRAMS U-235 OF U(5)O2-H2O ARE IN A 4 CYLINDER FUEL UNIT (≤437.5 GRAMS U-235/CYLINDER) OUTSIDE A CASK. THE CYLINDERS ARE 5" SCHEDULE 40 PIPES AND TOUCHING, CONTAINING ≥0.35" OD UO_2 PELLETS. THERE IS 12" OF WATER REFLECTION AROUND THE ARRAY. K-EFFECTIVE VALUES CONTAIN A BIAS OF 2.3 PERCENT IN THE MEAN VALUE AND 0.3 PERCENT IN THE 1 SIGMA VALUE. H/FISSILE = 276.

TABLE 6.3.1-1. MODEL 1

```
$$ASIS,ROUT(BL),T(:,8,16),KEYW(WRL)
$:IDENT:XXXX,WRL,VVV18,X4447
$:USERID:FS9911$XXXXXXX
$:NEED:P1
$:SELECT:CDCJOB
JOBNM,STMFZ,SN,T4444.
CHARGE.
STAGE,TAPE4,PE,POST,RP=60.
ATTACH(LLOYD,PROCLIB,ID=SCALE)
LIBRARY(LLOYD)
SCALE,CSAS2.
EXIT.
***EOS
KEFF 2000 CASK 500 GMS U235 U(100)-H2O H/F=519.47  FUEL CENTERED  SINGLE CASK
27GROUPNDF4  7 9 1  INFHOMMEDIUM  1  0
U-235  1 0. 0.000128168 END
H  1 0. 0.06657886 END
O  1 0. 0.03328943 END
H2O  2 1. END
H2O  3 1. END
AL  4 1. END
H2O  5 8.8-5 END
SS304  6 1. END
PB  7 1. END
 IUS=1 END
KEFF 2000 CASK 500 GMS U235 U(100)-H2O H/F=519.47  FUEL CENTERED  SINGLE CASK
15.0 5 300 3 1 1 1 1 0
SPHERE  1 13.365 -0.5
CUBOID  3 13.365 -13.365 13.365 -13.365 13.365 -13.365 -0.5
ARRAY BDY  3 13.365 -13.365 13.365 -13.365 13.365 -13.365 -0.5
CYLINDER  3 33.655 123.795 -13.365 -0.5
CYLINDER  6 34.925 127.605 -14.635 -0.5
CYLINDER  7 47.625 140.305 -27.335 -0.5
CYLINDER  6 48.895 144.750 -28.605 -0.5
CUBOID  3 79.375 -79.375 79.375 -79.375 175.230 -59.085 -0.5
END GEOMETRY
END KENO
***EOI
$:ENDJOB
```

TABLE 6.3.1-2. MODEL 2

```
$$ASIS,ROUT(BL),T(:,8,16),KEYW(WRL)
$:IDENT:XXXX,WRL,VVV18,X4447
S;USERID:FS9911$XXXXXXX
$:NEED:P1
$:SELECT:CDCJOB
JOBNM,STMFZ,SN,T4444.
CHARGE.
STAGE,TAPE4,PE,POST,RP=60.
ATTACH(LLOYD,PROCLIB,ID=SCALE)
LIBRARY(LLOYD)
SCALE,CSAS2.
EXIT.
***EOS
KEFF 2000 CASK 300 GMS PU239(0PU240)-H2O H/F=881.53  FUEL CENTERED  SINGLE
CASK
27GROUPNDF4  7 9 1  INFHOMMEDIUM  1  0
PU-239  1 0. 0.0000756111 END
H  1 0. 0.06665328 END
O  1 0. 0.03332664 END
H2O  2 1. END
H2O  3 1. END
AL  4 1. END
H2O  5 8.8-5 END
SS304  6 1. END
PB  7 1. END
 IUS=1  END
KEFF 2000 CASK 300 GMS PU239(0PU240)-H2O H/F=881.53  FUEL CENTERED  SINGLE
CASK
15.0 5 300 3 1 1 1 1 0
SPHERE  1 13.365 -0.5
CUBOID  3 13.365 -13.365 13.365 -13.365 13.365 -13.365 -0.5
ARRAY BDY  3 13.365 -13.365 13.365 -13.365 13.365 -13.365 -0.5
CYLINDER  3 33.655 123.795 -13.365 -0.5
CYLINDER  6 34.925 126.970 -14.635 -0.5
CYLINDER  7 47.625 139.670 -27.335 -0.5
CYLINDER  6 48.895 144.115 -28.605 -0.5
CUBOID  3 79.375 -79.375 79.375 -79.375 174.595 -59.085 -0.5
END GEOMETRY
END KENO
***EOI
$:ENDJOB
```

TABLE 6.3.1-3. MODEL 3

```
$$ASIS.ROUT(BL),T(:,8,16),KEYW(WRL)
$:IDENT:XXXX,WRL,VVV18,X4447
$:USERID:FS9911$XXXXXXX
$:NEED:P1
$:SELECT:CDCJOB
JOBNM,STMFZ,SN,T4444.
CHARGE.
STAGE,TAPE3,PE,POST,RP=60.
ATTACH(LLOYD,PROCLIB,ID=SCALE)
LIBRARY(LLOYD)
SCALE,CSAS2.
EXIT.
***EOS
KEFF 2000 CASK 1175 GMS U235 0.30 POD H/F=386.21  FUEL CENTERED  SINGLE CASK
27GROUPNDF4  7 9 2  LATTICECELL  0 0
U-235  1 0. 0.001238175 END
U-238  1 0. 0.023228182 END
O  1 0. 0.04893271 END
H2O  2 1. END
H2O  3 1. END
AL  4 1. END
H2O  5 8.8-5 END
H2O  6 1. END
PB  7 1. END
TRIANGPITCH  2.07334 0.762 1 2 END
KEFF 2000 CASK 1175 GMS U235 0.30 POD H/F=386.21  FUEL CENTERED  SINGLE CASK
0.30 POD
15.0 5 300 3 1 1 1 1 0
SPHERE  500 16.799 -0.5
CUBOID  3 16.799 -16.799 16.799 -16.799 16.799 -16.799 -0.5
ARRAY BDY  3 16.799 -16.799 16.799 -16.799 16.799 -16.799 -0.5
CYLINDER  3 33.655 120.361 -16.799 -0.5
CYLINDER  6 34.925 124.171 -18.069 -0.5
CYLINDER  7 47.625 136.871 -30.769 -0.5
CYLINDER  6 48.895 141.316 -32.039 -0.5
CUBOID  3 79.375 -79.375 79.375 -79.375 171.796 -62.519 -0.5
END GEOMETRY
END KENO
***EOI
$:ENDJOB
```

TABLE 6.3.1-4. MODEL 4

```
$$ASIS,ROUT(BL),T(:,8,16),KEYW(WRL)
$:IDENT:XXXX,WRL,VVV18,X4447
$:USERID:FS9911$XXXXXXX
$:NEED:Pl
$:SELECT:CDCJOB
JOBNM,STMFZ,SN,T4400.
CHARGE.
STAGE,TAPE3,PE,POST,RP=60.
ATTACH(LLOYD,PROCLIB,ID=SCALE)
LIBRARY(LLOYD)
SCALE,CSAS2.
EXIT.
***EOS
KEFF 2000 CASK 1750 GMS U235 4 CYLS H/F=198.95 0.30"POD  FUEL CENTERED  SINGLE
CASK
27GROUPNDF4  7 9 2  LATTICECELL  0 0
U-235  1 0. 0.001238175 END
U-238  1 0. 0.023228182 END
O  1 0. 0.04893271 END
H2O  2 1. END
H2O  3 1. END
AL  4 1. END
H2O  5 8.8-5 END
SS304  6 1. END
PB  7 1. END
TRIANGPITCH  1.83347 0.889 1 2 END
KEFF 2000 CASK 1750 GMS U235 4 CYLS H/F=198.95 0.30"POD  FUEL CENTERED  SINGLE
CASK
15.0 5 300 3 1 2 2 1 0
CYLINDER  500 6.477 32.232 -0. -0.5
CYLINDER  3 7.065 32.232 -0.588 -0.5
CUBOID  3 7.065 -7.065 7.065 -7.065 32.232 -0.588 -0.5
ARRAY BDY  3 14.13 -14.13 14.13 -14.13 32.232 -0.588 -0.5
CYLINDER  3 33.655 137.16 -0. -0.5
CYLINDER  6 34.925 140.97 -1.27 -0.5
CYLINDER  7 47.625 153.67 -13.97 -0.5
CYLINDER  6 48.895 158.115 -15.24 -0.5
CUBOID  3 79.735 -79.735 79.735 -79.735 188.595 -45.72 -0.5
END GEOMETRY
END KENO
***EOI
$:ENDJOB
```

TABLE 6.3.1-5. MODEL 1A

```
$$ASIS,ROUT(BL),T(:,8,16),KEYW(WRL)
$:IDENT:XXXX,WRL,VVV18,X4447
$:USERID:FS9911$XXXXXXX
$:NEED:P1
$:SELECT:CDCJOB
JOBNM,STMFZ,SN,T4400.
CHARGE.
STAGE,TAPE4,PE,PRE,VSN=047843.
ATTACH(LLOYD,PROCLIB,ID=SCALE)
LIBRARY(LLOYD)
KENO.
EXIT.
***EOS
KEFF 2000 CASK 500 GMS U235 U(100)-H2O H/F=519.47  2 CASKS SIDE-BY-SIDE
15.0 103 300 3 27 27 15 8 18 10 2 1 1 3 -15 0 0 2000 00 6 1 1 0 0 104 00 0 0
        1    -92235   1.28165E-04     8    -92235   1.28165E-04
        1      1001   6.65789E-02     8      1001   6.65789E-02
        1      8016   3.32894E-02     8      8016   3.32894E-02
        2         3   6.67555E-02     2         7   3.33777E-02
        3         4   6.67555E-02     3         8   3.33777E-02
        4     13027   6.02383E-02
        5         5   5.87448E-06     5         9   2.93724E-06
        6     24304   1.74239E-02     6     25055   1.73634E-03
        6     26304   5.93526E-02     6     28304   7.72036E-03
        7     82000   3.29882E-02
BOX TYPE  1
GENERAL  1 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  6 6*0. 27*0.5
GENERAL  7 6*0. 27*0.5
CUBOID  3 97.800 -97.800 48.900 -48.900 158.116 -15.25 27*0.5
BOX TYPE  2
CUBOID  3 97.800 -97.800 48.900 -48.900 30.48 -0. 27*0.5
CORE BDY  3 97.800 -97.800 48.900 -48.900 188.596 -45.73 27*0.5
CUBOID  3 128.28 -128.28 79.38 -79.38 188.596 -45.73 27*0.5
2 1 1 1 1 1 1 1 3 1 0 1 1 1 1 1 1 1 2 2 1 9
    2
ZONE1 XENDS -97.79000,   0.     ,  97.79000
ZONE1 YENDS -48.89500,  48.89500
ZONE1 ZENDS -15.24000, 158.11500
ZONE      1    1    1
BLOK1 XENDS -97.79000,   0.
BLOK1 YENDS -48.89500,  48.89500
BLOK1 ZENDS -15.24000, -13.97000,  -1.27000,   0.      ,  26.73000,
 137.16000, 140.97000, 153.67000, 158.11500
BLOCK     1    1    1
MEDIA           4,     5,     5,     5,     5,     5
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    2
MEDIA           4,     6,     6,     6,     6,     6
SURFACES         1,     2,     3,     4,     5
```

TABLE 6.3.1-5. MODEL 1A (CONTINUED)

```
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1     1     3
MEDIA            4,     5,     5,     5,     5,     5
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1     1     4
MEDIA            4,     5,     6,     5,     3,     1
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1     1     5
MEDIA            4,     5,     6,     5,     3,     1
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1     1     6
MEDIA            4,     5,     5,     5,     5,     5
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1     1     7
MEDIA            4,     6,     6,     6,     6,     6
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1     1     8
MEDIA            4,     5,     5,     5,     5,     5
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
```

TABLE 6.3.1-5. MODEL 1A (CONTINUED)

```
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     2    1    1
BLOK1 XENDS   0.       ,  97.79000
BLOK1 YENDS -48.89500,  48.89500
BLOK1 ZENDS -15.24000, -13.97000,  -1.27000,    0.      ,  26.73000,
 137.16000, 140.97000, 153.67000, 158.11500
BLOCK     1    1    1
MEDIA             4,     5,     5,     5,     5,     5
SURFACES          6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    2
MEDIA             4,     6,     6,     6,     6,     6
SURFACES          6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    3
MEDIA             4,     5,     5,     5,     5,     5
SURFACES          6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    4
MEDIA             4,     5,     6,     5,     3,     1
SURFACES          6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    5
MEDIA             4,     5,     6,     5,     3,     1
SURFACES          6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    6
MEDIA             4,     5,     5,     5,     5,     5
SURFACES          6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
```

TABLE 6.3.1-5. MODEL 1A (CONTINUED)

```
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    7
MEDIA            4,     6,     6,     6,     6,     6
SURFACES         6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    8
MEDIA            4,     5,     5,     5,     5,     5
SURFACES         6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
   10 EQUATIONS
       1.0XSQ         1.0YSQ      0.              97.79000X    $
       1.0XSQ         1.0YSQ    122.5804          97.79000X    $
       1.0XSQ         1.0YSQ   1219.7555          97.79000X    $
       1.0XSQ         1.0YSQ   1170.9654          97.79000X    $
       1.0XSQ         1.0YSQ    818.24603         57.21000X
       1.0ZSQ    -26.73000Z    $
       1.0XSQ         1.0YSQ      0.             -97.79000X    $
       1.0XSQ         1.0YSQ    122.5804         -97.79000X    $
       1.0XSQ         1.0YSQ   1219.7556         -97.79000X    $
       1.0XSQ         1.0YSQ   1170.9654         -97.79000X    $
       1.0XSQ         1.0YSQ    818.24603        -57.21000X
       1.0ZSQ    -26.73000Z    $
150 1 1 2  -28.605 0. 13.365 300 1 1 2  28.605 0. 13.365
END KENO
***EOI
$:ENDJOB
```

TABLE 6.3.1-6. MODEL 2A

```
$$ASIS,ROUT(BL),T(:,8,16),KEYW(WRL)
$:IDENT:XXXX,WRL,VVV18,X4447
$:USERID:FS9911$XXXXXXX
$:NEED:P1
$:SELECT:CDCJOB
JOBNM,STMFZ,SN,T4400.
CHARGE.
STAGE,TAPE4,PE,PRE,VSN=013188.
ATTACH(LLOYD,PROCLIB,ID=SCALE)
LIBRARY(LLOYD)
KENO.
EXIT.
***EOS
KEFF 2000 CASK 300 GMS FU239(0PU240)-H2O H/F=881.53  2 CASKS SIDE-BY-SIDE
15.0 103 300 3 27 27 15 8 18 10 2 1 1 3 -15 0 0 2000 00 6 1 1 0 0 104 00 0 0
        1     -94239   7.56111E-05     8     -94239   7.56111E-05
        1       1001   6.66396E-02     8       1001   6.66396E-02
        1       8016   3.33198E-02     8       8016   3.33198E-02
        2          3   6.67555E-02     2          7   3.33777E-02
        3          4   6.67555E-02     3          8   3.33777E-02
        4      13027   6.02383E-02
        5          5   5.87448E-06     5          9   2.93724E-06
        6      24304   1.74239E-02     6      25055   1.73634E-03
        6      26304   5.93526E-02     6      28304   7.72036E-03
        7      82000   3.29882E-02
```

The remainder of the input is the same as Table 6.3.1-5 from the BOX TYPE 1 card to the and of the table.

TABLE 6.3.1-7. MODEL 3A

```
$$ASIS,ROUT(BL),T(:,8,16),KEYW(WRL)
$:IDENT:XXXX WRL,VV718,X4447
$:USERID:FS9911$XXXXXXX
$:NEED:P1
$:SELECT:CDCJOB
JOBNM,STMFZ,SN,T4400.
CHARGE.
STAGE,TAPE4,PE,PRE,VSN=014022.
ATTACH(LLOYD,PROCLIB,ID=SCALE)
LIBRARY(LLOYD)
KENO.
EXIT.
***EOS
KEFF 2000 CASK 1175 GMS U235 U(5)O2-H2O H/F-386.21 0.30"POD 2 CSKS SIDE-BY-
SIDE
15.0 103 300 3 27 27 15 8 20 10 2 1 1 3 -15 0 0 2000 00 6 1 1 0 0 104 00 0 0
        1    -92235   1.23818E-03     8    -92235   1.51674E-04
        1     92238   2.32282E-02     8     92238   2.84540E-03
        1      8016   4.89327E-02     8      8016   5.99415E-03
        2         4   3.33777E-02     8         4   2.92890E-02
        2      1001   6.67555E-02     8      1001   5.85781E-02
        3         5   3.33777E-02     3         8   6.67555E-02
        4     13027   6.02383E-02
        5         6   2.93724E-06     5         9   5.87448E-06
        6     24304   1.74239E-02     6     25055   1.73634E-03
        6     26304   5.93526E-02     6     28304   7.72036E-03
        7     82000   3.29882E-02
BOX TYPE  1
GENERAL  8 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  6 6*0. 27*0.5
GENERAL  7 6*0. 27*0.5
CUBOID  3 97.800 -97.800 48.900 -48.900 158.116 -15.25 27*0.5
BOX TYPE 2
CUBOID  3 97.800 -97.800 48.900 -48.900 30.48 -0. 27*0.5
CORE BDY  3 97.800 -97.800 48.900 -48.900 188.596 -45.73 27*0.5
CUBOID  3 128.28 -128.28 79.38 -79.38 188.596 -45.73 27*0.5
2 1 1 1 1 1 1 1 3 1 0 1 1 1 1 1 1 1 2 2 1 9
    2
ZONE1 XENDS -97.79000,    0.      ,  97.79000
ZONE1 YENDS -48.89500,  48.89500
ZONE1 ZENDS -15.24000, 158.11500
ZONE        1    1    1
BLOK1 XENDS -97.79000,    0.
BLOK1 YENDS -48.89500,  48.89500
BLOK1 ZENDS -15.24000, -13.97000,  -1.27000,    0.      ,  33.59800,
 137.16000, 140.97000, 153.67000, 158.11500
BLOCK       1    1    1
MEDIA            4,     5,     5,     5,     5,     5
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK       1    1    2
```

TABLE 6.3.1-7. MODEL 3A (CONTINUED)

```
MEDIA            4,     6,     6,     6,     6,     6
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    3
MEDIA            4,     5,     5,     5,     5,     5
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    4
MEDIA            4,     5,     6,     5,     3,     1
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    5
MEDIA            4,     5,     6,     5,     3,     1
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    6
MEDIA            4,     5,     5,     5,     5,     5
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    7
MEDIA            4,     6,     6,     6,     6,     6
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1    1    8
MEDIA            4,     5,     5,     5,     5,     5
SURFACES         1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
```

TABLE 6.3.1-7. MODEL 3A (CONTINUED)

```
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
ZONE       2     1     1
BLOK1 XENDS   0.        ,  97.79000
BLOK1 YENDS -48.89500,  48.89500
BLOK1 ZENDS -15.24000, -13.97000,  -1.27000,    0.       ,  33.59800,
 137.16000, 140.97000, 153.67000, 158.11500
BLOCK      1     1     1
MEDIA               4,     5,     5,     5,     5,     5
SURFACES            6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK      1     1     2
MEDIA               4,     6,     6,     6,     6,     6
SURFACES            6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK      1     1     3
MEDIA               4,     5,     5,     5,     5,     5
SURFACES            6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK      1     1     4
MEDIA               4,     5,     6,     5,     3,     1
SURFACES            6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK      1     1     5
MEDIA               4,     5,     6,     5,     3,     1
SURFACES            6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK      1     1     6
MEDIA               4,     5,     5,     5,     5,     5
SURFACES            6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
```

TABLE 6.3.1-7. MODEL 3A (CONTINUED)

```
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1     1     7
MEDIA             4,     6,     6,     6,     6,     6
SURFACES          6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
BLOCK     1     1     8
MEDIA             4,     5,     5,     5,     5,     5
SURFACES          6,     7,     8,     9,    10
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
   10 EQUATIONS
       1.0XSQ         1.0YSQ       0.             97.79000X     $
       1.0XSQ         1.0YSQ     122.5804         97.79000X     $
       1.0XSQ         1.0YSQ    1219.7556         97.79000X     $
       1.0XSQ         1.0YSQ    1170.9654         97.79000X     $
       1.0XSQ         1.0YSQ    1026.4975         64.07800X
       1.0ZSQ    -33.59800Z     $
       1.0XSQ         1.0YSQ       0.            -97.79000X     $
       1.0XSQ         1.0YSQ     122.5804        -97.79000X     $
       1.0XSQ         1.0YSQ    1219.7556        -97.79000X     $
       1.0XSQ         1.0YSQ    1170.9654        -97.79000X     $
       1.0XSQ         1.0YSQ    1026.4975        -64.07800X
       1.0ZSQ    -33.59800Z     $
150 1 1 2  -32.039 0. 16.799 300 1 1 2  32.039 0. 16.799
END KENO
***EOI
$:ENDJOB
```

TABLE 6.3.1-8. MODEL 4A

```
$$ASIS,ROUT(BL),T(:,8,16),KEYW(WRL)
$:IDENT:XXXX,WRL,VVV18,X4447
$:USERID:FS9911$XXXXXXX
$:NEED:P1
$:SELECT:CDCJOB
JOBNM,STMFZ,SN,T4400.
CHARGE.
STAGE,TAPE4,PE,PRE,VSN=049749.
ATTACH(LLOYD,PROCLIB,ID=SCALE)
LIBRARY(LLOYD)
KENO.
EXIT.
***EOS
KEFF 2000 CASK 1750 GMS U235 4 CYLS H/F=198.95  0.35"POD  2 CSKS SIDE-BY-SIDE
15.0 103 300 3 27 27 15 8 20 10 2 1 1 3 -15 0 0 2000 00 6 1 1 0 0 104 00 0 0
        1    -92235   1.23818E-03     8    -92235   2.63996E-04
        1     92238   2.32282E-02     8     92238   4.95257E-03
        1      8016   4.89327E-02     8      8016   1.04331E-02
        2         4   3.33777E-02     8         4   2.62611E-02
        2      1001   6.67555E-02     8      1001   5.25223E-02
        3         5   3.33777E-02     3         8   6.67555E-02
        4     13027   6.02383E-02
        5         6   2.93724E-06     5         9   5.87448E-06
        6     24304   1.74239E-02     6     25055   1.73634E-03
        6     26304   5.93526E-02     6     28304   7.72036E-03
        7     82000   3.29882E-02
BOX TYPE  1
GENERAL  8 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  6 6*0. 27*0.5
GENERAL  7 6*0. 27*0.5
CUBOID  3 97.800 -97.800 48.900 -48.900 158.116 -15.25 27*0.5
BOX TYPE  2
CUBOID  3 97.800 -97.800 48.900 -48.900 30.48 -0. 27*0.5
CORE BDY  3 97.800 -97.800 48.900 -48.900 188.596 -45.73 27*0.5
CUBOID  3 128.28 -128.28 79.38 -79.38 188.596 -45.73 27*0.5
2 1 1 1 1 1 1 1 3 1 0 1 1 1 1 1 1 1 2 2 1 9
    2
ZONE1 XENDS -97.79000,   0.      ,  97.79000
ZONE1 YENDS -48.89500,  48.89500
ZONE1 ZENDS -15.24000, 158.11500
ZONE       1    1    1
BLOK1 XENDS -97.79000,   0.
BLOK1 YENDS -48.89500,  48.89500
BLOK1 ZENDS -15.24000, -13.97000,  -1.27000,    0.      ,  32.23200,
 137.16000, 140.97000, 153.67000, 158.11500
BLOCK      1    1    1
MEDIA            4,     5,     5,     5,     5,     5,     5,     5,     5,     5,
    5,     5,     5,
SURFACES         1,     2,     3,     4,     5,     6,     7,     8,     9,    10,
   11,    12
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
```

TABLE 6.3.1-8. MODEL 4A (CONTINUED)

```
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
BLOCK     1    1    2
MEDIA            4,     6,     6,     6,     6,     6,     6,     6,     6,     6,
    6,     6,    6,
SURFACES         1,     2,     3,     4,     5,     6,     7,     8,     9,    10,
   11,    12
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
BLOCK     1    1    3
MEDIA            4,     5,     5,     5,     5,     5,     5,     5,     5,     5,
    5,     5,    5,
SURFACES         1,     2,     3,     4,     5,     6,     7,     8,     9,    10,
   11,    12
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
BLOCK     1    1    4
MEDIA            4,     5,     6,     5,     3,     2,     1,     2,     1,     2,
    1,     2,    1,
SURFACES         1,     2,     3,     4,     5,     6,     7,     8,     9,    10,
   11,    12
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
```

TABLE 6.3.1-8. MODEL 4A (CONTINUED)

```
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
BLOCK      1     1     5
MEDIA              4,      5,      6,      5,      3,      3,      3,      3,      3,      3,
    3,      3,      3,
SURFACES           1,      2,      3,      4,      5,      6,      7,      8,      9,     10,
   11,     12
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
BLOCK      1     1     6
MEDIA              4,      5,      5,      5,      5,      5,      5,      5,      5,      5,
    5,      5,      5,
SURFACES           1,      2,      3,      4,      5,      6,      7,      8,      9,     10,
   11,     12
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
BLOCK      1     1     7
MEDIA              4,      6,      6,      6,      6,      6,      6,      6,      6,      6,
    6,      6,      6,
SURFACES           1,      2,      3,      4,      5,      6,      7,      8,      9,     10,
   11,     12
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
```

TABLE 6.3.1-8. MODEL 4A (CONTINUED)

```
BLOCK      1     1     8
MEDIA            4,     5,     5,     5,     5,     5,     5,     5,     5,     5,
    5,     5,     5,
SURFACES         1,     2,     3,     4,     5,     6,     7,     8,     9,    10,
   11,    12
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
BLOCK      2     1     1
BLOK1 XENDS   0.       , -97.79000
BLOK1 YENDS -48.89500,  48.89500
BLOK1 ZENDS -15.24000, -13.97000,  -1.27000,   0.       ,  32.23200,
 137.16000, 140.97000, 153.67000, 158.11500
BLOCK      1     1     1
MEDIA            4,     5,     5,     5,     5,     5,     5,     5,     5,     5,
    5,     5,     5,
SURFACES        13,    14,    15,    16,    17,    18,    19,    20,    21,    22,
   23,    24
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
BLOCK      1     1     2
MEDIA            4,     6,     6,     6,     6,     6,     6,     6,     6,     6,
    6,     6,     6,
SURFACES        13,    14,    15,    16,    17,    18,    19,    20,    21,    22,
   23,    24
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
```

TABLE 6.3.1-8. MODEL 4A (CONTINUED)

```
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
BLOCK     1     1     3
MEDIA           4,     5,     5,     5,     5,     5,     5,     5,     5,     5,
    5,     5,     5,
SURFACES       13,    14,    15,    16,    17,    18,    19,    20,    21,    22,
   23,    24
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
BLOCK     1     1     4
MEDIA           4,     5,     6,     5,     3,     2,     1,     2,     1,     2,
    1,     2,     1,
SURFACES       13,    14,    15,    16,    17,    18,    19,    20,    21,    22,
   23,    24
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
BLOCK     1     1     5
MEDIA           4,     5,     6,     5,     3,     3,     3,     3,     3,     3,
    3,     3,     3,
SURFACES       13,    14,    15,    16,    17,    18,    19,    20,    21,    22,
   23,    24
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
```

TABLE 6.3.1-8. MODEL 4A (CONTINUED)

```
BLOCK      1     1     6
MEDIA            4,     5,     5,     5,     5,     5,     5,     5,     5,     5,
    5,     5,     5,
SURFACES         13,    14,    15,    16,    17,    18,    19,    20,    21,    22,
   23,    24
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
BLOCK      1     1     7
MEDIA            4,     6,     6,     6,     6,     6,     6,     6,     6,     6,
    6,     6,     6,
SURFACES         13,    14,    15,    16,    17,    18,    19,    20,    21,    22,
   23,    24
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
BLOCK      1     1     8
MEDIA            4,     5,     5,     5,     5,     5,     5,     5,     5,     5,
    5,     5,     5,
SURFACES         13,    14,    15,    16,    17,    18,    19,    20,    21,    22,
   23,    24
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
```

TABLE 6.3.1-8. MODEL 4A (CONTINUED)

```
  24 EQUATIONS
       1.0XSQ           1.0YSQ     0.              97.79000X    $
       1.0XSQ           1.0YSQ   122.5804          97.79000X    $
       1.0XSQ           1.0YSQ  1219.7556          97.79000X    $
       1.0XSQ           1.0YSQ  1170.9654          97.79000X    $
       1.0XSQ           1.0YSQ   541.06142         46.52146X
 -14.13002Y    $
       1.0XSQ           1.0YSQ   549.02426         46.52156X
 -14.13002Y    $
       1.0XSQ           1.0YSQ   541.06142         46.52156X
  14.13002Y    $
       1.0XSQ           1.0YSQ   549.02426         46.52156X
  14.13002Y    $
       1.0XSQ           1.0YSQ  1398.07178         74.78160X
 -14.13002Y    $
       1.0XSQ           1.0YSQ  1406.03462         74.78160X
 -14.13002Y    $
       1.0XSQ           1.0YSQ  1398.07178         74.78160X
  14.13002Y    $
       1.0XSQ           1.0YSQ  1406.03462         74.78160X
  14.13002Y    $
       1.0XSQ           1.0YSQ     0.             -97.79000X    $
       1.0XSQ           1.0YSQ   122.5804         -97.79000X    $
       1.0XSQ           1.0YSQ  1219.7556         -97.79000X    $
       1.0XSQ           1.0YSQ  1170.9654         -97.79000X    $
       1.0XSQ           1.0YSQ   541.06142        -46.52146X
 -14.13002Y    $
       1.0XSQ           1.0YSQ   549.02426        -46.52156X
 -14.13002Y    $
       1.0XSQ           1.0YSQ   541.06142        -46.52156X
  14.13002Y    $
       1.0XSQ           1.0YSQ   549.02426        -46.52156X
  14.13002Y    $
       1.0XSQ           1.0YSQ  1398.07178        -74.78160X
 -14.13002Y    $
       1.0XSQ           1.0YSQ  1406.03462        -74.78160X
 -14.13002Y    $
       1.0XSQ           1.0YSQ  1398.07178        -74.78160X
  14.13002Y    $
       1.0XSQ           1.0YSQ  1406.03462        -74.78160X
  14.13002Y    $
 38 1 1 2 -23.26073 7.065 16   75 1 1 2 -23.26073 -7.065 16.
113 1 1 2 -37.3908  7.065 16. 150 1 1 2 -37.3908  -7.065 16.
188 1 1 2  23.26073 7.065 16. 225 1 1 2  23.26073 -7.065 16.
263 1 1 2  37.3908  7.065 16. 300 1 1 2  37.3908  -7.065 16.
END KENO
***EOI
$:ENDJOB
```

TABLE 6.3.1-9. MODEL 1B

```
$$ASIS.ROUT(BL),T(:,8,16),KEYW(WRL)
$:IDENT:XXXX,WRL,VVV18,X4447
$:USERID:FS9911$XXXXXXX
$:NEED:P1
$:SELECT:CDCJOB
JOBNM,STMFZ,SN,T4400.
CHARGE.
STAGE,TAPE4,PE,PRE,VSN=047843.
ATTACH(LLOYD,PROCLIB,ID=SCALE)
LIBRARY(LLOYD)
KENO.
EXIT.
***EOS
KEFF 2000 CASK 500 GMS U235 U(100)-H2O H/F=519.47 SINGLE CASK
15.0 103 300 3 27 27 15 8 18 18 3 1 1 3 -15 0 0 2000 00 3 1 1 0 0 104 00 0 0
        1    -92235   1.28165E-04     8    -92235    1.28165E-04
        1      1001   6.65789E-02     8      1001    6.65789E-02
        1      8016   3.32894E-02     8      8016    3.32894E-02
        2         3   6.67555E-02     2         7    3.33777E-02
        3         4   6.67555E-02     3         8    3.33777E-02
        4     13027   6.02383E-02
        5         5   5.87448E-06     5         9    2.93724E-06
        6     24304   1.74239E-02     6     25055    1.73634E-03
        6     26304   5.93526E-02     6     28304    7.72036E-03
        7     82000   3.29882E-02
BOX TYPE  1
GENERAL  1 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  6 6*0. 27*0.5
GENERAL  7 6*0. 27*0.5
CUBOID  3 48.900 -48.900 48.900 -48.900 13.366 -13.366 27*0.5
BOX TYPE  2
CYLINDER  3 33.655 0. -110.428 27*0.5
CYLINDER  6 34.925 3.81 -110.428 27*0.5
CYLINDER  7 47.625 16.51 -110.428 27*0.
CYLINDER  6 46.895 20.955 -110.428 27*0.5
CUBOID  3 48.900 -48.900 48.900 -48.900 20.955 -110.428 27*0.5
BOX TYPE  3
CYLINDER  6 34.925 0. -1.27 27*0.5
CYLINDER  7 47.625 0. -13.97 27*0.5
CYLINDER  6 48.895 0. -15.24 27*0.5
CUBOID  3 48.900 -48.900 48.900 -48.900 0. -15.24 27*0.5
CORE BDY  3 48.900 -48.900 48.900 -48.900 86.6775 -86.6775 27*0.5
CUBOID  3 79.38 -79.38 79.38 -79.38 117.1575 -117.1575 27*0.5
1 1 1 1 1 1 1 1 3 1 0 2 1 1 1 1 1 1 1 1 1 0 3 1 1 1 1 1 1 3 3 1 9
    2
ZONE1 XENDS -48.89500,  48.89500
ZONE1 YENDS -48.89500,  48.89500
ZONE1 ZENDS -13.36500,  13.36500
ZONE       1     1     1
BLOK1 XENDS -48.89500,  48.89500
BLOK1 YENDS -48.89500,  48.89500
BLOK1 ZENDS -13.36500,  13.36500
```

TABLE 6.3.1-9. MODEL 1B (CONTINUED)

```
BLOCK       1    1    1
MEDIA            4,    5,    6,    5,    3,    1,
SURFACES         1,    2,    3,    4,    5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
    5 EQUATIONS
       1.0XSQ           1.0YSQ  -2390.7210     $
       1.0XSQ           1.0YSQ  -2268.1406     $
       1.0XSQ           1.0YSQ  -1219.7556     $
       1.0XSQ           1.0YSQ  -1132.6590     $
       1.0XSQ           1.0YSQ   233.06088       -40.58000X
       1.0ZSQ  $
1 1 2 20.290 0. 0.
END KENO
***EOI
$:ENDJOB
```

TABLE 6.3.1-10. MODEL 2B

```
$$ASIS.ROUT(BL),T(:,8,16),KEYW(WRL)
$:IDENT:XXXX,WRL,VVV18,X4447
$:USERID:FS9911$XXXXXXX
$:NEED:P1
$:SELECT:CDCJOB
JOBNM,STMFZ,SN,T4400.
CHARGE.
STAGE,TAPE4,PE,PRE,VSN=013188.
ATTACH(LLOYD,PROCLIB,ID=SCALE)
LIBRARY(LLOYD)
KENO.
EXIT.
***EOS
KEFF 2000 CASK 300 GMS PU239(0PU240)-H2O H/F=881.53 SINGLE CASK
15.0 103 300 3 27 27 15 8 18 18 3 1 1 3 -15 0 0 2000 00 3 1 1 0 0 104 00 0 0
        1    -94239   7.56111E-05     8    -94239   7.56111E-05
        1      1001   6.66396E-02     8      1001   6.66396E-02
        1      8016   3.33198E-02     8      8016   3.33198E-02
        2         3   6.67555E-02     2         7   3.33777E-02
        3         4   6.67555E-02     3         8   3.33777E-02
        4     13027   6.02383E-02
        5         5   5.87448E-06     5         9   2.93724E-06
        6     24304   1.74239E-02     6     25055   1.73634E-03
        6     26304   5.93526E-02     6     28304   7.72036E-03
        7     82000   3.29882E-02
BOX TYPE  1
GENERAL  1 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  6 6*0. 27*0.5
GENERAL  7 6*0. 27*0.5
CUBOID  3 48.900 -48.900 48.900 -48.900 13.366 -13.366 27*0.5
BOX TYPE  2
CYLINDER  3 33.655 0. -110.428 27*0.5
CYLINDER  6 34.925 3.81 -110.428 27*0.5
CYLINDER  7 47.625 16.51 -110.428 27*0.
CYLINDER  6 48.895 20.955 -110.428 27*0.5
CUBOID  3 48.900 -48.900 48.900 -48.900 20.955 -110.428 27*0.5
BOX TYPE  3
CYLINDER  6 34.925 0. -1.27 27*0.5
CYLINDER  7 47.625 0. -13.97 27*0.5
CYLINDER  6 48.895 0. -15.24 27*0.5
CUBOID  3 48.900 -48.900 48.900 -48.900 0. -15.24 27*0.5
CORE BDY  3 48.900 -48.900 48.900 -48.900 86.6775 -86.6775 27*0.5
CUBOID  3 79.38 -79.38 79.38 -79.38 117.1575 -117.1575 27*0.5
1 1 1 1 1 1 1 1 3 1 0 2 1 1 1 1 1 1 1 1 1 0 3 1 1 1 1 1 1 3 3 1 9
    2
ZONE1 XENDS -48.89500,  48.89500
ZONE1 YENDS -48.89500,  48.89500
ZONE1 ZENDS -13.36500,  13.36500
ZONE       1     1     1
BLOK1 XENDS -48.89500,  48.89500
BLOK1 YENDS -48.89500,  48.89500
BLOK1 ZENDS -13.36500,  13.36500
```

TABLE 6.3.1-10. MODEL 2B (CONTINUED)

```
BLOCK      1    1    1
MEDIA           4,     5,     6,     5,     3,     1,
SURFACES        1,     2,     3,     4,     5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
    5 EQUATIONS
       1.0XSQ         1.0YSQ  -2390.7210     $
       1.0XSQ         1.0YSQ  -2268.1406     $
       1.0XSQ         1.0YSQ  -1219.7556     $
       1.0XSQ         1.0YSQ  -1132.6590     $
       1.0XSQ         1.0YSQ   233.06088      -40.58000X
       1.0ZSQ  $
1 1 2 20.290 0. 0.
END KENO
***EOI
$:ENDJOB
```

TABLE 6.3.1-11. MODEL 3B

```
$$ASIS.ROUT(BL),T(:,8,16),KEYW(WRL)
$:IDENT:XXXX,WRL,VVV18,X4447
$:USERID:FS9911$XXXXXXX
$:NEED:P1
$:SELECT:CDCJOB
JOBNM,STMFZ,SN,T4400.
CHARGE.
STAGE,TAPE4,PE,PRE,VSN=014022.
ATTACH(LLOYD,PROCLIB,ID=SCALE)
LIBRARY(LLOYD)
KENO.
EXIT.
***EOS
KEFF 2000 CASK 1175 GMS U235 U(5)O2-H2O H/F=386.21 0.30"POD  SINGLE CASK
15.0 103 300 3 27 27 15 8 20 18 3 1 1 3 -15 0 0 2000 00 3 1 1 0 0 104 00 0 0
        1    -92235   1.23818E-03     8    -92235   1.51674E-04
        1     92238   2.32282E-02     8     92238   2.84540E-03
        1      8016   4.89327E-02     8      8016   5.99415E-03
        2         4   3.33777E-02     8         4   2.92890E-02
        2      1001   6.67555E-02     8      1001   5.85781E-02
        3         5   3.33777E-02     3         8   6.67555E-02
        4     13027   6.02383E-02
        5         6   2.93724E-06     5         9   5.87448E-06
        6     24304   1.74239E-02     6     25055   1.73634E-03
        6     26304   5.93526E-02     6     28304   7.72036E-03
        7     82000   3.29882E-02
BOX TYPE  1
GENERAL  8 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  6 6*0. 27*0.5
GENERAL  7 6*0. 27*0.5
CUBOID  3 48.900 -48.900 48.900 -48.900 16.800 -16.800 27*0.5
BOX TYPE  2
CYLINDER  3 33.655 0. -102.972 27*0.5
CYLINDER  6 34.925 3.81 -102.972 27*0.5
CYLINDER  7 47.625 16.51 -102.972 27*0.
CYLINDER  6 48.895 20.955 -102.972 27*0.5
CUBOID  3 48.900 -48.900 48.900 -48.900 20.955 -102.972 27*0.5
BOX TYPE  3
CYLINDER  6 34.925 0. -1.27 27*0.5
CYLINDER  7 47.625 0. -13.97 27*0.5
CYLINDER  6 48.895 0. -15.24 27*0.5
CUBOID  3 48.900 -48.900 48.900 -48.900 0. -15.24 27*0.5
CORE BDY  3 48.900 -48.900 48.900 -48.900 86.6775 -86.6775 27*0.5
CUBOID  3 79.38 -79.38 79.38 -79.38 117.1575 -117.1575 27*0.5
1 1 1 1 1 1 1 1 3 1 0 2 1 1 1 1 1 1 1 1 1 0 3 1 1 1 1 1 1 3 3 1 9
    2
ZONE1 XENDS -48.89500,  48.89500
ZONE1 YENDS -48.89500,  48.89500
ZONE1 ZENDS -16.79900,  16.79900
ZONE      1    1    1
BLOK1 XENDS -48.89500,  48.89500
BLOK1 YENDS -48.89500,  48.89500
BLOK1 ZENDS -16.79900,  16.79900
```

TABLE 6.3.1-11. MODEL 3B (CONTINUED)

```
BLOCK      1    1    1
MEDIA           4,    5,    6,    5,    3,    1,
SURFACES        1,    2,    3,    4,    5
SECTOR  1  0  0  0  0
SECTOR -1  1  0  0  0
SECTOR  0 -1  1  0  0
SECTOR  0  0 -1  1  0
SECTOR  0  0  0 -1  1
SECTOR  0  0  0  0 -1
    5 EQUATIONS
       1.0XSQ           1.0YSQ  -2390.7210      $
       1.0XSQ           1.0YSQ  -2268.1406      $
       1.0XSQ           1.0YSQ  -1219.7556      $
       1.0XSQ           1.0YSQ  -1132.6590      $
       1.0XSQ           1.0YSQ     1.91834       -33.71200X
      1.0ZSQ  $
1 1 2 16.856 0. 0.
END KENO
***EOI
$:ENDJOB
```

TABLE 6.3.1-12. MODEL 4B

```
$$ASIS.ROUT(BL),T(:,8,16),KEYW(WRL)
$:IDENT:XXXX,WRL,VVV18,X4447
$:USERID:FS9911$XXXXXXX
$:NEED:P1
$:SELECT:CDCJOB
JOBNM,STMFZ,SN,T4400.
CHARGE.
STAGE,TAPE4,PE,PRE,VSN=049749.
ATTACH(LLOYD,PROCLIB,ID=SCALE)
LIBRARY(LLOYD)
KENO.
EXIT.
***EOS
KEFF 2000 CASK 1750 GMS U235 4 CYLS H/F=198.95 0.35"POD SINGLE CASK
15.0 103 300 3 27 27 15 8 20 19 3 1 1 3 -15 0 0 2000 00 6 1 1 0 0 104 00 0 0
        1    -92235   1.23818E-03     8    -92235   2.63996E-04
        1     92238   2.32282E-02     8     92238   4.95257E-03
        1      8016   4.89327E-02     8      8016   1.04331E-03
        2         4   3.33777E-02     8         4   2.62611E-02
        2      1001   6.67555E-02     8      1001   5.25223E-02
        3         5   3.33777E-02     3         8   6.67555E-02
        4     13027   6.02383E-02
        5         6   2.93724E-06     5         9   5.87448E-06
        6     24304   1.74239E-02     6     25055   1.73634E-03
        6     26304   5.93526E-02     6     28304   7.72036E-03
        7     82000   3.29882E-02
BOX TYPE  1
GENERAL  8 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  3 6*0. 27*0.5
GENERAL  6 6*0. 27*0.5
GENERAL  7 6*0. 27*0.5
CUBOID  3 48.900 -48.900 48.900 -48.900 16.117 -16.117 27*0.5
BOX TYPE  2
CYLINDER  3 33.655 0. -104.338 27*0.5
CYLINDER  6 34.925 3.81 -104.338 27*0.5
CYLINDER  7 47.625 16.51 -104.338 27*0.
CYLINDER  6 48.895 20.955 -104.338 27*0.5
CUBOID  3 48.900 -48.900 48.900 -48.900 20.955 -104.338 27*0.5
BOX TYPE  3
CYLINDER  3 33.655 0.588 -0. 27*0.5
CYLINDER  6 34.925 0.588 -1.27 27*0.5
CYLINDER  7 47.625 0.588 -13.97 27*0.5
CYLINDER  6 48.895 0.588 -15.24 27*0.5
CUBOID  3 48.900 -48.900 48.900 -48.900 0.588 -15.24 27*0.5
CORE BDY  3 48.900 -48.900 48.900 -48.900 86.6775 -86.6775 27*0.5
CUBOID  3 79.38 -79.38 79.38 -79.38 117.1575 -117.1575 27*0.5
1 1 1 1 1 1 1 1 3 1 0 2 1 1 1 1 1 1 1 1 1 0 3 1 1 1 1 1 1 3 3 1 9
    2
ZONE1 XENDS -48.89500,  48.89500
ZONE1 YENDS -48.89500,  48.89500
ZONE1 ZENDS -16.11600,  16.11600
ZONE      1    1    1
BLOK1 XENDS -48.89500,  48.89500
BLOK1 YENDS -48.89500,  48.89500
BLOK1 ZENDS -16.11600,  16.11600
```

TABLE 6.3.1-12. MODEL 4B (CONTINUED)

```
BLOCK      1     1     1
MEDIA            4,     5,     6,     5,     3,     2,     1,     2,     1,     2,
   1,     2,     1
SURFACES         1,     2,     3,     4,     5,     6,     7,     8,     9,    10,
  11,    12
SECTOR  1  0  0  0  0  0  0  0  0  0  0  0
SECTOR -1  1  0  0  0  0  0  0  0  0  0  0
SECTOR  0 -1  1  0  0  0  0  0  0  0  0  0
SECTOR  0  0 -1  1  0  0  0  0  0  0  0  0
SECTOR  0  0  0 -1  1  0  0  0  0  0  0  0
SECTOR  0  0  0  0 -1  1  0  0  0  0  0  0
SECTOR  0  0  0  0  0 -1  1  0  0  0  0  0
SECTOR  0  0  0  0  0  0 -1  1  0  0  0  0
SECTOR  0  0  0  0  0  0  0 -1  1  0  0  0
SECTOR  0  0  0  0  0  0  0  0 -1  1  0  0
SECTOR  0  0  0  0  0  0  0  0  0 -1  1  0
SECTOR  0  0  0  0  0  0  0  0  0  0 -1  1
SECTOR  0  0  0  0  0  0  0  0  0  0  0 -1
   12 EQUATIONS
       1.0XSQ         1.0YSQ  -2390.7210      $
       1.0XSQ         1.0YSQ  -2268.1406      $
       1.0XSQ         1.0YSQ  -1219.7556      $
       1.0XSQ         1.0YSQ  -1132.6590      $
       1.0XSQ         1.0YSQ   657.11324       -51.26844X
 -14.13002Y    $
       1.0XSQ         1.0YSQ   665.07607       -51.26844X
 -14.13002Y    $
       1.0XSQ         1.0YSQ   657.11324       -51.26844X
  14.13002Y    $
       1.0XSQ         1.0YSQ   665.07607       -51.26844X
  14.13002Y    $
       1.0XSQ         1.0YSQ   132.34202       -23.00800X
 -14.13002Y    $
       1.0XSQ         1.0YSQ   140.30485       -23.00800X
 -14.13002Y    $
       1.0XSQ         1.0YSQ   132.34202       -23.00800X
  14.13002Y    $
       1.0XSQ         1.0YSQ   140.30485       -23.00800X
  14.13002Y    $
75 1 1 2 25.63422 7.065 0.  150 1 1 2 25.63422 -7.065 0.
225 1 1 2 11.504 7.065 0.  300 1 1 2 11.504 -7.065 0.
END KENO
***EOI
$:ENDJOB
```

TABLE 6.4.2-1. KEFF 2000 CASK 500 GMS U235 U(100)-H2O H/F=519.47
2 CASKS SIDE-BY-SIDE

MIXTURE	NUCLIDE	DENSITY	MIXTURE	NUCLIDE	DENSITY
1	-92235	1.28165E-04	8	-92235	1.28165E-04
1	1001	6.65789E-02	8	1001	6.65789E-02
1	8016	3.32894E-02	8	8016	3.32894E-02
2	3	6.67555E-02	2	7	3.33777E-02
3	4	6.67555E-02	3	8	3.33777E-02
4	13027	6.02383E-02			
5	5	5.87448E-06	5	9	2.93724E-06
6	24304	1.74239E-02	6	25055	1.73634E-03
6	26304	5.93526E-02	6	28304	7.72036E-03
7	82000	3.29882E-02			

```
CROSS SECTIONS READ FROM TAPE
NUCLIDE =      1001   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =         3   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =         4   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =         5   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =      8016   O-16 1276 218 GP 030476(7)
NUCLIDE =         7   O-16 1276 218 GP 030476(7)
NUCLIDE =         8   O-16 1276 218 GP 030476(7)
NUCLIDE =         9   O-16 1276 218 GP 030476(7)
NUCLIDE =     13027   AL-27 1193 218 GP 040375(5)
NUCLIDE =     24304   CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =     25055   MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =     26304   FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)`
NUCLIDE =     28304   NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =     82000   PB   1288 218NGP 042375 P-3 293K
NUCLIDE =     92235   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
ARRAY DESCRIPTION
  2
  1
  2
NO. OF INITIAL
 GENERATIONS      AVERAGE                      NUMBER OF
   SKIPPED      K-EFFECTIVE      DEVIATION     HISTORIES
      3           .90307    + OR -  .00538      21600
FREQUENCY FOR GENERATIONS    4 TO   75
 .8222 TO  .8453      *******
 .8453 TO  .8684      *************
 .8684 TO  .8915      ********
 .8915 TO  .9146      ********************
 .9146 TO  .9377      ********
 .9377 TO  .9608      ******
 .9608 TO  .9839      *******
 .9839 TO 1.0070
1.0070 TO 1.0301      **
```

TABLE 6.4.2-2. KEFF 2000 CASK 500 GMS U235 U(100)-H2O H/F=519.47 SINGLE CASK

MIXTURE	NUCLIDE	DENSITY	MIXTURE	NUCLIDE	DENSITY
1	-92235	1.28165E-04	8	-92235	1.28165E-04
1	1001	6.65789E-02	8	1001	6.65789E-02
1	8016	3.32894E-02	8	8016	3.32894E-02
2	3	6.67555E-02	2	7	3.33777E-02
3	4	6.67555E-02	3	8	3.33777E-02
4	13027	6.02383E-02			
5	5	5.87448E-06	5	9	2.93724E-06
6	24304	1.74239E-02	6	25055	1.73634E-03
6	26304	5.93526E-02	6	28304	7.72036E-03
7	82000	3.29882E-02			

```
CROSS SECTIONS READ FROM TAPE
NUCLIDE =        1001   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =           3   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =           4   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =           5   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =        8016   O-16 1276 218 GP 030476(7)
NUCLIDE =           7   O-16 1276 218 GP 030476(7)
NUCLIDE =           8   O-16 1276 218 GP 030476(7)
NUCLIDE =           9   O-16 1276 218 GP 030476(7)
NUCLIDE =       13027   AL-27 1193 218 GP 040375(5)
NUCLIDE =       24304   CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =       25055   MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =       26304   FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =       28304   NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =       82000   PB   1288 218NGP 042375 P-3 293K
NUCLIDE =       92235   U-235 1261 SIGP=5+4 NEWXLACS 218NCP P-3 293K(3)
ARRAY DESCRIPTION
  2
  1
  3
NO. OF INITIAL
 GENERATIONS      AVERAGE                    NUMBER OF
   SKIPPED      K-EFFECTIVE      DEVIATION   HISTORIES
      3           .89759    + OR -   .00566     26700
FREQUENCY FOR GENERATIONS     4 TO    92
 .7475 TO  .7706     *
 .7706 TO  .7937     *
 .7937 TO  .8168     ****
 .8168 TO  .8399     ********
 .8399 TO  .8629     **********
 .8629 TO  .8860     ***********
 .8860 TO  .9091     ****************
 .9091 TO  .9322     ******************
 .9322 TO  .9553     *********
 .9553 TO  .9784     *****
 .9784 TO 1.0015     ****
1.0015 TO 1.0246     **
```

TABLE 6.4.2-3. KEFF 2000 CASK 300 CMS PU239(0PU240)-H2O H/F=881.53
2 CASKS SIDE-BY-SIDE

MIXTURE	NUCLIDE	DENSITY	MIXTURE	NUCLIDE	DENSITY
1	-94239	7.56111E-05	8	-94239	7.56111E-05
1	1001	6.66396E-02	8	1001	6.66396E-02
1	8016	3.33198E-02	8	8016	3.33198E-02
2	3	6.67555E-02	2	7	3.33777E-02
3	4	6.67555E-02	3	8	3.33777E-02
4	13027	6.02383E-02			
5	5	5.87448E-06	5	9	2.93724E-06
6	24304	1.74239E-02	6	25055	1.73634E-03
6	26304	5.93526E-02	6	28304	7.72036E-03
7	82000	3.29882E-02			

CROSS SECTIONS READ FROM TAPE

NUCLIDE =	1001	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	3	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	4	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	5	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	8016	O-16 1276 218 GP 030476(7)
NUCLIDE =	7	O-16 1276 218 GP 030476(7)
NUCLIDE =	8	O-16 1276 218 GP 030476(7)
NUCLIDE =	9	O-16 1276 218 GP 030476(7)
NUCLIDE =	13027	AL-27 1193 218 GP 040375(5)
NUCLIDE =	24304	CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =	25055	MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =	26304	FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =	28304	NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =	82000	PB 1288 218NGP 042375 P-3 293K
NUCLIDE =	94239	PU-239 1264 SIGP=5+4 NEWXLACS 218NGP P-3 293K

ARRAY DESCRIPTION
2
1
2

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE		DEVIATION	NUMBER OF HISTORIES
3	.90225	+ OR -	.00468	21900

FREQUENCY FOR GENERATIONS 4 TO 76

.7752 TO .7983	*
.7983 TO .8214	
.8214 TO .8445	****
.8445 TO .8676	********
.8676 TO .8907	*****************
.8907 TO .9138	*****************
.9138 TO .9369	************
.9369 TO .9600	*********
.9600 TO .9831	***
.9831 TO 1.0062	**

TABLE 6.4.2-4. KEFF 2000 CASK 300 GMS PU239(0PU240)-H2O H/F=881.53
SINGLE CASK

```
     MIXTURE  NUCLIDE   DENSITY      MIXTURE  NUCLIDE   DENSITY
        1     -94239   7.56111E-05      8     -94239   7.56111E-05
        1       1001   6.66396E-02      8       1001   6.66396E-02
        1       8016   3.33198E-02      8       8016   3.33198E-02
        2          3   6.67555E-02      2          7   3.33777E-02
        3          4   6.67555E-02      3          8   3.33777E-02
        4      13027   6.02383E-02
        5          5   5.87448E-06      5          9   2.93724E-06
        6      24304   1.74239E-02      6      25055   1.73634E-03
        6      26304   5.93526E-02      6      28304   7.72036E-03
        7      82000   3.29882E-02
CROSS SECTIONS READ FROM TAPE
NUCLIDE =       1001   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          3   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          4   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          5   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =       8016   O-16 1276 218 GP 030476(7)
NUCLIDE =          7   O-16 1276 218 GP 030476(7)
NUCLIDE =          8   O-16 1276 218 GP 030476(7)
NUCLIDE =          9   O-16 1276 218 GP 030476(7)
NUCLIDE =      13027   AL-27 1193 218 GP 040375(5)
NUCLIDE =      24304   CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      25055   MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =      26304   FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      28304   NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      82000   PB   1288 218NGP 042375 P-3 293K
NUCLIDE =      94239   PU-239 1264 SIGP=5+4 NEWXLACS 218NGP P-3 293K
ARRAY DESCRIPTION
  2
  1
  3
NO. OF INITIAL
 GENERATIONS      AVERAGE                        NUMBER OF
   SKIPPED      K-EFFECTIVE      DEVIATION       HISTORIES
      3            .90702   + OR -   .00508       27300
FREQUENCY FOR GENERATIONS     4 TO   94
 .7800 TO  .8031      *
 .8031 TO  .8262      ***
 .8262 TO  .8493      *********
 .8493 TO  .8724      *********
 .8724 TO  .8955      *****************
 .8955 TO  .9186      ****************
 .9186 TO  .9417      *************
 .9417 TO  .9648      **********
 .9648 TO  .9878      *********
 .9878 TO 1.0109      ***
1.0109 TO 1.0340      *
```

TABLE 6.4.2-5. KEFF 2000 CASK 1175 GMS U235 U(5)O2-H2O H/F=386.21 0.30"POD
2 CASKS SIDE-BY-SIDE

MIXTURE	NUCLIDE	DENSITY	MIXTURE	NUCLIDE	DENSITY
1	-92235	1.23818E-03	8	-92235	1.51674E-04
1	92238	2.32282E-02	8	92238	2.84540E-03
1	8016	4.89327E-02	8	8016	5.99415E-03
2	4	3.33777E-02	8	4	2.92890E-02
2	1001	6.67555E-02	8	1001	5.85781E-02
3	5	3.33777E-02	3	8	6.67555E-02
4	13027	6.02383E-02			
5	6	2.93724E-06	5	9	5.87448E-06
6	24304	1.74239E-02	6	25055	1.73634E-03
6	26304	5.93526E-02	6	28304	7.72036E-03
7	82000	3.29882E-02			

```
CROSS SECTIONS READ FROM TAPE
NUCLIDE =       1001   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          8   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          9   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =       8016   O-16 1276 218 GP 030476(7)
NUCLIDE =          4   O-16 1276 218 GP 030476(7)
NUCLIDE =          5   O-16 1276 218 GP 030476(7)
NUCLIDE =          6   O-16 1276 218 GP 030476(7)
NUCLIDE =      13027   AL-27 1193 218 GP 040375(5)
NUCLIDE =      24304   CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      25055   MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =      26304   FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      28304   NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      82000   PB   1288 218NGP 042375 P-3 293K
NUCLIDE =      92235   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =      92238   U-238 218GP RE 5-17-78(1)
ARRAY DESCRIPTION
  2
  1
  2
NO. OF INITIAL
 GENERATIONS      AVERAGE                      NUMBER OF
   SKIPPED      K-EFFECTIVE     DEVIATION     HISTORIES
      3           .90547   + OR -  .00471       23100
FREQUENCY FOR GENERATIONS     4 TO    80
 .7785 TO  .8016      *
 .8016 TO  .8246      **
 .8246 TO  .8477      ****
 .8477 TO  .8708      ********
 .8708 TO  .8939      ************
 .8939 TO  .9170      ******************
 .9170 TO  .9401      ******************
 .9401 TO  .9632      **********
 .9632 TO  .9863      **
 .9863 TO 1.0094      **
```

TABLE 6.4.2-6. KEFF 2000 CASK 1175 GMS U235 U(5)O2-H2O H/F=386.21
0.30" POD SINGLE CASK

MIXTURE	NUCLIDE	DENSITY	MIXTURE	NUCLIDE	DENSITY
1	-92235	1.23818E-03	8	-92235	1.51674E-04
1	92238	2.32282E-02	8	92238	2.84540E-03
1	8016	4.89327E-02	8	8016	5.99415E-03
2	4	3.33777E-02	8	4	2.92890E-02
2	1001	6.67555E-02	8	1001	5.85781E-02
3	5	3.33777E-02	3	8	6.67555E-02
4	13027	6.02383E-02			
5	6	2.93724E-06	5	9	5.87448E-06
6	24304	1.74239E-02	6	25055	1.73634E-03
6	26304	5.93526E-02	6	28304	7.72036E-03
7	82000	3.29882E-02			

```
CROSS SECTIONS READ FROM TAPE
NUCLIDE =      1001   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =         8   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =         9   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =      8016   O-16 1276 218 GP 030476(7)
NUCLIDE =         4   O-16 1276 218 GP 030476(7)
NUCLIDE =         5   O-16 1276 218 GP 030476(7)
NUCLIDE =         6   O-16 1276 218 GP 030476(7)
NUCLIDE =     13027   AL-27 1193 218 GP 040375(5)
NUCLIDE =     24304   CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =     25055   MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =     26304   FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =     28304   NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =     82000   PB   1288 218NGP 042375 P-3 293K
NUCLIDE =     92235   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =     92238   U-238 218GP RE 5-17-78(1)
ARRAY DESCRIPTION
  2
  1
  3
NO. OF INITIAL
 GENERATIONS      AVERAGE                      NUMBER OF
   SKIPPED      K-EFFECTIVE     DEVIATION     HISTORIES
      3           .90333    + OR -   .00442     27600
FREQUENCY FOR GENERATIONS    4 TO   95
 .7994 TO  .8225      **
 .8225 TO  .8456      ********
 .8456 TO  .8687      ***********
 .8687 TO  .8918      *************
 .8918 TO  .9149      ********************
 .9149 TO  .9380      ******************
 .9380 TO  .9611      **************
 .9611 TO  .9842      ****
 .9842 TO 1.0073      **
```

TABLE 6.4.2-7. KEFF 2000 CASK 1750 GMS U235 4 CYLS H/F=198.95
0.35" POD 2 CASKS SIDE-BY-SIDE

MIXTURE	NUCLIDE	DENSITY	MIXTURE	NUCLIDE	DENSITY
1	-92235	1.23818E-03	8	-92235	2.63996E-04
1	92238	2.32282E-02	8	92238	4.95257E-03
1	8016	4.89327E-02	8	8016	1.04331E-02
2	4	3.33777E-02	8	4	2.62611E-02
2	1001	6.67555E-02	8	1001	5.25223E-02
3	5	3.33777E-02	3	8	6.67555E-02
4	13027	6.02383E-02			
5	6	2.93724E-06	5	9	5.87448E-06
6	24304	1.74239E-02	6	25055	1.73634E-03
6	26304	5.93526E-02	6	28304	7.72036E-03
7	82000	3.29882E-02			

CROSS SECTIONS READ FROM TAPE

```
NUCLIDE =     1001   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =        8   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =        9   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =     8016   O-16 1276 218 GP 030476(7)
NUCLIDE =        4   O-16 1276 218 GP 030476(7)
NUCLIDE =        5   O-16 1276 218 GP 030476(7)
NUCLIDE =        6   O-16 1276 218 GP 030476(7)
NUCLIDE =    13027   AL-27 1193 218 GP 040375(5)
NUCLIDE =    24304   CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =    25055   MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =    26304   FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =    28304   NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =    82000   PB   1288 218NGP 042375 P-3 293K
NUCLIDE =    92235   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =    92238   U-238 218GP RE 5-17-78(1)
ARRAY DESCRIPTION
  2
  1
  2
NO. OF INITIAL
 GENERATIONS      AVERAGE                         NUMBER OF
   SKIPPED      K-EFFECTIVE       DEVIATION      HISTORIES
      3            .87728    + OR - .00678        15600
FREQUENCY FOR GENERATIONS    4 TO   55
 .7503 TO  .7734      *
 .7734 TO  .7965      *
 .7965 TO  .8195      **
 .8195 TO  .8426      ********
 .8426 TO  .8657      ************
 .8657 TO  .8888      *********
 .8888 TO  .9119      ********
 .9119 TO  .9350      ****
 .9350 TO  .9581      ***
 .9581 TO  .9812      ***
 .9812 TO 1.0043
1.0043 TO 1.0274      *
```

TABLE 6.4.2-8. KEFF 2000 CASK 1750 GMS U235 4 CYLS H/F=198.95
0.35" POD SINGLE CASK

MIXTURE	NUCLIDE	DENSITY	MIXTURE	NUCLIDE	DENSITY
1	-92235	1.23818E-03	8	-92235	2.63996E-04
1	92238	2.32282E-02	8	92238	4.95257E-03
1	8016	4.89327E-02	8	8016	1.04331E-02
2	4	3.33777E-02	8	4	2.62611E-02
2	1001	6.67555E-02	8	1001	5.25223E-02
3	5	3.33777E-02	3	8	6.67555E-02
4	13027	6.02383E-02			
5	6	2.93724E-06	5	9	5.87448E-06
6	24304	1.74239E-02	6	25055	1.73634E-03
6	26304	5.93526E-02	6	28304	7.72036E-03
7	82000	3.29882E-02			

```
CROSS SECTIONS READ FROM TAPE
NUCLIDE =      1001   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =         8   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =         9   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =      8016   O-16 1276 218 GP 030476(7)
NUCLIDE =         4   O-16 1276 218 GP 030476(7)
NUCLIDE =         5   O-16 1276 218 GP 030476(7)
NUCLIDE =         6   O-16 1276 218 GP 030476(7)
NUCLIDE =     13027   AL-27 1193 218 GP 040375(5)
NUCLIDE =     24304   CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =     25055   MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =     26304   FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =     28304   NI 1190 WT SS-304(1/EST) P-3 293K 3P-5+4(42375)'
NUCLIDE =     82000   PB   1288 218NGP 042375 P-3 293K
NUCLIDE =     92235   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =     92238   U-238 218GP RE 5-17-78(1)
ARRAY DESCRIPTION
  2
  1
  3
NO. OF INITIAL
 GENERATIONS      AVERAGE                          NUMBER OF
   SKIPPED      K-EFFECTIVE       DEVIATION        HISTORIES
      3           .90459    + OR -  .00533          19800
FREQUENCY FOR GENERATIONS    4 TO   69
 .7776 TO  .8007     *
 .8007 TO  .8238
 .8238 TO  .8469     ***
 .8469 TO  .8699     *********
 .8699 TO  .8930     ***************
 .8930 TO  .9161     ************
 .9161 TO  .9392     ***********
 .9392 TO  .9623     *********
 .9623 TO  .9854     ****
 .9854 TO 1.0085     *
1.0085 TO 1.0316
1.0316 TO 1.0547     *
```

TABLE 6.4.2-9. KEFF 2000 CASK 500 GMS U235 U(100)-H2O H/F=519.47
FUEL CENTERED IN CASK

```
 MIXTURE  NUCLIDE   DENSITY     MIXTURE  NUCLIDE   DENSITY
     1    -92235   1.28165E-04     8    -92235   1.28165E-04
     1      1001   6.65789E-02     8      1001   6.65789E-02
     1      8016   3.32894E-02     8      8016   3.32894E-02
     2         3   6.67555E-02     2         7   3.33777E-02
     3         4   6.67555E-02     3         8   3.33777E-02
     4     13027   6.02383E-02
     5         5   5.87448E-06     5         9   2.93724E-06
     6     24304   1.74239E-02     6     25055   1.73634E-03
     6     16304   5.93526E-02     6     28304   7.72036E-03
     7     82000   3.29882E-02
 * NMAT=15  MATT= 8  NMIX=18
CROSS SECTIONS READ FROM TAPE
NUCLIDE =       1001   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          3   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          4   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          5   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =       8016   O-16    1276 218 GP 030476(7)
NUCLIDE =          7   O-16    1276 218 GP 030476(7)
NUCLIDE =          8   O-16    1276 218 GP 030476(7)
NUCLIDE =          9   O-16    1276 218 GP 030476(7)
NUCLIDE =      13027   AL-27 1193 218 GP 040375(5)
NUCLIDE =      24304   CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      25055   MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =      26304   FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      28304   NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      82000   PB      1238 218NGP 042375 P-3 293K
NUCLIDE =      92235   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NO. OF INITIAL
 GENERATIONS      AVERAGE                        NUMBER OF
   SKIPPED      K-EFFECTIVE       DEVIATION     HISTORIES
      3           .90294    + OR -  .00487        30000
FREQUENCY FOR GENERATIONS     4 TO  103
 .7759 TO  .7990     ***
 .7990 TO  .8221     **
 .8221 TO  .8452     *******
 .8452 TO  .8683     **************
 .8683 TO  .8914     **********
 .8914 TO  .9145     *************************
 .9145 TO  .9376     ************
 .9376 TO  .9607     ***************
 .9607 TO  .9838     ******
 .9838 TO 1.0069     ******
```

TABLE 6.4.2-10. KEFF 2000 CASK 300 GMS PU239(0PU240)-H2O H/F=881.53
FUEL CENTERED IN CASK

MIXTURE	NUCLIDE	DENSITY	MIXTURE	NUCLIDE	DENSITY
1	-94239	7.56111E-05	8	-94239	7.56111E-05
1	1001	6.66396E-02	8	1001	6.66396E-02
1	8016	3.33198E-02	8	8016	3.33198E-02
2	3	6.67555E-02	2	7	3.33777E-02
3	4	6.67555E-02	3	8	3.33777E-02
4	13027	6.02383E-02			
5	5	5.87448E-06	5	9	2.93724E-06
6	24304	1.74239E-02	6	25055	1.73634E-03
6	26304	5.93526E-02	6	28304	7.72036E-03
7	82000	3.29882E-02			

```
  * NMAT=15  MATT= 8  NMIX=18
CROSS SECTIONS READ FROM TAPE
NUCLIDE =      1001   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =         3   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =         4   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =         5   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =      8016   O-16 1276 218 GP 030476(7)
NUCLIDE =         7   O-16 1276 218 GP 030476(7)
NUCLIDE =         8   O-16 1276 218 GP 030476(7)
NUCLIDE =         9   O-16 1276 218 GP 030476(7)
NUCLIDE =     13027   AL-27 1193 218 GP 040375(5)
NUCLIDE =     24304   CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =     25055   MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =     26304   FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =     28304   NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =     82000   PB   1288 218NGP 042375 P-3 293K
NUCLIDE =     94239   PU-239 1264 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NO. OF INITIAL
 GENERATIONS      AVERAGE                    NUMBER OF
   SKIPPED      K-EFFECTIVE     DEVIATION    HISTORIES
     3            .89590    + OR -   .00529     30000
FREQUENCY FOR GENERATIONS     4 TO  103
 .7689 TO  .7920      ****
 .7920 TO  .8151      *****
 .8151 TO  .8382      ****
 .8382 TO  .8613      ***********
 .8613 TO  .8844      ***************
 .8844 TO  .9074      ********************
 .9074 TO  .9305      **************
 .9305 TO  .9536      *************
 .9536 TO  .9767      ********
 .9767 TO  .9998      ****
 .9998 TO 1.0229      **
```

TABLE 6.4.2-11. KEFF 2000 CASK 1175 GMS U235 H/F=386.21

0.30" POD FUEL CENTERED IN CASK

MIXTURE	NUCLIDE	DENSITY	MIXTURE	NUCLIDE	DENSITY
1	-92235	1.23818E-03	8	-92235	1.51674E-04
1	92238	2.32282E-02	8	92238	2.84540E-03
1	8016	4.89327E-02	8	8016	5.99415E-03
2	4	3.33777E-02	8	4	2.92890E-02
2	1001	6.67555E-02	8	1001	5.85781E-02
3	5	3.33777E-02	3	8	6.67555E-02
4	13027	6.02383E-02			
5	6	2.93724E-06	5	9	5.87448E-06
6	24304	1.74239E-02	6	25055	1.73634E-03
6	26304	5.93526E-02	6	28304	7.72036E-03
7	82000	3.29882E-02			

```
  * NMAT=15  MATT= 8  NMIX=20
CROSS SECTIONS READ FROM TAPE
NUCLIDE =       1001   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          8   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          9   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =       8016   O-16 1276 218 GP 030476(7)
NUCLIDE =          4   O-16 1276 218 GP 030476(7)
NUCLIDE =          5   O-16 1276 218 GP 030476(7)
NUCLIDE =          6   O-16 1276 218 GP 030476(7)
NUCLIDE =      13027   AL-27 1193 218 GP 040375(5)
NUCLIDE =      24304   CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      25055   MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =      26304   FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      28304   NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      82000   PB   1288 218NGP 042375 P-3 293K
NUCLIDE =      92235   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =      92238   U-238 218GP RE 5-17-78(1)
NO. OF INITIAL
 GENERATIONS      AVERAGE                      NUMBER OF
   SKIPPED      K-EFFECTIVE      DEVIATION    HISTORIES
     3            .89535    + OR -   .00384     30000
FREQUENCY FOR GENERATIONS     4 TO  103
 .8145 TO  .8376     *******
 .8376 TO  .8607     *************
 .8607 TO  .8838     **********************
 .8838 TO  .9069     ******************
 .9069 TO  .9300     *********************
 .9300 TO  .9531     ************
 .9531 TO  .9762     *****
 .9762 TO  .9993     *
 .9993 TO 1.0224     *
```

TABLE 6.4.2-12. KEFF 2000 CASK 1750 GMS U235 4 CYLS H/F=198.95
0.35" POD FUEL CENTERED IN CASK

```
     MIXTURE  NUCLIDE   DENSITY     MIXTURE  NUCLIDE   DENSITY
         1    -92235   1.23818E-03      8    -92235   2.63996E-04
         1     92238   2.32282E-02      8     92238   4.95257E-03
         1      8016   4.89327E-02      8      8016   1.04331E-02
         2         4   3.33777E-02      8         4   2.62611E-02
         2      1001   6.67555E-02      8      1001   5.25223E-02
         3         5   3.33777E-02      3         8   6.67555E-02
         4     13027   6.02383E-02
         5         6   2.93724E-06      5         9   5.87448E-06
         6     24304   1.74239E-02      6     25055   1.73634E-03
         6     26304   5.93526E-02      6     28304   7.72036E-03
         7     82000   3.29882E-02
  * NMAT=15  MATT= 8  NMIX=20
CROSS SECTIONS READ FROM TAPE
NUCLIDE =       1001   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          8   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          9   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =       8016   O-16 1276 218 GP 030476(7)
NUCLIDE =          4   O-16 1276 218 GP 030476(7)
NUCLIDE =          5   O-16 1276 218 GP 030476(7)
NUCLIDE =          6   O-16 1276 218 GP 030476(7)
NUCLIDE =      13027   AL-27 1193 218 GP 040375(5)
NUCLIDE =      24304   CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      25055   MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =      26304   FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      28304   NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      82000   PB   1288 218NGP 042375 P-3 293K
NUCLIDE =      92235   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =      92238   U-238 218GP RE 5-17-78(1)
NO. OF INITIAL
 GENERATIONS      AVERAGE                          NUMBER OF
   SKIPPED      K-EFFECTIVE      DEVIATION        HISTORIES
      3           .86450    + OR -  .00413          30000
FREQUENCY FOR GENERATIONS    4 TO  103
 .7606 TO  .7837      *
 .7837 TO  .8068      ******
 .8068 TO  .8299      ***************
 .8299 TO  .8530      *******************
 .8530 TO  .8760      *********************
 .8760 TO  .8991      **************
 .8991 TO  .9222      ****************
 .9222 TO  .9453      ******
 .9453 TO  .9684      *
 .9684 TO  .9915      *
```

TABLE 6.4.2-13. KEFF 2000 CASK 1750 GMS U235 4 CYLS H/F=198.95

0.35" POD FUEL OUTSIDE CASK

MIXTURE	NUCLIDE	DENSITY	MIXTURE	NUCLIDE	DENSITY
1	-92235	1.23818E-03	8	-92235	2.63996E-04
1	92238	2.32282E-02	8	92238	4.95257E-03
1	8016	4.89327E-02	8	8016	1.04331E-02
2	4	3.33777E-02	8	4	2.62611E-02
2	1001	6.67555E-02	8	1001	5.25223E-02
3	5	3.33777E-02	3	8	6.67555E-02
4	13027	6.02383E-02			
5	6	2.93724E-06	5	9	5.87448E-06
6	24304	1.74239E-02	6	25055	1.73634E-03
6	26304	5.93526E-02	6	28304	7.72036E-03
7	82000	3.29882E-02			

```
 * NMAT=15  MATT= 8  NMIX=20
CROSS SECTIONS READ FROM TAPE
NUCLIDE =       1001   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          8   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =          9   H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =       8016   O-16 1276 218 GP 030476(7)
NUCLIDE =          4   O-16 1276 218 GP 030476(7)
NUCLIDE =          5   O-16 1276 218 GP 030476(7)
NUCLIDE =          6   O-16 1276 218 GP 030476(7)
NUCLIDE =      13027   AL-27 1193 218 GP 040375(5)
NUCLIDE =      24304   CR 1191 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      25055   MN-55 1197 SIGP=5+4 NEWXLAC$ 218NGP P-3 293K
NUCLIDE =      26304   FE 1192 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      28304   NI 1190 WT SS-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =      82000   PB   1288 218NGP 042375 P-3 293K
NUCLIDE =      92235   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =      92238   U-238  218GP RE 5-17-78(1)
NO. OF INITIAL
 GENERATIONS      AVERAGE                        NUMBER OF
   SKIPPED      K-EFFECTIVE      DEVIATION      HISTORIES
      3           .86881    + OR -   .00437       30000
FREQUENCY FOR GENERATIONS    4 TO  103
 .7649 TO  .7880      **
 .7880 TO  .8111      ********
 .8111 TO  .8342      **********
 .8342 TO  .8573      *******************
 .8573 TO  .8804      **********************
 .8804 TO  .9035      *******************
 .9035 TO  .9265      **********
 .9265 TO  .9496      *******
 .9496 TO  .9727      *
 .9727 TO  .9958      **
```

TABLE 6.4.2-14. OLD CASK DESIGN - MERIT AND KENO-IV COMPARISON

SCALE SYSTEM/KENO-IV

Calculated k-eff	0.90547 ± 0.00471 (1 sigma)		
Benchmark bias	0.023		
Bias uncertainty (applied as a bias)	0.003		
Case uncertainty	0.00942 (2 sigma)		
Maximum k-eff	0.94089	→	k-eff = 0.941

MERIT

Calculated k-eff	0.9245 ± 0.0031 (1 sigma)		
Benchmark bias	0.0051		
Bias uncertainty	0.0044 (2 sigma)		
Case uncertainty	0.0062 (2 sigma)		
Maximum k-eff	0.9402	→	k-eff = 0.940

% Difference: (0.941 - 0.940)/0.940 = 0.0011 = 0.11%

TABLE 6.4.2-15. FINAL CASK K-EFF CALCULATIONS

MERIT

Calculated k-eff	0.9208 ± 0.0040 (1 sigma)		
Benchmark bias	0.0051		
Bias uncertainty	0.0044 (2 sigma)		
Case uncertainty	0.0080 (2 sigma)		
Maximum k-eff	0.9383	→	k-eff = 0.938

TABLE 6.5.1-1. CRITICAL EXPERIMENTS FOR COMPUTATIONAL TOOL EVALUATION

Experiment Name	References
A. TRX-1 & TRX-2 Low-Enriched Uranium Rods in Water	A.1. J. Hardy, Jr., D. Klein and J. J. Volpe; "A Study of Physics Parameters In Several Water-Moderated Lattices of Slightly Enriched and Natural Uranium", WAPD-TM-931; March, 1970.
	A.2. J. Hardy, Jr., D. Klein and J. J. Volpe; Nucl. Sci. Eng. 40, 101 (1970). J. J. Volpe, J. Hardy, Jr., and D. Klein, Nucl. Sci. Eng. 40, 116 (1970).
	A.3. J. Hardy, Jr., D. Klein and R. Dannels; Nucl. Sci. Eng. 26, 462 (1966).
	A.4. J. R. Brown et al., "Kinetics and Buckling Measurements in Lattices of Slightly Enriched U or UO_2 Rods In H_2O", WAPD-176 (January, 1958).
	A.5. R. Sher and S. Fiarman, "Studies of Thermal Reactor Benchmark Data Interpretation: Experimental Corrections", EPRI NP-209; October, 1976.
B. ORNL 1-4 & ORNL 10 Fully Enriched Uranium Spherical Solutions	B.1. R. Gwin and D. W. Magnuson, "Eta of U-233 and U-235 for Critical Experiments", Nuc. Sci. Eng. 12, 364 (1962).
	B.2. A. Staub et al., "Analysis of A Set of Critical Homogeneous U-H_2O Spheres", Nuc. Sci. Eng. 34, 263 (1968).
C. PNL 1-5 Plutonium Spherical Solutions	C.1. R. C. Lloyd et al., "Criticality Studies With Plutonium Solutions", Nuc. Sci. Eng. 25, 165 (1966).
	C.2. L. E. Hansen and E. D. Clayton, "Theory-Experiment Tests Using ENDF/B Version II Cross-Section Data", Trans. Amer. Nuc. Soc. 15, 309 (June, 1972).
	C.3. F. E. Kruesi et al., "Critical Mass Studies of Plutonium-Nitrate Solution", HW-24514 (1952).

TABLE 6.5.1-1. CRITICAL EXPERIMENTS FOR COMPUTATIONAL TOOL EVALUATION

(CONTINUED)

D.	Babcock & Wilcox Small Lattice Facility Low-Enriched UO_2 Rods in Water MO_2 Rods in Water	D.1. M. N. Baldwin et al., "Physics Verification Program - Part III", BAW-3647-6, Babcock & Wilcox, 1970. D.2. G. T. Fairburn et al., "Pu Lattice Experiments In Uniform Test Lattice of UO_2-1.5% PuO_2 Fuel", BAW-1357, Babcock & Wilcox; August, 1970.

TABLE 6.5.2-1. TRX-1 CRITICAL EXPERIMENT MODEL

```
KEFF TRX-1 763 U METAL RODS 1.291W/O WAPD 176 JAN. 1958
27GROUPNDF4  7 10 4 LATTICECELL  0 0
U-235  1 0. 6.253-4 END
U-238  1 0. 0.047205 END
AL  2 0. 0.06025 END
H  3 0.06676 END
O  3 0. 0.03338 END
H2O  4 8.8-5 END
H  5 0. 0.06676 END
O  5 0. 0.03338 END
FE  6 1. END
AL  7 0. 0.06025 END
TRIANGPITCH  1.806 0.983 1 3 1.1506 2 1.0084 4 END
KEFF TRX-1 763 U METAL RODS 1.291W/O WAPD 176 JAN. 1958
15.0 103 300 3 6 60 33 2 0
BOX TYPE  1
ZHEMICYL+X  7 0.5753 0. -15.24 -0.5
CUBOID  5 0. -0.903 -O. 0.782 -0.782 0. -15.24 -0.5
CUBOID  500 0. -0.903 -0. 0.782 -0.782 0. -76.20 -0.5
CUBOID  6 0.903 -0. 0.782 -0.782 5.08 -76.20 -0.5
BOX TYPE  2
ZHEMICYL-X  7 0.5753 0. -15.24 -0.5
CUBOID  5 0. -0.903 0.782 -0.782 0. -15.24 -0.5
CUBOID  500 0. -0.903 0.782 -0.782 0. -76.20 -0.5
CUBOID  6 0. -0.903 0.782 -0.782 5.08 -76.20 -0.5
BOX TYPE  3
ZHEMICYL+X  7 0.5753 20.32 -0. -0.5
CUBOID  5 0.903 -0. 0.782 -0.782 20.32 -0. -0.5
CUBOID  500 0.903 -0. 0.782 -0.782 81.28 -0. -0.5
CUBOID  6 0.903 -0. 0.782 -0.782 81.28 -1.27 -0.5
BOX TYPE  4
ZHEMICYL-X  7 0.5753 20.32 -0. -0.5
CUBOID  5 0. -0.903 0.782 -0.782 20.32 -0. -0.5
CUBOID  500 0. -0.903 0.782 -0.782 81.28 -O. -0.5
CUBOID  6 0. -0.903 0.782 -0.782 81.28 -1.27 -0.5
BOX TYPE  5
CUBOID  5 0.903 -0. 0.782 -0.782 0. -76.20 -0.5
CUBOID  6 0.903 -0. 0.782 -0.782 5.08 -76.20 -0.5
BOX TYPE  6
CUBOID  5 0.903 -O. 0.782 -0.782 81.28 -0. -0.5
CUBOID  6 0.903 -0. 0.782 -0.782 81.28 -1.27 -0.5
ARRAY BDY  5 27.090 -27.090 25.806 -25.806 81.915 -81.915 -0.5
CUBOID  5 57.090 -57.090 55.806 -55.806 81.915 -81.915 -0.5
END GEOMETRY
 5  1 60 1  1 33 1 2 2 1 0 6  1 60 1  1 33 1 1 1 1 0 2 24 38 2  1 33 2 2 2 1 0
 1 25 39 2  1 33 2 2 2 1 0 2 17 43 2  2 32 2 2 2 1 0 1 18 44 2  2 32 2 2 2 1 0
 2 14 46 2  3 31 2 2 2 1 0 1 15 47 2  3 31 2 2 2 1 0 2 13 47 2  4 30 2 2 2 1 0
 1 14 48 2  4 30 2 2 2 1 0 2 12 48 2  5 29 2 2 2 1 0 1 13 49 2  5 29 2 2 2 1 0
 2  9 51 2  6 28 2 2 2 1 0 1 10 52 2  6 28 2 2 2 1 0 2  8 52 2  7 27 2 2 2 1 0
 1  9 53 2  7 27 2 2 2 1 0 2  7 53 2  8 26 2 2 2 1 0 1  8 54 2  8 26 2 2 2 1 0
 2  6 54 2  9 25 2 2 2 1 0 1  7 55 2  9 25 2 2 2 1 0 2  5 55 2 10 24 2 2 2 1 0
 1  6 56 2 10 24 2 2 2 1 0 2  4 56 2 11 23 2 2 2 1 0 1  5 57 2 11 23 2 2 2 1 0
 2  3 57 2 12 22 2 2 2 1 0 1  4 58 2 12 22 2 2 2 1 0 2  2 58 2 13 21 2 2 2 1 0
 1  3 59 2 13 21 2 2 2 1 0 2  1 59 2 16 18 2 2 2 1 0 1  2 60 2 16 18 2 2 2 1 0
 4 24 38 2  1 33 2 1 1 1 0 3 25 39 2  1 33 2 1 1 1 0 4 17 43 2  2 32 2 1 1 1 0
 3 18 44 2  2 32 2 1 1 1 0 4 14 46 2  3 31 2 1 1 1 0 3 15 47 2  3 31 2 1 1 1 0
 4 13 47 2  4 30 2 1 1 1 0 3 14 48 2  4 30 2 1 1 1 0 4 12 48 2  5 29 2 1 1 1 0
 3 13 49 2  5 29 2 1 1 1 0 4  9 51 2  6 28 2 1 1 1 0 3 10 52 2  6 28 2 1 1 1 0
 4  8 52 2  7 27 2 1 1 1 0 3  9 53 2  7 27 2 1 1 1 0 4  7 53 2  8 26 2 1 1 1 0
 3  8 54 2  8 26 2 1 1 1 0 4  6 54 2  9 25 2 1 1 1 0 3  7 55 2  9 25 2 1 1 1 0
 4  5 55 2 10 24 2 1 1 1 0 3  6 56 2 10 24 2 1 1 1 0 4  4 56 2 11 23 2 1 1 1 0
 3  5 57 2 11 23 2 1 1 1 0 4  3 57 2 12 22 2 1 1 1 0 3  4 58 2 12 22 2 1 1 1 0
 4  2 58 2 13 21 2 1 1 1 0 3  3 59 2 13 21 2 1 1 1 0 4  1 59 2 16 18 2 1 1 1 0
 3  2 60 2 16 18 2 1 1 1 9
END KENO
```

TABLE 6.5.2-2. TRX-2 CRITICAL EXPERIMENT MODEL

```
KEFF TRX-2 577 U METAL RODS 1.291W/0 WAPD 176 JAN. 1958
27GROUPNDF4  7 10 4 LATTICECELL  0 0
U-235  1 0. 6.253-4 END
U-238  1 0. 0.047205 END
AL  2 0. 0.06025 END
H  3 0. 0.06676 END
O  3 0. 0.03338 END
H2O  4 8.8-5 END
H  5 0. 0.06676 END
O  5 0. 0.03338 END
FE  6 1. END
AL  7 0. 0.06025 END
TRIANGPITCH  2.174 0.983 1 3 1.1506 2 1.0084 4 END
KEFF TRX-2 577 U METAL RODS 1.291W/0 WAPD 176 JAN. 1958
15.0 103 300 3 6 52 29 2 0
BOX TYPE  1
ZHEMICYL+X  7 0.5753 0. -15.24 -0.5
CUBOID  5 1.087 -0. 0.941 -0.941 0. -15.24 -0.5
CUBOID  500 1.087 -0. 0.941 -0.941 0. -76.20 -0.5
CUBOID  6 1.087 -0. 0.941 -0.941 5.08 -76.20 -0.5
BOX TYPE  2
ZHEMICYL-X  7 0.5753 0. -15.24 -0.5
CUBOID  5 0. -1.087 0.941 -0.941 0. -15.24 -0.5
CUBOID  500 0. -1.087 0.941 -0.941 0. -76.20 -0.5
CUBOID  6 0. -1.087 0.941 -0.941 5.08 -76.20 -0.5
BOX TYPE  3
ZHEMICYL+X  7 0.5753 20.32 -0. -0.5
CUBOID  5 1.087 -0. 0.941 -0.941 20.32 -0. -0.5
CUBOID  500 1.087 -0. 0.941 -0.941 81.28 -0. -0.5
CUBOID  6 1.087 -0. 0.941 -0.941 81.28 -1.27 -0.5
BOX TYPE  4
ZHEMICYL-X  7 0.5753 20.32 -0. -0.5
CUBOID  5 0. -1.087 0.941 -0.941 20.32 -0. -0.5
CUBOID  500 0. -1.087 0.941 -0.941 81.28 -0. -0.5
CUBOID  6 0. -1.087 0.941 -0.941 81.28 -1.27 -0.5
BOX TYPE  5
CUBOID  5 1.087 -0. 0.941 -0.941 0. -76.20 -0.5
CUBOID  6 1.087 -0. 0.941 -0.941 5.08 -76.20 -0.5
BOX TYPE  6
CUBOID  5 1.087 -0. 0.941 -0.941 81.28 -0. -0.5
CUBOID  6 1.087 -0. 0.941 -0.941 81.28 -1.27 -0.5
ARRAY BDY  5 28.262 -28.262 27.289 -27.289 81.915 -81.915 -0.5
CUBOID  5 58.262 -58.262 57.289 -57.289 81.915 -81.915 -0.5
END GEOMETRY
 5  1 52 1  1 29 1 2 2 1 0 6  1 52 1  1 29 1 1 1 1 0 2 22 32 2  1 29 2 2 2 1 0
 1 23 33 2  1 29 2 2 2 1 0 2 15 37 2  2 28 2 2 2 1 0 1 16 38 2  2 28 2 2 2 1 0
 2 12 40 2  3 27 2 2 2 1 0 1 13 41 2  3 27 2 2 2 1 0 2 11 41 2  4 26 2 2 2 1 0
 1 12 42 2  4 26 2 2 2 1 0 2 10 42 2  5 25 2 2 2 1 0 1 11 43 2  5 25 2 2 2 1 0
 2  7 45 2  6 24 2 2 2 1 0 1  8 46 2  6 24 2 2 2 1 0 2  6 46 2  7 23 2 2 2 1 0
 1  7 47 2  7 23 2 2 2 1 0 2  5 47 2  8 22 2 2 2 1 0 1  6 48 2  8 22 2 2 2 1 0
 2  4 48 2  9 21 2 2 2 1 0 1  5 49 2  9 21 2 2 2 1 0 2  3 49 2 10 20 2 2 2 1 0
 1  4 50 2 10 20 2 2 2 1 0 2  2 50 2 11 19 2 2 2 1 0 1  3 51 2 11 19 2 2 2 1 0
 2  1 51 2 14 16 2 2 2 1 0 1  2 52 2 14 16 2 2 2 1 0 4 22 32 2  1 29 2 1 1 1 0
 3 23 33 2  1 29 2 1 1 1 0 4 15 37 2  2 28 2 1 1 1 0 3 16 38 2  2 28 2 1 1 1 0
 4 12 40 2  3 27 2 1 1 1 0 3 13 41 2  3 27 2 1 1 1 0 4 11 41 2  4 26 2 1 1 1 0
 3 12 42 2  4 26 2 1 1 1 0 4 10 42 2  5 25 2 1 1 1 0 3 11 43 2  5 25 2 1 1 1 0
 4  7 45 2  6 24 2 1 1 1 0 3  8 46 2  6 24 2 1 1 1 0 4  6 46 2  7 23 2 1 1 1 0
 3  7 47 2  7 23 2 1 1 1 0 4  5 47 2  8 22 2 1 1 1 0 3  6 48 2  8 22 2 1 1 1 0
 4  4 48 2  9 21 2 1 1 1 0 3  5 49 2  9 21 2 1 1 1 0 4  3 49 2 10 20 2 1 1 1 0
 3  4 50 2 10 20 2 1 1 1 0 4  2 50 2 11 19 2 1 1 1 0 3  3 51 2 11 19 2 1 1 1 0
 4  1 51 2 14 16 2 1 1 1 0 3  2 52 2 14 16 2 1 1 1 9
END KENO
```

TABLE 6.5.2-3. ORNL-1, ORNL-2, PNL-1, AND PNL-2 CRITICAL EXPERIMENT MODELS

```
KEFF ORNL-1 NSE 34 263-274 (1968P) SCALE MODEL
27GROUPNDF4  1 7 1 INFHOMMEDIUM  1 0
U-235  1 0. 4.8066-5 END
U-238  1 0. 2.807-6 END
U-234  1 0. 5.38-7 END
U-236  1 0. 1.38-7 END
N  1 0. 1.869-4 END
O  1 0. 0.033736 END
H  1 0. 0.066228 END
 ISN=12 IIM=40 ICM=70 IUS=1 END
KEFF ORNL-1 NSE 34 263-274 (1968P) SCALE MODEL
15.0 103 300 3 0 0 0 0 0
SPHERE  1 34.5948 -0.5
END GEOMETRY
END KENO

KEFF ORNL-2 NSE 34 263-274 (1968P) SCALE MODEL
27GROUPNDF4  1 8 1 INFHOMMEDIUM  1 0
U-235  1 0. 5.6205-5 END
U-238  1 0. 3.28-6 END
U-234  1 0. 6.31-7 END
U-236  1 0. 1.63-7 END
N  1 0. 2.129-4 END
O  1 0. 0.0338 END
H  1 0. 0.066148 END
B-10  1 0. 1.0286-6 END
 ISN=12 IIM=40 ICM=70 IUS=1 END
KEFF ORNL-2 NSE 34 263-274 (1968P) SCALE MODEL
15.0 103 300 3 0 0 0 0 0
SPHERE  1 34.5948 -0.5
END GEOMETRY
END KENO

KEFF PNL-1 NSE 25 165 (1966)
27GROUPNDF4  1 5 1 INFHOMMEDIUM  1 0
PU-239  1 0. 9.373-5 END
PU-240  1 0. 4.501-6 END
N  1 0. 6.216-4 END
0  1 0. 0.03456 END
H  1 0. 0.06563 END
 ISN=12 IIM=40 ICM=70 IUS=1 END
KEFF PNL-1 NSE 25 165 (1966)
15. 103 300 3 0 0 0 0 0
SPHERE  1 19.509 -0.5
END GEOMETRY
END KENO

KEFF PNL-2 NSE 25 165 (1966)
27GROUPNDF4  1 5 1 INFHOMMEDIUM  1 0
PU-239  1 0. 4.141-4 END
PU-240  1 0. 1.988-5 END
N  1 0. 4.720-3 END
0  1 0. 0.03977 END
H  1 0. 0.05416 END
 ISN=12 IIM=40 ICM=70 IUS=1 END
KEFF PNL-2 NSE 25 165 (1966)
15. 103 300 3 0 0 0 0 0
SPHERE  1 19.509 -0.5
END GEOMETRY
END KENO
```

TABLE 6.5.2-4. B&W UO2 AND MO2 ROD CRITICAL EXPERIMENT MODELS

```
B&W UO2 EXP CELL  SCALE MODEL  ENDFB-IV LATTICE SELFSHLD
27GROUPNDF4  3 7 3  LATTICECELL   0 0
O       1  0.  4.472785-2  END
U-235   1  0.  5.570288-4  END
U-238   1  0.  2.180690-2  END
AL      2  0.  6.051481-2  END
H       3  0.  6.668320-2  END
B-10    3  0.  2.243000-5  END
O       3  0.  3.334160-2  END
SQUAREPITCH   1.6256 1.0434   1  3 1.2060 2 END
B&W UO2 EXP CELL  SCALE MODEL  ENDFB-IV LATTICE SELFSHLD
15.  103  300  3  4R1  1
6R1
CYLINDER  1  .521716  .8128  -.8128  -.5
CYLINDER  2  .603     .8128  -.8128  -.5
CUBOID    3  .8128  -.8128  .8128  -.8128  .8128  -.8128  -.5
END GEOMETRY
END KENO

B&W MUO2 EXPERIMENT  SCALE MODEL  LATTICECELL SELFSHIELDIN
27GROUPNDF4  3 12 3  LATTICECELL   0 0
O          1  0.  4.358350-2  END
U-235      1  0.  1.543510-4  END
U-238      1  0.  2.131198-2  END
FU-239     1  0.  2.646750-4  END
PU-240     1  0.  5.295900-5  END
PEJ-241    1  0.  5.271000-6  END
PU-242     1  0.  8.320000-7  END
AM-241     1  0.  1.616000-6  END
ZIRCALLOY  2  1.019225        END
H          3  0.  6.668320-2  END
B-10       3  0.  2.465000-5  END
O          3  0.  3.334160-2  END
SQUAREPITCH  1.89738  1.2751  1  3  1.4275  2  END
B&W MUO2 EXPERIMENT SCALE MODEL LATTICE SLFSHLDING
10.  103  300  3  4R1  1
6R1
CYLINDER  1  .63754   .94869  -.94869                                -.5
CYLINDER  2  .71374   .94869  -.94869                                -.5
CUBOID    3  .94869  -.94869   .94869  -.94869  .94869  -.94869  -.5
END GEOMETRY
END KENO
```

TABLE 6.5.3-1. SUMMARY OF CRITICAL EXPERIMENTS - SCALE

Experiment	Feature	K-eff ± 2 Sigma
ORNL-1	Fully Enriched	1.0021 ± 0.0060
ORNL-2	U-235 Nitrate	0.9977 ± 0.0068
TRX-1	Low Enriched	0.9773 ± 0.0060
TRX-2	U-235 Rods	0.9820 ± 0.0060
PNL-1	Plutonium	1.0157 ± 0.0108
PNL-2	Nitrate (5Pu240)	1.0105 ± 0.0114
B&W	UO_2 Rod	0.9920 ± 0.0046
B&W	MO_2 Rod	0.9972 ± 0.0054

TABLE 6.5.3-2. SUMMARY OF CRITICAL EXPERIMENTS - MERIT

Experiment	Feature	K-eff ± 1 Sigma
ORNL-1	Fully Enriched	0.9911 ± 0.0028
ORNL-2	U-235 Nitrate	0.9933 ± 0.0046
TRX-1	Low Enriched	0.9998 ± 0.0013
TRX-2	U-235 Rods	0.9924 ± 0.0010
PNL-1	Plutonium	1.0194 ± 0.0055
PNL-2	Nitrate (5Pu240)	1.0143 ± 0.0060
B&W	UO_2 Rod	0.9950 ± 0.0021
B&W	MO_2 Rod	0.9960 ± 0.0018

6.6.2 Supplemental Criticality Safety Analysis for the General Electric Model 2000 Shipping Cask

Supplemental Criticality Safety Analysis for the General Electric Model 2000 Shipping Cask

Prepared by: [signature] Date: AUG. 31, 1994
J.S. Bowman

1. FUEL PACKAGE LOADING

The purpose of this report is to identify, describe, discuss and analyze the principal criticality engineering physics design of the packaging and components important to safety for the Model 2000 shipping cask. This report is intended to demonstrate compliance with the criticality safety standards of the International Atomic Energy Agency (IAEA).

The Model 2000 cask is a cylindrical steel case with lead shielding. The cask has a cavity that is 26.5 inches inside diameter by 54 inches long for holding material, including special nuclear material. The type of fuel proposed for transport is UO_2 fuel pellets. Segmented fuel rods containing UO_2 pellets with diameters greater than or equal to 0.889 cm (0.35 inches), with enrichments less than or equal to 5 w/o in ^{235}U are considered. The fuel can be either fresh or exposed (either fully or partially spent). Also, this analysis can be extended to any fuel design where the material and form of the fuel are consistent with the basis of this analysis. Note that the Model 2000 design does not rely on neutron poison material(s) to achieve criticality safety.

This report is a supplement to the original criticality safety analysis [3]. Dimensions and drawings of the Model 2000 cask are contained in the original Safety Analysis Report (SAR). The results presented in this report indicate that the previous analysis for UO_2 pellets in the Model 2000 cask is conservative. This is due to modelling differences between the new and old (KENO based) analysis. In this analysis, fuel pellets are explicitly (discretely) modelled, which is a change from the previous KENO model.

2. FUEL PACKAGE LOADING

Criticality safety is demonstrated for the following fuel packages in the Model 2000 shipping cask.

- Fresh or irradiated UO_2 fuel rods that may be segmented and contain 1,750 grams of ^{235}U, provided the enrichment is ≤ 5 w/o in ^{235}U. The minimum pellet outside diameter is ≥ 0.35 inches (0.889 cm). There is no restriction on cladding material (none is considered in the analysis). The fuel shall be contained within closed (but not leak-tight) 5 inch Schedule 40 pipes with a maximum useable length of 39 5/8 inches (100.65 cm). No more than 437.5 grams of ^{235}U is allowed per Schedule 40 pipe.

For criticality safety, the Model 2000 cask has a Transport Index (T.I.) of 50. The number of allowable casks per shipment is one (N=I).

3. MODELLING

In order to comply with the IAEA standards, three specific cases must be considered for the purpose of the criticality analysis. These cases are outlined in "Specific Requirements for Packages Containing Fissile Material," paragraphs 559 through 568 of the IAEA standards [4]. Subcriticality is demonstrated for the following cases.

- Single Containers – A package must be analyzed with optimum moderation and reflection. This is accomplished by including water within the cask and contents (intimately with the fuel and in spaces within the container) and by closely surrounding the cask with at least 20 cm of water reflector.

- Arrays of Packages in the Normal Condition of Transport – Analyze at least 5 × N undamaged packages in close contact (with nothing between), closely reflected by at least 20 cm of water.
- Arrays of Damaged Packages – Analyze at least 2 × N damaged packages with optimum interspersed hydrogenous moderation and closely reflected by at least 20 cm of water.

The previous analysis [3] demonstrated that the single container case is subcritical, so only the two array cases are considered here. In addition, the single container case is a subset of the accident array. Since water is assumed to flood the cask and contents under accident conditions, the accident array incorporates two containers under the same optimum moderation conditions as the single container case. The accident array is expected to bound the single container case.

3.1 MODEL SPECIFICATION

In all cases, the Model 2000 cask is analyzed in 3 dimensions. Tolerances are accounted for in a conservative manner by reducing thickness of structural materials (reducing the amount of material that may serve as parasitic neutron absorbers). In addition, dimensions are reduced where they may provide more favorable geometry for neutron multiplication.

Two models are considered for the "normal array" case. First, 7 casks in a tightly packed triangular array are modelled. The array is reflected by 30.5 cm (12 inches) of full density water. The k-effective values for the 7 casks with dry contents are extremely low, supporting the conclusions from the previous analysis that (1) the casks are essentially neutronically de-coupled and (2) dry fuel is extremely undermoderated. Note that "dry" is treated as containing water at 5% of full density (i.e., 5% of 1.0 gm/cm^3), which is several hundred times greater than the density of saturated water vapor at 120°F. Thus, humidity or condensation that could occur in the normal condition is accounted for.

Next, an infinite square array of dry packages is considered. A single package with a reflective boundary condition is used to model an infinite array of side-by-side casks. In this case, the fuel density is reduced, increasing the fuel volume and maximizing the projected target area of the fuel. This tends to increase the reactivity of the infinite system (the fuel is essentially "black" to a neutron despite the reduction in density). This conservative (no leakage) model demonstrates that dry fuel is extremely unreactive and that the number of normal packages in a system does not significantly affect criticality.

The model for the accident condition is two casks, side-by-side and touching. The cask and its contents are flooded with water. The interspersed moderation (both inside and outside of the container) is varied to achieve optimum moderation. Also, the two cask array is surrounded by 30.5 cm (12 inches) of full density water.

In both the normal and accident arrays, the fuel is modelled as a hexagonally arranged set of pellet stacks (in a triangular array). The pellet stacks are conservatively modelled without cladding material, which would displace water in the calculation. The pipes are filled with full density water; optimum moderation is achieved by varying the pitch of the lattice (which changes the hydrogen-to-fissile ratio). The Schedule 40 pipes are conservatively modelled by reducing the wall thickness by 10% to account for tolerance. Also, the pipe material is modelled as plain carbon steel (no credit is taken for weak neutron absorbing materials, which may be present in other types of steel).

The fuel pellets are explicitly modelled using the repeating geometry features of the GEMER01V code. No special cross-section treatments are used to account for the non-homogeneous nature of the fuel. Several arrangements of fuel pellet stacks within the Schedule 40 pipes are investigated. The hexagonal grouping was chosen to minimize leakage while conforming to the dimensions of the pipe (the pipes are not large enough to accommodate spheres of fuel pellets at the mass loading specified in Section 2).

3.2 CALCULATIONAL METHOD

The GEMER01V Monte Carlo neutron transport computer program [1], is used to demonstrate subcriticality of the Model 2000 cask with contents. GEMER is an enhanced version of the GE MERIT Monte Carlo code, incorporating the cross-section processing of MERIT and the geometry handling capabilities of KENO-1V [2]. Previous analyses of the criticality safety of the Model 2000 cask have been performed using the MERIT computer code and associated ENDF/B library set [5]. Critical benchmark experiments verify the accuracy of the calculational method chosen for the present analyses and provide the basis for the calculational bias.

3.3 CRITICAL BENCHMARK EXPERIMENTS

The GEMER01V code has been validated by comparison against 123 critical experiments [1]. These experiments form the database from which the GEMER bias is calculated.

Validation of GEMER01V against experimental data was performed using the same cases which were developed for benchmarking the original version of GEMER. The validation consisted of performing a set of 123 calculations that were taken from the following experiments:

Table 3-1. Summary of GEMER01V Validation Cases

Name of Experiment	Reference Document No.	No. Used in Benchmark
Handley-Hopper (Y-1948)	[8]	40
Handley-Hopper (Y-1858 Set A)	[71	21
Handley-Hopper (Y-1858 Set B)	[71	22
Bierman (NUREG/CR-0796)	[12]	19
Rocky Flats (NUREG/CR-0674)	[11]	10
RSIC	[9]	9
TRX (WAPD-TM-931)	[10]	2

Because calculational biases are normally due to the cross-section treatment rather than the geometry treatment, good agreement with the original validation and critical experiment is expected. The experimental parameters are described very briefly below. Consult the appropriate Reference Document for further information on the experiments themselves.

Handley-Hopper Critical Experiments

- Fuel forms of UF_4, UO_2F_2, U-metal or UNH
- Enrichments ranging from 1.4 wt% to 93.8 wt%
- Moderators of water, paraffin or none
- Reflectors of water, graphite, oil or bare

Bierman et. al. Critical Experiments

- Fuel form is UO_2
- Enrichments of 2.35 wt% to 4.29 wt%
- Moderator and reflectors of water

Rocky Flats Critical Experiments

- Uranium form of U_30_8
- Enrichment is 4.46 wt%
- Moderator is water
- Reflectors of concrete, plastic or steel

RSIC Critical Experiments

- Fuel form is UO_2
- Enrichment of 2.35 wt%
- Moderator and reflectors of water

TRX Critical Experiments

- Fuel form is U-metal
- Enrichment of 1.3 wt%
- Moderator and reflectors of water

Detailed results of the benchmark calculations for the GEMER criticality code are provided in Reference [1].

The results of the validation cases are compared to experiment and a calculational bias is determined from this comparison. Validation cases have been developed previously and were not newly created for this analysis. Obviously, for critical experiments, the value of k-effective is 1.000. No attempt has been made to include the experimental uncertainties into the models or the development of the calculated bias.

K-effectives for these cases have been selected based on the following selection technique. A Monte Carlo code begins with a source distribution and generates a new source distribution from each subsequent batch of neutrons. This allows the solution to converge to a correct distribution at a rate which is dependent upon the neutronic coupling of the model. K-effective is determined by discarding an appropriate number of initial batches so that the remaining batches are all representative subsets of the converged source distribution. The user generally specifies the number of initial batches to be skipped. However, since models do not converge at the same rate, the user is responsible for ensuring that the k-effective selected is a conservative one for criticality analyses. An approach to ensure this is to choose k-effective such that:

$$k_{eff} = \max\left[\sum_{l=n}^{m}\frac{(k_i - 3\sigma_i)}{(m-n)}\right] \tag{1}$$

providing that ($\sigma_i \geq 0$ and $\sigma_i \leq \sigma_{i+1}$, where m is the number of the last batch and n is the number of batches skipped.

Since the validation cases fit into the category of criticality calculation, and the models were developed with such guidelines as are used in criticality analyses, this selection technique was used to develop the bias. It is not necessary to further include uncertainty into the bias, since it is already included in the bias correlation.

The bias calculated for GEMER01V is identical to the bias developed for the PRIME version of GEMER. The differences in k-effective calculated by skipping the first two batches between the two codes are calculated and an average value and spread of this difference is found. The differences in k-effectives selected as described above are also found and the average of these is calculated.

The GEMER critical benchmark bias, which is known as a function of hydrogen-to-^{235}U ratio, was used to determined from the critical experiments. When the bias is positive (i.e., neutron multiplication is overpredicted) it is conservative to omit this positive bias as a reduction in k_{eff}.

K-effective results for the cross-section set used by GEMER have also been benchmarked using the original MERIT code for the ORNL, PNL, TRX, and B&W critical experiments. In the TRX cases, MERIT and the associated ENDF/B-IV cross-section set was used to compute k_∞. This k_∞ together with the leakage corrections from Reference [14] were applied to obtain k_{eff}. For all other calculations, the MERIT models used full three-dimensional geometric representations. For the Cross Section Evaluation Working Group (CSEWG) problems, the cross section processing is generally in agreement (within statistics) with the other calculations; agreeing especially well with the detailed BAPL (Bettis Atomic Power Laboratories) Monte Carlo calculations. For the two B&W critical experiments with boron curtains and gadolinia rods, the cross sections underpredict the eigenvalue by approximately 0.3 to 0.5 percent. The previous CSEWG evaluations of the ENDF/B-IV files [13] concluded that the experimental k_{eff} is generally overpredicted by 1-2% for plutonium nitrate systems and underpredicted by approximately 0.5 percent for high moderator-to-fuel ratios, to approximately 1.5 percent for low moderator-to-fuel ratios in water moderated uranium lattices. The MERIT results confirm these biases, thus supporting the CSEWG conclusions.

4. RESULTS

4.1 MODEL 2000 CASK VALIDATION CASE

In order to validate the Model 2000 cask GEMER model for the analysis, a case from the previous criticality safety analysis is repeated. Table 4-1 shows the effective multiplication factor for a homogeneous UO_2 and water sphere. The fuel is 500 grams of UO_2, 100 w/o ^{235}U and located near the lead (Pb) top within the cask. These results are virtually identical to previous calculations made with both KENO and MERIT [3]. The peak k-effective calculated with KENO was 0.92 at $H/^{235}U$ ratios of 500 ~ 600.

Table 4-1. GEMER Results for a Spherical, Homogeneous Fuel and Water Mixture

Amount of H_2O in Fuel (kg)	$H/^{235}U$	k-effective	$\pm\sigma$	Lower 3σ Limit for Bias	keff + 2σ – Bias
6	313	0.87597	0.00354	-0.00822	0.891
8	418	0.89463	0.00323	-0.01203	0.913
10	521	0.89477	0.00333	-0.01521	0.917
12	626	0.89175	0.00324	-0.01786	0.916
14	731	0.88354	0.00321	-0.01996	0.910
16	835	.86897	0.00291	-0.02160	0.896

A sample GEMER input deck (containing material number densities) for this case is provided in Appendix A, together with plots showing the arrangement of the cask and fuel. Since the inputs closely resemble those for the popular KENO program, no further explanation is given.

4.2 NORMAL ARRAY

Table 4-2 contains results for the infinite normal array. In these cases, the water density in the cask and between fuel pellet stacks is fixed at 5% of full density. The water density between casks is varied to show that moderation outside the casks does not improve the neutron economy. Moderation is most efficient near the fuel. Note that the bias column is zero, since no credit is taken for a positive bias (indicating that GEMER overpredicts k-infinity).

For the cases shown in Table 4-2, the fuel is treated as 37 pellet stacks, hexagonally arranged with a triangular pitch (1.86 cm) inside 4 Schedule 40 pipes. The pipes containing the fuel are optimally arranged in a square array (the reactivity effect of the pipe arrangement was investigated in the previous analysis [3]). The fuel density is decreased to 40% of theoretical to increase the volume and projected target area. The effect of "smearing" the fuel atoms over the larger volume is somewhat negligible; increasing the fuel density to 100% of theoretical only reduces reactivity by 0.6% Δk. Again, treating the array as infinite is very conservative, since no neutron leakage is calculated. A sample GEMER input deck (containing material number densities) and plots for this case are provided in Appendix B.

Table 4-2. GEMER Results for an Infinite Array of Undamaged Casks

H_2O Density Outside of Cask (gm/cm^3)	k-effective	$\pm\sigma$	Lower 3σ Limit for Bias	$k\infty + 2\sigma$ – Bias
0.0	0.18252	0.00115	0	0.185
0.02	0.16733	0.00156	0	0.170
0.05	0.15232	0.00116	0	0.155
0.10	0.14144	0.00108	0	0.144

No attempt is made to vary the fuel lattice pitch to demonstrate optimum moderation. Since there is so little water in the fuel lattice, varying the pitch would not significantly improve the hydrogen-to-fissile ratio. No significant increase in multiplication would be expected.

The 7 cask array for the normal conditions of transport gives a k-effective of 0.1435 ± 0.0012. These casks are arranged in a close packed, triangular array. The water density in the fuel and cask is 5% of full density. There is no water between casks, which produces the highest k-effective for the model. The entire array of casks is surrounded by 30.5 cm. (12 inch) of full density water. The fuel is arranged in 37 stacks, with a 1.85 cm triangular pitch, inside the Schedule 40 pipes. No attempt is made to vary the fuel lattice pitch to demonstrate optimum moderation. Again, varying the pitch would not significantly improve the hydrogen-to-fissile ratio. A sample GEMER input deck (containing material number densities) and plots for this case are provided in Appendix B.

4.3 ACCIDENT ARRAY

Table 4-3 shows results for the accident array. The GEMER model consists of two Model 2000 casks, side-by-side and touching, surrounded by a 30.5 cm (12 inch) thick water reflector. The fuel is modelled as hexagonally arranged pellet stacks with a triangular pitch. The water density in the cask and between fuel pellet stacks is 100% of full density (optimum for the system). The lattice pitch is varied to change the water-to-fuel ratio. The fuel pellets are contained within the Schedule 40 pipes, which are optimally arranged and as close as possible to the pipes in the other container. Note again that the previous analysis [3] found no significant sensitivity with respect to pipe orientation within the cask and that the casks are essentially de-coupled neutronically.

The water density inside the cask and fuel is optimum at 100% of full density. Decreasing the water density in the fuel region decreases the $H/^{235}U$ ratio, promoting undermoderation. Decreasing the water density outside the Schedule 40 pipes increases neutron leakage from the fuel region.

The highest k-effective is 0.704 for the 37 element array of fuel. The 37 element, 1.85 cm pitch array has the optimum configuration for neutron multiplication. Increasing the number of stacks decreases the moderator-to-fuel ratio, undermoderating the fuel. Decreasing the number of stacks improves the moderator-to-fuel ratio, but increases the leakage. The Schedule 40 pipes work to keep the system subcritical by promoting unfavorable geometry. Note that the height of the pellet stacks is given in parenthesis in the first column of the table. A sample GEMER input deck (containing material number densities) and plots for this case are provided in Appendix C.

The fuel is modelled as centered (axially) within the cask. The effect of locating the fuel next to the lead (Pb) cask top was investigated and found to be insignificant. The results of this analysis were not statistically different from the other results. These results are shown in Table 4-4. The vertical orientation of the fuel and/or neutron reflection from the lead cask top is not significant in these results.

Table 4-3. GEMER Results for the Accident Array

Number of Pellet Stacks/Pipe	Pitch (cm)	$H/^{235}U$	k-effective	$\pm\sigma$	Lower 3σ Limit for Bias	$k_{eff} + 2\sigma -$ Bias
61 (23.9 cm)	1.0	38	0.47281	0.00321	0	0.479
	1.2	54	0.56100	0.00306	0	0.567
	1.4	74	0.65302	0.00339	0	0.660
37 (39.4 cm)	1.75	115	0.67458	0.00298	0	0.681
	1.80	122	0.68712	0.00307	0	0.693
	1.85	129	0.69743	0.00318	0	0.704
	1.86	130	0.69353	0.00317	0	0.700
19 (76.8 cm)	2.30	199	0.57845	0.00239	-0.00333	0.587
	2.40	217	0.59438	0.00316	-0.00415	0.604
	2.50	236	0.59696	0.00283	-0.00497	0.608
	2.60	255	0.60282	0.00279	-0.00581	0.614
	2.70	275	0.60580	0.00293	-0.00666	0.618
	2.80	296	0.60728	0.00309	-0.00752	0.621

Table 4-4. GEMER Results for the Accident Array with Fuel Located Near the Pb Cask Top

Number of Pellet Stacks/Pipe	Pitch (cm)	$H/^{235}U$	k-effective	$\pm\sigma$	Lower 3σ Limit for Bias	$k_{eff} + 2\sigma -$ Bias
37 (39.4 cm)	1.80	122	0.68718	0.00314	0	0.693
	1.85	129	0.69722	0.00291	0	0.703
	1.86	130	0.70336	0.00296	0	0.709

5. REFERENCES

[1] GEMER01V User's Manual, K. R. Fletcher, June 1993, NEDE-32172P.

[2] KENO-IV: An Improved Monte Carlo Criticality Program, L. M. Petrie and N. F. Cross, ORNL-4938, November 1975.

[3] Safety Analysis Report for Packaging: Model 2000 Radioactive Transport Package, R. J. Pomares and P. A. Peterson, April 1988.

[4] Regulations for the Safe Transport of Radioactive Material, 1985 Edition (as Amended in 1990), IAEA Safety Standards, Safety Series No. 6, Vienna, 1990.

[5] Criticality Safety Analysis for the Model 2000 Shipping Cask (with HFIR Fuel), General Electric Design Record File AOO-0563 1, May 1993.

[6] "Critical Lattices of High Flux Isotope Reactor Fuel Elements," E. B. Johnson, Oak Ridge National Laboratory, March 20, 1967, ORNL-TM-1808.

[7] Y-1858, "Validation Checks of the 'ANISN' and 'KENO' Codes by Correlation with Experimental Data," G.R. Handley and C. M. Hopper, ORNL, November 20,1972.

[8] Y-1948, "Validation of the 'KENO' code for Nuclear Criticality Safety Calculations of Moderated Low-Enriched Uranium Systems," G. R. Handley and C. M. Hopper, ORNL, June 13, 1974.

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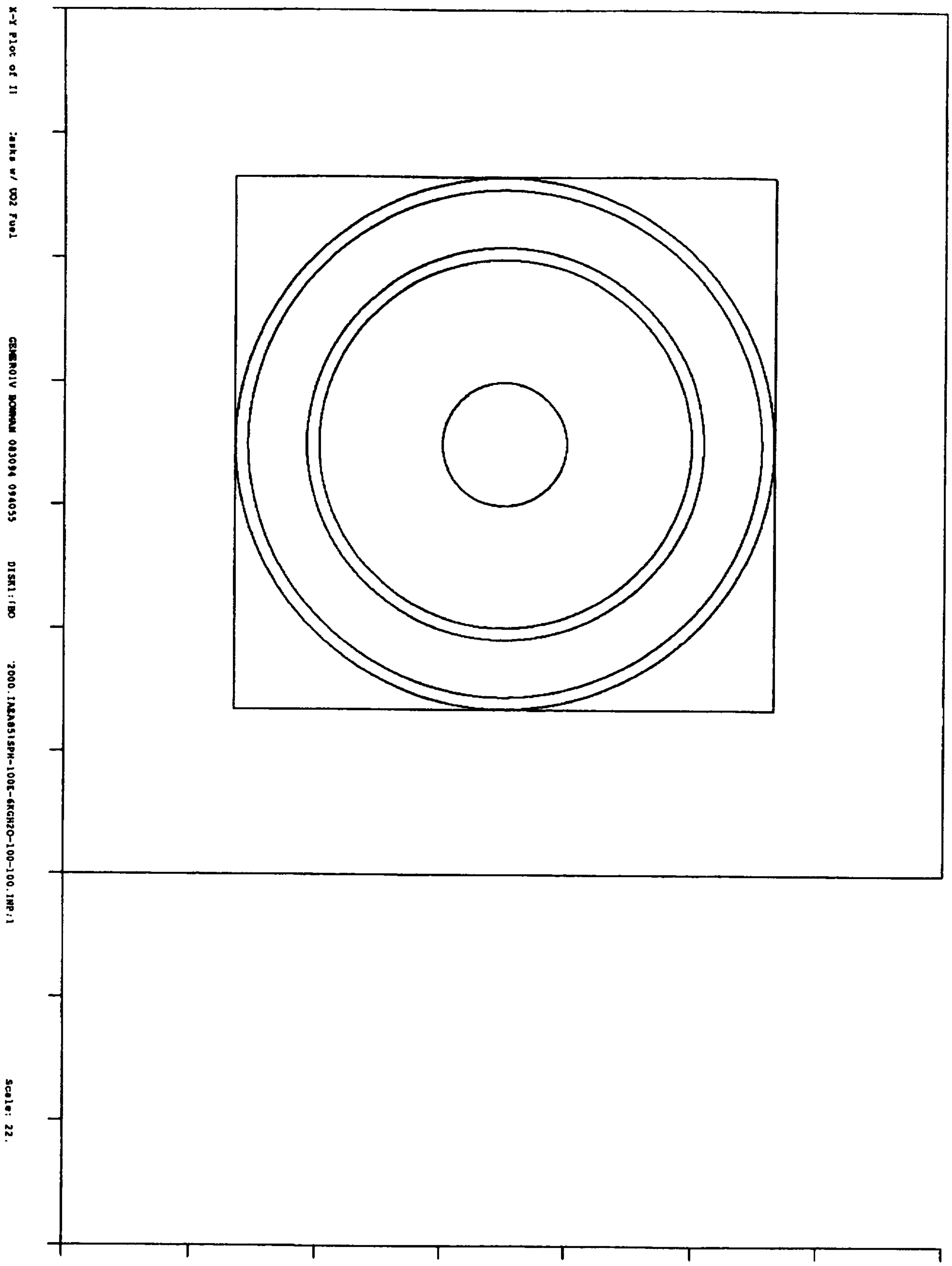
[11] NUREG/CR-0674, "Benchmark Critical Experiments on Low-enriched Uranium Oxide Systems with H/U=0.77," G. Tuck, I. Oh, Rockwell International, August, 1979.

[12] NUREG/CR-0796, "Criticality Experiments with Subcritical Clusters of 2.35 wt% 235-U Enriched UO_2 Rods in Water with Uranium or Lead Reflecting Walls," S. R. Bierman, B.M. Durst, E.D. Clayton, Batelle Pacific Northwest Laboratory, April 1979.

[13] "Benchmark testing on ENDF/B-IV," E. M. Bohn (ed.), et al., ENDF-230, Vol. 1, March 1976.

[14] Hardy, J., Jr., et al., Nuclear Science Engineering, 40, 101, 1970.

APPENDIX A


X-Y Plot of II
asks w/ UO2 Fuel
GENER01V BOWMAN 083094 094055
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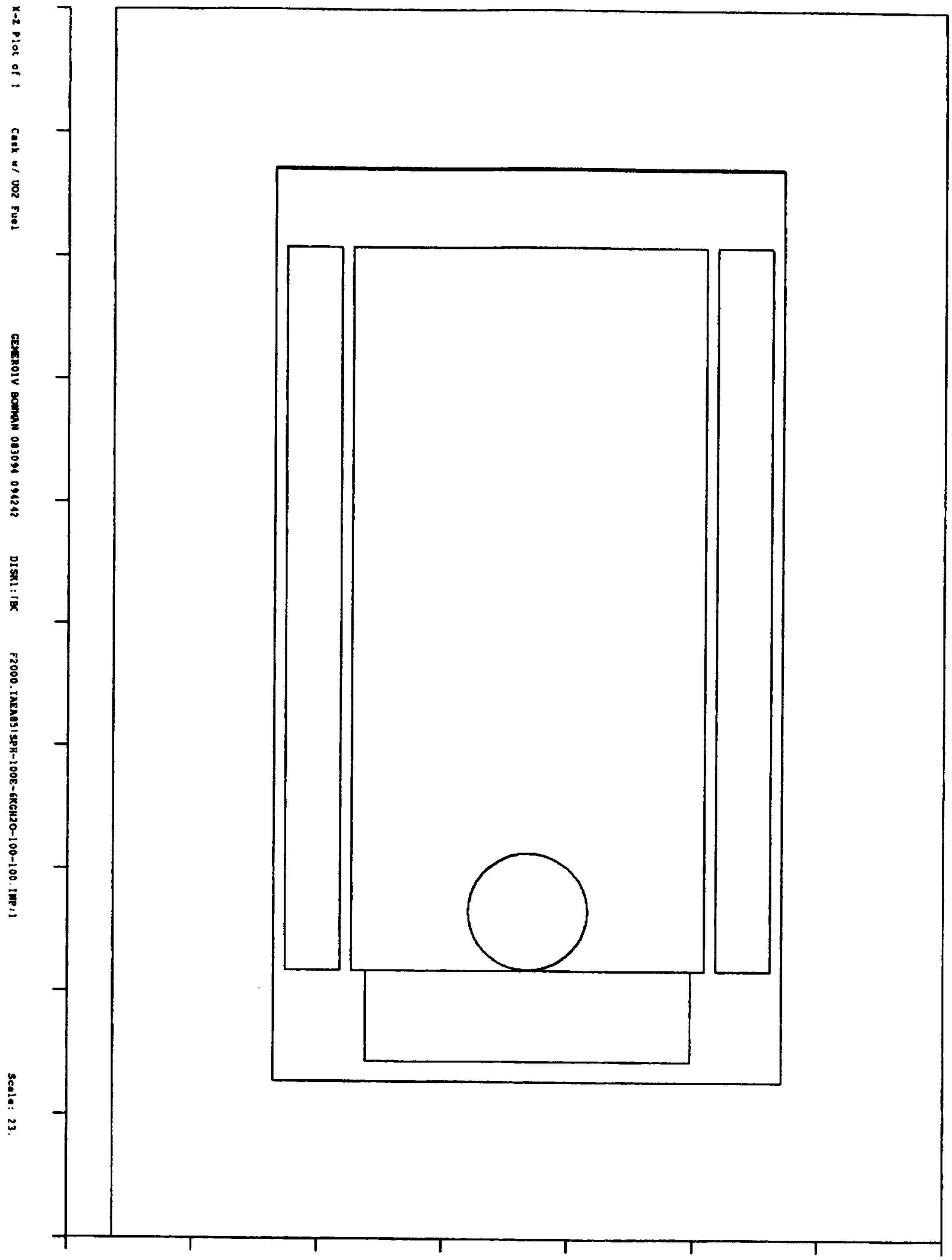
Scale: 22.

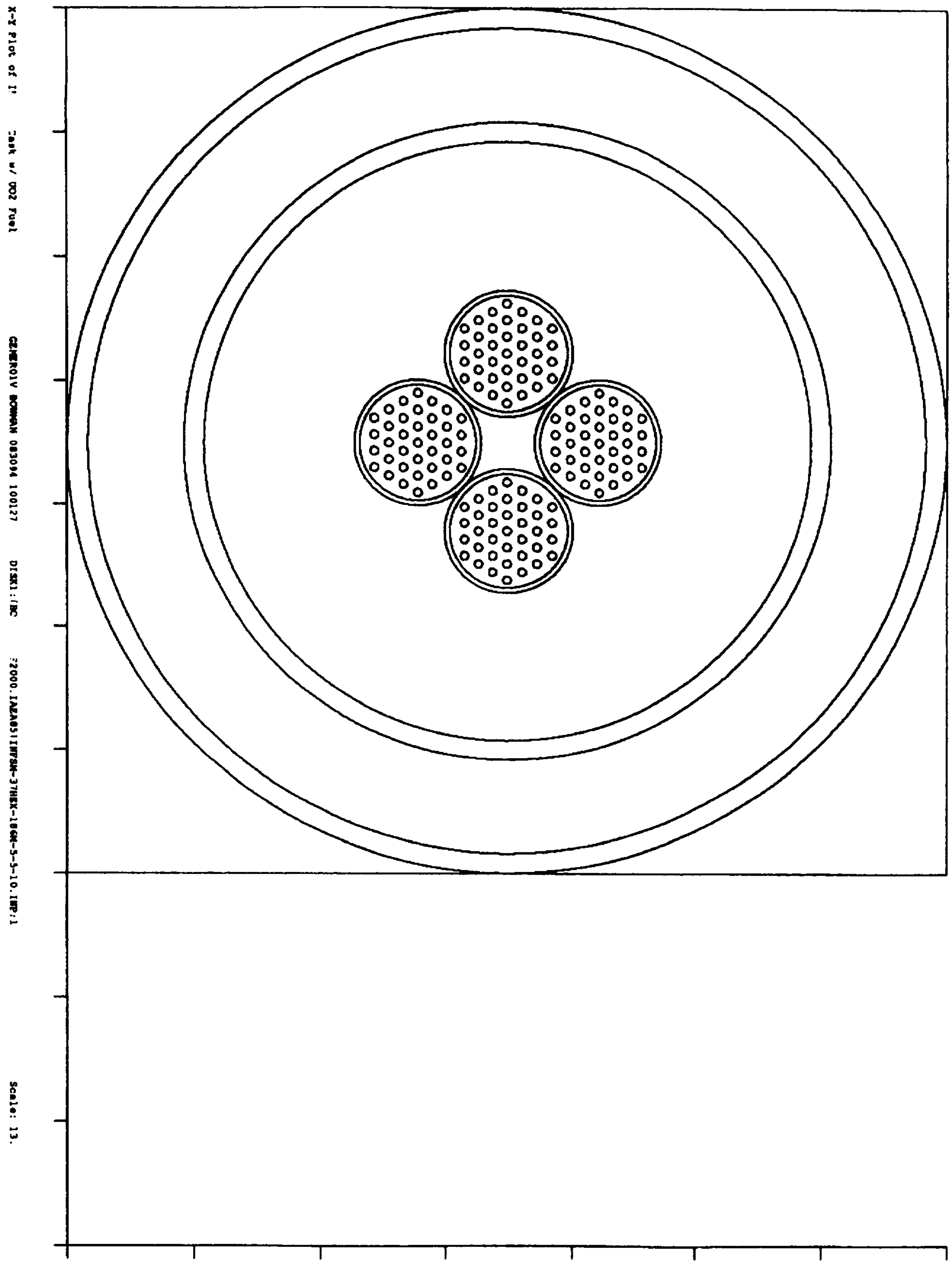

X-Z Plot of 1
Cask w/ UO2 Fuel
GEMER01V BOWMAN 083094 094242
DISK1:[BK
F2000.IAEA851SPH-100E-6KGH2O-100-100.INP;1
Scale: 23.

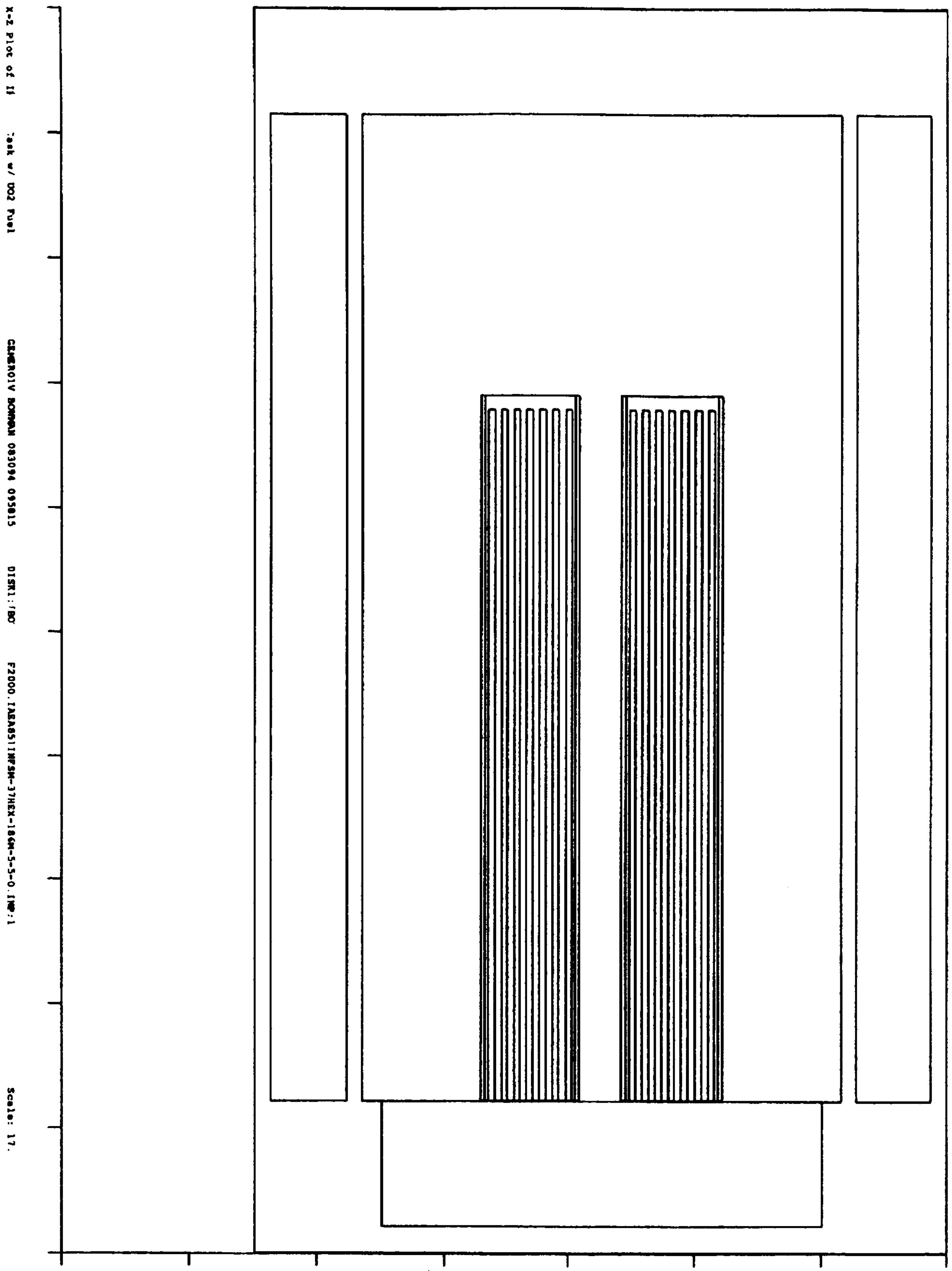
IF2000 Input Generation Worksheet
(For Casks with < 5% e Pellets - IAEA '85)

```
Fuel Description                                Regional Number Densities
Enrichment U-235        1.00                    Avagadro              0.6022 cm2/bn-mol
Mass U235/mol       235.0439 gm/mol                      fuel                               Mass Check:
Mass U238/mol       238.0508 gm/mol             N-235               2.12E-04 atom/bn-cm            500.05 gm U-235
Mass U/Mol           235.044 gm/mol             N-238               0.00E+00 atom/bn-cm
Fraction-U           0.88017                    N-Oxygen            3.36E-02 atom/bn-cm
Tot Mass U-235           500 gm                 N-Hydrogen                   6.63E-02 atom/bn-cm,
Tot Mass UO2         568.072 gm                          full density H2O
T.D. UO2               10.96 gm/cm3             N-H                 6.69E-02 atom/bn-cm
Fraction T.D.           1.00                    N-Oxy               3.34E-02 atom/bn-cm

Fuel & Water Mixture                            H/U-235                313.1          -0.008223 GEMER Bias
Water Mass in Fuel      6000 gm
System Mass             6568 gm                 Geometry
Weight Fract H2O      0.9135                    Rad UO2/H2O Sphere    11.305 cm
Mixture Density       1.0853 gm/cm3             Margin to Wall        22.345 cm
Total Volume            6052 cm3
                                Spec.Grav.Intrsp.H2O      1.00 (Inside Cask)
                                Spec.Grav.Intrsp.H2O      1.00 (Outside Cask)

/PRW6,SPH-100E-6KGH2O-100-100.INP@@             Begin Input Deck

IF2000 Cask w/ Homogeneous U(100.0%)O2 + 91.4% H2O Mixture (RHOmix = 1.0853 gm/cm3)
      65 /* NUM OF BATCHES
    1000 /* NUM OF NEUTRONS PER BATCH
       5 /* NUM OF BATCHES TO SKIP
 8762569 /* INITIAL SEED
       0 /* "IDUMP"
       0 /* "NRSTRT"
       0 /* "NBTED"
       0 /* "KRED"
      0  293  10  7
      3  293  0  0  MIXTURE: 8.7% U(100.0%)O2 + 91.4% H2O
    2351    2.11700000E-04
       1    6.62810000E-02
      16    3.35640000E-02
      2  293  0  0 Full Density Water: 1.0 gm/cm3
       1    6.68550000E-02
      16    3.34270000E-02
      2  293  0  0  Interspersed Water Inside Cask 1.00 gm/cm3
       1    6.68550010E-02
      16    3.34270010E-02
      2  293  0  0  Interspersed Water Outside Cask 1.00 gm/cm3
       1    6.68550010E-02
      16    3.34270010E-02
```

```
      1  293  0  0  Lead Shielding
      82    3.29890E-02
      7  293  0  0  Type 304 Stainless Steel
      12    6.82690E-05
      14    8.53360E-04
      24    1.53600E-02
      26    6.04950E-02
      28    6.82690E-03
      55    1.70670E-03
    1316    2.56010E-05
    2  293   0  0  Plain Carbon Steel AISI-SAE 1095
      12    3.744E-03
      26    8.353E-02
KENO GEOM
    10  /* "KREFM"
     4  /* "NBOX"
     1  /* "NBXMAX"
     1  /* "NBZMAX"
     0  /* "NXX"
     0  /* "NTYPST"
     1  /* "NEMBRG"
     0  /* "NGMCHK"
BOX TYPE      1    /* MODEL 2000 CASK (EMPTY)
CYLINDER      3     33.65    140.64    0.0      16*0.5
CYLINDER      6     35.85    140.64    0.0      16*0.5
CYLINDER      5     46.34    140.64    0.0      16*0.5
CYLINDER      6     48.56    140.64  -14.90     16*0.5
BOX TYPE      2    /* CASK TOP
CYLINDER      5     30.96    158.42  140.64     16*0.5
CYLINDER      6     48.56    162.23  140.64     16*0.5
BOX TYPE      3    /* UO2/WATER SPHERE
SPHERE        1     11.305     16*0.5
BOX TYPE      4    /* OVERALL BOX FOR THE PROBLEM
CUBOID        4    48.6  -48.6  48.60  -48.60  162.23  -15.24  16*0.5
CORE          0    48.6  -48.6  48.60  -48.60  162.23  -15.24  16*0.5
CUBOID        2    79.1  -79.1  79.10  -79.10  192.7   -45.8   16*0.5
4 1 1 1  1 1 1  1 1 1  1
BEGIN COMPLEX
/* LOAD FUEL INTO CASK
COMPLEX   1  3   0.00   0.00   129.20   1 1 1   0.0   0.0   0.0  /* NEAR TOP
/* LOAD CASK INTO PROBLEM BOX
COMPLEX   4  1   0.0    0.0    0.0   1 1 1    0.0    0.0   0.0  /*
/* LOAD CASK TOP INTO PROBLEM BOX
COMPLEX   4  2   0.0    0.0    0.0   1 1 1    0.0    0.0   0.0  /*
END GEOM
*END GEMER*
```

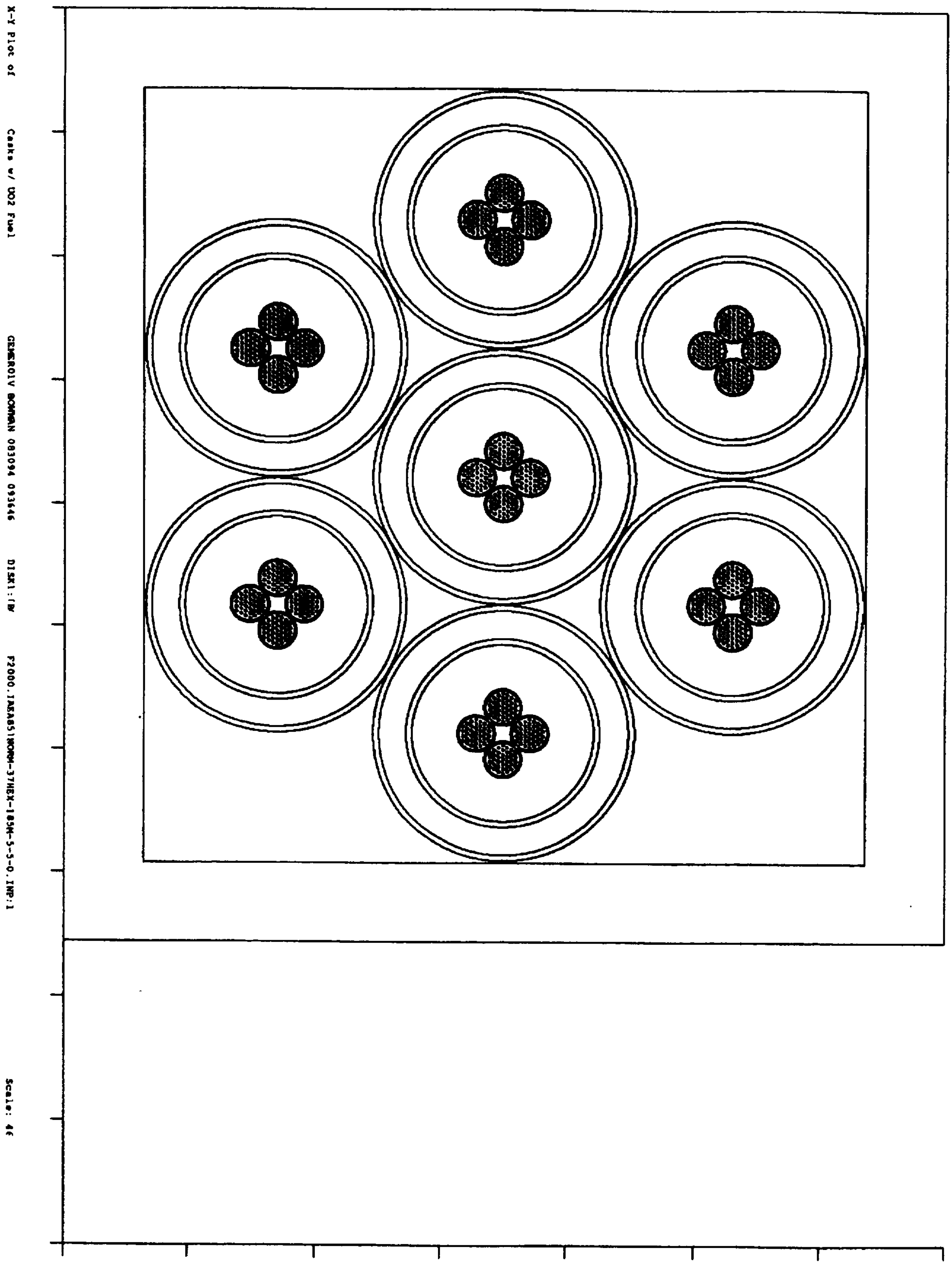
APPENDIX B


X-Y Plot of I!
Cask w/ UO2 Fuel
GENEROIV BOWMAN 083094 100127
DISK1:[BC
Scale: 13.


X-Z Plot of II
Scale: 17.

```
                    IF2000 Input Generation Worksheet
                    (For Casks with < 5% e Pellets - IAEA '85)

Fuel Description                                 Geometry Description
Enrichment U-235         0.05                    (1/4)Tot Fuel Vol    2264.5  cm3
Mass U235/mol        235.0439 gm/mol             Num of Pell Stacks/4     37
Mass U238/mol        238.0508 gm/mol             Pellet Dia                   0.889    cm (0.35 in)
Mass U/Mol              237.9 gm/mol             Stack Height           98.6 cm (38.82 in)        Mass Check:
Fraction-U             0.8814                    UO2 Mass per Stack   268.31 gm                      11.82 gm U235
Tot Mass U-235           1750 gm
Tot Mass UO2            39710 gm                 Pitch (triangular)     1.86 cm (0.73 in)
T.D. UO2                10.96 gm/cm3             Pitch/dia             2.092
Fraction T.D.            0.40                    Vol Ratio (W/F)       2.413
                              H/U-235 Ratio      16.3      GEMER Bias 0.0063272
Regional Number Densities                                  Pellet Array
Avagadro               0.6022 cm2/bn-mol         Max I                     7
    fuel                      Max J                   7
N-235                4.95E-04 atom/bn-cm         Array Width              12 cm
N-238                9.29E-03 atom/bn-cm         Array Height           10.6 cm
N-Oxy                1.96E-02 atom/bn-cm         Min. Diameter         12.87 cm           Margin:          0.62 %
    full density H2O
N-H       6.69E-02atom/bn-cm  Spec.Grav.Intrsp.H2O       0.05 (Inside Cask)
N-Oxy                3.34E-02 atom/bn-cm         Spec.Grav.Intrsp.H2O    0.00   (Outside Cask)
                              Spec.Grav.Intrsp.H2O       0.05 (Inside Fuel)

/PRW6,INFA-37HEX-186M-5-5-O.INP@@                Begin Input Deck:

Array of IF2000 Casks w/ 0.35 inch dia. pellets & 0.73 inch tri. pitch between pellet stacks
      65 /* NUM OF BATCHES
    1000 /* NUM OF NEUTRONS PER BATCH
       5 /* NUM OF BATCHES TO SKIP
 8762569 /* INITIAL SEED
       0 /* "IDUMP"
       0 /* "NRSTRT"
       0 /* "NBTED"
       0 /* "KRED"
      0  293  10  7
      3  293   0   0  U(5.0%)O2 40% OF T.D.
    2351    4.95000000E-04
    2381    9.28620000E-03
      16    1.95630000E-02
      2  293   0   0  Water Density in Fuel: 0.05 gm/cm3
       1    3.34275000E-03
      16    1.67135000E-03
      2  293   0   0  Interspersed Water Inside Cask 0.05 gm/cm3
       1    3.34275100E-03
      16    1.67135100E-03
      2  293   0   0  Interspersed Water Outside Cask 0.00 gm/cm3
       1    1.00000000E-09
      16    1.00000000E-09
       1  293   0   0  Lead Shielding
      82    3.29890E-02
       7  293   0   0  Type 304 Stainless Steel
```

```
      12    6.82690E-05
      14    8.53360E-04
      24    1.53600E-02
      26    6.04950E-02
      28    6.82690E-03
      55    1.70670E-03
    1316    2.56010E-05
       2  293  0  0  Plain Carbon Steel AISI-SAE 1095
      12    3.744E-03
      26    8.353E-02
KENO GEOM
    10  /* "KREFM"
     5  /* "NBOX"
     1  /* "NBXMAX"
     1  /* "NBYMAX"
     1  /* "NBZMAX"
     1  /* "NXX"
     0  /* "NTYPST"
     1  /* "NEMBRG"
     0  /* "NGMCHK"
    -1  -1  -1  -1  -1  -1  /* REFLECTED BOUNDARIES
BOX TYPE     1   /* MODEL 2000 CASK (EMPTY)
CYLINDER     3    33.65    140.64    0.0      16*0.5
CYLINDER     6    35.85    140.64    0.0      16*0.5
CYLINDER     5    46.34    140.64    0.0      16*0.5
CYLINDER     6    48.56    140.64  -14.90     16*0.5
BOX TYPE     2   /* CASK TOP
CYLINDER     5    30.96    158.42  140.64     16*0.5
CYLINDER     6    48.56    162.23  140.64     16*0.5
BOX TYPE     3   /* SCHEDULE 40 STEEL PIPE FUEL CONTAINER
CYLINDER     2     6.475   140.50   39.85     16*0.5
CYLINDER     7     7.065   140.50   39.85     16*0.5
BOX TYPE     4   /* UO2 PELLET STACK
CYLINDER     1     0.4445   140.50   41.900    16*0.5
BOX TYPE     5   /* BOX FOR THE PROBLEM
CUBOID       4    48.6  -48.6  48.6  -48.6  162.3  -15.0  16*0.5
5 1 1 1  1 1 1  1 1 1  1
BEGIN COMPLEX
/* HEX ARRAY OF UO2 PELLET STACKS IN SCH. 40 PIPE
COMPLEX   3  4   -5.580   0.0    0.0   7 1 1   1.86  0.0   0.0  /* MIDDLE ROW
COMPLEX   3  4   -4.650  -1.611  0.0   6 2 1   1.86  3.222  0.0  /* NEXT ROW
COMPLEX   3  4   -3.720  -3.222  0.0   5 2 1   1.86  6.443  0.0  /* NEXT ROW
COMPLEX   3  4   -2.790  -4.832  0.0   4 2 1   1.86  9.665  0.0  /* OUTER ROW
/* LOAD SCH. 40 PIPE AND  FUEL IN  CASK
COMPLEX   1  3  -10.01   0.00    0.0   2 1 1  20.02   0.0    0.0  /* ROW 1
COMPLEX   1  3    0.0  -10.01    0.0   1 2 1   0.0   20.02   0.0  /* ROW 2
/* LOAD CASKS, SCH. 40 PIPE, AND FUEL INTO PROBLEM BOX
COMPLEX   5  1   0.0    0.0    0.0    1 1 1   0.0  0.0  0.0  /* ONE CELL
/* LOAD CASK TOP INTO PROBLEM BOX
COMPLEX   5  2   0.0    0.0    0.0    1 1 1   0.0  0.0  0.0  /* ONE CELL
END GEOM
*END GEMER*
```


X-Y Plot of
Casks w/ UO2 Fuel
Scale: 46

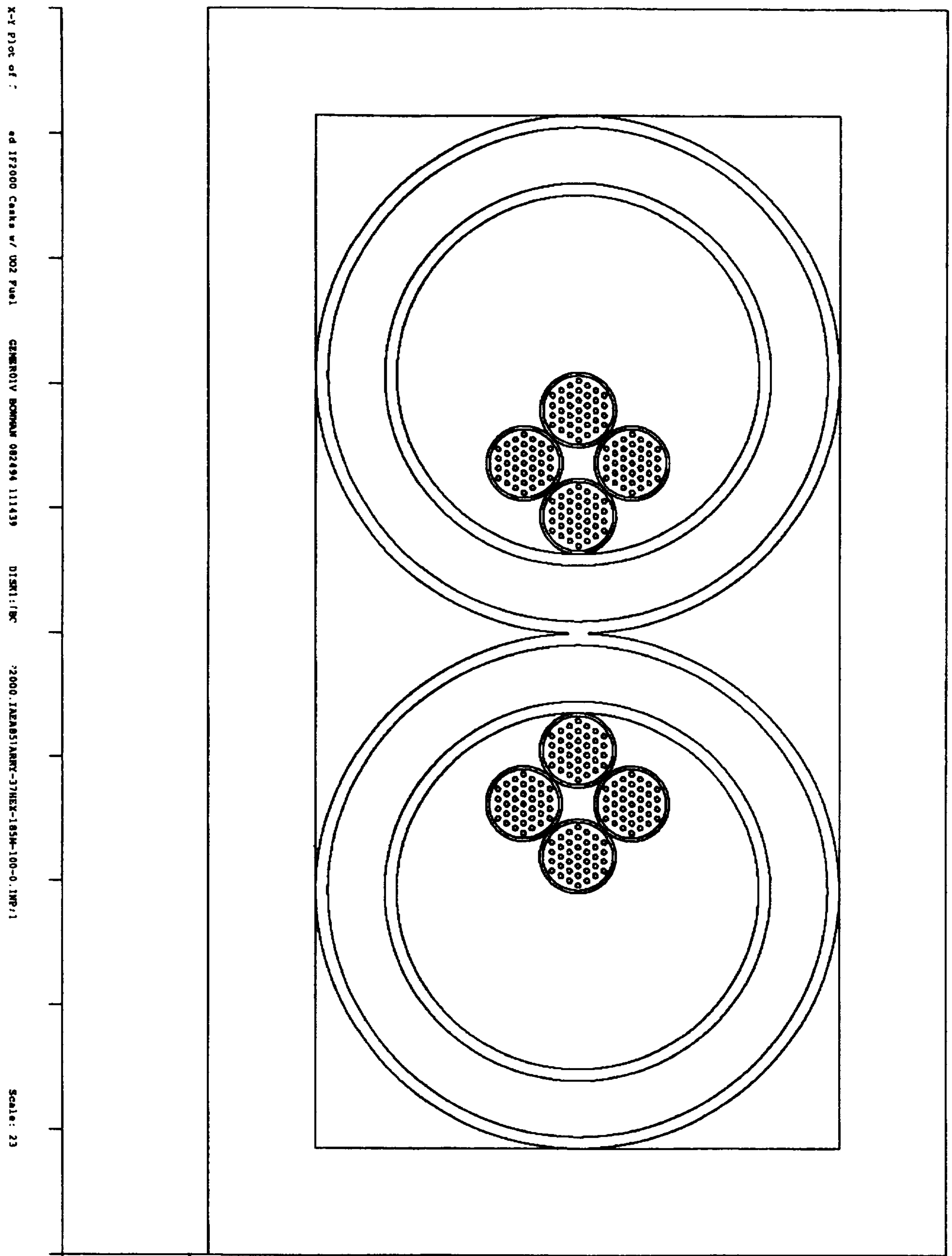
IF2000 Input Generation Worksheet
(For Casks with < 5% e Pellets - IAEA '85)

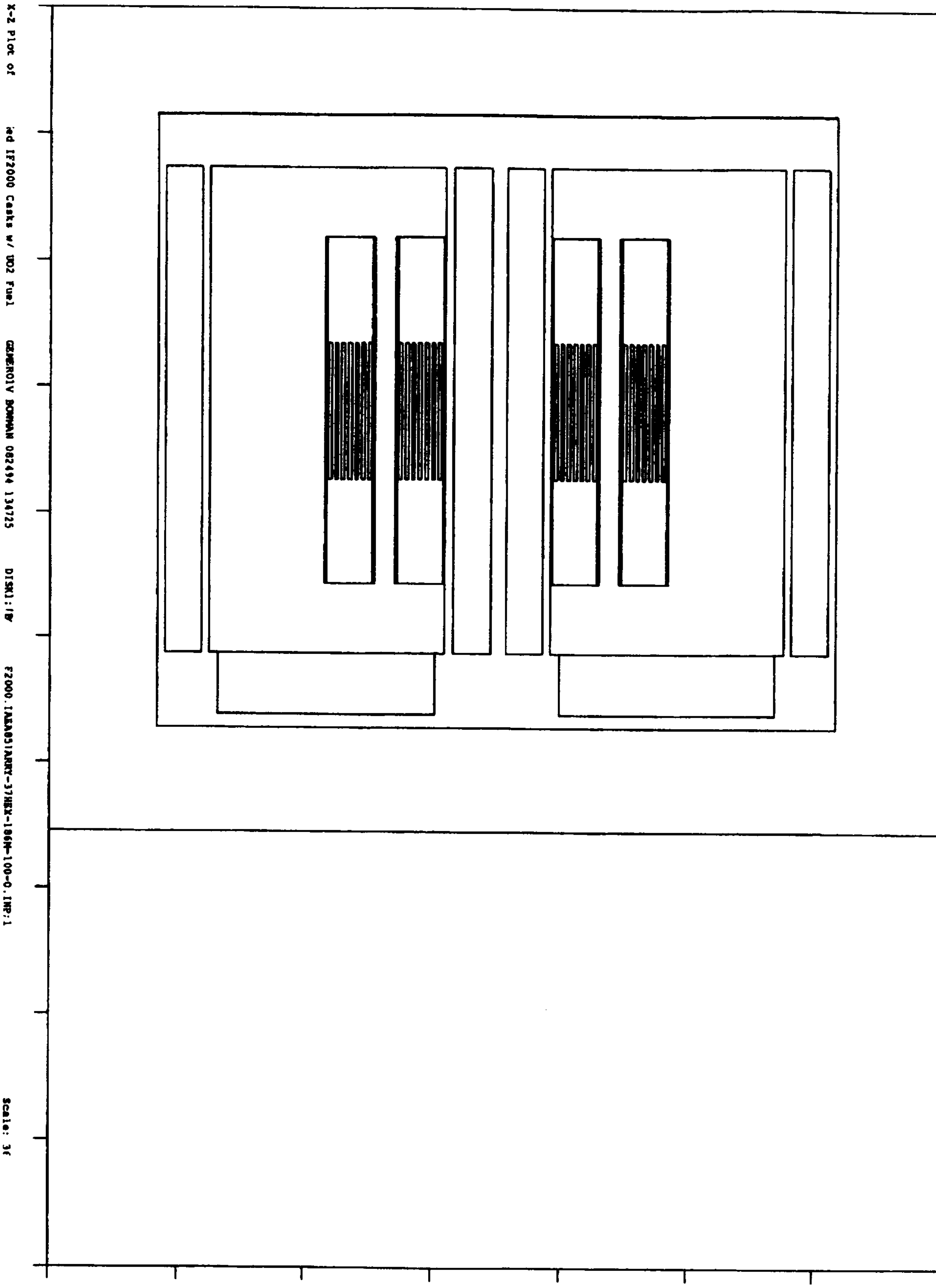
```
Fuel Description                                     Geometry Description
Enrichment U-235         0.05                        (1/4)Tot Fuel Vol     905.79 cm3
Mass U235/mol        235.0439 gm/mol                 Num of Pell Stacks/4      37
Mass U238/mol        238.0508 gm/mol                 Pellet Dia                   0.889   cm (0.35 in)
Mass U/Mol              237.9 gm/mol                 Stack Height           39.44 cm (15.53 in)    Mass Check:
Fraction-U             0.8814                        UO2 Mass per Stack    268.31 gm                      11.82 gm U235
Tot Mass U-235           1750 gm
Tot Mass UO2            39710 gm                     Pitch (triangular)     1.85 cm (0.73 in)
T.D. UO2                10.96 gm/cm3                 Pitch/dia             2.081
Fraction T.D.            1.00                        Vol Ratio (W/F)       2.388
                              H/U-235 Ratio          6.45     GEMER Bias 0.0069128
Regional Number Densities                            Pellet Array
Avagadro               0.6022 cm2/bn-mol             Max I                     7
    fuel                      Max J                            7
N-235                1.24E-03 atom/bn-cm             Array Width              12 cm
N-238                2.32E-02 atom/bn-cm             Array Height           10.5 cm
N-Oxy                4.89E-02 atom/bn-cm             Min. Diameter         12.77 cm           Margin:        1.39 %
    full density H2O                                          Cask Array
N-H        6.69E-02atom/bn-cm Max I,J                         3
N-Oxy                3.34E-02 atom/bn-cm             Cask Dia & Pitch       97.5 cm
                              Array Width            292.5    cm
                              Array Height           266.4    cm
                              Min. Diameter          381.2    cm

                              Spec.Grav.Intrsp.H2O            0.05 (Inside Cask)
                              Spec.Grav.Intrsp.H2O            0.00 (Outside Cask)
                              Spec.Grav.Intrsp.H2O            0.05 (Inside Fuel)

/PRW6,NORM-37HEX-185M-5-5-O.INP@@                    Begin Input Deck

Array of IF2000 Casks w/ 0.35 inch dia. pellets & 0.73 inch tri. pitch between pellet stacks
      65 /* NUM OF BATCHES
    1000 /* NUM OF NEUTRONS PER BATCH
       5 /* NUM OF BATCHES TO SKIP
 8762569 /* INITIAL SEED
       0 /* "IDUMP"
       0 /* "NRSTRT"
       0 /* "NBTED"
       0 /* "KRED"
      0  293  12  8
      3  293   0  0  U(5.0%)O2 100% OF T.D.
   2351     1.23750000E-03
   2381     2.32160000E-02
     16     4.89080000E-02
      2  293   0  0  Water Density in Fuel: 0.05 gm/cm3
      1     3.34275000E-03
     16     1.67135000E-03
      2  293   0  0  Interspersed Water Inside Cask 0.05 gm/cm3
```

```
        1    3.34275100E-03
       16    1.67135100E-03
        2  293  0  0  Interspersed Water Outside Cask 0.00 gm/cm3
        1    1.00000000E-09
       16    1.00000000E-09
        1  293  0  0  Lead Shielding
       82    3.29890E-02
        7  293  0  0  Type 304 Stainless Steel
       12    6.82690E-05
       14    8.53360E-04
       24    1.53600E-02
       26    6.04950E-02
       28    6.82690E-03
       55    1.70670E-03
     1316    2.56010E-05
        2  293  0  0  Plain Carbon Steel AISI-SAE 1095
       12    3.744E-03
       26    8.353E-02
        2  293  0  0  Full Density Water: 1.0 gm/cm3
        1    6.68550000E-02
       16    3.34270000E-02
KENO GEOM
     12  /* "KREFM"
      5  /* "NBOX"
      1  /* "NBXMAX"
      1  /* "NBYMAX"
      1  /* "NBZMAX"
      0  /* "NXX"
      0  /* "NTYPST"
      1  /* "NEMBRG"
      0  /* "NGMCHK"
BOX TYPE     1   /* MODEL 2000 CASK (EMPTY)
CYLINDER     3    33.65    140.64     0.0     16*0.5
CYLINDER     6    35.85    140.64     0.0     16*0.5
CYLINDER     5    46.34    140.64     0.0     16*0.5
CYLINDER     6    48.56    140.64   -14.90    16*0.5
BOX TYPE     2   /* CASK TOP
CYLINDER     5    30.96    158.42   140.64    16*0.5
CYLINDER     6    48.56    162.23   140.64    16*0.5
BOX TYPE     3   /* SCHEDULE 40 STEEL PIPE FUEL CONTAINER
CYLINDER     2     6.475   140.50    39.85    16*0.5
CYLINDER     7     7.065   140.50    39.85    16*0.5
BOX TYPE     4   /* UO2 PELLET STACK
CYLINDER     1     0.4445   140.50    101.060   16*0.5
BOX TYPE     5   /* BOX FOR THE PROBLEM
CUBOID       4    146.8  -146.8  133.7  -133.7  162.3  -15.0  16*0.5
CORE         0    146.8  -146.8  133.7  -133.7  162.3  -15.0  16*0.5
CUBOID       8    176.8  -176.8  163.7  -163.7  192.8  -45.5  16*0.5
5 1 1 1  1 1 1  1 1 1  1
```

```
BEGIN COMPLEX
/* HEX ARRAY OF UO2 PELLET STACKS IN SCH. 40 PIPE
COMPLEX   3  4    -5.550   0.0    0.0    7 1 1   1.85  0.0  0.0  /* MIDDLE ROW
COMPLEX   3  4    -4.625  -1.602  0.0    6 2 1   1.85  3.204  0.0  /* NEXT ROW
COMPLEX   3  4    -3.700  -3.204  0.0    5 2 1   1.85  6.409  0.0  /* NEXT ROW
COMPLEX   3  4    -2.775  -4.806  0.0    4 2 1   1.85  9.613  0.0  /* OUTER ROW
/* LOAD SCH. 40 PIPE AND FUEL IN CASK
COMPLEX   1  3  -10.01   0.00    0.0    2 1 1   20.02   0.0   0.0  /* ROW 1
COMPLEX   1  3    0.0  -10.01    0.0    1 2 1    0.0   20.02  0.0  /* ROW 2
/* LOAD CASKS, SCH. 40 PIPE, AND FUEL INTO PROBLEM BOX
COMPLEX   5  1    -97.5   0.0    0.0    3 1 1   97.5  0.0   0.0  /* MIDDLE ROW
COMPLEX   5  1    -48.8 -84.4    0.0    2 2 1   97.5  168.9  0.0  /* NEXT ROW
/* LOAD CASK TOPS INTO PROBLEM BOX
COMPLEX   5  2    -97.5   0.0    0.0    3 1 1   97.5  0.0   0.0  /* MIDDLE ROW
COMPLEX   5  2    -48.8  -84.4   0.0    2 2 1   97.5  168.9  0.0  /* NEXT ROW
END GEOM
*END GEMER*
```

APPENDIX C


X-Y Plot of : ed IF2000 Casks w/ UO2 Fuel GEMER01V BOWMAN 082494 111439 DISK1:[BC ?2000.IAEA851ARRY-37HEX-185M-100-0.INP;1
Scale: 23


X-Z Plot of
ed IF2000 Casks w/ UO2 Fuel

IF2000 Input Generation Worksheet
(For Casks with < 5% e Pellets - IAEA '85)

```
Fuel Description                                   Geometry Description
Enrichment U-235        0.05                       (1/4)Tot Fuel Vol       905.79 cm3
Mass U235/mol      235.0439 gm/mol                 Num of Pell Stacks/4      37
Mass U238/mol      238.0508 gm/mol                 Pellet Dia                   0.889    cm (0.35 in)
Mass U/Mol            237.9 gm/mol                 Stack Height             39.44 cm (15.53 in)    Mass Check:
Fraction-U           0.8814                        UO2 Mass per Stack      268.31 gm                      11.82 gm U235
Tot Mass U-235         1750 gm
Tot Mass UO2          39710 gm                     Pitch (triangular)        1.86 cm (0.73 in)
T.D. UO2              10.96 gm/cm3                 Pitch/dia                2.092
Fraction T.D.          1.00                        Vol Ratio (W/F)          2.413
                            H/U-235 Ratio          130.4     GEMER Bias 0.0000421
Regional Number Densities
Avagadro             0.6022 cm2/bn-mol             Max I                      7
   fuel                     Max J                            7
N-235              1.24E-03 atom/bn-cm             Array Width               12 cm
N-238              2.32E-02 atom/bn-cm             Array Height            10.6 cm
N-Oxy              4.89E-02 atom/bn-cm             Min. Diameter          12.87 cm          Margin:         0.62 $
   full density H2O
N-H       6.69E-02atom/bn-cm Spec.Grav.Intrsp.H2O       1.00 (Inside Cask)
N-Oxy              3.34E-02 atom/bn-cm             Spec.Grav.Intrsp.H2O    0.00  (Outside Cask)

/PRW6,ARRY-37HEX-186M-100-O.INP@@                  Begin Input Deck

IF2000 Cask w/ 0.35 inch dia. pellets 6 0.73 inch tri. pitch between pellet stacks
      65 /* NUM OF BATCHES
    1000 /* NUM OF NEUTRONS PER BATCH
       5 /* NUM OF BATCHES TO SKIP
 8762569 /* INITIAL SEED
       0 /* "IDUMP"
       0 /* "NRSTRT"
       0 /* "NBTED"
       0 /* "KRED"
      0  293  16  7
      3  293   0  0  U(5.0%)O2 100% OF T.D.
    2351    1.23750000E-03
    2381    2.32160000E-02
      16    4.89080000E-02
      2  293   0  0  Full Density Water: 1.0 gm/cm3
       1    6.68550000E-02
      16    3.34270000E-02
      2  293   0  0  Interspersed Water Inside Cask 1.00 gm/cm3
       1    6.68550010E-02
      16    3.34270010E-02
      2  293   0  0  Interspersed Water Outside Cask 0.00 gm/cm3
       1    1.00000000E-09
      16    1.00000000E-09
      1  293   0  0  Lead Shielding
      82    3.29890E-02
```

```
       7  293  0  0  Type 304 Stainless Steel
      12    6.82690E-05
      14    8.53360E-04
      24    1.53600E-02
      26    6.04950E-02
      28    6.82690E-03
      55    1.70670E-03
    1316    2.56010E-05
       2  293  0  0  Plain Carbon Steel AISI-SAE 1095
      12    3.744E-03
      26    8.353E-02
KENO GEOM
    16  /* "KREFM"
     6  /* "NBOX"
     1  /* "NBXMAX"
     1  /* "NBYMAX"
     1  /* "NBZMAX"
     0  /* "NXX"
     0  /* "NTYPST"
     1  /* "NEMBRG"
     0  /* "NGMCHK"
BOX TYPE     1   /* MODEL 2000 CASK (EMPTY)
CYLINDER     3    33.65    140.64    0.0      16*0.5
CYLINDER     6    35.85    140.64    0.0      16*0.5
CYLINDER     5    46.34    140.64    0.0      16*0.5
CYLINDER     6    48.56    140.64  -14.90     16*0.5
BOX TYPE     2   /* 2ND MODEL 2000 CASK (EMPTY)
CYLINDER     3    33.65    140.64    0.0      16*0.5
CYLINDER     6    35.85    140.64    0.0      16*0.5
CYLINDER     5    46.34    140.64    0.0      16*0.5
CYLINDER     6    48.56    140.64  -14.90     16*0.5
BOX TYPE     3   /* CASK TOP
CYLINDER     5    30.96    158.42  140.64     16*0.5
CYLINDER     6    48.56    162.23  140.64     16*0.5
BOX TYPE     4   /* SCHEDULE 40 STEEL PIPE FUEL CONTAINER
CYLINDER     2     6.475   120.64   19.996    16*0.5
CYLINDER     7     7.065   120.64   19.996    16*0.5
BOX TYPE     5   /* UO2 PELLET STACK
CYLINDER     1     0.4445   90.04   50.60     16*0.5
BOX TYPE     6   /* OVERALL BOX FOR THE PROBLEM
CUBOID       4   97.2  -97.2  48.60  -48.60  162.23  -15.24  16*0.5
CORE         0   97.2  -97.2  48.60  -48.60  162.23  -15.24  16*0.5
CUBOID       2  127.5  -127.5  79.10  -79.10  192.7  -45.8   16*0.5
6 1 1 1  1 1 1  1 1 1  1
BEGIN COMPLEX
/* HEX ARRAY OF UO2 PELLET STACKS IN SCH. 40 PIPE
COMPLEX   4  5   -5.580   0.0    0.0   7 1 1   1.86  0.0   0.0  /* MIDDLE ROW
COMPLEX   4  5   -4.650  -1.611  0.0   6 2 1   1.86  3.222  0.0  /* NEXT ROW
COMPLEX   4  5   -3.720  -3.222  0.0   5 2 1   1.86  6.443  0.0  /* NEXT ROW
```

```
COMPLEX   4  5   -2.790  -4.832  0.0   4 2 1   1.86   9.665  0.0  /* OUTER ROW
/* LOAD SCH. 40 PIPE AND FUEL IN CASK #1
COMPLEX   1  4    6.54   0.00    0.0   2 1 1   20.02   0.0   0.0  /* ROW 1
COMPLEX   1  4   16.56 -10.01    0.0   1 2 1    0.0   20.02  0.0  /* ROW 2
/* LOAD SCH. 40 PIPE AND FUEL IN CASK #2
COMPLEX   2  4  -26.56   0.00    0.0   2 1 1   20.02   0.0   0.0  /* ROW 1
COMPLEX   2  4  -16.56 -10.01    0.0   1 2 1    0.0   20.02  0.0  /* ROW 2
/* LOAD CASKS, SCH. 40 PIPE, AND FUEL INTO PROBLEM BOX
COMPLEX   6  1  -48.60   0.0     0.0   1 1 1    0.0    0.0   0.0  /* CASK #1
COMPLEX   6  2   48.60   0.0     0.0   1 1 1    0.0    0.0   0.0  /* CASK #2
/* LOAD CASK TOPS INTO PROBLEM BOX
COMPLEX   6  3  -48.60   0.0     0.0   2 1 1   97.20   0.0   0.0  /* 2 X 1 ARRAY
END GEOM
*END GEMER*
```

6.7 REFERENCES

1. Bucholz, J. A., "SCALE, A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation", NUREG/CR-0200, ORNL/NUREG/CSD/2, Volume 1, Oak Ridge National Laboratory; July, 1980.

2. Petrie, L. M. and Cross, N. F., "KENO-IV, An Improved Monte Carlo Criticality Program", ORNL-4938; November, 1975.

3. Irving, D. C. and Morrison, G. W., "PICTURE: An Aid In De-Bugging Geometry Input Data", ORNL-TM-2892; May 14, 1970.

4. Honeck, H. C., "THERMOS: A Thermalization Transport Code for Reactor Lattice Calculations", PNL-5826 (1961).

5. Hardy, J. Jr. et al., Nuclear Science Engineering, 40, 101 (1970).

6. Bohn, E. M., et al. (ED), "Benchmark Testing on ENDF/B-IV," ENDF-230, Vol. I; March, 1976.

7. C. M. Kang and E. C. Hansen, "ENDV/B-IV Benchmark Analyses With Full Spectrum Three-Dimensional Monte Carlo Models," paper presented in November, 1977, at the Winter San Francisco Meeting of the American Nuclear Society, Vol. 22, p. 891.

7. OPERATING PROCEDURES

Instructions for use of the Model 2000 Radioactive Transport Package are summarized below, beginning with Section 7.1. A more detailed description of these instructions is included in GE Specification 22A9380, *Operations and Maintenance of Model 2000 Transport Package* (O&M Manual). The transport package user follows the O&M Manual, but may expand it to include site-specific procedures. Some of the site-specific procedures in use at GE - Vallecitos Nuclear Center are included in Section 7.4, Appendix, for illustrative purposes only. During actual operation these procedures may be supplemented with engineering personnel, training classes, and/or site specific procedures as applicable.

Part of the Operating Procedure is a Pre-shipment Engineering Evaluation to ensure that the packaging with its proposed contents satisfies the applicable requirements of the package's license or certificate. This evaluation includes, but is not limited to, the review of:

- Proposed contents' isotopic composition, quantities, and decay heat;
- Proposed contents' form, weight, and geometry;
- Shielding, requirements;
- Structural requirements;
- Thermal requirements;
- Shipping hardware (liners, racks, dividers, baskets, shoring device, etc.)

7.1 PROCEDURES FOR LOADING THE PACKAGE

Operations at the loading facility include the span of activities from receiving and inspecting the packaging to preparing the loaded package for shipment. Each loading facility must provide fully trained personnel and detailed operating procedures to cover all of the activities.

7.1.1 Package Receiving and Inspection

a. The Model 2000 transport vehicle is positioned for packaging inspection upon arrival.

b. A visual inspection for damage is made.

7.1.2 Removal of the Package from the Transport Vehicle

a. The transport vehicle is positioned under an overhead crane.

b. The packaging tie-downs are removed.

c. The Spreader Bar is positioned and the appropriate slings and shackles are connected.

d. Depending on site-specific issues, either the overpack top section is lifted off the overpack base and placed on the overpack stand or the entire packaging is lifted free from the transport vehicle and set down. The overpack top section is then lifted from the overpack base and placed on the overpack stand.

7.1.3 Preparing To Load the Cask

a. A visual inspection is performed. Any damage or unusual conditions are noted. If functionality of the part is impaired, repair or replacement will be effected as required.

b. The cask ears are installed. If a forklift is to be used to transport the cask, the standard lifting ears must be used. If the cask is to be lifted by crane, then either the standard or auxiliary ears may be used. If lifted by crane, the lifting slings shall not make an angle of greater than 30° measured from the vertical.

c. With proper radiological protection and monitoring, the closure lid is removed for visual inspection of the cavity.

d. The cask may be loaded either from a hot cell or storage basin.

e. The cask and lid sealing surfaces are visually inspected for damage or foreign material. Any damage is noted and repair or replacement is effected as required.

f. The cask seal is visually inspected for damage. Any gouges or cuts in the seal area are cause for replacement.

g. The seal is placed over the alignment pins on the top of the cask.

7.1.4 Loading Irradiated Fuel Into the Cask

****CAUTION****

When loading MTR- or TRIGA-type fuels: The location of the fuel element within the Divider fuel cell shall depend on the decay heat content of the fuel in accordance with the following limits:

Decay Heat	Location (see Figure 7.1.4.1)
decay heat ≤ 35 watts	Lower and upper regions
35 watts < decay heat ≤ 85 watts	Lower fuel cell region

For a maximum of 120 watts per fuel cell and 1500 watts per shipment

a. The list of irradiated fuel material (in the form of rod, elements, or assemblies), transfer procedure, and cask loading diagram are obtained.

b. Perform a visual inspection of the appropriate basket (basket, liner, rack, divider). Examine welds and materials for potential defects. Verify all design features are present and in good condition.

c. Install the appropriate basket in the cask as applicable.

d. Fuel material is moved one at a time to the appropriate location in the basket. Fuel material position should be verified.

7.1.5 Loading Irradiated Hardware or Other Contents

a. A basket for the hardware to be transported is placed in the cask.

b. The hardware is loaded into the basket using appropriate shoring as required.

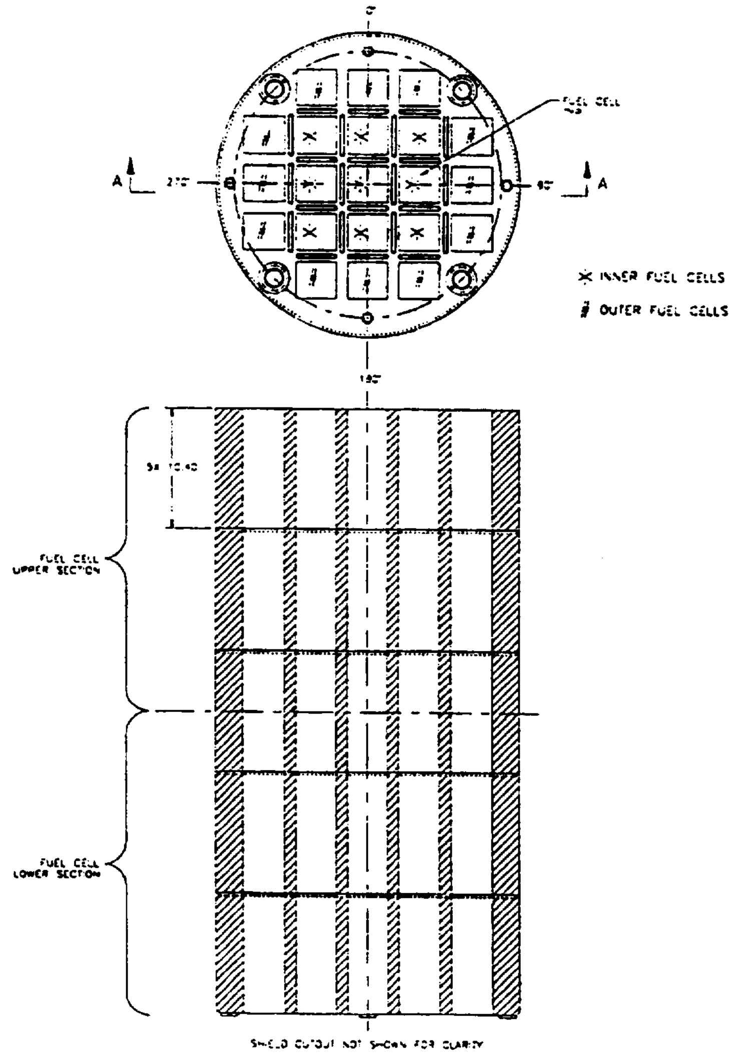


FIGURE 7.1.4.1. MTR TYPE FUEL SHIPPING DIVIDER

7.1.6 Installing the Cask Closure Lid

a. With proper rigging, the lid is slowly lowered onto the cask over the guide pins. This operation is closely watched to ensure that the lid is properly aligned.

7.1.7 Removing the Cask from the Loading Area

a. The cask radiation levels are carefully measured while removing the cask from the storage basin or cell area.

b. The lid bolts are installed hand tight.

c. If the cask was loaded under water, it will be drained by removing the drain plug and the lid vent plug. After the water has drained, the cask cavity is vacuum-dried until 1 torr pressure is obtained. The pressure in the cavity must be maintained at or below 1 torr for at least 30 minutes. The discharged gas of the vacuum pump is filtered. Refer to Figure 7.1.7.1 for a typical vacuum drying set up and its equipment. If the vacuum pump used in this procedure is equipped with a "gas ballast" device, this device must be inoperative during the cask vacuum drying operation. Gas ballast device is used to drive off any moisture that may have been trapped in the vacuum pump oil. If needed to remove water vapor from the pump oil during the vacuum drying operation, the system shall be isolated. Turn on the gas ballast device until the oil is cleared up, turn off the gas ballast, and then place the system back on line.

d. The cask is decontaminated to a level consistent with 49CFR173.443 and 10CFR71.87.

7.1.8 Securing the Cask Lid

a. The lid bolts are torqued to 690 ft-lb. in a crisscross pattern to ensure equal compression of the seal.

b. The drain and vent plugs are installed following the drying operation as applicable. Pipe thread sealant is applied over thread area on plugs prior to installation.

7.1.9 Assembly Verification Leakage Testing

a. Leakage testing of the cask closure seal and vent and drain threaded pipe plugs is performed with a thermal conductivity sensing instrument (see Appendix 7.4.2). This type of instrument is sensitive to any gas stream having a thermal conductivity different from the ambient air in which the instrument is being used. The cask cavity is pressurized with 15 psi of Helium at the completion of the vacuum drying procedure. Helium is introduced using the "quick connect" fitting at the vent port. See Figure 7.1.7.1.

b. The test instrument is set up and used according to written procedures and the manufacturer's instructions.

c. With the instrument calibrated to a sensitivity of at least 1×10^{-3} cm^3/sec (helium), the vent and drain threaded pipe plugs are checked for indications of leakage.

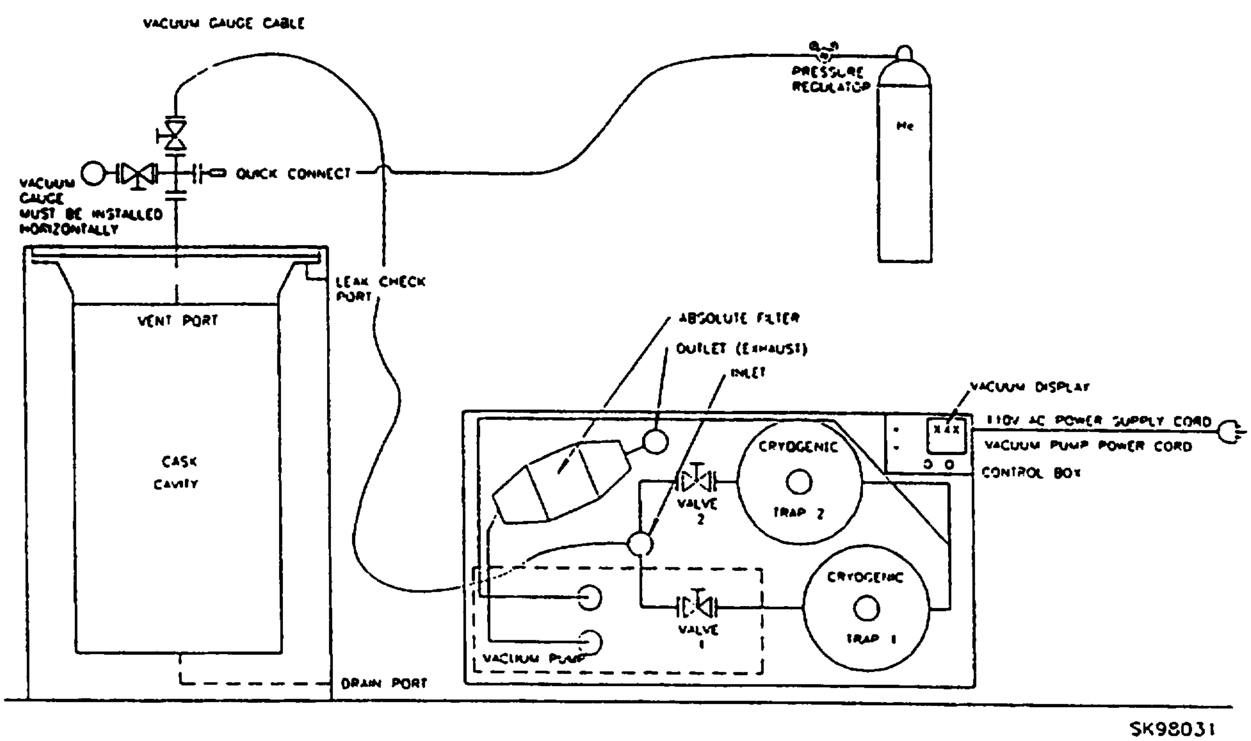


FIGURE 7.1.7.1. TYPICAL VACUUM DRYING SYSTEM SET UP AND EQUIPMENT

d. With the instrument calibrated to a sensitivity of at least 1 x 10^{-3} cm^3/sec (helium), the closure seal is checked for indications of leakage.

e. If leakage is detected during either of the above checks, the offending components are repaired or replaced and then re-tested for leakage.

7.1.10 Preparing the Cask for Transport of Irradiated Fuel or Other Radioactive Material

a. The cask is transported to and placed on the overpack base.

b. The cask lifting ears or redundant ears are removed from the cask.

c. The Spreader Bar is positioned over the overpack and the slings and shackles connected.

d. The overpack is slowly lowered over the cask with the locating pins aligned.

e. The overpack bolts are installed securing the top section to the base section. Note: An adhesive/sealant compound is applied to bolt threads prior to installation to prevent vibration loosening of bolts.

f. The package is positioned on the transport vehicle if required.

g. The shackle and slings are removed and the package is tied down to the transport vehicle. The Model 2000 does not have any parts or devices that would need to be rendered inoperable pursuant to 10CFR71.87(h).

h. The radiological survey of the package and transport vehicle consistent with IOCFR71.47, 71.87 and 10CFR173.441, 443 is completed. Note: A neutron radiation survey is performed in addition to a gamma radiation survey for irradiated fuel shipments.

i. The security seal is applied to the overpack.

7.2 PROCEDURES FOR UNLOADING THE PACKAGE

Operations at the unloading facility are largely the reverse of loading operations. Each unloading facility must provide fully trained personnel and will be supplied with detailed operating procedures to cover all activities as required by 10CFR71.89.

7.2.1 Package Receiving and Inspection

Steps 7.1.1a and b are repeated and a radiological survey (including neutron radiation for irradiated fuel shipments) is performed in accordance with the requirements of 10CFR20.205 or equivalent agreement state regulations.

7.2.2 Removal of the Package from the Transport Vehicle

a. The transport vehicle is positioned under an overhead crane.

b. The packaging tic-downs are removed.

c. The Spreader Bar is positioned and the appropriate slings and shackles are connected.

d. Depending on site-specific issues, either the overpack top section is lifted off the overpack base and placed on the overpack stand or the entire packaging is lifted free from the transport vehicle and set down, after which the overpack top section is lifted from the overpack base and placed on the overpack stand.

7.2.3 Preparing To Unload Irradiated Fuel

a. A visual inspection is performed. Any damage or unusual conditions are noted. If functionality of the part is impaired, repair or replacement will be effected as required. A radiological survey of the cask surface is performed, including neutron radiation.

b. The cask lifting ears or auxiliary ears (if applicable) are installed. The cask is transported to the unloading area.

c. With radiological monitoring and controlled ventilation in place, the vent plug and drain plugs are removed.

d. The lid bolts are removed for unloading in either a storage basin or hot cell.

e. The lid is removed following the placing of the cask within a hot cell or storage basin.

7.2.4 Preparing To Unload Irradiated Hardware or Other Contents

a. If the cask is to be unloaded underwater or in a hot cell, Steps 7.2.3.a through e are followed.

b. If the cask is to be unloaded in air at a waste disposal site, the cask is prepared for unloading following a procedure developed by the burial site and reviewed by General Electric.

7.2.5 Unloading Irradiated Fuel from the Cask

a. The list identifying fuel rods to be unloaded is obtained.

b. The fuel rod identification and location in the cask are verified.

c. The fuel rods are transferred one at a time in accordance with the site's fuel transfer procedure.

7.2.6 Unloading Irradiated Hardware or Other Contents

a. Unloading of irradiated hardware in air at a disposal site will follow a disposal site procedure.

b. If the irradiated hardware is unloaded underwater or in a hot cell, the work is performed as specified by procedure.

7.2.7 Installing the Cask Closure Lid

a. With proper rigging, the lid is slowly lowered onto the cask over the guide pins. This operation is closely watched to assure that the lid is properly aligned.

7.2.8 Removing the Cask from the Unloading Area

a. The lid bolts are installed hand-tight.

b. The cask is removed to the storage area.

7.2.9 Securing the Cask Lid

Steps 7.1.8a and b are repeated.

7.3 PREPARATION OF AN EMPTY CASK FOR TRANSPORT

The following operations are typically performed after transport of radioactive material.

7.3.1 Cask Cavity Inspection

a. The lid is removed from the empty cask.

b. A radiological survey of the cavity is made to determine extent of any contamination.

c. The cavity is decontaminated to the limits of 49CFR173.427 if the cask is shipped as an empty container as defined in the regulation.

d. The cavity is visually inspected to assure moisture has been removed.

7.3.2 Installation of the Cask Closure Lid

a. With proper rigging, the lid is slowly lowered onto the cask over the guide pins. This operation is closely watched to assure that the lid is properly aligned.

b. The head bolts are installed and torqued to 690 ft-lb. in a crisscross pattern to assure equal compression of the seal.

c. The cask is inspected to assure that all drain and vent plugs are properly installed.

7.3.3 Assembly Verification Leakage Testing

Leakage testing is not performed on the empty container.

7.3.4 Preparing the Empty Cask for Transport

The external surfaces of the cask are decontaminated to a level consistent with 490CFR173.427, "Empty Radioactive Materials Packaging".

7.4 APPENDIX

7.4.1 Typical Operating and Maintenance Procedures (For Illustrative Purposes Only)

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REVISION 2

CHAPTER:	SECTION:
I. ADMINISTRATIVE	AA. TYPE B SHIPMENT EVALUATION

1. Purpose

To delineate the requirements for review and approval of shipments of Type B quantities of radioactive material.

2. Scope

a. This procedure describes the required reviews for IPO radioactive materials shipping packages and other packages covered by QAP-1, to demonstrate compliance with the requirements and limitations expressed in the package certification and federal regulations. The scope includes:

1) A review of thermal, criticality, shielding and mechanical aspects to assure that the packaging and contents will meet regulatory requirements under all conditions of transport.

2) A review of operational aspects to assure that the packaging can be effectively utilized for the proposed contents.

b. These reviews will be required for shipments under NRC Licenses SNM-960 and SNM-1270, and CA State License 0017-60.

3. Evaluation Exemptions

a. DOT Specification Packages

NRC regulations permit shipments of Type B Quantities in certain DOT specification containers (ref. 49CFR173.416). The DOT regulations specify the allowable contents for each container. As long as these limits are not exceeded, further approval is not necessary. **Type B shipments in DOT specification package do not require specific contents approval.**

APPROVED: MANAGER RADIOACTIVE PRODUCTS AND SERVICES — DATE: 11/9/84

REVIEWED: ☐ QA ☒ MGR. NE ☒ CRIT ☐ INDUST. SAFETY

SOP REVIEW DATE CHANGED ☒ ☒ Marketing ☒ MGR. RMO ☒ ANALYST

SMF REVISION ☒ NO ☐ YES BY: ☒ EQUIP. ENGR. ☒ MGR. RMO ☐

DATE ISSUED NOV 9 1984	SUPERSEDES ISSUE	PAGE 1 OF 11
ISSUED BY: J. I. Tenorio	DATED: 12/18/80	REVIEW DATE 10/88

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b. Customer Owned Packages

IPO's "Quality Assurance Plan for Shipping Packages for Radioactive Material" (QAP-1) requires procedures for loading and unloading package contents for customer owned packages. Only IPO **standard products in Type B Quantities or in quantities less than or equal to the amount allowed by the package certificate of compliance** are loaded. Shipments prepared within these limits **do not require specific contents approval.**

c. Rental and Lease of IPO Shipping Packages

QAP-I does not include or require review of customer (leasee) plans or activities. These activities would be subject to the requirements of the leasee's QA plan. IPO is obligated, when requested, to supply sufficient information pertaining to GE's packages and certificates to allow the leasee to evaluate their own activities.

d. Empty Package

Empty packages do not require any contents review but must comply with contamination limits of 49CFR173.427.

4. Definitions

a. **Basket, Holder, Spacer, Spider, etc.** - Typical terms used to describe mechanisms which restrain or support the contents to prevent movement, during transport. Such components are considered part of the packaging and are supplemental to the basic description in the package certificate.

b. **Containment System, Container** - Refers to the packaging component which is designed to provide the principal containment boundary for the radioactive contents during transport. A package may contain a single principal or primary containment or multiple redundant containment barriers.

c. **Contents or Load** - The total assembly of radioactive materials, encapsulations, containers and spacers, etc. which are installed in the Internal cavity of the packaging.

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d. **DOT Specification Packaging -** Refers to packaging components designed to meet and are in compliance with the requirements expressed in 49CFR178.

e. **Maximum Accident Condition Pressure (MACP) -** The maximum pressure (gage) developed in the primary containment system during or following exposure of the package to accident conditions postulated by federal regulations.

f. **Maximum Normal Operating Pressure (MNOP) -** The maximum pressure (gage) that would develop in the primary Containment system if the package were exposed to maximum environmental conditions postulated by federal regulations (100°F ambient and maximum insolation) on a continuous basis for a period of one year.

g. **Normal Form Radioactive Materials -** All radioactive material not meeting the requirements of special form.

h. **Package -** Means the packaging and its radioactive contents.

i. **Packaging, Transport Container, Shipping Container, etc. -** These terms refer to the articles of packaging and containment excluding the radioactive material, but including all devices for shielding, cooling, spacing, shock absorption, moderation, etc.

j. **Safety Related Component -** A Safety Related Component is a component, part, or assembly which performs a function or functions necessary to prevent the release of radioactive contamination or radiation exposure of the general public in excess of levels permitted by regulations under normal or accident conditions of transport or which has been designated by the NRC as safety related.

k. **Special Form Radioactive Materials -** Refers to radioactive materials which, if released from a package, might present some direct radiation hazard but would present little hazard due to radiotoxicity and little possibility of contamination. Special Form materials are capable of enduring severe

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mechanical test conditions without dispersion or loss of integrity. [Ref. 10CFR71.75; 49CFR173.469]. It is either a single solid piece or is contained in a sealed capsule that can be opened only by destroying the capsule.

l. **Type A Quantity** - That quantity of aggregate radioactivity which does not exceed A_1 limits for special form radioactive material or A_2 limits for normal form radioactive material. [Ref. 10CFR71.4.]

m. **Type B Quantity** - That quantity of aggregate radioactivity which is greater than the Type A Quantity limits for special form or normal form radioactive material. [Ref. 10CFR71.4; 49CFR173.431; 49CFR173.4163.

5. References

a. 10CFR71
b. 49CFR173.401-.478, 49CFRI78
c. IAEA Safety Series No. 6, 1973
d. QAP-1
e. Applicable NRC Certificates of Compliance and DOT Certificates of Competent Authority covering IPO's and customers' Type B radioactive shipping packages.

6. Review Requirements

a. All proposed package contents (loadings) must be reviewed for compliance with regulatory and internal GE requirements and approved prior to the first release of the package for shipment.
b. The review is the responsibility of RP&S Equipment Engineering or an RP&S Equipment Engineering designated alternate.
c. Reviews and approvals may be made of individual, non-routine shipments, or the review may be performed to allow blanket approval of routine shipments within established boundary conditions.

d. All product line radioisotope shipments will normally be released under blanket approvals and will not require further engineering review.

e. The "Type B Package Contents Evaluation and Approval", RP&S form R-99 (see Attachment 1), is used to document engineering reviews.

7. Packaging Selection

Shipments of radioactive material from VNC or under an IPO administrated license are divided into two general categories. The first category includes all of IPO's Standard Product lines. The second category includes all other shipments.

a. IPO Product Shipments

1) IPO's radioactive products are normally shipped in packages expressly designed or uniquely suited for the transportation of specific products.

2) IPO Marketing initiates an "Apparatus Requisition" (see Attachment 2) or an "Instruction Sheet" (see Attachment 3) on the basis of a customer order.

3) The RP&S Analyst/Custodian or Product Manager is responsible for checking the blanket approval for the selected package to assure that the contents are within the previously established boundary conditions.

4) If the contents do not fall within boundary conditions or have not been previously analyzed, the Analyst/Custodian or Product Manager will initiate RP&S Form R-99, "Type B Package Contents Evaluation and Approval", and obtain Engineering approval prior to the release of the shipment.

5) RP&S Equipment Engineering performs or obtains appropriate analysis of the proposed package and contents per Part 9, Contents Evaluation of this procedure. The approved data package, including the R-99 form and applicable blanket description is returned to the RP&S Analyst/Custodian.

6) The Analyst/Custodian reviews or obtains external reviews of this data package, and issues blanket approval descriptions to Product Manager.

7) The responsible RP&S Product Manager initiates preparation of the package by issuing an RP&S Form R-8, "Cask Shipping Checksheet" (see Attachment 4).

8) The Analyst/Custodian or Product Manager signify that they have compared the product specifications to the individual or blanket approval referenced on the R-8 form for that combination of packaging and contents, and found them in agreement by signing the last line on the R-8 form, thus releasing the shipment.

b. Other Shipments

1) When a non-product shipment is requested, the package selection is normally proposed by the requestor or Marketing.

2) An RP&S Form R-38, "Request for Shipment of Radioactive Material" (Attachment 5) is submitted to the Analyst/Custodian.

3) The selection is subject to package availability and approval of the proposed contents.

4) Several different IPO packagings are equally capable of safely transporting a particular load of radioactive material. Selection of the specific packaging for a given load is based on the criteria discussed in Part 7.c, "Packaging Selection Criteria".

5) Selection of a packaging using these criteria normally does not require extensive engineering analysis.

6) Package selection should be completed prior to initiating detailed engineering evaluations.

7) As with product line shipments, the Analyst/Custodian obtains engineering review and approval by initiating RP&S Form R-99.

8) The shipment requestor or Analyst/Custodian initiates preparation of the package by issuing an RP&S "Cask Shipping Checksheet", R-8 (Attachment 4).

9) The Analyst/Custodian or shipment requestor signify that they have compared the contents specifications to the individual or blanket approval referenced on the R-8 form for that combination of packaging and contents, and found them in agreement by signing the last line on the R-8 form, thus releasing the shipment.

c. Packaging Selection Criteria

1) The following list contains the minimum factors which should be addressed by a shipment requestor in the initial selection of an IPO shipping package:

Factor	Discussion
Dimensional Compatibility	• Contents must physically fit into the container cavity. • Must also include the necessary secondary containment (if required) to meet regulatory requirements. • Minimal cavity clearances must be maintained. • Contents with excessive clearance must be restrained or supported (shoring) to preclude free movement during transport.
NRC Certificate of Compliance or DOT Specification	• Contents must meet all certificate requirements for the package. • Type and form of material. • Gram limits of SNM. • Total heat load. • Containment requirements.

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Factor	Discussion
Shippers or Receivers Material Handling Capabilities	• Address the material handling capabilities and limitations of the package recipient. • Lift truck or crane required. • Floor loading capabilities • Any unique regulatory requirements such as redundant rigging. • Include any special contents loading or unloading methods, restrictions and equipment requirements.
Receivers Material License	• Verification that the recipient is licensed to receive the proposed radioactive material. • Ref. RP&S SOP I:Y, "License Verification"
Misc. Factors	• Proposed loadings of irradiated SNM, the NEBO Transportation unit (IT&HM) must arrange routing approval. • If GE does not act as the shipper, the shipper must be registered as a package user with the NRC. • Handling procedure for package.

2) When all of the factors are resolved, the requestor makes the preliminary package selection and forwards the completed R-38 form to the RP&S Analyst/Custodian.

3) Routinely, the smallest, lightest compatible package is used to transport the proposed load.

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8. Information Requirements

   a. The Product Manager or Shipment Requestor is responsible to provide the necessary information to be used in evaluation and analysis of proposed package contents.

   b. The information requirements are described on RP&S Form R-38, "Request for Shipment of Radioactive Material" and Form R-38A, "Irradiated Fuel Nuclear and Thermal Data" (Attachment 6).

   c. These forms are intended to assure that all information necessary for analysis is available and meets the requirements of 10CFR71.91(5)(11). Attachment 7 gives typical examples of this information.

9. Contents Evaluation

   a. **IPO Product Shipments** - If a blanket approval has been issued, proceed to step 15).

      1) Equipment Engineering (EE) reviews Form R-99 and associated data for completeness.

      2) EE makes initial determination of internal package hardware requirements to evaluate the package.

      3) If EE determines that package hardware is available, a contents review package is assembled. (Proceed to step 9).

      4) If appropriate package hardware is not available, EE establishes the boundary conditions for blanket approval and assigns design responsibility for hardware design.

      5) A Design Basis is prepared by EE for approval by the Product Manager, RHO, and EE.

      6) Preliminary design, proposed classification, and appropriate fabrication specifications are issued by EE and a log number is assigned from the Cask Contents Evaluation Log.

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7) Concurrently or following step 6, a package contents analysis is prepared. The purpose and scope of contents analysis are described in Attachment 10, "Engineering Evaluation of Type B Shipments" and are summarized as follows:
   (a) Thermal Evaluation
   (b) Mechanical Evaluation
   (c) Fissile limit verification
8) Following receipt of the proposed package design and analysis, a formal Design Review is conducted in accordance with the Engineering Practices and Procedures specification 62A4070, "Engineering Design Review".
9) If the internal package hardware is already in existence or is unnecessary, the package contents analysis is conducted at this time.
10) EE assembles the Analysis Data package.
11) EE prepares or assigns responsibility for any special instructions and develops a technical description of the boundary conditions for blanket approval.
12) EE approves the Data Package, Blanket Description, and Form R-99, and forwards it to the RP&S Analyst/Custodian.
13) The Analyst/Custodian reviews the Data Package for completeness and determines If an external review is required.
14) Following the review, the Analyst/Custodian approves the R-99 form, distributes the Contents Approval and returns the Analysis Data Package to EE for filing.
15) The Analyst/Custodian or Product Manager verifies that the product specification is within the bounds of the Contents Approval and is authorized to sign the R-8 form, list the Approval Log No. and release the shipment.

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b. Other Shipments

1) The outlined procedure contained in Attachment 9, "Requested Shipments SNM/IRR HDWE" is adopted in lieu of text.

2) "GETR Fuel Shipments"; for purposes of allowing evaluations to be completed on an interim basis, the outlined procedure contained in Attachment 11, "GETR Fuel Shipments" is adopted in lieu of text.

10. Documentation

a. RP&S Equipment Engineering initiates a review of proposed contents upon receipt of a R-99 form from the Analyst/Custodian.

b. Each analysis is assigned a consecutive number from a "Cask Contents Evaluation Log" maintained by Equipment Engineering.

c. The logbook serves as a cross reference between the Engineering File and the Analyst/Custodian's shipping file.

d. All documentation of contents approval will be filed in the engineering file and maintained for at least two years after the last shipment of that combination of packaging and contents.

e. Abbreviated flow sheets describing the steps and routine of contents approval are attached to this document (Attachment 8, describing IPO products and Attachment 9, describing other requested shipments.)

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ATTACHMENT 1

TYPE B PACKAGE CONTENTS EVALUATION AND APPROVAL

Shipment Requestor ________________ Date ____________ Shipment ID No. __________

Shipment From __________________ To ___________________ Sched. for FW __________

Contents Description: ____ ☐ Listing Attached

Radionuclides & Ci Qty: ____ ☐ Listing Attached

Fissile Gm Qty & % Enr: ____ ☐ Listing Attached

Decay Heat Load: ____ ☐ Listing Attached

Rad. Material in: ☐ Normal Form ☐ Special Form Dwg. No. ________________

Proposed Packaging: Model No. ____________ NRC Cert No. ____________ Rev. ________

Contents to be: ☐ Dry Loaded ☐ Wet Loaded

Inner Container Descr.: ____________________________ Dwg. No. ________________

Inner Cont. Leak Test Req'd: ☐ No ☐ Yes Method ____________________________

Internal Spacer: ☐ Not Req'd ☐ Req'd-To Be Built ☐ Req'd-Avail. Dwg. No. __________

Pack. Assembly Dwg. No. ________________

RP&S-EE Prelim. Evaluation By: ______________________ Date ______________

☐ Contents Acceptable Under Existing Contents Evaluation Log(CEL) No. ____________

☐ Contents Evaluation Required:

☐ Thermal ☐ Mechanical ☐ Package Dose Rate

☐ Existing Internal Hardware Acceptable ☐ New Hardware Req'd (Design Loop)

☐ Fissile Load Within Package Cert. Limits ☐ Heat Load Within Package Cert. Limit

Thermal Analysis By: ______________________________ Date ______________

☐ Specific Analysis ☐ Limit Analysis for Bounding Parameters

☐ Contents Within Estab. Boundary Limits; Therm. Analysis Not Req'd (Ref.CEL No. _____)

Contents Temp. limit: __________ Basis: ____

Internal Hardware: ☐ Safety-Related ☐ Not Safety-Related

Thermal Analysis Reviewed and Approved By: ______________________ Date ____________

Mechanical Analysis By: ______________________________ Date ______________

☐ Shoring Not Req'd; Pack. Internals Adequately Restrict Movement ☐ Shoring Req'd

Residual Water Limit: ____

Mechanical Analysis Reviewed and Approved by: ____________________ Date ____________

Package Dose Rate Evaluation By: ____________________________ Date ____________

☐ Dose Rates Acceptable by Precedent. Ref. ______________________________

☐ Calculated Dose Rates: _____ mRem/h @ Pack. Surf.; _____ mRem/h @ Truck Edge

_____ mRem/h @ 3' from Pack Surf.; _____ mRem/h @ 6' from Truck Edge

Package Dose Rates: ☐ Will Not Exceed Limits ☐ May Exceed Limits

☐ Pack. Approved Under Contents Eval. Log No. _____ With Special Requirements (Attached)

☐ Pack. Approved Under Contents Evaluation Log No. _____ as Proposed

RP&S-EE ____________________________ Date ________________

RP&S Analyst ________________________ Date ________________

Ref: RP&S SOP I.AA, Type B Shipment Evaluation

Distribution: (1) RP&S Analyst
(2) Requestor
(3) Shipping File
(4) EE File

NFRnXXXX

ATTACHMENT 2

GENERAL ELECTRIC
APPARATUS REQUISITION

Accounts Billing	867
M. Dixon	847
~~G. Jones~~	~~V01~~
B. Streitz	V01
R. Quisol	512
Shipping	V07
QA	V18
B. Whitehurst	V18
RF/Finance	V18
J. Montemurro	IDS-NY

Requisition No. J-H31411 · 12356-01

P4F61 762 284 810 103 N 55 11 284 000 98

Siemens Corporation
186 Wood Avenue South
Iselin, New Jersey 08830
ATTN: Accounting/Auditing Dept. MS11,03

Rhein-Landesfrayebjkuhl
Vogelsangstr. 106
5600 Wuppertal 1
Germany

Customer Order No. 14/370.988 · Order Date 11-4-80 · F R A N C E

CO 60 LTL 60

[redacted]

UNCONTROLLED FACSIMILE

Product:	Co-60 Teletherapy Source
Specification:	22A9050 latest revision
Quantity:	1 each
Size:	2.0 cm
Nominal Output:	3000 RHM
Fabricate To:	3000 + 10% -0 (Not to exceed 2600 Ci)
Calibration Date:	2/1/81
Shipping Date:	Later (Approximately mid January 1981)
Drawer Number:	252
Cask Number:	1055
Selling Price:	[redacted]
Destination:	Later
Final Shipping Info:	Will be supplied by Siemens upon completion of source
Export License:	10CFR-110.24(a)
Shipping Info:	To be furnished after completion of source.

[redacted]

D. W. France
D. W. France
IPO Marketing
12/ /80

Placed by 2.4-IPO · S. J. Lenz · IPO Marketing · 12/10/80

ATTACHMENT 3

GENERAL ELECTRIC
REQUISITION
INSTRUCTION
SHEET

284-P3N63

P3N63

Gamma Industries

0041 -

UNCONTROLLED FACSIMILE

284-P3N63

IS # 41

SUBJECT: <u>Shipping Instructions</u>

Reference IS #39 and 40

Please ship both the 1350 Ci cobalt source (IS #39) and 1000 Ci bulk cobalt (IS #40) in a GE 100 series cask on the General Electric truck scheduled to depart VNC on December 19, 1980.

D. W. France
IPO Marketing
12/10/80

DISTRIBUTION:

Accounts Billing	867
M. Dixon	847
T. C. Hall	V01
G. E. Cunningham	V18
J. H. Cherb	V18
R. Jones	V01
B. Streitz	V01
Shipping	V07
RF/Finance	V18

ATTACHMENT 4

CASK SHIPPING CHECKSHEET

Cask No. ______ Jacket No. ______ Initiated by ____________________ Date ________

Ship to ______________________ Required Shipping Date/Time ________________

Cask Contents ______________________________ Contents Approval No. ________

Internal cask hardwarerequired: ________________ Safety-Related: Yes ☐ No ☐

Proper Shipping Name ____

Max. Allowable Cavity Contamination __________ cpm Job Order No. ____________

Date of Last Annual Inspection ______ Inspection req'd: ☐ Pre-shipment only ☐ Pre-shipment + Annual

Special Instructions ____

INITIAL ACCEPTABLE CONDITIONS ONLY - INDICATE UNACCEPTABLE BY * - NOT APPLICABLE BY N/A

☐ Cask Pre-Shipment Inspection

_____ Cavity contam: Initial __________ cpm _____ **Lid bolts**

After cleaning __________ cpm _____ **Gasket** condition acceptable

_____ Drain line contam: Initial _______ cpm _____ **Drain plug**

After cleaning ________ cpm _____ Drain line

_____ **Lid** cond.(seal surface,cracks,deform.) _____ **Ear bolts** (tight)

_____ **Cask** cond.(seal surface,cracks,deform.) _____ Nameplate(secure,legible,location)

☐ Cask Annual Inspection

_____ **Ear bolts** (length,ident.,cond.) _____ **New gasket** installed: Date _______ Type _______ S/N _______

Length gage S/N ________ _____ Cavity leak test (R-28 attached)

_____ **Redundant ears/bolts**

Remarks: ____

Cask inspected and found acceptable except as noted: ______________________
(Inspector) (Date)

Unacceptable conditions: ______________________________________

Maintenance Checksheet (R-9, attached) Initiated by: ______________________
(Custodian) (Date)

Shipping:	Performed	Verified	Date
Special shielding, moderators, or internal hardware properly installed, and cavity inspected for prohibited items	_____	_____	_____
Contents properly loaded. Contents: ______________	_____	_____	_____
Gasket, lid bolts, drain plug, and other closure devices properly installed	_____	_____	_____
Lid bolts tight. Plastic wrap or other covering removed	_____	_____	_____
☐ FULL ☐ EMPTY label applied to cask	_____	_____	_____
Cask/Jacket inspection/maintenance completed(R-7/R-9 attached)	_____	_____	_____
Proper shipping name attached to jacket nameplate	_____	_____	_____
Security Seal No. ________ and DOT labels applied to jacket	_____	_____	_____

Package meets all Certification, Regulatory, and Contents Approval (R-99) requirements and is approved for shipment: ______________________
(Custodian) (Date)

ATTACHMENT 5

R-38
1/81

REQUEST FOR SHIPMENT OF RADIOACTIVE MATERIAL

PART I. GENERAL SHIPPING INFORMATION

Requestor:__________________ Phone:__________ Date:__________

GE Req. No.:________ Proj. No.:________ Comp. No.:________ ☐ PPD ☐ COLL

Job Order Nos: Labor & Mat'l__________ Transportation__________

Type Shipment:

☐ Empty Container; Mat'l Pickup and Return to VNC

☐ Full Container; Return Empty to VNC

☐ Other, Specify:__________

Ship to (Facility Name & Address):

Attention:__________

Facility License No.__________

Approx. Shipping Dates: From VNC__________; To VNC__________

Return Shipment to VNC Under: ☐ Facil. License ☐ GE SNM-1270

Request for NRC Route Approval (Irrad. Fuel Only) Subm. to IT&HM: Date__________

PART II. DESCRIPTION OF RADIOACTIVE MATERIAL

☐ Irradiated Reactor Fuel (SNM):

Type: ☐ Intact Rods ☐ Failed Rods ☐ Rod Sections (Cut)

☐ Other, Specify:__________

No. Items of Each Type:__________

External Dimensions of Each Type:__________

☐ Dwgs/Sketches Attached

Nuclear & Thermal Data for Each Item: ☐ RP&S Form R-38A Attached.

☐ By-Product Material (Reactor Hardware, Sealed Sources, etc.):

General Description of Item(s) and No. of Each Type:__________

☐ List Attached

External Dimensions of Each Type:__________

☐ Dwgs/Sketches Attached

Radionuclides and Total Ci of Each:__________

☐ List Attached

Total Decay Heat of Material:__________Watts

PART III. SHIPPING CONTAINER REQUIREMENTS

Container Proposed: No. Req'd______ VNC Model No.______ Other__________

Internal Contamination Limits:__________ ☐ N/A

Loading/Unloading @ Rec. Facil: ☐ Wet ☐ Dry ☐ Redundant Ears Req'd

Internal Holder/Spacer/Containment Reqmts:__________

Other Special Requirements:__________

Distribution: Orig. + 1 copy - RP&S Analyst
1 copy - Requestor

ATTACHMENT 6

IRRADIATED FUEL NUCLEAR AND THERMAL DATA

SHIPMENT FROM ______________ TO ______________ SHIPPING DATE ______________

ITEM NO.	SERIAL NO. AND/OR OTHER DESIGNATED IDENT. NO.	REFERENCE DWG NO.	ACTIVE FUEL LENGTH, in.	% U-235 ENRICHMENT		CURRENT WT. SNM, GM			FISSILE EQUIV. MASS, gm (U-235+1.67Pu)	Fuel Burnup, GWd/MTM	IRRADIATION TIME, days	COOLING TIME,* days	TOTAL DECAY HEAT,** watts	TOTAL MFP+Pu ACTIVITY,** Ci	REMARKS
				ORIGINAL	CURRENT	U	U-235	Pu							
				SUB-TOTALS							SUB-TOTALS				
				TOTALS							TOTALS				

Page ___
of ___

*FROM REACTOR SHUTDOWN TO SHIPPING DATE
**AT SHIPPING DATE

Distribution:
Orig. + 1 copy - RP&S Analyst
1 copy - Originator

PREP.BY ______________
EXT. ______________
DATE ______________

ATTACHMENT 7

Typical Examples of Information for Proposed Contents

1 . Generic Form of Radioactive Materials -

examples: Intact fuel rods}

Failed or cut fuel rods, or sections

Irradiated metal hardware

Sealed sources (gamma or neutron)

Liquid radioisotopes

2. Number of discrete items; identification and physical size of each - examples: 30 each SRP fuel rods

1. serial no. STR-110 12BD5283 G12

1 ea. std. 250 ml. polyethylene bottle

2.600" od x 5.75" high

3. Specific Radioactive Nuclides and Quantities, including SNM (ref. 49CFR173.390) Curie quantity of each major nuclide or family and/or if fissile material, the quantities of each fissile constituent (U-233, U-235, Pu) in grams, and original enrichment. If neutron source, give the total source strength (N/s/cc)

examples: 350 g U-235, MFP, 60,000 Ci. 2.8% enrich.

240 Ci. Mo-99, 150 ml, 1600 mCi/ml

4. Special Loading Requirements -

examples: Power Reactor Pool Loading; under SNM-1270

Redundant Ears required

5. Thermal Characteristics

examples: Average decay heat, 6.4 Watts/Rod

Peak decay heat, 0.3 Watts/in.

6. Expected Removable Surface Contamination -

   examples: < 200 CPM/Total

   < 5000 CPM/100 sq cm

7. Containment Leak Tested?

   examples: Helium leak test < 1 x 10^{-8} atm cc/sec

   Entire bundle sipped prior to disassembly

8. Irradiation and Decay History for irradiated fissile material

ATTACHMENT 8

IPO Products

IPO Marketing initiates Reg. or IS (IPM)

Product Mgr. Rec. Req/IS and checks info against blanket approvals

Initiates package and production schedule commitments

If Under Blanket

If Not

Initiates R-99 & Data Pkg. input to RP&S EE

RP&S EE Reviews R-99 & Data for completeness

Makes initial determination Hdwe. req

If Hdwe Avail

If Not

Estab. blanket criteria

Assign design resp.

Assigns Rev. No. from Eng. Log

Prep. prelim-design, class, specs

Accompl/Assign Prelim cont. reviews

Initiate Design Review

Issued Design-dwgs, specs

Assigns Final Cont. review

Assembles Review Data Dwg.

Blanket Description

Preps/assigns special loading instr

RP&S EE approves pkg/blanket

RP&S Analyst-Reviews Data Pkg. & determines if external review is required

Analyst approves shipment - blanket data pkg to EE

Prod. Mgr., initiates R-8 to RHO. Custodian/Product Manager checks blanket, lists Log No. RHO loads, assembles and ships - 747 file, etc.

ATTACHMENT 9

REQUESTED SHIPMENTS SNM/IRR HDWE

FO&T/CMT - proposes shipment, initiates R-38, 38A, etc.

Cask Coordinator (Cust/Analyst) -
- Rec. R-38 & reviews input for completeness
- Makes initial determination of compatibility
- Initiates cask availability check
- Makes initial schedule reservations
- Initiates R-99 & input to RP&S EE
- Confirms notification of IT&HM for routing, etc.

RP&S EE →
- Review R-99 & attachments for completeness
- Makes initial determination of Hdwe requirements
- Determines if shipment is within exist blanket

If Hdwe is Available

If Hardware is Not Available

RP&S EE-Establishes Blanket Criteria

Assigns Review No. from cask contents

Evaluation Log

Assign Design, Resp

Prep. prelim design class, specs

Accompl./Assign Prelim cont reviews

Initiates Design Review-New Hdwe

Issues Design-dwg. specs

With Blanket Approval

Analyst Approves Blanket Compl.
and Shipment

Without Blanket Approval

EE assigns content reviews as approp.
Assembles review data pkg (prep. spec. loading instr. as required)
Approves Pkg/Blanket Desc.

RP&S Analyst - Reviews Data Pkg. & determines if ext. review is required
RP&S Analyst - Approves shipment, Blanket Description
Data Pkg. to EE file - initiate Hdwe Fab (if required)

Initiates R-8 to RHO
RHO Conducts inspections
Cask Loading Checksheet & Instr.
Load cask & assemble pkg.374, Ship package, File

ATTACHMENT 10

ENGINEERING EVALUATION OF TYPE B SHIPMENTS

1. THERMAL ANALYSIS

The purpose of the thermal analysis is to assure that the proposed contents which may comply with the maximum thermal loading allowed by the package certification also meet individual Engineering requirements for the internal containment or encapsulation. This analysis shall demonstrate that the surface temperature of the inner container, will not exceed the melting point of the contents, the encapsulation, or the containment seal. Other specific considerations or conditions may warrant unique criteria and these should be addressed using sound engineering practice.

2. MECHANICAL EVALUATION

The purpose of the mechanical evaluation is to assure compliance with the appropriate packaging certification and other regulatory requirements.

a. Many of the certificates covering IPO's packages require "shoring" to "minimize movement of contents during accident conditions". Compliance with this requirement is met by providing internal holders or spacers which limit the movement of the contents relative to the package containment. The holders or spacers must also fit snugly into the package cavity. If the results of a thermal analysis indicate that the holder/spacer is not required in order to remain below critical temperature limits, and mechanical displacement cannot reduce criticality safety below the allowable limit, then the holder or spacer will not be considered a Safety Related component of the package. If both of these criteria are not met, the holder or spacer shall generally be considered Safety Related unless specific analysis indicates otherwise.

b. The effects of residual water contained in the cask shall be evaluated for shipments that are loaded underwater. Underwater loads will normally be thoroughly and completely drained prior to installation of the drain plug.

3. CRITICALITY ANALYSIS

Criticality Analysis of IPO's Package is handled as follows:

a. Any package may be used for quantities of fissile material < 15 grams.

b. Any package with a current fissile classification can be used to transport up to 500 grams of U-235, or 300 grams of U-233, or 300 grams of Pu, or any combination wherein the fractional sum does not exceed unity.

3. CRITICALITY ANALYSIS (Continued)

(e.g., $\frac{3 \times \text{gms U - 235}}{1500} + \frac{5 \times \text{gms U - 233}}{1500} + \frac{5 \times \text{gms Pu}}{1500}$

These quantities are based on commonly accepted values for __________ quantity of material to remain subcritical under Optimum __________ conditions.

c. Some of IPO's packages are approved for a 1200 gram U-235 __________ gm U-235 = 1.66 gms U-233 = 1.66 gm Pu) limit. Each package ________ number of requirements/constraints imposed by its Certificate of Compliance, and each of these must be uniquely addressed in writing of a proposed shipment. Other proposed loadings must be completely analyzed and approved by the NRC (revision of the certificate is the only acceptable instrument of approval).

d. In any case where Pu is in excess of 20 Ci, the Pu must be __________ of the metal, a metal alloy, or in the form of reactor fuel ________.

RP&S SOP I:AA, REV. 2

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ATTACHMENT 11

GETR IRRADIATED FUEL SHIPMENTS

GETR SNM Custodian -
- Reviews input for completeness
- Makes initial determination of compatibility
- Initiates cask availability check
- Makes initial schedule reservations
- Initiates R-99 & input to RP&S EE
- Confirms notification of IT&HM for routing, etc.

RP&S EE
- Review R-99 & attachments for completeness
- Makes initial determination of Hdwe requirements
- Determines if shipment is within exist blanket

If Hdwe is Available

If Hardware is Not Available

RP&S EE-Establishes Blanket Criteria

Assigns Review No. from cask contents

Evaluation Log

Assign Design, Resp

Prep. prelim design class, specs

Accompl./Assign Prelim cont reviews

Initiates Design Review-New Hdwe

Issues Design-dwg. specs

With Blanket Approval

Analyst Approves Blanket Compl. and Shipment

Without Blanket Approval

EE assigns content reviews as approp.
Assembles review data pgk (prep. spec. loading instr. as required)
Approves Pkg/Blanket Desc.

GETR Analyst - Reviews Data Pkg. & determines if ext. review is required
GETR Analyst - Approves shipment, Blanket description
Data Pkg. to EE file -

GETR SNM Custodian initiates ORF to conduct inspections
Cask Loading
Load cask & assemble pkg.
374, Ship package, File

NOTE: All 18 shipments will be reviewed and approved on one R-99 form.

RP&S SOP I:AA, Rev. 2

ATTACHMENT 12

SUMMARY OF RESPONSIBILITIES

TASK	REQUESTOR	RP&S ANALYST	RP&S EE	DES	MKTG
Initiate requisition or Instruction Sheet					X
Complete R-38, "Request for Shipment Radioactive Material"	X				
Submit R-38 to RP&S Analyst	X				
Select proposed packaging	X	X			X
Initiate R-99, "Type B Package Contents Evaluation & Approval"	X	X			
Submit R-99 to RP&S-EE with required evaluation data	X	X			
Complete preliminary package contents evaluation based on R-99 data			X		
Determine package internal hardware requirements	X		X		X
Supply required internal hardware	X		X		X
Perform required engineering analysis		X	X	X	
Review and approve engineering analysis			X		
Final approval of R-99 and data package			X		
Issue approved R-99 with any special requirements		X			
Initiate package preparation with R-7 and R-8		X			
Shipment release	X	X			

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2/79

GENERAL ELECTRIC

IRRADIATION PROCESSING OPERATION
RADIOACTIVE PRODUCTS AND SERVICES
OPERATING PROCEDURE

REVISION 0

CHAPTER:	SECTION:
I. ADMINISTRATIVE	CC. QA Procedures for Packaging Components Meeting USDOT Specifications

1. Scope

This procedure describes the applicability of the 18 Criteria of the General Electric Vallecitos Nuclear Center's Quality Assurance Program for Shipping Packages for Radioactive Material (QAP-1) to routine use and maintenance of packaging components designed to USDOT Specifications.

2. Criteria

Compliance of the DOT Specification packaging components with each criterion is as follows:

a. Organization

The organization(s) responsible for the DOT Specification packaging is described in QAP-I, Section 1.

b. Quality Assurance Program

Quality Assurance Program for DOT Specification packaging is set forth in Section 2, QAP-1.

c. Design Control

Design control criteria for DOT Specification packaging is described in QAP-1, Section 3.

d. Procurement Document Control

Material Requests (MR) for material associated with DOT Specification packaging as described in Section 2g of this procedure will be issued by RP&S and controlled in accordance with Standard Operating Procedure RP&S, Chapter I, Section 0. Because of minimum control for this type of material, QA approval of MR's is not necessary. QA approval is required for fabrication of new DOT specification packaging.

APPROVED: MANAGER RADIOACTIVE PRODUCTS AND SERVICES DATE: 12/19/80

REVIEWED: ☐ MGR. SQ ☒ MGR.NST ☒ MGR.OP ☐ INDUST.SAFETY

REVIEWED: SOP REVIEW DATE CHANGED ☒ ☒ MGR.RHO ☒ ANALYST

DMF REVISION ☒ NO ☐ YES BY: ☒ MGR. EE ☒ MGR. IPM ☐ MGR. PD&S

DATE ISSUED 12/18/80	SUPERSEDES ISSUE	PAGE 1 OF 3
ISSUED BY: R. R. Light	DATED: NEW	REVIEW DATE 7/89

CHAPTER:	SECTION:
I. ADMINISTRATIVE	CC. QA Procedures for Packaging Components Meeting USDOT Specifications

2. Criteria (continued)

   e. Instruction, Procedures, and Drawings

      Instruction, Procedure, and Drawing controls specified in QAP-1, Section 5 is applicable to DOT Specification packaging.

   f. Document Control

      Document control as specified in QAP-1, Section 6 is applicable to DOT Specification packaging.

   g. Control of Purchased Material, Equipment, and Services

      Purchased material, equipment, and services will be standard commercial grade [Ref. 49CFR173.24(c) and 178.194-2(1) and (2)] requiring no special control program.

   h. Identification and Control of Materials, Parts, and Components

      The identification and control of materials, parts, and components will be conducted in a manner consistent with Section 2.g of this procedure.

   i. Control of Special Processes

      Special processes will be performed in a workmanship manner applicable to the process being performed or as otherwise specified in 49CFR173.24 and 178.194.

   j. Inspection

      Inspection processes will be routine inspections performed by Remote Handling Operations personnel and limited to the requirements of 49CFR178.194-4. These inspections will be performed in accordance with QA approved RP&S procedures.

   k. Test Control

      DOT Specification packaging is designed to establish criteria specified in DOT Regulations. Any further testing is not applicable.

GENERAL ELECTRIC
IRRADIATION PROCESSING OPERATION
RADIOACTIVE PRODUCTS AND SERVICES
OPERATING PROCEDURE

CHAPTER:	SECTION:
I. ADMINISTRATIVE	CC. QA Procedures for Packaging Components Meeting USDOT Specifications

2. Criteria (continued)

l. Control of Measuring and Test Equipment

No test or precision measurements will be performed. Therefore, control of measuring and test equipment is not applicable to DOT Specification packaging.

m. Handling, Storage, and Shipping

Handling, storage, and shipping criteria described in QAP-1, Section 13 is applicable to DOT Specification packaging.

n. Inspection, Test, and Operating Status

The inspection, test, and operating status of DOT Specification packages will be consistent with Sections G, H, J, K, and L of this specification.

o. Nonconforming Materials, Parts, or Components

Nonconforming materials, parts, or components criteria described in QAP-1, Section 15, is applicable to DOT Specification packaging.

p. Corrective Action

Corrective Action procedures described in QAP-1, Section 16 are applicable to DOT Specification packaging.

q. Quality Assurance Records

Quality Assurance records as appropriate to DOT Specification packaging are maintained as described in QAP-1, Section 17.

r. Audits

The Audit system as described in QAP-1, Section 18 is applicable to DOT Specification packaging.

DATE ISSUED 12/18/80	SUPERSEDES ISSUE	REVISION No. 0	PAGE 3 OF 3
ISSUED BY: R. R. Light	DATED: NEW		

GENERAL ELECTRIC

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8/87

IRRADIATION PROCESSING
RADIOACTIVE MATERIALS SERVICES
REMOTE HANDLING OPERATIONS
STANDARD OPERATING PROCEDURE

REVISION 6

CHAPTER:	SECTION:
III. SHIPPING AND RECEIVING	B. Shipping and Receiving Radioactive Materials

APPROVED: Manager, ☐ Radioactive Mat'ls Services ☒ Remote Handling Operation; DATE: 11-3-87

REVIEWED: ☐ SQ ☒ MGR. NS ☒ QA ☐ INDUST. SAFETY

REVIEWED: ☐ ☒ MGR. RHO ☐

SMF REVIEW: ☒ NO ☐ YES; BY: ☒ SUPV. ☒ MGR. ☒ Traffic-S

1. Purpose

To insure personnel safety and compliance with State and Federal license conditions and regulations when shipping or receiving radioactive material.

2. Special Requirements

a. Requirements of the following shall apply:

1) Department of Transportation (DOT) Regulations
2) Nuclear Regulatory Commission (NRC) Regulations
3) Quality Assurance Program for Shipping Packages for Radioactive Material, QAP-1
4) VNC Safety Standards 7.5 "On-Site Transfers of Radioactive Material", 7.6 "Radioactive Material Shipments and Receipts". and 7.3 "Radioactive Waste Handling".
5) NRC Certificates of Compliance for Type B and fissile shipping containers.

b. Any container or vehicle received with contamination in excess of VNC site release limits...or any container received with dose rates in excess of DOT regulations, will be quarantined and reported to Manager, Nuclear Safety and Manager, Remote Handling Operations.

c. The Special Requirements section of SOP 111:U "GE Models 100, 200, and 300 Cask Transfers" must be adhered to.

d. All on-site transfers of contaminated casks must be communicated to and approved by the receiving component prior to the transfer.

DATE ISSUED 11/3/87	SUPERSEDES ISSUE	PAGE 1 OF 13
ISSUED BY: J. I. Tenorio	DATED: 10/6/83	REVIEW DATE 11/89

CHAPTER:	SECTION:
III. SHIPPING AND RECEIVING	B. Shipping and Receiving Radioactive Materials

e. Casks for off-site shipments shall not be painted in order to "fix" contamination.

f. NO RADIOACTIVE MATERIAL MAY BE TRANSPORTED IN PERSONAL VEHICLES.

g. Shipments from VNC to San Jose are off-site shipments and the appropriate portions of this procedure shall apply. Verbal license verification may be obtained from the Senior Licensing Engineer.

h. The "Cask Shipping Checksheet", R-8; "Fireshield Checksheet", R-7; "Waste Cask Loading Checksheet", R-73; and other appropriate checksheets as listed in SOP I:P, "Controlled Forms" are permanent records.

i. The Senior Licensing Engineer shall determine what customer/license documentation is required prior to using or renting a customer-owned container.

j. The responsible project engineer (shipment requestor) is responsible for complying with the requirements of SOP I:AA, Type B Shipping Contents Evaluation and for generating the Request for Shipment of Radioactive Material, R-38. RMS is responsible for performing the contents evaluation and documenting approval on the Type B Contents Approval form R-99.

k. The Department of Transportation (DOT) regulations, 49CFR173.415(a), require that each shipper of a Spec. 7A packaging maintain on file for at least one year after the latest shipment a complete certification and supporting safety analysis demonstrating that the construction methods, packaging design, and materials of construction are in compliance with the specification.

l. Use of non-GE manufactured or owned 7A containers requires:

1) A written certification statement from the container owner that the packaging sects the Specification 7A standards,

2) Drawings of the container are available for review,

3) Any necessary loading/unloading instructions are available to operations,

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REMOTE HANDLING OPERATIONS
STANDARD OPERATING PROCEDURE

CHAPTER:	SECTION:
III. SHIPPING AND RECEIVING	B. Shipping and Receiving Radioactive Materials

4) A review of the design and physical inspection of the container to assure compliance with documents is conducted.

m. There should be no fixed contamination on the external surfaces of the assembled package, e.g. fireshield, pallet, etc.

3. <u>On-Site Transfer of-Radioactive Materials</u>

a. Contact the receiving Custodian and verify that the receiving component has a valid Radioisotope Authorization or Change Authorization for the amount of material to be transferred, if applicable.

b. Record the Authorization (CA) number on the "On-Site Radioactive Transfer Record and Check List", VNC 706.

c. IF THE FACILITY DOES NOT HAVE THE NECESSARY RADIOISOTOPE AUTHORIZATION OR CHANGE AUTHORIZATION, DO NOT MAKE THE TRANSFER.

d. Inform the receiving Custodian of the following:

1) The type of material to be transferred; radionuclide and estimated activity.

2) The approximate time of the shipment.

3) The doze rate at the surface of the container.

4) The dose rate of the item at contact, if necessary.

5) The amount of smearable contamination on the shipping container.

6) The physical description of the shipping container; i.e., gallon can, 250 lb. cask, etc.

e. The shipper arranges for transportation.

4. <u>VNC 706, "On-Site Radioactive Transfer Record and Checklist</u>

a. A VNC 706 Form must be completed for all on-site radioactive materials transfers, except for radwaste and material transfers to Shipping & Receiving (S&R) for offsite shipment, or other exemptions listed in VSS 7.5, "On-Site Transfers of Radioactive Material".

b. The receiving facility must have a license, Radioisotope Authorization, or Change Authorization to receive the item being transferred.

c. Special instructions or unusual conditions should be listed on the VNC-706 form.

d. All blanks on the VNC 706 must be initialed or marked "N/A" (not applicable) before the transfer is made.

e. Any radioactive material received from other components at VNC must be accompanied by the VNC 706 (except for radwaste which utilizes Form R-36, "Radwaste Transfer Record"). The receiving engineer and/or technician shall initial VNC 706 to indicate receipt and proper storage of the item(s).

f. All Special Nuclear Material (SNM) transferred into or out of Plant 1 (ICA-21) or Plant 6 (ICA-29) must also be accompanied by a NED 48 "Source and Special Nuclear Material Transfer" form. A transfer to NTR for neutrography of less than 24 hrs. does not require a NED-48.

g. The originator of the VNC 706 Form for transfers from the RHO retains a copy for the Custodian or Shipping Clerk.

h. The balance of the form is transferred with the material to the receiving component.

i. Radioactive materials transfers into or out of the RHO are recorded in the Shipping & Receiving Logbook maintained by RHO.

5. <u>In-Transit Transfers</u>

Radioactive materials that remain the property of RHO but are transferred to another facility for nondestructive analyzes and then returned to RHO, within a 24 hour or less turn-around period (e.g. fuel specimens to NTR for neutrography) require:

a. An approved Change Authorization or Experiment Approval that describes and evaluates the activity.

b. Concurrence from the component performing the analyses. The requirements of NTR SOP 10.9, "Neutrography of Radioactive Material - North Room" apply.

c. The following information in required on the VNC 706 form:

1) Date and time of the transfer.
2) Fuel rod burnup - maximum 60,000 MWD/T.
3) Fuel rod decay time - minimum 6 months.
4) Maximum decay heat is 1150 watts.
5) Neutrography paddle Number NR21.
6) Weight and enrichment of fuel. Fuel must be uranium oxide.
7) Cask number.
8) The RHO license number and the license number of the receiving facility.

(Note: Although the material may remain the property of RHO, it is used under the license of the receiving facility.)

d. A Form 48 is required for transfers of SNM if the material will remain for >24 hours.

6. Requirements for Off-Site Shipment of Radioactive Material

a. Verify that the receiving facility is licensed to receive the material per the requirements of SOP I:Y, "License Verification".

b. A copy of the receiving facility license verification shall accompany the shipping documents to Shipping & Receiving for any radioactive material shipment except:

1) Routine radioisotope shipments of Xe-133 and Co-60.
2) Radwaste shipments
3) Laundry shipments
4) Shipments to Wilmington
5) Shipments to Morris
6) Shipments to San Jose
7) Shipments to DOE facilities
8) Exports

CHAPTER:	SECTION:
III. SHIPPING AND RECEIVING	B. Shipping and Receiving Radioactive Materials

c. Verify that the receiving facility, if required, has a current copy of the appropriate loading/unloading procedure described in SOP Chapter XVIII, Shipping Package Assembly/Disassembly. A logbook of facilities that have received controlled copies of the procedure is maintained by the Shipping Clerk.

d. The appropriate checksheets (ref. 49CFR173.475) will be initiated by the responsible Specialist, Engineer, or alternate, and must be completed before shipment.

e. The "Checksheet" must be initiated when the container is prepared for shipment and continue until final approval is obtained from the Area Supervisor. Custodian or alternate designated by the Manager, RHO.

f. Use of the checksheet must be adhered to as described in SOP I:A, "Logbooks and Checksheets".

g. THE PROPER LOADING/UNLOADING PROCEDURE WILL BE SUPPLIED BY THE RESPONSIBLE SPECIALIST OR ENGINEER BEFORE HANDLING ANY CUSTOMER-OWNED CASK.

h. Deficiencies in IP-owned shipping containers which have been identified during inspection shall be corrected and documented in accordance with the appropriate Chapter XVII "Cask/Fireshield Maintenance" procedures.

i. Shipping document requirements and responsibilities for their preparation for various types of shipments are as follows:

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REMOTE HANDLING OPERATIONS
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CHAPTER:	SECTION:
III. SHIPPING AND RECEIVING	B. Shipping and Receiving Radioactive Materials

Type Shipment	Required Forms R-38	FF736	NED610	374	747A	747B	NEO186	R-99	48	Preparation Responsibility
Radwaste		X					X			Mgr., RHO
Xe-133						X				Responsible Engineer
Radioisotope Prod.				X or	X					Responsible Engineer
Irrad. Test Mat'ls		X		X						Responsible Engineer
SNM Custodian		X		X					X	Custodian
Reactor Equipment		X		X						Responsible Engineer
Empty Rental		X		X						Custodian
Empty Sold Casks			X	X						Custodian
Type B Cask	X									Responsible Engineer/ Requestor
Type B Cask								X		RMS Engineering

j. RHO/RMS prepares the shipping papers for Shipping & Receiving as appropriate for the shipment:

1) NEO Form 747A, "Isotope Shipping Memo" or 747B, "Isotope Shipping Memo (Xe-133)" for all processed radioisotope product shipments.

2) NEO Form 374, "Radioactive Material Packaging and Shipping Record" for shipments of fissile material and/or radioactive materials other than processed radioisotope products.

3) "Request for Issuance of Shipping Notice", Form FF-736, for radioactive materials other than radioisotope products.

4) A "Delivery to Shipping" NO 610, is required for other than radioisotope products if the material is to be sold.

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5) A copy of the receiver's license verification issued within 12 months prior to shipping date is required. License verification files are maintained by the Shipping Clerk.

6) A NEO 186, "Radwaste Shipping Memo", for all radwaste shipments.

7) Completed Form 48's for SNM shipments shall be forwarded to the Specialist, Safeguards, for preparation of the DOE/NRC Form 741 required for transfer of the SNM from General Electric to the receiver.

8) A Request for Shipment of Radioactive Material, R-38 is required for all Type B shipments in casks and is generated by the requestor.

9) A Type B Contents Approval, R-99, is required for all Type B cask shipments and is prepared by RMS Engineering.

k. Completed copies of the shipping documents are returned by Shipping & Receiving to the RHO Shipping Clerk for filing.

l. The requirements of SOP III:Y "Processed isotope Shipment Document Preparation" will apply as appropriate.

m. The requirements of SOP XVI:D, "Radwaste Shipping Documents" shall apply to all shipments of radioactive waste.

n. All shipments shall be recorded in a Shipping and Receiving Log.

o. All Contents Approval Evaluations and assigned approval numbers shall be recorded in the Contents Evaluation Log (CEL) per requirements of SOP I:AA, "Type B Shipment Evaluation".

7. Receipt of Radioactive Materials

a. Radioactive material may not be received at the RHO facilities unless the following conditions are met:

1) The Custodian or Area Supervisor has been informed of material identity and the radiation levels involved.

2) An approved Radioisotope Authorization or Change Authorization covering the material is on file.

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3) A NED Form 48 has been completed by the Specialist, Safeguards and is forwarded to the Custodian for SNM shipments.

4 Noncompliance with 7.a.2) and 7.a.3) will result in quarantine of the shipment in the Quarantine Area until proper documentation is received.

5) Shipping containers will not be accepted if it is doubtful that the radioactive material can be unloaded and handled with existing equipment.

6) Any container or vehicle received with contamination in excess of VNC site release limits, or any container received with dose rates in excess of DOT regulations, will be quarantined and reported to Manager, Nuclear Safety and Manager. Remote Handling Operations.

7) Transfer of casks, boxes, drums, or other containers of radioactive material to any RHO facility must be approved by the Custodian, RHO Manager, or other personnel specifically designated by the Manager, RHO.

b. Copies of all incoming paperwork shall accompany all items being transferred from Shipping & Receiving to RHO and shall be forwarded to the Shipping Clerk for logging.

c. The Custodian will notify the Responsible Engineer and the Area Supervisor that the material has boon received and forward any special precautions or handling instructions received from the shipper.

d. No work shall be performed on radioactive material until the "Hazards Control" form, R-52, has boon completed per the requirements of SOP I:H, Hazard Control.

e. The Responsible Engineer shall verify the item received and sign the VNC 706.

f. one copy of the signed 706 shall be forwarded to the Custodian or Shipping Clark for entry into the Shipping and Receiving Log.

g. A signed copy in returned to the shipper/originator for their records.

h. The proper loading/unloading procedure will be supplied to Operations by the Responsible Engineer before handling any customer-owned shipping containers.

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8. Special Handling Instructions

   a. A red FULL tag is to be attached to any cask or container that contains radioactive or 'COLD" samples.

   b. A white VNC EMPTY tag is to be attached to any cask that is 'empty". A notation must be made if the cask contains a bucket or other inner container.

   c. A yellow and magenta RADIATION tag is to be attached to all "FULL" casks or "EMPTY" casks with internal contamination.

   d. THIS SIDE UP stickers must be applied to all containers of liquid radioactive materials.

   e. Each contents tag must be completed and signed, as necessary, by the person knowledgeable about the condition of the cask.

   f. Nuclear Safety will release all casks for shipment outside the RHO areas.

   g. A "CP" or *PIC-6A" MUST ALWAYS be used while opening a cask regardless of the type of tag.

   h. All lid retaining bolts or similar devices must be securely in place before and during any movement of a cask,

   i. To minimize contamination, cover casks completely with paper or plastic before transferring them into a contaminated area.

   j. Empty cask shipments must comply with 49CFR173.427 for contamination levels. Actual internal contamination levels must be recorded on the appropriate shipping checksheets. A WHITE 6" x 6" DOT EMPTY LABEL SHALL BE USED ON ANY EMPTY CONTAINER SHIPPED OFF SITE.

9. Shipping Incident

   a. A radiation shipping incident is defined as any problem occurring with a shipment of radioactive material, either shipped by RHO/RMS or to RHO/RMS, that requires notification of a State or Federal licensing agency or a customer.

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b. Any RHO/RP&S personnel receiving information indicating an incident has occurred must notify the following Personnel: Manager, Nuclear Safety; Marketing (if applicable); Manager, RHO; and IP Senior Licensing Engineer or other Nuclear Safety representative.

c. Telephone call records mat be maintained of all off-site telephone communications concerning the incident.

d. RHO/RP&S will request Marketing to issue a Customer Complaint, NS to issue a Corrective Action Report (CAR), or to assure the scheduling of a formal Type I or II investigation to document the investigation of the incident.

e. RHO/RP&S will provide VNC-SR and the Specialist, Facilities Protection with an appropriate list of personnel to notify during an off-shift emergency. The Custodian will be responsible to maintain the list current.

f. The person receiving a call reporting an incident should attempt to establish:

1) Nature of problem - spill, contamination, accident, etc.
2) Determine if any or what type of assistance is needed.
3) Accurate description of problem.
4) Name of caller.
5) Company
6) Location and phone number
7) Other organization already contacted; NRC, DOT, State, etc.

10. NRC/DOT Packaging, Marking, and Labeling Requirements

The originator of the radioactive shipment, the Custodian, or alternate designated by the Manager, RHO, shall:

a. Determine the Quantity Type (e.g. Type A, Type B, fissile, etc.) of the radionuclide by reference to 49CFR Part 173, Subpart I - Radioactive Materials.

b. Determine if the item is Normal Form or Special Form per 49 CFR 173.403(s) and (z).

c. Based on the form of the material, amount (Ci), and the quantity type, determine the packaging required; i.e., cask model, 7A box, drum, other special containers.

d. The DOT/NRC package marking should then be determined by consulting as appropriate, the following:

1) 49CER172, Subpart D - Marking
2) 49CFR Section 173.24(c) DOT Specification Container Marking
3) 49CFR Section 173.425(b)(8) LSA exclusive use
4) Appropriate specific DOT specifications; 7A, 49CFR178.350, 6M, 49CFR178.104, etc.
5) U.S. NRC Certificate
6) IAEA Certificate

e. Determine hazard classification per 49CFR172.101 and Attachment II. Apply appropriate Hazard Identification Number to the package, as required.

f. Determine if material is a hazardous substance per appendix to 49CFR172.101. Apply appropriate marking as required.

g. Complete the appropriate contents approval, shipping/loading checksheets and shipping documents. Verify compliance with quality control requirements of 49CFR173.475.

h. Request NS to survey and release the container per the requirements of VSS 7.6, 'Radioactive Material Shipments and Receipts".

i. Determine which radioactive label is required per instructions on Attachments I and III and 49 CFR Part 172, Subpart E - Labeling.

j. Enter the Transport Index (TI) on the radioactive label, as required.

k. Complete the appropriate radioactive label per the instructions on Attachments IV, V, and 49CFR172, Subpart E - Labeling. Complete the appropriate portions of the shipping checksheets.

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l. Complete the appropriate areas on the shipping documents.

m. Attach the required two radioactive labels to opposite sides of the container.

n. The Custodian or alternate and the Area Manager sign the shipping document. The signing of the shipping document indicates that all checksheets are completed as required for the shipment, and that the package and contents comply with all applicable Federal and State regulations.

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ATTACHMENT I

RADIOACTIVE MATERIAL PACKAGES LABEL CRITERIA

[49CFRI72.4033] DOSE RATE LIMITS

LABEL	AT ANY POINT ON ACCESSIBLE SURFACE OF PACKAGE	AT ONE METER FROM EXTERNAL SURFACE OF PACKAGE (TRANSPORT INDEX)
RADIOACTIVE-WHITE I(1)	≤ 0.5 mRem/hr	N/A
RADIOACTIVE-YELLOW II	>0.5 ≤ 50 mRem/hr	≤ 1.0 mRem/h
RADIOACTIVE-YELLOW III(2)	> 50 ≤ 200 mRem/hr	> 1.0 ≤ 10 mRem/hr

(1) Is not a Fissile Class 11 or III and does not contain a Highway Route Controlled Quantity of radioactive material, as defined in 173.403(1).

(2) Requires Vehicle Placarding
(This label mandatory for any Fissile Class 111 [173.4173 or Highway Route Controlled Quantity (173.403(1)).

RADIOACTIVE MATERIALS MAXIMUM RADIATION LEVEL LIMITATIONS
[See 49CFR173.441]

Radiation levels (dose rate) for any radioactive materials package may not exceed:

A. 200 mRem/hour at contact on the external package surface.
B. 10 mRem/hour at 1 meter (TRANSPORT INDEX may not exceed 10).

Whenever the packages are consigned to a "SOLE USE" or "EXCLUSIVE USE" closed transport vehicle (except aircraft) the maximum radiation levels may be:

A. 1,000 mRem/hour at contact on the external package surface.
B. 200 mRem/hour at any external surface of the vehicle.
C. 10 mRem/hour at 2 meters from external lateral surface of the vehicle.
D. 2 mRem/hour in any position of the vehicle which may be occupied by a person.

The maximum radiation levels for open transport, "Sole Use", or "Exclusive Use" vehicles are:

A. 200 mRem/hour at contact an "a external package surface.
B. 200 mRem/hour at any point on the vertical planes projected from the outer edges of the vehicle, on "a upper surface of the food, and on the lower external surface of "a vehicle.
C. 10 mRem/hour at 2 motors from the vertical planes projected from the outer edges of the vehicle.
D. 2 mRem/hour in any position of the vehicle which may be occupied by a person.

ATTACHMENT II

MATERIAL

HAZARDS CLASSIFICATION

(REF. 49CFR172.101)

Proper Shipping Name	Hazard Identification No.
Radioactive Material, empty packages	UN2908
Radioactive Material, instruments and Articles	UN2911
Radioactive Material limited quantity: n.o.s.	UN2910
Radioactive Material, low specific activity, n.o.s.	UN2912
LSA, n.o.s.	UN2912
Radioactive Material, n.o.s.	UN2982
Radioactive Material, special form, n.o.s	UN2974
Radioactive Material, fissile, n.o.s.	UN2918

ATTACHMENT III

RADIOACTIVE LABELS

There are three hazardous materials warning labels used to identify a shipment of radioactive materials - RADIOACTIVE I, RADIOACTIVE II, RADIOACTIVE III. Each RADIOACTIVE label contains at the lower half a space for the shipper to add the "CONTENTS:", and the "ACTIVITY". In addition, RADIOACTIVE II AND RADIOACTIVE III include a black box which the shipper must complete with the "Transport Index: (Maximum of 50 Per vehicle or area)". The entries may be completed by legible printing, manual or mechanical, using a durable weather-resistant means of marking -

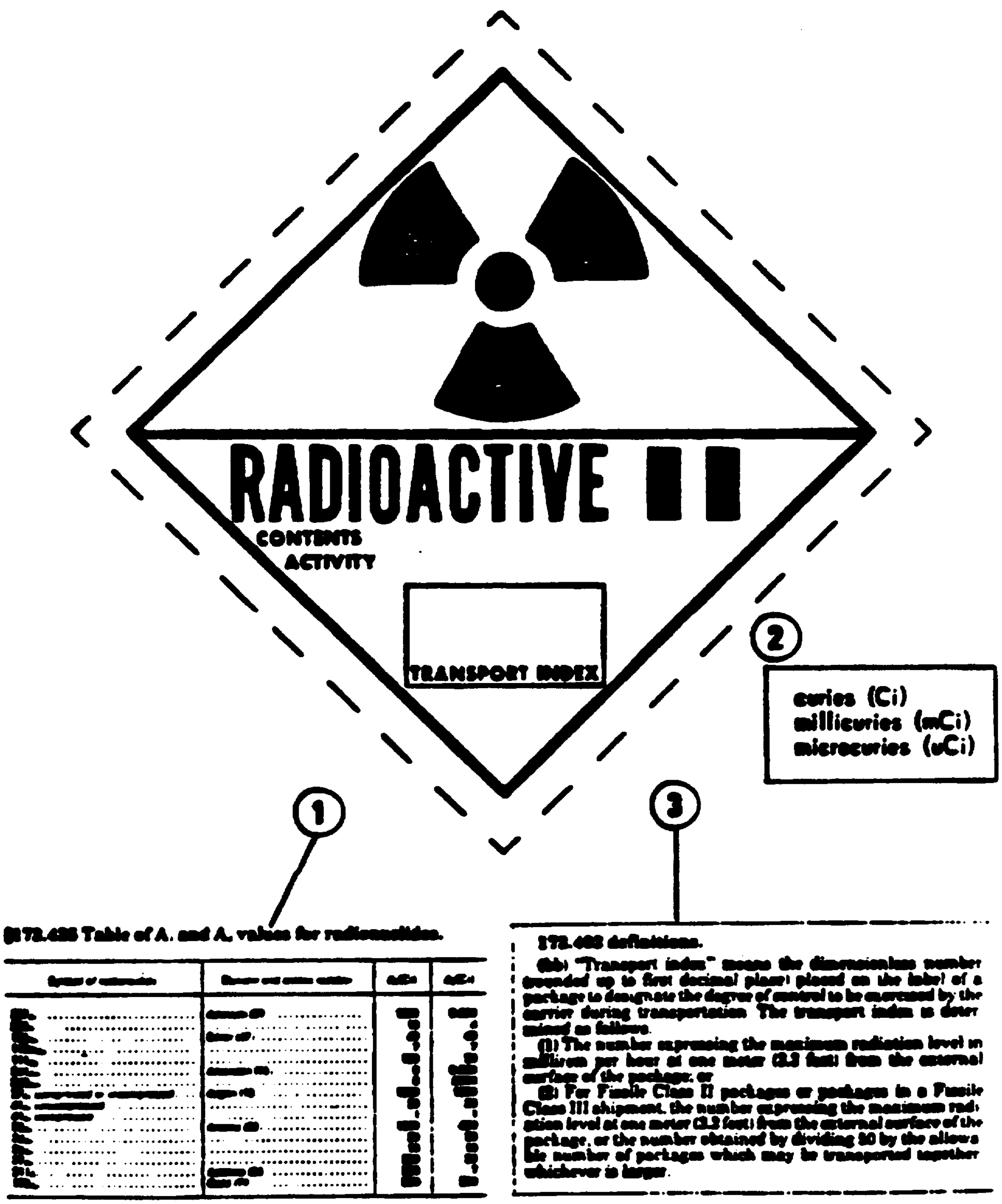
CONTENTS - Name of Radionuclides as contained in 173.435 (Symbols, "99Mo, etc" authorized). For mixtures most restrictive radionuclides based an radio-toxicity, listed as space allows)(1)

ACTIVITY - Units expressed in appropriate curie units and abbreviations authorized (for fissile Materials weight in grams or kilograms may also be inserted in addition)(2)

TRANSPORT INDEX - Designates degree of control required in transportation(3)

ATTACHMENT III (cont)

RADIOACTIVE LABELS

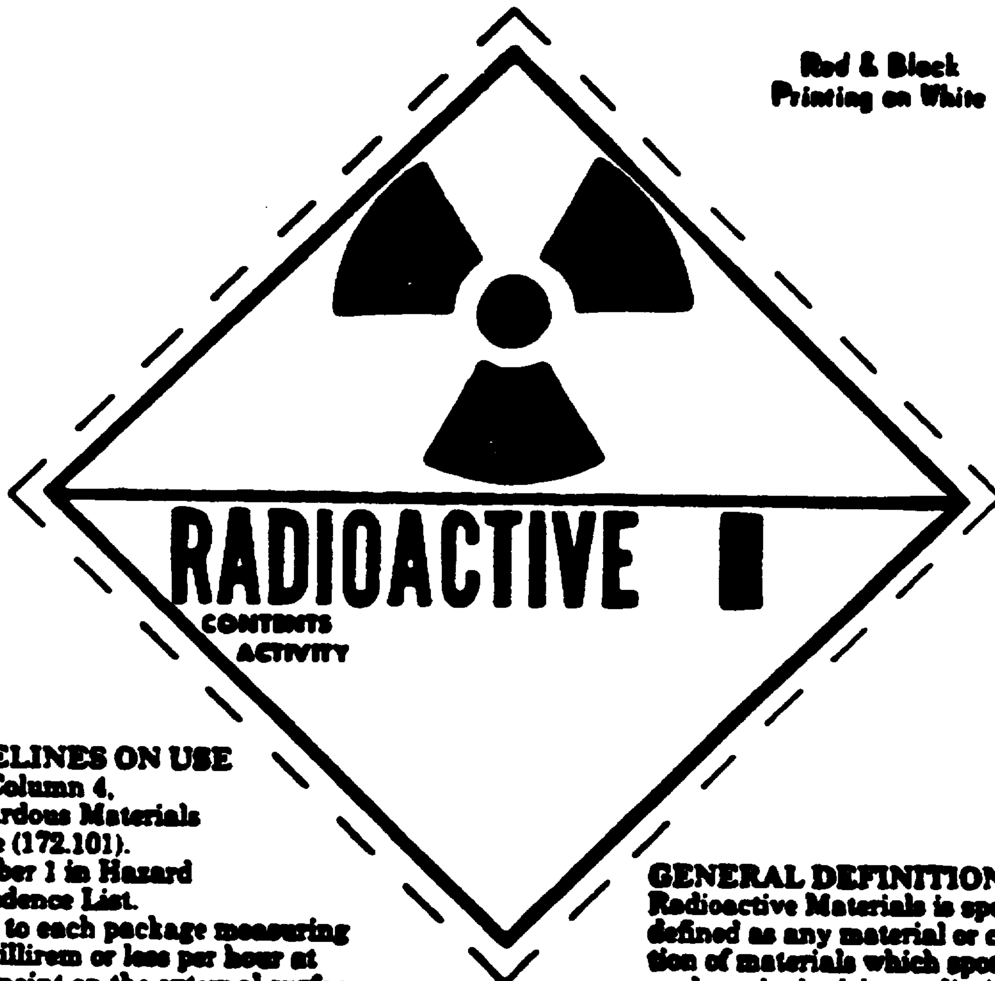


GUIDELINES ON LABELS.

RADIOACTIVE MATERIALS

RADIOACTIVE WHITE I

Red & Black
Printing on White



GUIDELINES ON USE

1. See Column 4, Hazardous Materials Table (172.101).
2. Number 1 in Hazard Precedence List.
3. Affix to each package measuring 0.5 millirem or less per hour at each point on the external surface of the package, provided package is not Fissile Class II or Class III, or does not contain a "large quantity" of radioactive material.
4. See multiple hazard and additional labeling requirements.
5. Complete "Contents" and "No. of Curies".
6. Label one on each side or both ends (excluding bottom).

GENERAL DEFINITION
Radioactive Materials is specifically defined as any material or combination of materials which spontaneously emits ionizing radiation, and has a specific activity greater than 0.002 microcuries per gram.

DIMENSIONS
Minimum size 4 inches on each side (101 mm).

U.N. Class Number - 7

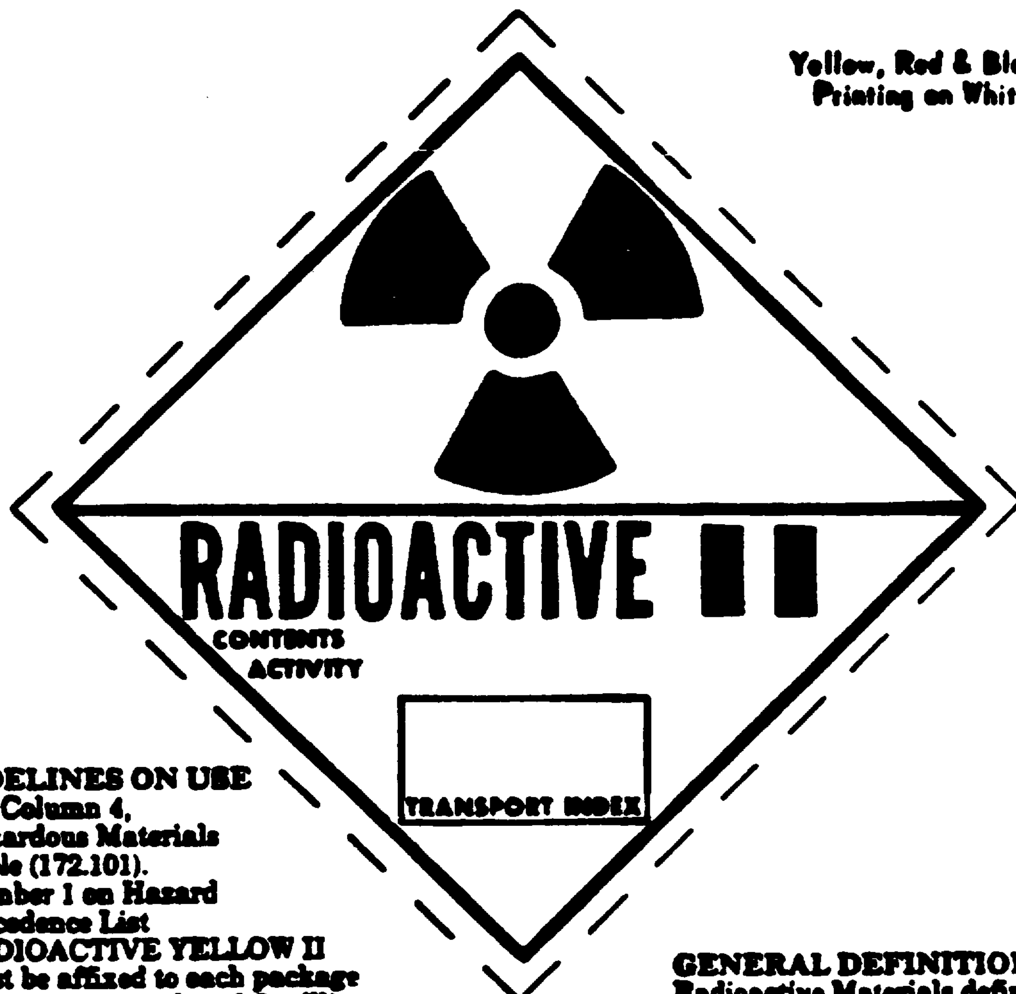
ATTACHMENT IV (cont)

GUIDELINES ON LABELS,

RADIOACTIVE MATERIALS

RADIOACTIVE YELLOW II

Yellow, Red & Black Printing on White



GUIDELINES ON USE

1. See Column 4, Hazardous Materials Table (172.101).
2. Number 1 on Hazard Precedence List
3. RADIOACTIVE YELLOW II must be affixed to each package measuring more than 0.5 millirem per hour at each point, not exceeding 1.0 millirem per hour at three feet from each point on external surface of the package, or Fissile Class II package having a transport index of 1.0 or less.
4. See Multiple hazard and Additional Labeling requirements.
5. Complete "Contents", "No. of Curies" and "Transport Index".
6. Display labels on each side or each end, excluding bottom.

GENERAL DEFINITION
Radioactive Materials defined as any material or combination of materials which spontaneously emits ionizing radiation, and has a specific activity greater than 0.002 microcuries per gram.

DIMENSIONS
Minimum size 4 inches (101 mm) on each side.

U.N. Class Number - 7

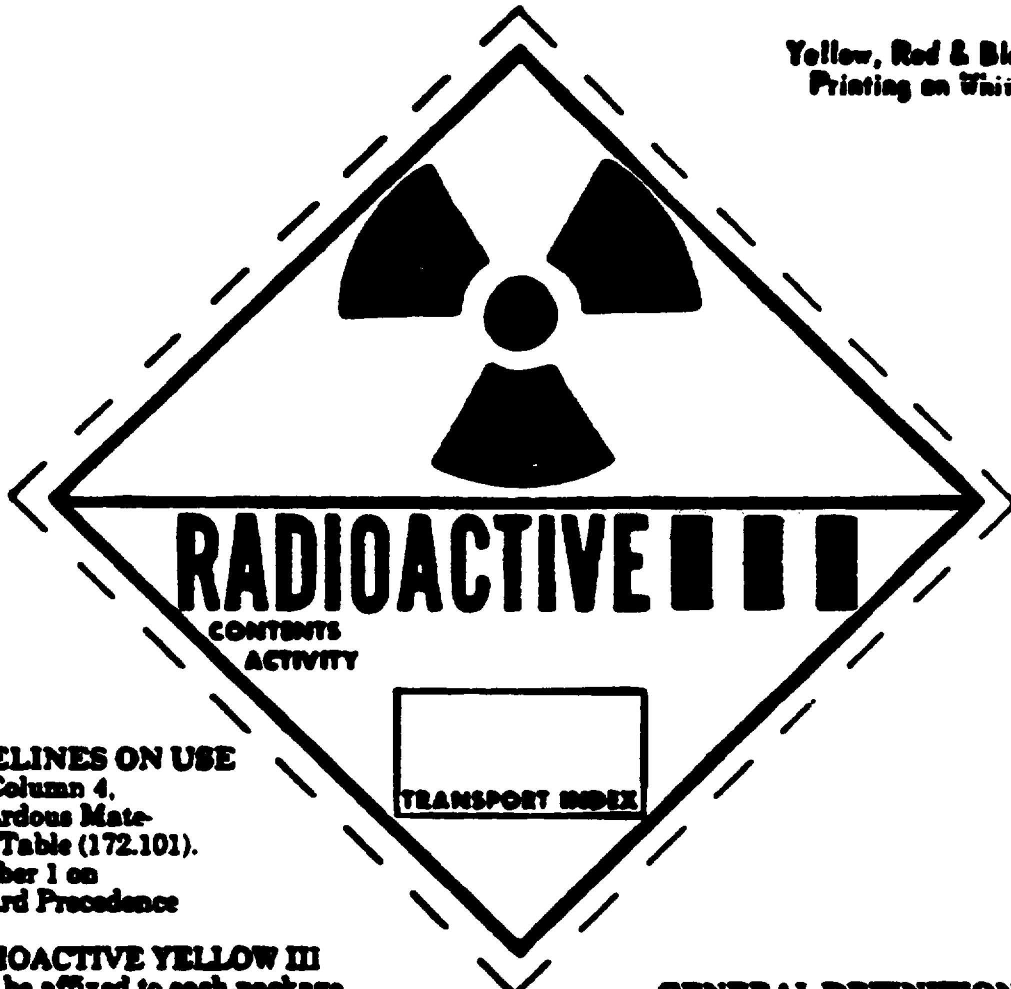
ATTACHMENT IV (cont)

GUIDELINES ON LABELS,

RADIOACTIVE MATERIALS

RADIOACTIVE YELLOW III

Yellow, Red & Black Printing on White



GUIDELINES ON USE

1. See Column 4, Hazardous Materials Table (172.101).
2. Number 1 on Hazard Precedence List.
3. RADIOACTIVE YELLOW III must be affixed to each package measuring more than 50 millirem per at hour at each point on package or exceeds 1.0 millirem per hour at three feet from each point on the external surface, or a Fissile Class III, or contains a large quantity of radioactive materials.
4. See Multiple Hazard and Additional Labeling requirements
5. Complete "Contents", "No. of Curies" and "Transport Index".
6. Display labels (total 2) on each side or on each end, excluding bottom.

GENERAL DEFINITION
Radioactive materials is defined as any material or combination of materials which spontaneously emits ionizing radiation, and has a specific activity greater than 0.002 microcuries per gram.

DIMENSIONS
Minimum size 4 inches (101 mm) on each side.

U.N. Class Number - 7

ATTACHMENT V

§172.403 Radioactive material.

(a) Unless excepted from labeling by §§173.421 or 173.425 of this subchapter, each package of radioactive material must be labeled as provided in this section.

(b) The proper label to affix to a package of radioactive material is based on the radiation level at the surface of the package, the transport index (§173.403 of this subchapter) and, if appropriate, the fissile characteristics of the package. The proper category of label shall be determined in accordance with paragraph (c) of this section. The label to be applied shall be the highest category required for any of the three determining conditions for the package. Radioactive White-I is the lowest category and Radioactive Yellow-III is the highest. For example, a package with a transport index of 0.8 and a maximum surface radiation level of 60 millirem per hour which contains no fissile material must bear a Radioactive Yellow-III label.

(c) Category of Label to be Applied to Radioactive Materials Packages.

[illegible]	[illegible]	[illegible]	[illegible]
0	[illegible]	[illegible]	White-I
0<TI≤1.0	[illegible]	[illegible]	Yellow-II
1.0<TI	[illegible]	[illegible]	Yellow-III

[illegible] §173.403 [illegible]

(d) [Reserved].

(e) Each package containing a radioactive material that also meets the definition of one or more additional hazards must be labeled as a radioactive material as required by this section and for each additional hazards. For example

(1) Packages containing the solid nitrates of uranium or thorium must be labeled RADIOACTIVE and OXIDIZER.

(2) Packages containing nitric acid solutions of radioactive material must be labeled RADIOACTIVE and CORROSIVE.

(f) Each package required by this section to be labeled with a RADIOACTIVE label must have two of these labels, affixed to opposite sides of the package. (See §172.[illegible] for freight container label requirements.)

(g) The following applicable items of information must be entered in the blank spaces on the RADIOACTIVE label by legible printing (manual or mechanical) using durable weather resistant means of marking.

(1) "Contents." The name of the radionuclides as taken from the listing of radionuclides in §173.435 (symbols which conform to established radiation protection terminology are authorized i.e., Mo, Co, etc.) For mixtures of radionuclides, the most restrictive radionuclides on the basis of radiotoxicity must be listed as space on the label allows.

(2) "Activity." Units shall be expressed in appropriate curie units, i.e., curies (Ci), millicuries (mCi) or microcuries (µCi) (abbreviations are authorized). For a fissile material the weight in grams or kilograms of the fissile radioisotope also may be inserted.

(3) "Transportation index." (See §173.403.)

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REVISION 1

APPROVED: MANAGER RADIOACTIVE PRODUCTS AND SERVICES; DATE: 6-13-84

REVIEWED: SQ; MGR. NS; QA; INDUST. SAFETY

REVIEWED: SOP REVIEW DATE CHANGED; MGR. RHO; ANALYST

DMF REVISION: NO / YES; BY: EQUIP. ENGRG 6/8/84; MGR. RHO

CHAPTER:	SECTION:
III. SHIPPING AND RECEIVING	R. Loading and Unloading of Fuel Casks

1. Introduction

Fuel rods and encapsulated fuel rods of various sizes are transferred in assorted GE and customer-owned containers in the RP&S. This procedure outlines the steps for the safe handling of fuel rods and capsules and will apply to the containers used by RP&S.

2. Purpose

To define the requirements for loading and unloading casks containing fuel rods and to assure compliance with RP&S and/or customer handling requirements.

3. Special Requirements

a. Applicable portions of SOP III:B, "Shipping and Receiving of Radioactive materials" will apply.

b. Applicable portions of SOP III:U, "G.E. Models 100, 200, and 300 Cask Transfers" will apply.

c. Applicable portions of SOP I:J, "Personnel Working in Corridor Areas" will apply.

d. Instructions contained in Radioactive Materials Services (RMS) Detailed Work Plans will be followed.

e. Before shipping/receiving any SNM material into or out of RP&S, check the Locator, Area CLA log, and all shipping papers to assure the receiving CLA area and/or shipping container can accommodate the fissile gram loading.

f. **The Model 300 series casks we used for on-site transfers only.**

g. Customer owned casks requiring special loading/unloading techniques will be covered by an approved procedure or instruction.

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h. Verify with the Custodian that state license requirements for by-product material have not been exceeded.

i. Do not accept any shipment without proper documentation; i.e., NED Form 48 and VNC-706.

j. "Cask Shipping Checksheet", R-8, is a permanent record; all critical steps must be initialed and verified.

4. General Unloading Procedure

a. The responsible RMS Engineer will request the cask transfer using Form R-49, "Request for Transfer".

b. Corridor technicians will transfer the cask to be unloaded into the requested cell interlock. Dose rates will be monitored while operating the interlock doors.

c. Remove all lid bolts. Place bolts on tray in lock or other acceptable location. Wipe crane hook with massolin cloth and attach hook to cask lid eye as required. Close outer door of interlock.

d. Observe quantity of fuel rods or capsules and verify amount with the "On-Site Radioactive Transfer Record and Checklist", VNC-706, or other receiving document such as the NED Form 48. Verify that cell CLA has fissile capacity to receive rods.

5. The 310 Cask Unloading

a. Remotely remove extension using the crane in the interlock.

b. Verify the quantity of rods with the shipping papers.

C. Open inner doors of call interlock. Stop door at the required height.

d. Use the extended reach interlock manipulator to raise each rod or capsule individually from the cask cavity to a point where both interlock manipulators can be used. Use the PAR or GM to unload heavy items such as NTR paddles.

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e. Securely grasp the rod or capsule with the second manipulator and continue to raise the item until it is clear of the cask cavity. **Do not drop, bend or damage fuel rod or capsule.**

f. The item can now be tilted toward the cell. The upper end will be placed on the cell deck.

g. The rod or capsule is moved into the cell by sliding It along the deck. Identify the rod or capsule. Record on appropriate checksheet or in project logbook.

h. After the majority of the rod or capsule is in the cell, unlock the interlock manipulators. Complete the transfer using the cell manipulators.

i. Repeat unloading until all rods or capsules have been unloaded. Make appropriate entries in the Locator.

j. Replace lid on the cask. Close the interlock inner doors. **Make sure no equipment is in path of door.**

k. Verify the position of each rod and/or capsule identification number using the Kollmorgen as necessary. Have the identification numbers verified by the responsible Engineer and sign NED Form 48 and/or the VNC-706.

6. <u>The 2000/1600/600 Cask Unloading</u>

a. Remove cask lid using the interlock crane.

b. In most cases when the 2000, 1600, or 600 series cask is used to transfer rods, there will be a spacer or holder for the rods in the cask cavity.

c. Verify the quantity of rods with the shipping papers.

d. The responsible Engineer or a second technician should be present for verifying during fuel rod unloading.

e. Using the interlock extend-reach manipulator, lift a single rod to a point where both interlock manipulators can be used.

f. With both interlock manipulators securely locked onto the rod, raise It until the holder-spacer has been cleared. **Do not drop, bend, or damage fuel rods or capsules.**

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g. Tilt the rod toward the cell and position the upper end over the cell deck.

h. Lower the rod until the upper end is resting on the cell deck.

i. Using the interlock manipulators, slide the rod into the cell until at least 3/4 of the rod length is on the deck.

j. Release interlock manipulators. Transfer the rod into the cell with the cell manipulators.

k. Each rod should be identified and its location in the holder/spacer verified before removal of the next rod.

l. Area and location fields on the Locator sheets should be completed as the rods are stored.

m. Repeat unloading until all rods have been unloaded.

n. Replace lid on cask and close interlock inner door.

o. Verify the position of each rod and/or capsule identification number using the Kollmorgen as necessary. Have the identification numbers verified by the responsible Engineer and sign NED Form 48 and/or the VNC-706.

7. General Loading Procedure

a. Corridor technicians will transfer the cask to be loaded into the requested interlock. Dose rates will be monitored while operating the interlock doors.

b. Remove all lid bolts. Place bolts on tray in lock or other acceptable location. Use massolin cloth to clean crane hook and attach hook to cask lid eye as required. Close the door to lock.

c. All necessary paperwork must be completed for on- or off-site shipments, NED Form 374, NED 48, or VNC-706.

d. All lid bolts, gaskets, and cask components must be inspected and defective parts replaced for all off-site shipments in RP&S and customer-owned containers.

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III. SHIPPING AND RECEIVING	R. Loading and Unloading of Fuel Casks

8. <u>310 Cask Loading</u>

   a. The 310 cask is used only for on-site transfers of encapsulated fuel rods or unencapsulated fuel rods located in an NTR holder (paddle). Check internal cask contamination level.

   b. All encapsulated rods must be identified and verified by the responsible Engineer prior to loading.

   c. All necessary paperwork must be completed before loading begins; i.e., VNC 706, NED 48ts, as required for on-site transfers.

   d. Open inner cell door. Remove extension from 310 cask with interlock crane. Encapsulated rods can be loaded singly using the cell and interlock manipulators.

   e. Clean the rods thoroughly using damp absorbent pads. Clean the cell deck thoroughly.

   f. With the cell manipulators, slide the capsule along the deck toward the open interlock until sufficient portion of the capsule is in position for safe handling with interlock manipulators. Heavy items may require using the PAR/GM.

   g. Firmly and securely grasp the capsule with interlock manipulators and lock in place. The cell manipulators can now be released.

   h. Slide the capsule into the interlock to a position over the 310 cask.

   i. Carefully lower the capsule into the cask cavity.

   j. Repeat until all capsules to be shipped are loaded.

   k. Position the extension over the top of the loaded capsules with the interlock crane.

   l. Using extreme care not to bind any existing bales, lower the extension until the tops of all capsules are safely inside the extension cavity. Continue lowering until the extension rests securely on the 310 cask.

   m. When loading an NTR holder with fuel rods, use the same basic procedure; however, in this case the assistance of a second technician and the PAR-General Mills may be required.

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n. Close interlock doors and notify the corridor crew that the cask is loaded and ready to remove and transfer.

o. Make all appropriate Locator changes.

9. <u>2000/1600/600 Cask Loading</u>

a. The 2000, 1600 or 600 series cask is usually used when unencapsulated rods are to be shipped off-site and a spacer-holder will be used to contain the rods within the cask cavity.

b. Clean the exterior surfaces of the fuel rod thoroughly with damp absorbent pads. Clean cell deck work area.

c. Detailed loading instructions normally will be provided by the responsible Engineer for 2000, 1600 and 600 series cask fuel rod loading.

d. Make all appropriate Locator changes.

10. <u>Liner Transfers - Cell, Pit, Hillside</u>

a. The responsible RMS Engineer will supply the identification of the items to be stored.

b. The responsible Engineer should verify the identification prior to loading the item into the liner.

c. The exterior surfaces of the fuel rods and capsules, or irradiated hardware should be cleaned with damp absorbent pads. The cell deck work area must also be cleaned.

d. The liner must be properly identified with a number from the Container Logbook. The identification number is supplied by the Area Supervisor or Custodian.

e. Delete the transferred items from the CLA Log Sheet and make the appropriate Locator changes. Initial all entries and changes.

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III. SHIPPING AND RECEIVING	R. Loading and Unloading of Fuel Casks

f. Notify the Area Supervisor or Custodian of the fissile gram loading in the liner so the required changes can be made on the Pit or Bunker CLA sheet. The maximum amount of fissile material per liner is 300 grams.

g. If a full liner is being received in a cell, verify the receiving CLA can accept the fissile amount before transfer is made.

h. Make the necessary changes in the CLA sheets of the Locator to reflect new amounts.

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REVISION 1

APPROVED: MANAGER RADIOACTIVE PRODUCTS AND SERVICES; DATE: 5/21/81

REVIEWED: ☐ MGR. SQ; ☒ MGR. NS; ☒ MGR. OA; ☐ INDUST. SAFETY

REVIEWED: SOP REVIEW DATE CHANGED ☒ 9/26/85; ☒ Mgr. SQ; ☒ MGR. RHO; ☒ ANALYST

DMF REVISION ☒ NO ☐ YES; BY: ☒ MGR. EE 3/5; ☐ MGR. IPM; ☒ MGR. PDAS

CHAPTER:	SECTION:
VIII. QUALITY CONTROL	F. Safety Related Material Control

1. Purpose

To establish control requirements for the safety related components used in Type B radioactive materials shipping packages.

2. Applicability

a. This procedure applies to the safety related components under QAP-1, "Quality Assurance Program for Shipping Packages for Radioactive Material" and NRC 10CFR21.

b. This procedure applies only to the materials and components received and used by RP&S for Type B shipping packages.

3. Definition of Safety Related Materials

Safety related materials are components or materials used during the fabrication or assembly of Type B packaging described by the "Quality Assurance Program for Shipping Packages for Radioactive Material" (QAP-1), that are defined as safety related components, by RP&S Engineering in the Quality Attribute Specifications or other RP&S approved procedure.

4. Material Control Documents

a. Material Specifications
b. Material Requests (MR)
c. Drawings
d. Material Logbook
e. Purchase Orders (P.O.)
f. Inspection Reports (IR)
g. Type B Packaging Maintenance/Inspection Checksheet, R-9

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CHAPTER:	SECTION:
VIII. QUALITY CONTROL	F. Safety Related Material Control

h. Engineering Release (ER)

i. Operation Request Form (ORF)

j. Quality Attribute Specifications

5. Material Procurement

a. Materials are ordered on a Material Request (MR) according to the appropriate Quality Attribute Specification. A copy of the specification should accompany the MR.

b. A "Q" is placed in the inspection block on the MR to indicate a Quality Assurance (QA) review is required prior to purchasing.

c. The MR is reviewed and approved by the responsible RP&S Manager.

d. When noncommercial grade Items are ordered the MR shall be marked with the words, "The provisions of NRC 10CFR21 apply to this order".

e. The Remote Handling Operation (RHO) shall be responsible for entering the material requested in the Material Logbook located in the Shipping Office.

f. The Material Logbook is used to assign a sequential serial number to the Item that may be used in item identification. The Material Log Number should be assigned prior to sending the MR to QA.

g. The MR is forwarded to IPO-Quality Assurance for review and approval.

h. Any changes made by QA shall be done only with the concurrence of the requestor.

i. After QA approval, the MR is processed per appropriate Finance and Purchasing procedures.

6. Receipt and Storage

a. Purchased materials are delivered to the RP&S Receiving Area and held in quarantine pending inspection.

b. The RHO will be responsible for recording the Material Log Number and the material description on the package/container.

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CHAPTER:	SECTION:
VIII. QUALITY CONTROL	F. Safety Related Material Control

c. The RHO shall perform a visual inspection of the container for obvious damage and notify QA immediately if the container is damaged.

d. The RHO will notify QA that materials have arrived and are ready for receiving inspection. The material requestor will prepare an Engineering Release (ER) requesting QC to perform the receiving inspection.

e. QC shall inspect materials per QAI-1056, "Receiving Inspection".

f. After the receiving inspection is complete, RHO will record the quantity of approved material in the Material Logbook and file a copy of Purchase Order and Inspection Report (IR) in the appropriate Engineering file.

g. RHO will prepare an Engineering Release (ER) and a copy of the IR to transfer the bulk items (Materials such as tubing, angles, plates, etc. required for parts fabrication) to the controlled Storage Area in the 106 Shop.

h. The RHO will transfer the prefabricated approved material to the RP&S Controlled Storage Area. Each storage location (box, crate, bin, cage, etc.) will be identified with the material description and/or the Material Log Number.

7. Release of Materials

a. An inspection resulting in the need to replace a safety related component will result in the preparation of a "Type B Packaging Maintenance/ Inspection Checksheet", R-9, by the Analyst/Custodian or the designated alternate.

b. The Area Supervisor may release material from controlled storage only when authorized in writing with the "Type B Packaging Maintenance/Inspection Checksheet", R-9 or an approved ORF/ER.

c. The Area Supervisor will permit removal of the specified materials from the controlled area, only by the bearer of an approved "Type B Packaging Maintenance/Inspection Checksheet", R-9.

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VIII. QUALITY CONTROL	F. Safety Related Material Control

d. Materials stored in the 106 Shop controlled Area shall be released using an ER. The ER will receive QA/QC approval prior to fabrication of an item.

e. Before returning unused material to controlled storage, QA must perform inspection of the material per QAI-1056 and the appropriate specification.

f. A copy of the Inspection Report will be filed, and an entry will be made in the Materials Logbook stating quantity returned.

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IRRADIATION PROCESSING OPERATION
RADIOACTIVE PRODUCTS AND SERVICES OPERATING PROCEDURE

REVISION 0

APPROVED — MANAGER RADIOACTIVE PRODUCTS AND SERVICES — DATE: 10/29/80

REVIEWED — MGR. SQ — MGR. NST — MGR. OR — INDUST. SAFETY

REVIEWED — SOP REVIEW DATE CHANGED: — MGR. RHO — ANALYST

DMF REVISION — NO — YES — BY: — MGR. EE — MGR. IPM — MGR. PD&S

CHAPTER:	SECTION:
XVII. CASK/FIRESHIELD MAINTENANCE	B. Cask Ear Bolts

1. Purpose

To describe the measurement and replacement activities for the high strength cask ear bolts.

2. Applicability

This procedure and the following drawings are applicable to the ear bolts for the Model 200, 600, 1600 and 2000 casks:

Model	Drawing No.	Nominal Bolt Size
200	129D4560 P3	3/4"10 x 3 in.
600	212E247 P6	1"8 x 2-3/4 in.
1600	212E255 P23	1"8 x 2-3/4 in.
2000	129D4891	14 x 4-1/4 in.

3. Special Requirements

a. Activities involving the high strength cask ear bolts shall be performed following the requirements of RP&S Quality Attribute Specification No. 22A9289.

b. The routine inspections shall be documented on the "Cask Shipping Checksheet", R-8.

c. The annual measurement operation and/or replacement activities shall be documented on the "Type B Packaging Maintenance/Inspection Checksheet", R-9, and recorded in the Cask PM Logbook.

d. The length of the in-service high strength cask ear bolts shall be measured once each year or during assembly, whichever comes later

*Per RP&S OCN 938 **Per RP&S OCN 980

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CHAPTER:	SECTION:
XVII. CASK/FIRESHIELD MAINTENANCE	B. Cask Ear Bolts

4. Equipment

   a. GO-NO-GO length gage.

   b. ASTM-A-193 Grade B6 bolts.

   c. Lid bolt wrench.

5. Preparation Procedure

   a. Decontaminate the outside of the cask to less than 5000 cpm smearable contamination (total area) as determined with an HP-210 probe.

6.* 600/1600/2000 Routine Inspection

   a. Visually inspect the bolts in the installed condition for:
      1.) obvious damage/defects.
      2.) ASTM Grade No. B6.

   b. Initial the appropriate item on the "Cask Shipping Checksheet", R-8 for acceptable bolts.

   c. If bolts are not acceptable, record reason for non-acceptance on the Checksheet, initial entry, and obtain replacement bolts from the Area Supervisor.

7.* 600/1600/2000 Routine Inspection

   a. Carefully remove the four bolts of one cask ear or obtain the redundant cask ear/bolts from the 7A storage container located in the High Radiation Quarantine Area.

*Per RP&S OCN 938

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XVII. CASK/FIRESHIELD MAINTENANCE	B. Cask Ear Bolts

7.* 600/160o/2000 Annual Inspection (continued)

b. Record the serial number and the calibration date of the GO-NO-GO gage on the "Type B Packaging Maintenance/Inspection Checksheet", R-9.

c. Visually inspect each bolt for proper ASTM grade identification, obvious wear, corrosion, or mechanical damage to the bolt shank or threads.

d. Pass each bolt through the GO-NO-GO gage.

e. Record the bolt serial number and results of the GO-NO-GO test on the R-9 Checksheet.

f. Obtain replacement bolts from the Area Supervisor for any bolt failing the GO-NO-GO test.

g. Repeat the inspection for each cask ear and/or redundant ear.

h. Discard all reject bolts to radioactive waste.

8. Model 200 Routine Inspection

a. Obtain the redundant ear bolts from storage/shipping container.

b. Visually inspect the bolts for obvious damage/defects and the ASTM grade No. B6 identification markings.

c. Initial the "Cask Shipping Checksheet", R-8, for acceptable bolts.

*Per RP&S OCN 938

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XVII. CASK/FIRESHIELD MAINTENANCE	B. Cask Ear Bolts

8. Model 200 Routine Inspection (continued)

   d. Record reason for non-acceptance on the Checksheet and obtain the replacement bolts from the Area Supervisor.

   e. Discard all reject bolts to radioactive waste.

9. Model 200 Annual Inspection

   a. Obtain the redundant ear bolts from the storage/shipping container.

   b. Record the serial number and the calibration date of the GO-NO-GO gage on the "Type B Packaging Maintenance/Inspection Checksheet", R-9.

   c. Visually inspect each bolt for proper ASTM grade identification, obvious wear, corrosion, or mechanical damage to the bolt shank or threads.

   d. Pass each bolt thru the GO-NO-GO gage.

   e. Record the bolt serial number and the results of the GO-NO-GO test on the R-9 Checksheet.

   f. Obtain replacement bolts from the Area Supervisor for any bolt(s) failing the GO-NO-GO test.

   g. Discard all reject bolts to radioactive waste.

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XVII. CASK/FIRESHIELD MAINTENANCE	B. Cask Ear Bolts

10. Assembly/Documentation

a. Re-install the cask ears using the original or replacement high strength bolts or store the bolts in the redundant ear storage/shipping container.

b. Tighten the ear abolts with the lid bolt wrench.

c. Return the completed Checksheets to the Area Supervisor for review.

d. Record replacement and/or R-9 activities in the Cask PM Logbook-Initial and date the entry.

e. The Area Supervisor shall review and sign/initial the Checksheet and/or Logbook entries.

f. The "Cask Shipping Checksheet", R-8 shall be filed in the customer shipping file; the "Type B Packaging Maintenance/Inspection Checksheet", R-9, shall be filed in the cask file.

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RADIOACTIVE MATERIALS SERVICES
REMOTE HANDLING OPERATIONS
STANDARD OPERATING PROCEDURE

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REVISION 1

APPROVED: Manager, ☐ Radioactive Mat'ls Services ☒ Remote Handling Operation
DATE: 7-24-87

REVIEWED: ☐ SG ☒ MGR. NE ☒ QA ☐ INDUST. SAFETY

REVIEWED: ☐ ☒ MGR. RHO ☐

DRRF REVISION ☒ NO ☐ YES
BY: ☒ EQUIP. ENG'G 7/24/87 ☒ MGR. RHO 7/24/87 ☐

CHAPTER: XVII. CASK/FIRESHIELD MAINTENANCE

SECTION: D. Metal Fireshield Inspection

1. Purpose

To describe the inspection activities for the metal protective jackets (fireshields).

2. Applicability

This procedure is applicable to the following cask models:

Cask Model	Jacket Drawing No.
100	706E578
200	706E788
400	277E411
500	706E790
600	161F470
700	289E647
900	277E409
1000	161F479
1100	277E416
1400	277E412
1500	706E792
1600	174F237
2000	129D4891

3. Special Requirements

a. Routine and annual inspections shall be documented on the "Fireshield Checksheet", R7, and the "Type B Packaging Maintenance/Inspection Checksheet", R9, respectively.

b. Replacement activities shall be documented on the R9 checksheet and should be recorded in the Cask PM Logbook.

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ISSUED BY: J. I. Tenorio | DATED: 12/19/80 | REVIEW DATE 7/89

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CHAPTER:	SECTION:
XVII. CASK/FIRESHIELD MAINTENANCE	D. Metal Fireshield Inspection

c. Routine inspections are performed prior to each assembly. Annual inspections are performed prior to assembly, every twelve months, or prior to shipment, whichever comes later.

d. Inspection and repair/replacement of fireshield components shall be performed following the applicable procedure listed in SOP Chapter XVII, Cask/Fireshield Maintenance.

e. The requirements of SOP VII:F, "Safety Related Material Control" shall apply.

4. Inspection Procedure

a. Determine the smearable and/or fixed contamination level. Contact the Area Supervisor and/or Nuclear Safety to evaluate smear results.

b. All smearable and fixed radioactive contamination must be removed prior to shipment.

c. Visually inspect the metal fireshield for indications of damage.

1) Signs of excessive heat or fire
2) Punctures, holes, or other surface failures
3) Crushed sides or ends indicating a package drop or severe impact.
4) Defects resulting from normal or abnormal wear.

d. Record the inspection results on the appropriate checksheet.

e. Inspect the fireshield components - skirt, nameplate, paint, bolts, nuts, and anti-tiedown cover - per the applicable procedure listed in Chapter XVII.

f. Document the inspection activities on the appropriate checksheet and in the logbook, if applicable.

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CHAPTER:	SECTION:
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5. Repair/Replacement Procedure
   a. Repair or replace the identified items/conditions per the requirements of the applicable procedure.
   b. Any damage recorded per the inspection of 4.c, shall require the initiation of a Deviation Report (DR) and the convening of a Material Review Board (MRB) .
   c. Any such damage shall also require notification of the Senior Engineer, Licensing, Manager, RMS, and the Manager, RHO facilities.

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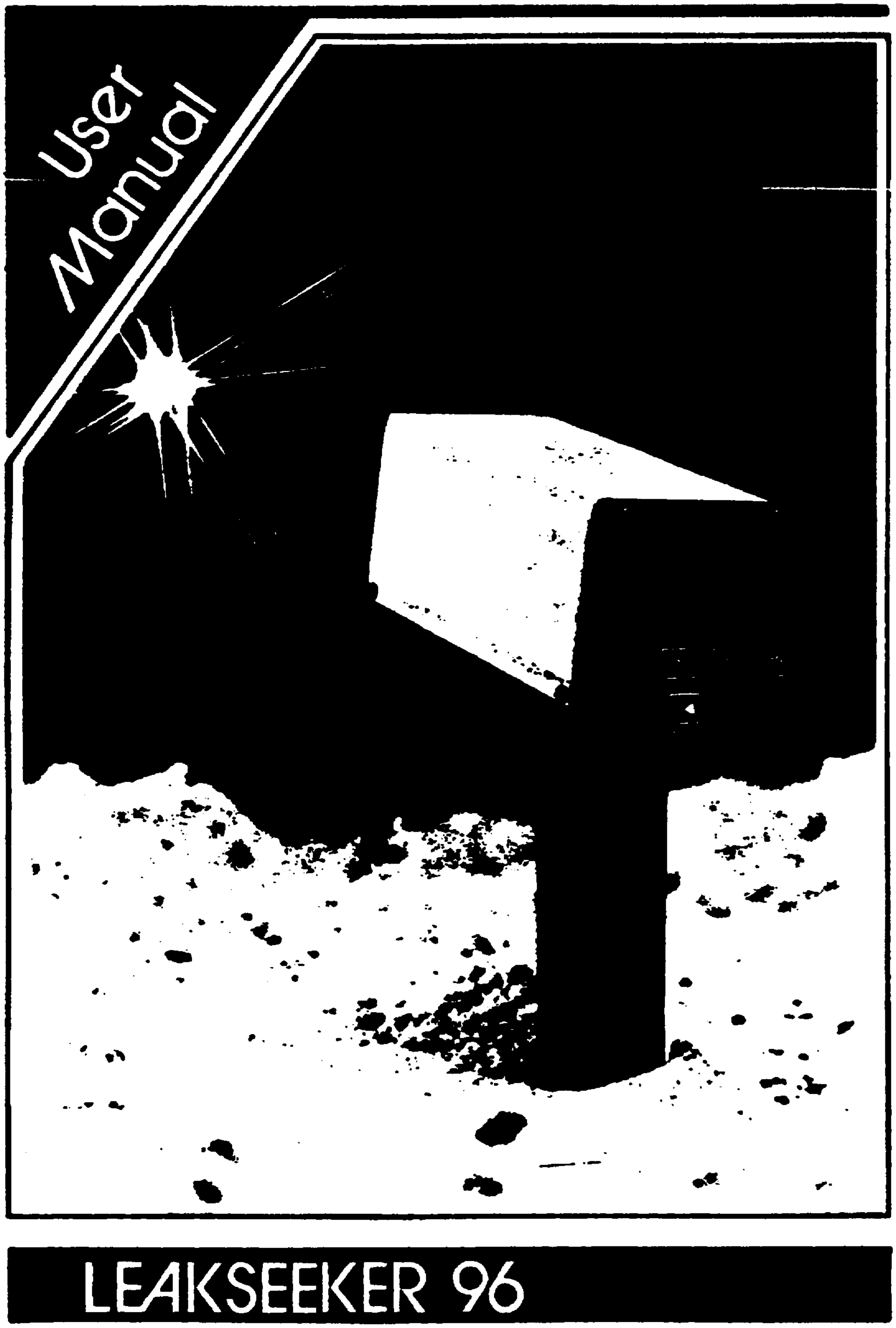
7.4.2 Thermal Conductivity Sensing Instrument



Excerpts from the Leakseeker 96 User Manual

Specifications

Detector: Micro volume thermal conductivity cell

Detects: Any gas with a different thermal conductivity to reference ambient stream (air).

Response Time: Less than 1 second

Recovery Time: 1 second

Audio: Fixed volume, variable frequency audio; loudspeaker mounted in gun housing

Diagnostic: Battery low indication; detector cell failure alarm

Sensitivity

The instrument is sensitive to any gas stream having a thermal conductivity different from the ambient air in which the instrument is being used. The sensitivity of the equipment is mainly dependent on the ratio of the thermal conductivity of the gas coming from the leak and the thermal conductivity of air. A table of typical responses of some of the more common gases is given below.

Gas	Response Sense (Automatically Displayed)	Typical Leak Rate, atm. cc/sec (Max. Resolution) With Outer Probe Removed
Hydrogen	Positive	8.3×10^{-6}
Helium	Positive	1.0×10^{-5}
Methane	Positive	2.6×10^{-5}
Carbon Dioxide	Negative	3.5×10^{-5}
Freon-R12	Negative	1.2×10^{-5}

8. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The acceptance tests and maintenance program for the Model 2000 Transport Package included here, consolidated the information presented in the corresponding chapters of the various Model 2000 Safety Analysis Reports. Specifically, Chapter 8 of this Report has been combined with the Chapter 8's of the HFIR Fuel (NEDO-32229), the 2000 Watt (NEDO-32318), and the MTR-Type Fuel (NED0-32408) applications.

8.1 ACCEPTANCE TEST

The inspection and acceptance tests are specified in the fabrication specifications and engineering drawings for the Model 2000 Transport Packaging and are governed by GE Quality Assurance Program QAP-1. QAP-1 has been approved by the NRC (Docket Number 71-0170).

8.1.1 Visual Inspection

Visual examinations of all welds and dimensions are conducted during fabrication. In addition, all welds within the cask containment boundary are liquid penetration tested (root and final passes); also, the welds forming the toroidal shell are 100% radiographed. These inspections are performed to insure no cracks, incomplete fusion or lack of penetration exist. Parts that do not meet the established criteria are repaired or replaced in accordance with written procedures. Nondestructive examination (NDE) procedures and acceptance standards are based on the ASME Code, Section 111, Subsection NG. The above criteria applied to the fabrication of packaging serial number (S/N) 2001. All future fabrication will meet the requirements of the ASME code, Section III as follows:

<u>Cask assembly including ears</u>:

- Materials per NB-2000, Certification NCA-3800
- Fabrication per NB-4000
- NDE per NB-5000
- Pressure testing per NB-6000

The following components of the cask assembly will be excluded of the above requirements:

- Shielding lead and its installation
- Elastomers
- Seals and test port components
- Electro-polishing
- Miscellaneous equipment like name plate and its screws, honeycomb, and thread inserts.

Overpack assembly:

- Materials per NF-2000
- Fabrication per NF-4000
- NDE per NF-5000

Support Structures for Criticality:

- Materials per NG-2000
- Neutron Absorbing Materials - Electron beam techniques and neutron radiography are performed to establish concentration and distribution of Boron- 10 in the material to verify compliance with the criteria given in Chapter 6.
- Fabrication per NG-4000
- NDE per NG-5000

8.1.2 Structural and Pressure

The inner and outer cylinder welds of the cask are leak tested with a helium Mass Spectrometer Leak Detector (MSLD) by surrounding the cask with He and evacuating the plenum or by pressurizing the lead region of the cask and sniff all cask body welds. These test methods have a minimum sensitivity level of 10^{-6} atm cm^3/s. If any helium is detected above the minimum sensitivity, the failed weld area will be located, repaired, and reinspected.

In addition to the above test, the cask cavity is hydrostatically tested, to ensure that it is tight, per the requirements of NB6200, Subsection NB, Section III of the ASME Code. The test pressure is 45 psia.

8.1.3 Leak Tests

The assembled cask is leak tested by pressurizing the cavity to 15 psig with helium. Leak testing of the vent and drain plugs as well as the lid seal is performed using a MSLD with a sensitivity of <1 x 10^{-9} atm cc/sec. The lid seal is tested by connecting the test probe to a test port between the two seal rings of the seal and determining the leak rate. A leak-tightness criterion of 10^{-7} atm cm^3/s or less based on dry air at 25ºC and for a pressure differential of 1 atm is used. If the leaktightness criterion is not met, a new seal will be tested.

8.1.4 Component Tests

8.1.4.1 Valves, Rupture Discs, and Fluid Transport Devices

Component tests of valves, rupture discs and/or fluid transport devices are not applicable, since these parts do not exist in the Model 2000 packaging design.

8.1.4.2 Seal Testing

The procedure for testing the seals is based on ANSI 14.5-1977, "Standard for Leakage Tests on Packages for Shipment of Radioactive Materials". The seal material is tested under normal, high and low temperature environments. The temperatures are 70°F, 400°F and -40°F, respectively. The seal material is mounted in a test flange and leak tested with a MSLD. Seal material exceeding the allowable leak rate is rejected. The test seal/flange joint used for the tests is scaled by matching the force per inch on the seal, and the flange stiffness so they are the same as for the actual joint. Results of the initial seal qualification tests are presented in Subsection 4.4.1.

8.1.4.3 Honeycomb Testing

The honeycomb energy absorber is tested in accordance with military specification MIL-STD-401B, Sandwich Constructions and Core Materials, General Test Methods.

The test procedure determines the compressive properties of the honeycomb material in the direction normal to the plane of facings. The test produces a load deformation curve, and from this curve the compressive stress at proportional limit load is computed. If the honeycomb material does not meet the required crush strength, the material will be rejected.

8.1.5 Shielding Integrity Test

The lead shielding is inspected for integrity by placing a cobalt source inside the cask and surveying the outside of the cask with a gamma detection instrument. The cask outside surface is divided by radial lines 12º apart and by equally spaced circumferential lines along the vertical axis. Dose rate readings are taken over each of the 420 rectangular regions (~4 in. square); see Figure 8.1. If an area of void is detected, radiographic film is placed over this area to determine the size and location of the void. The criterion used to evaluate the effect of the void is that the dose rate may not exceed one and one-half times the mean dose rate. Any void area that does not meet the criteria will be repoured with lead.

8.1.6 Thermal Acceptance Tests

A thermal test is performed on the first unit built of the Model 2000 packaging to determine the thermal performance of the system versus what is predicted by the analysis. Corrective measures will be taken to prevent the temperature of the seal area from exceeding 400ºF and/or the temperature of the lead body from exceeding 600ºF.

8.1.6.1 Discussion of Test Setup

Two thermal tests are conducted, one each with 600- and 2000-watt heat source. The heat source is installed concentrically within the cask cavity. Thermocouples are strategically placed within the cavity and the external portions of the cask and overpack surfaces as schematically shown in Figure 8.2.

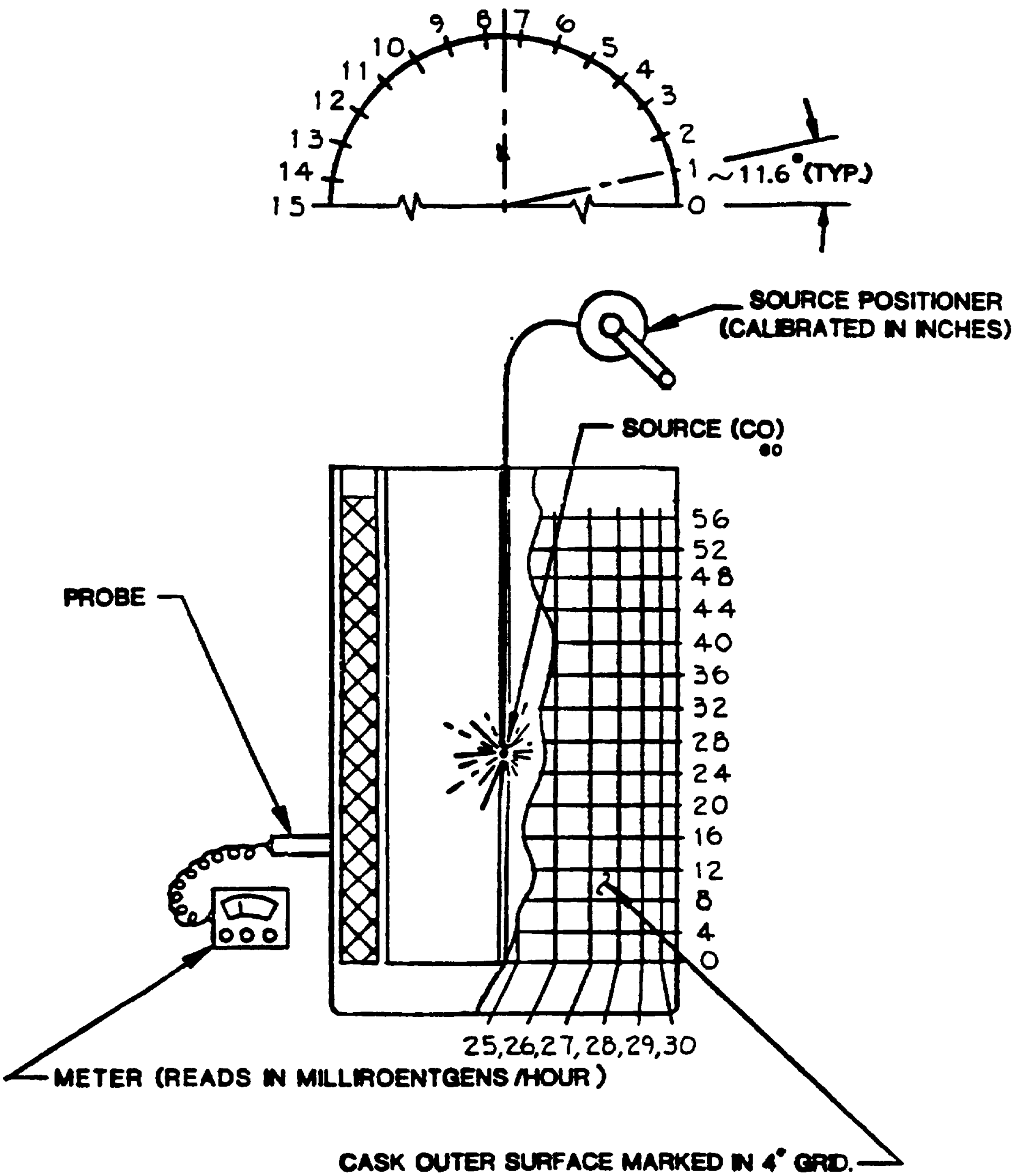


FIGURE 8.1. CASK SHIELDING INSPECTION POINTS

8.1.6.2 Test Procedure

The test is conducted with each of the heat source in a controlled ambient environment to simulate normal conditions of transport. The temperature data are recorded every 30 minutes with a data acquisition system, permitting easy analysis and plotting of the results. Data are recorded until temperature remains significantly unchanged for a one-hour period.

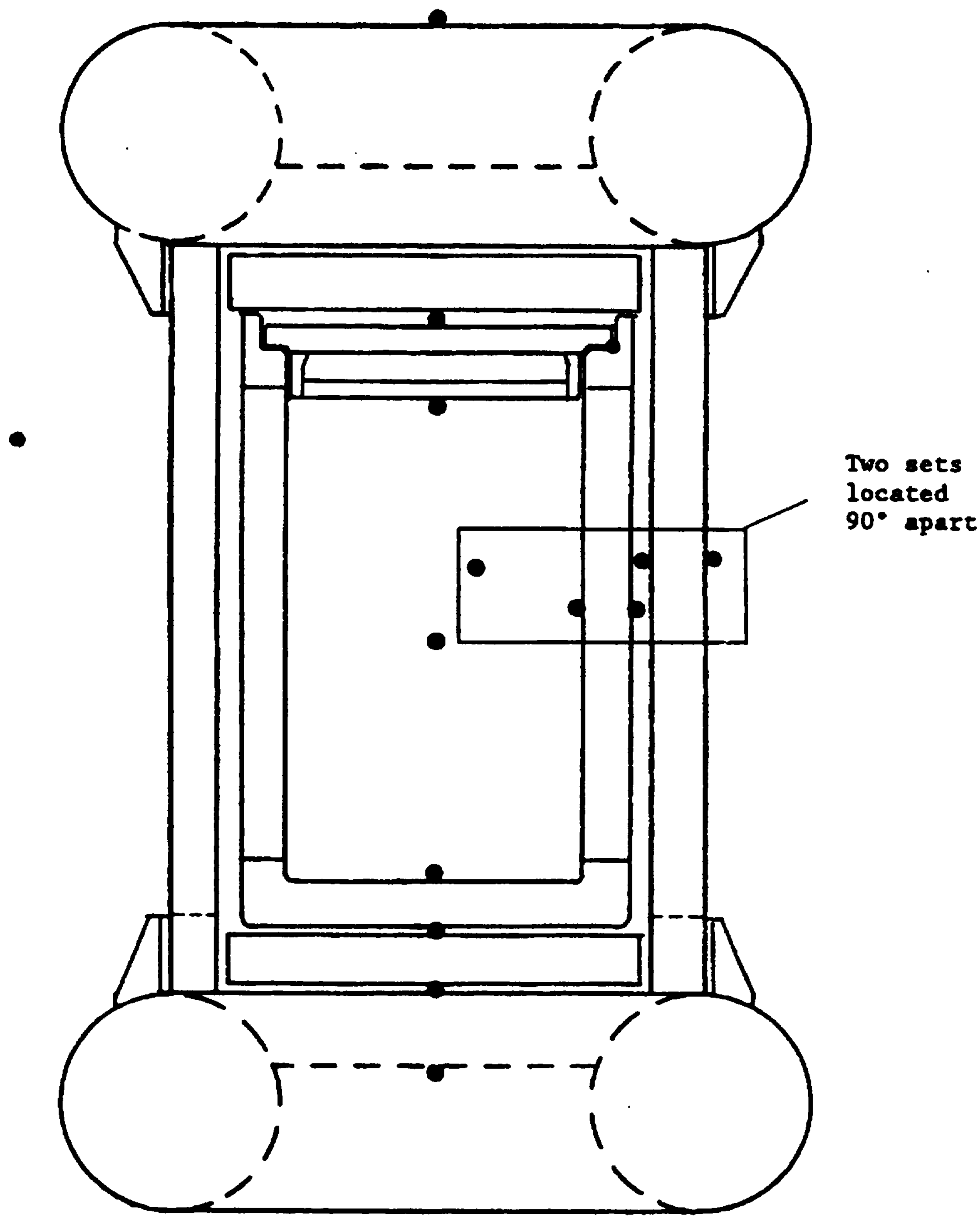
8.1.6.3 Acceptance Criteria

The results of the thermal test are evaluated against the predicted thermal performances. If the evaluation shows a discrepancy, the analytical thermal model is corrected based on the test results, and a new thermal analysis will be conducted. If the new analysis results indicate deficiency in the thermal characteristics of the packaging, thermal barrier coating could be applied to the inner surface of the overpack structure as a corrective measure.

8.2 MAINTENANCE PROGRAM

The cask maintenance program is described in detail in GE Specification 22A9380, *Operations and Maintenance of the Model 2000 Transport Package*. The Specification was developed to implement the requirements established in this Chapter. Operators of the Model 2000 Package may develop procedures of their own within the requirements of the GE Specification to include site-specific procedures.

Routine inspections are performed prior to each assembly and prior to each shipment. These inspections include visual checks of the packaging and any support structure(s) or device(s) required to properly assembly the package. It also includes pressurization of the cask cavity. This pressurization is part of the leak check procedure. Additional, more detailed, inspections are also performed every 12 usages or once a year which ever comes first.



Black dots denote TC locations.

FIGURE 8.2. THERMOCOUPLE LOCATIONS

8.2.1 Structural and Pressure Tests

8.2.1.1 Routine Inspection

Prior to each loading and assembly operation, the packaging is inspected for physical damage, especially the bolt holes, vent ports and sealing surfaces. The lid bolts, port plugs and 0-rings, and lid gasket are all inspected visually and for proper dimensions and identification. As part of the leak check, the cask cavity is pressurized to 15 psig with helium.

Any support structure(s) or device(s) (lead liner, fuel divider, rack, etc.) used with the packaging are also visually inspected for signs of damage, wear, cracked welds, deformation, etc.

8.2.1.2 Periodic Inspections

After every 12 usages or 12 months, whichever comes first, the following inspections are made. Any maintenance work required is identified on a maintenance checksheet.

a. Overpack

The overpack is inspected for:

1) Signs of excessive heat or fire.

2) Punctures, holes, or other surface defects.

3) Crushed sides or ends indicating a drop or severe impact.

4) Defects resulting from normal or abnormal wear.

5) Compression or damage to the honeycomb absorber material.

6) Cracks or other damage to welds

7) Proper identification and damage to the bolts.

b. Cask

The cask is inspected for:

1) Wear, corrosion or damage to the vent and drain port plugs, caps, and O-rings.

2) Damage to sealing surfaces on the cask and lid.

3) Damage or cracks to welds on the cask and lid.

4) Proper identification or damage to the lid and ear bolts.

c. MTR-Type Fuel Divider

The Fuel divider is inspected for:

1) Wear, corrosion or damage to the fuel cavities

2) Damaged or cracked welds

3) Wear or tear of elevating pads

8.2.2 Leak Tests

a. Routine

Leakage testing of the cask closure seal and vent and drain threaded pipe plugs is performed with a thermal conductivity sensing instrument. The test is performed by pressurizing the cask cavity to 15 psig with helium then "sniffing" with the instrument which senses differences in the thermal conductivity of the sampled gas if helium is present. The instrument will be calibrated to a sensitivity of 1×10^{-5} atm cm^3/sec (helium). If leakage greater than 1×10^{-3} atm cm^3/sec is detected, the suspect components will be repaired or replaced and then retested for leakage.

b. Periodic

After every 12 usages or 12 months, whichever comes first, the cask closure seal and vent and drain threaded pipe plugs will be leak checked with a helium Mass Spectrometer Leak Detector (MSLD). This instrument has a sensitivity of $< 1 \times 10^{-9}$ atm cm^3/sec (helium). This test is performed by pressurizing the cask cavity to 15 psig and then testing for leaks. If any leaks 1×10^{-7} atm cm^3/sec are detected, the suspect component will be repaired or replaced and then retested.

8.2.3 Subsystems Maintenance

There are no auxiliary cooling systems or other subsystems requiring maintenance.

8.2.4 Valves, Rupture Disks, and Gaskets on Containment Vessel

The cask closure seal will be used until either the routine or periodic test inspections identify the seal as needing replacement. The O-rings on the three penetration caps will be replaced when visual or leak test inspections identify them as defective, or during the periodic inspection, whichever comes first.

8.2.5 Shielding

The shielding material is lead. The initial tests for voids during fabrication and the required radiological surveys following each loading assure shielding integrity.

If the results of surveys exceed the regulatory requirements, the contents are reduced and/or the lead liner is installed.

8.2.6 Thermal

Thermal testing is only performed following fabrication of the first unit built, Serial Number 2001. Because the cask is constructed of lead and steel, no thermal degradation will occur during normal transport operations.